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C2 Approaches: Looking for the "Sweet Spot"

Track 2: Approaches and Organizations

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Abstract

The dimensions of the C2 Approach Space identify the three key characteristics of a C2 Approach as: the allocation of decision rights, the patterns of interaction and the distribution of information. Advances in information-related technologies have changed the economics of information resulting in the richer interactions between and among geographically dispersed entities and increased access to information. This has made more of the C2 Approach Space accessible. The seminal Network Centric Warfare literature asserts that in order to take full advantage of the opportunities afforded by communications and information technologies, C2 Approaches need to co-evolve. That is, there needs to be a balance achieved among the three C2 Approach dimensions. The NATO NEC C2 Maturity Model depicts a set of increasingly network-enabled C2 Approaches along the diagonal of the C2 Approach Space. The placement of these C2 Approach options along this diagonal could be interpreted as representing instances of approach co-evolution. This paper uses data from simulation experiments to explore a set of the hypothesis that involve the relationship between specific regions of the C2 Approach Space and effectiveness and agility.

C2 Approaches: Looking for the "Sweet Spot"

Introduction

There are many ways to accomplish the functions we associate with command and control. Different organizations, with different capabilities, undertaking different missions, under differences sets of circumstances, at different times have successfully employed a variety of C2 Approaches. This paper explores differences in mission effectiveness and agility between and among C2 Approaches that are located in different regions of the C2 Approach Space using the results of a set of experiments conducted by members of NATO Research Group SAS-085.

This paper specifically addresses the following position-related hypotheses:

- The C2 Approach Space provides a useful way of characterizing and depicting the differences between and among C2 Approaches.
- The actual positions of a set of C2 Approaches may differ from their intended positions.
- For a given C2 Approach, those closest to the 'diagonal' are more effective.
- The dimensions of the C2 Approach Space are positively correlated to agility.

Testing these hypotheses requires a method of mapping specific instantiations of C2 Approaches to unique locations in the C2 Approach Space as well as experimental results that provide values for measures of effectiveness for each C2 Approach under a variety of circumstances. Thus, we begin by discussing the C2 Approach Space as it has been articulated by NATO Research Group SAS-050 and used by SAS-065 to portray a set of increasingly network-enabled C2 Approach options.

The C2 Approach Space[1]

While differences in the ways that individual commanders and military organizations have approached command and control have been recognized and discussed for centuries, until quite recently there was no analytical conceptual framework that could be used to systematically describe and categorize these differences. Developing the "option space" for Command and Control requires that the major differences between possible approaches are identified.

[1] This section is taken from the SAS-050 Final Report because it represents the consensus reached by this international group on how to define and describe this fundamental concept.

NATO Research Group SAS-050[2] undertook this task and, in 2006, introduced the C2 Approach Space (Figure 1). They identified three major axes or dimensions of C2. These relate to the way (1) decision rights are allocated across an enterprise, (2) the permissible interactions among entities within the enterprise and permissible interactions between enterprise entities and others, and (3) information flows and is distributed.

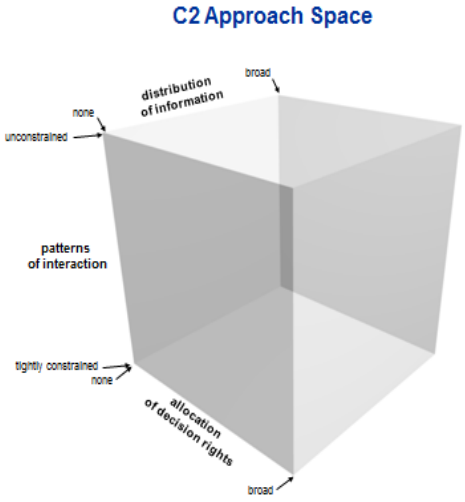


Figure 1: C2 Approach Space

When it was introduced in 2006, this three dimensional C2 Approach Space was purely conceptual in that its authors, while identifying each of its dimensions (allocation of decision rights, patterns of interaction, and distribution of information) and labeling the end points, did not specify or even suggest how these dimensions were to be quantitatively measured and scaled. Nevertheless, the C2 Approach Space has encouraged and facilitated a conversation about the ways that approaches to C2 could and/or should differ and has provide a way to visualize these differences.

The C2 Approach Space, taken at face value, only provides a taxonomy that allows us to describe significant differences between and among different approaches to C2. It says nothing about the relative merits of the possible C2 Approaches contained within. However, the very existence of more than one approach can be interpreted to mean that C2 Approaches:

1) located in certain parts of this space are 'better' than those located in other parts of this space and/or,

2) located in different regions are more appropriate for different organizations, missions, and circumstances than others.

[2] SAS-050 Exploring New Command and Control Concepts and Capabilities – Final Report, CCRP Publications 2006, Figure 2 page 6, http://dodccrp.org/files/SAS-050%20Final%20Report.pdf

Traditional v. Edge Approaches to Command and Control

A few years before the introduction of the C2 Approach Space, *Power to the Edge (2003)* was published by the CCRP. This publication discussed the potential of edge approaches to organization and command and control. In its forward, the then US Assistant Secretary of Defense stated that his organization was dedicated to putting in place the "policies, technologies, processes and systems to enable people to have the accesses they need to information and each other."[3] The result of these initiatives and investments was to make more of the C2 Approach Space accessible to the US Military and hence provide more C2 options from which they could choose.

Following upon the heels of *Power to the Edge*, attention was immediately focused upon two of the corners of the C2 Approach Space. The region about the first of these two corners is where traditional approaches to C2 are located while "edge" approaches, those that require robustly connected networks and exhibit networking behaviors, are located in the vicinity of the opposite corner (Figure 2). Note that, as depicted, classic or traditional C2 occupies a relatively small area in one corner of this space, while edge approaches are located in a relatively small area in the opposite corner of the space. Both visually and in practice there are many conceivable C2 Approaches that fall "in between" these two poles.

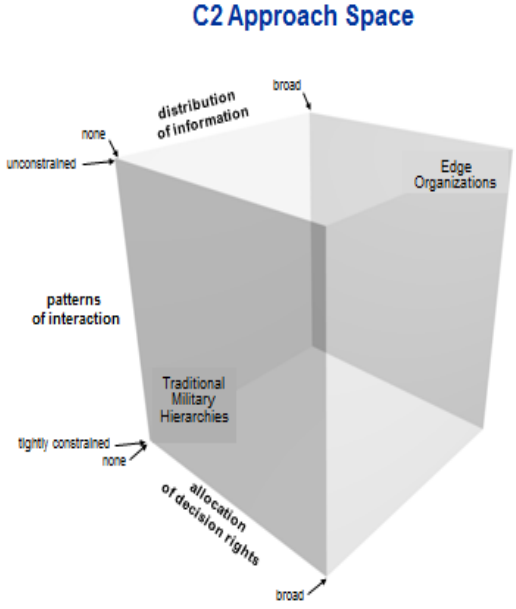


Figure 2: C2 Approach Space with a depiction of the regions associated with traditional military hierarchies and edge organizations

Given the attention being given to network-enabled approaches and the fact that Edge C2 requires robustly networked entities, some concluded that the C2 Approach Space was meant to convey the message that the closer a C2 Approach was to the "edge corner" the better. Thus, entities should work to develop and employ more network-enabled C2. The C2 Approach Space, of in itself, makes no such assertion. However, the C2 Approach Space definitely suggests that regions other than that those associated with traditional military command and control merit exploration. Furthermore, proponents of NEC have argued that more networked enabled approaches offer militaries an opportunity to be more effective and/or efficient.

[3] Forward to Alberts and Hayes, Power to the Edge (2003) p xvi
http://www.dodccrp.org/files/Alberts_Power.pdf

NATO NEC C2 Maturity Model Approaches to C2

The US was not alone in its interest in network-enabled organizations and approaches to command and control. NATO identified Network Enabled Capability (NEC) as a high priority alliance goal. NATO Research Group SAS-065 supported this set of initiatives by looking at the implications for command and control and developing a NEC C2 Maturity Model[4] SAS-065 identified a set of five C2 Approaches that were increasingly network-enabled, qualitatively described each of these dimensions and graphically located the approaches in the C2 Approach Space.

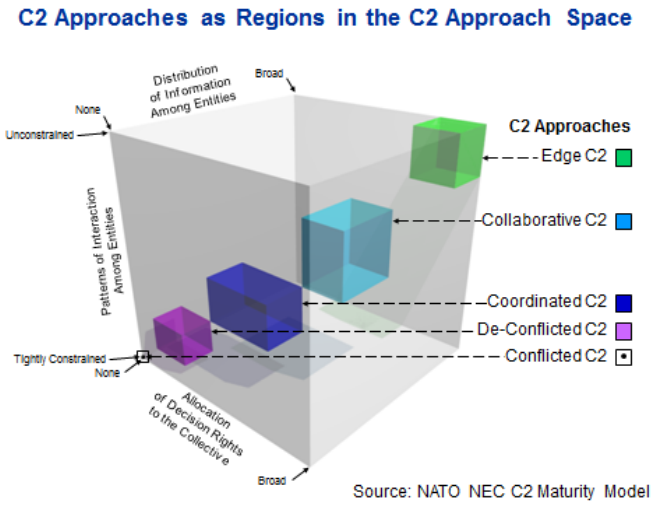


Figure 3 NATO C2 Maturity Model C2 Approaches

Graphically, these C2 Approaches are depicted as regions (not as points) and appear to be centered on a diagonal of the cube that connects two opposite corners. First, the corner of the C2 Approach Space associated with traditional military hierarchies (de-conflicted C2[5]) and its opposite corner, associated with edge organizations. This depiction seems to suggest that in looking for new network-enabled approaches to command and control that one's search should be not stray too far away from this diagonal.

[4] NATO NEC C2 Maturity Model http://dodccrp.org/files/N2C2M2_web_optimized.pdf

[5] The focus of SAS-065 was on coalitions rather than single entities. A de-conflicted approach is one that assigns decision rights along functional, geographic, or temporal lines. When applied to a coalition or collective, de-conflicted C2 assigns different responsibilities to different members of the coalition. This is organizationally equivalent to the way a traditional military headquarters decomposes itself along function lines. For example, a joint US military headquarters is organized into the following functional areas: Administrative (J1), Intelligence (J2), Operations (J3), Logistics (supply) (J4), Plans (J5), Command and Control, Communications Systems, CIO (J6), Doctrine and Training (J7), and Analysis (J8).

Locating a C2 Approach in the Approach Space

The first hypothesis, that the C2 Approach Space provides a useful way of characterizing and depicting the differences between and among C2 Approaches depends upon the ability to accurately locate the position of a given C2 Approach within this space. This requires that a set of scales, preferably quantitative scales, defined for each of the three dimensions of the Approach Space with values that correspond to each of the end points and to a set of intervals in between. A method of measurement also needs to be specified. The qualitative nature of the NATO NEC C2 Maturity Model's Approach Space does not provide these. Thus, SAS-085's first task, that of making the C2 Approach Space more useful to both researchers and practitioners, was to consider ways to quantify the dimensions of the Approach Space and thus, enable one to determine the position in the Approach Space that corresponds to a given C2 Approach.

While expert opinion could be used to locate a given C2 Approach in the Approach Space, this would require a great many assessments, assessments that could differ significantly across experts. Because the members of SAS-085 wanted to be able to test their hypotheses in a number of different experimental venues, and be able to replicate these experiments, actual measurement of the three C2 Approach dimensions was preferable. This required the development of quantitative scales for each of the three dimensions of the C2 Approach Spaces and instrumented environments to capture the data required.

There are, of course, many ways that one can think of to scale each of these these dimensions and we lack the experience and the empirical data to suggest which of these methods best reflects the behaviors involved. Furthermore, given the multi-dimensional aspects of each of these dimensions, it is unlikely that a simple scale (consisting of one variable) will be able to capture all of the factors of interest. For example, not all decisions, interactions, and pieces of information are of equal value and thus any scale that simply 'counts' these will not capture important nuances. While we can expect that we will find better ways to measure each of the dimensions of the C2 Approach Space as we gain experience, we needed to start somewhere.

Figure 4 presents the methods used in one of the SAS-085 experiments[6] to calculate the actual position of a C2 Approach and locate it within the Approach Space.

C2 Approach Dimension	Nature of Measure	ELICIT Metric
Allocation of Decision Rights (ADR)	degree to which decision rights are distributed; a measure of participation in decision making	ratio of the number of individuals exercising decision rights to the total number of individuals
Pattern of Interactions (PoI)	density of interactions between and among individuals; a measure of quality, frequency, and reach	square root of the number of information-related transaction and scaling them between 0 and 1 based upon the maximum number of transactions observed
Distribution of Information (DoI)	degree to which individuals have access to available information	average percent of available factoids received by an individual

Figure 4: Metrics Used to Locate the Actual Positions of C2 Approaches

However, simply being able to locate a C2 Approach in the Approach Space does not make the Approach Space useful. The differences in the positions must accurately reflect differences in behaviors that translate into differences in effectiveness and/or agility. That is, the positional differences must be logically consistent and significant.

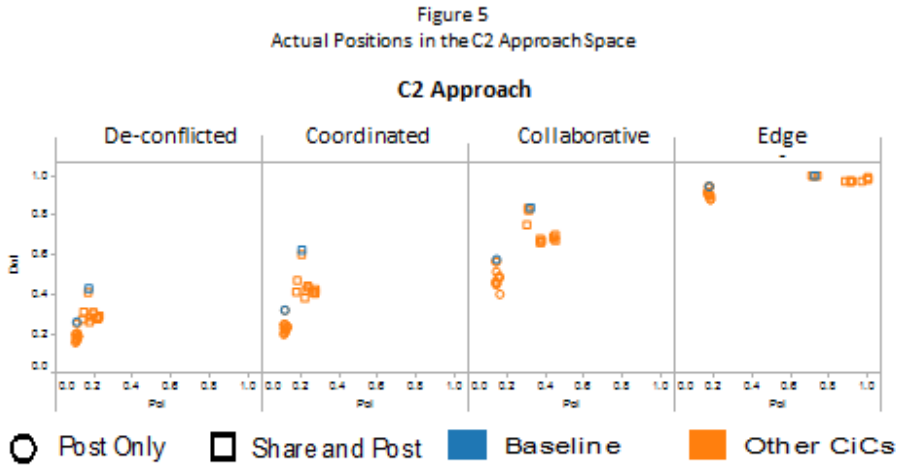


Figure 5 looks at the results from one of the sets of abELICIT experiments (ELICIT-IDA) for four different C2 Approaches. It allows us to compare the actual (observed) positions for two variants of each C2 Approach over a set of circumstances (each point corresponds to a specific set of circumstances).

The two C2 Approach variants differ in the ways individuals share information. In the first variant, individuals both share information directly with one another as well as posting information to designated websites (Share and Post) while in the second case, they only use

[6] These metrics were employed by researchers that used the ELICIT environment. Other SAS-085 experiments each used somewhat different methods. This will be discussed later in this paper.

websites (Post Only). Readers will note that for these abELICIT runs, the Share and Post variant positions observed indicate that more information is being shared then is the case with the Post Only variant, although this difference is far less in the case of the Edge C2 Approach than in less network-enabled approaches. From the PoI positions, we see that, as the C2 Approaches become more network-enabled, the number of interactions increases significantly. At some point, these interactions can reach levels that adversely impact communications network performance and can overwhelm individuals' 'inboxes'. When this happens, a Post Only Approach is not only more efficient, it is also more effective. However, if the communications network is damaged, the redundancy provided by a Share and Post variant serves to ensure that information is adequately shared.

SAS-085 designed and conducted multiple sets of experiments to see if, despite different ways of measuring and quantifying the dimensions of the C2 Approach Space, different instantiations of the NATO NEC C2 Approaches, different scenarios and different measures of effectiveness, findings were consistent across these experiments. Each of these experiments is described in the SAS-085 Final Report – Peer Review Draft and documented in papers referenced therein. ELICIT employs a 'who what when where' problem challenge and was used by three of the members of SAS-085 albeit with different measures of success and different constructions of the Endeavor Space. (see - http://dodccrp.org/html4/elicit.html for more information) IMAGE (see Lizotte et al., 2008; Lizotte, Bernier, Mokhtari, & Boivin, 2013) was developed as a suite of generic representation, "scenarization", simulation and visualization tools aiming at improving the understanding of complex situations. For SAS-085, a simulation-based experiment was designed with IMAGE to investigate how C2 Approaches instantiated in a specific operational context impact agility and mission effectiveness (Bernier, 2012). The Wargame Infrastructure and Simulation Environment (WISE) was designed to address initially Manoeuvre Operations at Formation level. In addition to its C2 functionality, WISE is designed to operate as either a simulation or a wargame, in which the players replace a node in the command chain and act accordingly. PANOPEA (Bruzzone, Tremori, & Merkuryev, 2011) reproduces a piracy scenario in the Horn of Africa, a very critical area in terms of pirates' attacks against cargo ships. This scenario includes navy vessels and helicopters, intelligence assets, ground bases, cargos as well as other boats (i.e. fisherman and yachts) and pirates hiding in the general traffic. The entities are directed by IA-CGF (Intelligent Agents Computer Generated Forces) and apply strategies for succeeding based on their scenario awareness.

Figure 6 depicts the positions for the different C2 Approaches observed in these different NATO SAS-085 experiments.

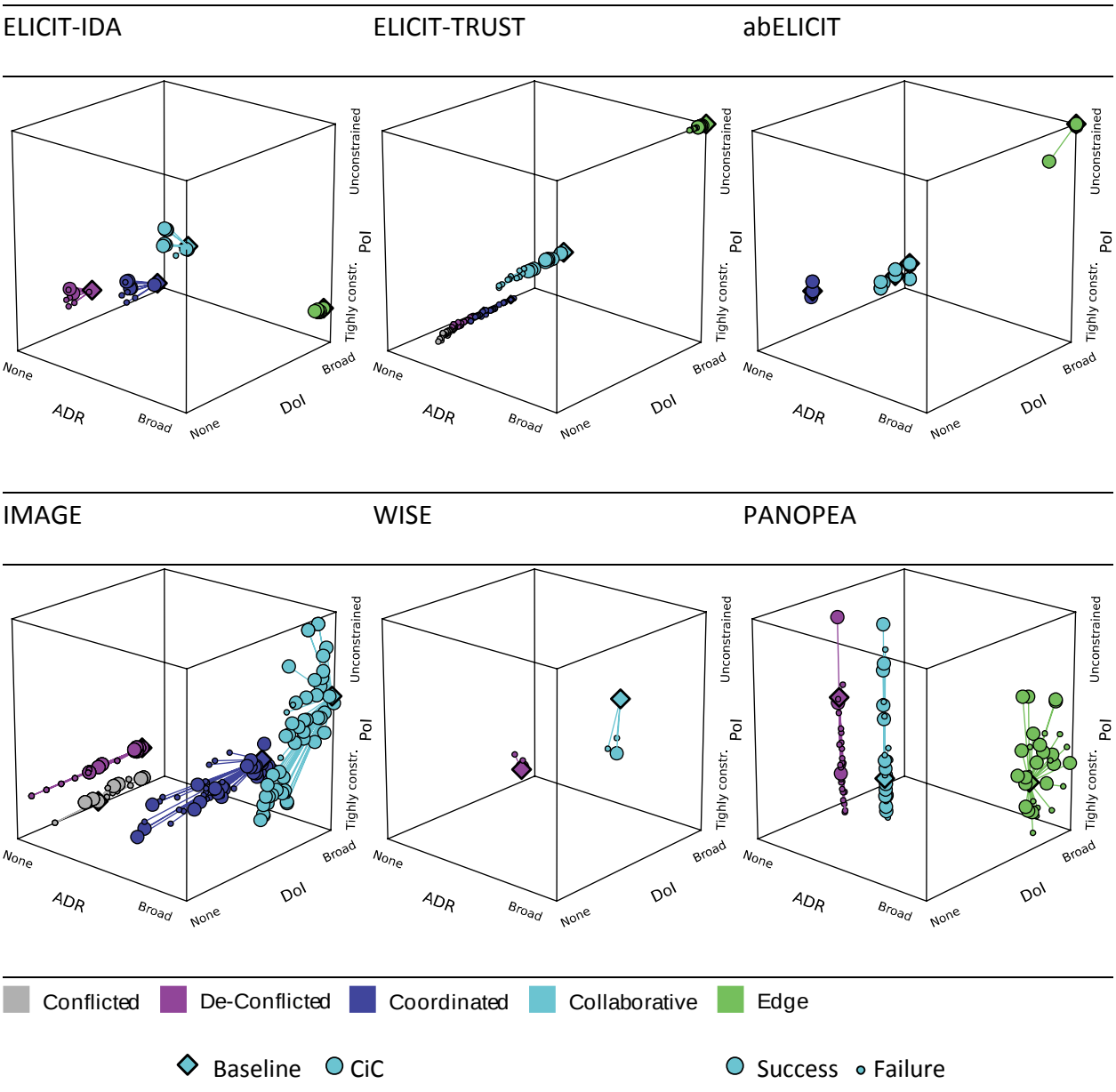


Figure 6: Actual positions in the C2 Approaches for SAS-085 experiments.

From Figures 5 and 6 we see that differences in C2 Approach behavior translate into differences in position that makes sense. The positions observed are impacted by the circumstances associated with each of the simulation runs. Figure 7 depicts the average of the observed

positions (over all of the SAS-085 experiments) by C2 Approach and their 0.95 confidence intervals. Across the set of SAS-085 experiments, the loci of the positions for each of the C2 Approaches migrate across the space in a manner consistent with the NATO NEC C2 Maturity Model.

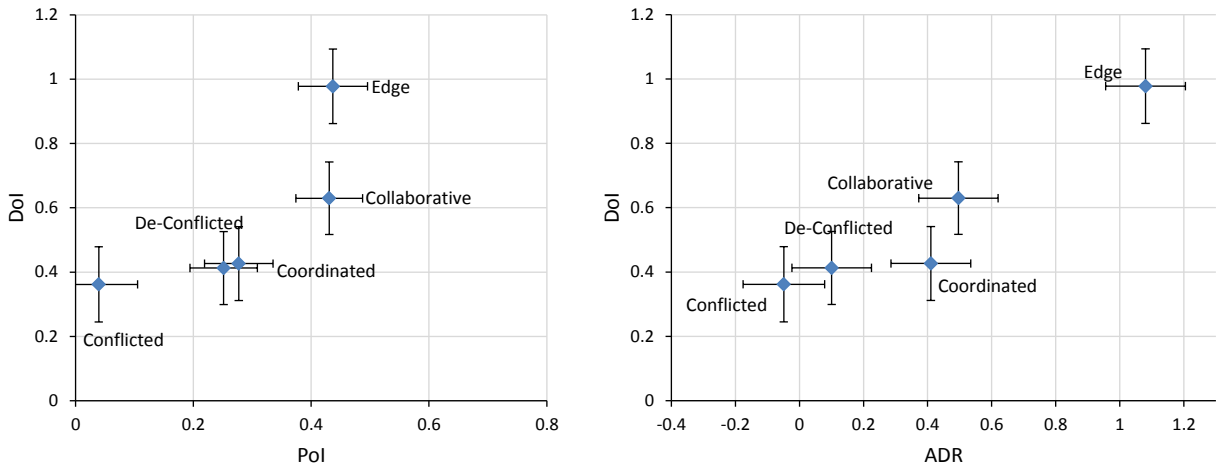


Figure 7: Average location for each C2 Approach

The separation seen between the regions associated with these two variants increases as the C2 Approaches move to the Edge corner. This makes sense given the non-linear increase in the number of 'share' transactions from one C2 Approach to another. The results of this set of experiment produced footprints for the C2 Approaches that overlap. For example, in ELICIT, a Post Only Collaborative C2 Approach and a Share and Post Coordinated C2 Approach occupy locations that are close to one another under some circumstances. However, this is not surprising since SAS-065 noted that the lines between de-conflicted and coordinated and between coordinated and collaborated were not definitive.[7]

Based upon these observations, we can say that the C2 Approach Space is useful because it captures important behaviors and depicts the differences within, between, and among instantiations of each of the C2 Approaches. However, for the C2 Approach Space to be useful these differences in positions must translate into differences in effectiveness and/or agility. The remainder of this paper looks to if differences in position translates into differences in effectiveness and/or agility and if so, when. For example, we will see if these two approach variants share the same level of effectiveness and agility and thus represent, for all intents and

[7] See Figure 15 in the NATO NEC C2 Maturity Model which provides qualitative descriptions of where on the three dimensions each of the C2 approaches is located and portrays the boundaries between de-conflicted and coordinated and coordinated and collaborative by dotted lines.

circumstances, the same C2 Approach regardless of how they are labeled here or if there is a significant difference in their levels of effectiveness and they should be consider different approaches.

Intended v. Actual Positions

It is important to be able to make a distinction between the intended location of a C2 Approach in the C2 Approach Space and its actual location in practice. The location of a C2 Approach that is used to understand behaviors and their consequences should reflect reality rather than be estimated from the formal organization chart, policy, organizational aspirations, or doctrine. For example, the allocation of decision rights in practice includes the informal ways an entity functions, not just its formal structure. Similarly, the patterns of interaction observed reflect those interactions that actually occur, not those that are supposed to occur. Finally, the distribution of information to use in locating a C2 Approach on the DoI axis should be based upon what information is actually available or that which participants receive, not the ideal called for by information sharing policies and procedures. While in many cases, the actual value on these three scales may be closer to the origin than the intended position, this is not necessarily the case. For example, there may be more sharing and interactions than intended because the opportunities exist. The implications of exceeding the intended value will be a function of the situation. On the one hand, the extra sharing may be a result of something unexpected happening and creates value while, on the other hand, it may simply be a result of undisciplined activity than has adverse consequences. Thus, it is important to understand what is actually happening in order to properly assess the appropriateness of various C2 approaches given a particular mission / circumstance and the reasons for success or failure.

Where organizations are able to position themselves along each of the three C2 Approach dimensions is, in part, constrained or determined by individual characteristics and attitudes, organizational culture, training, the capabilities of C2 systems, and the state of these systems as they are impacted by the situation and related circumstances. Clearly, there is the potential that C2 Approaches cannot be implemented by a particular organization or will not work, as they were designed or intended. Thus, the actual position of a C2 Approach in the Approach Space cannot be determined with any degree of certainty *a priori*. This is clearly the case when an entity is subjected to attacks on its communications infrastructure that, to the extent that they are successful, interfere with the ability of individuals to share information and to interact with one another. This may also be the case when a variety of other stresses are encountered. Thus, a C2 Approach that in theory is balanced may not turn out to be balanced in practice.

To test hypotheses related to a C2 Approaches' position in the C2 Approach Space, it is necessary not only to score an approach as it is intended to work but also to 'observe' each

approach in practice under all of the missions and circumstances that form the Endeavor Space to ascertain whether or not the practice conforms to that which was intended, and if not, under what circumstances this occurs.

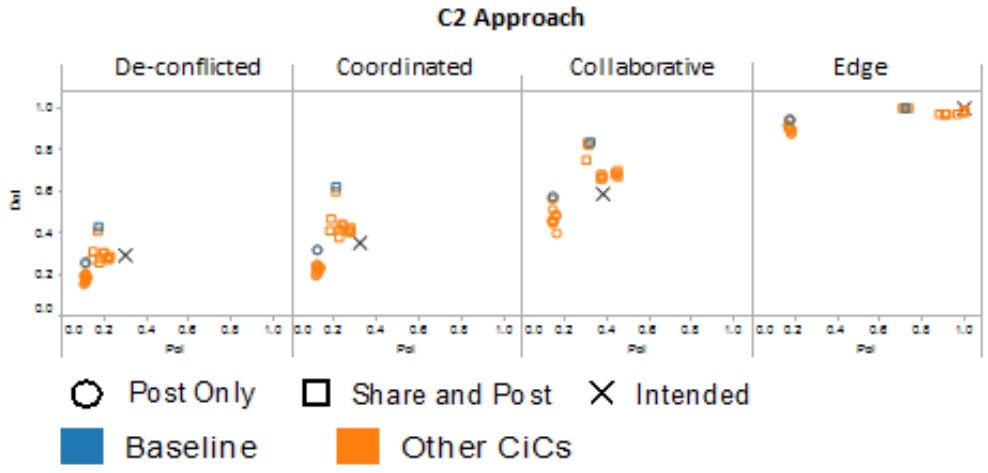
Figure 8 presents the results of calculations[8] of the intended positions of the C2 Approach options considered in the ELICIT-IDA experiment.

C2 Approach	ADR	PoI	DoI
Hierarchy-De-conflicted	.059	.299	.294
Coordinated	.059	.320	.353
Collaborative	.294	.381	.588
Edge	1.000	1.000	1.000

Figure 8 - Intended Positions of C2 Approaches

Figure 9 compares these intended positions with the actual or observed positions. Readers will see that the intended positions are not at the centroid of scatter plot of the actual positions but instead they are located at or near the right hand edge (along the PoI axis) of the respective C2 approach regions. In all cases, the Post Only C2 variant never achieves the level of DoI intended, while the Share and Post variants almost always exceeds the intended level of DoI.

Figure 9
Intended vs. Actual Positions in the C2 Approach Space



[8] ADR was calculated by taking the ratio of the number of individuals with decision rights to the total number of individuals, PoI by using a measure of connectedness scaled to a maximum of 1; and DoI by the average percentage of information individual were intended to access.

The variations in the positions in Approach Space are a result of the C2 Approach adopted and the stresses created by the circumstances associated with each experimental run. More network-enabled C2 Approaches involve greater numbers of interactions and more information sharing while the amount of noise that is present direct impacts the number of information-related interaction (PoI), the load on the communication networks (which may create delays) and individual workload (which may create backlogs and ultimately the inability to process and share all of the important information. Looking at figure 7, one can also see that the impact on position in the Approach Space of these circumstances is less for entities employing a Post Only policy that a Share and Post policy (the grouping of points are significantly tighter). This may, when other factors are considered, be a significant observation that should impact the choice of information sharing policy in certain cases.

Figure 9 provides only information about where in the C2 Approach Space these entities were operating, not how successfully they were operating. The relationship between one's position in the C2 Approach Space and mission effectiveness or agility will be discussed next.

At this point in the analysis, there is evidence that supports the first two hypotheses: 1) the C2 Approach Space provides a useful way of characterizing and depicting the differences between and among C2 Approaches. And 2) the actual positions of a set of C2 Approaches may differ from their intended positions.

Position, Effectiveness and Agility

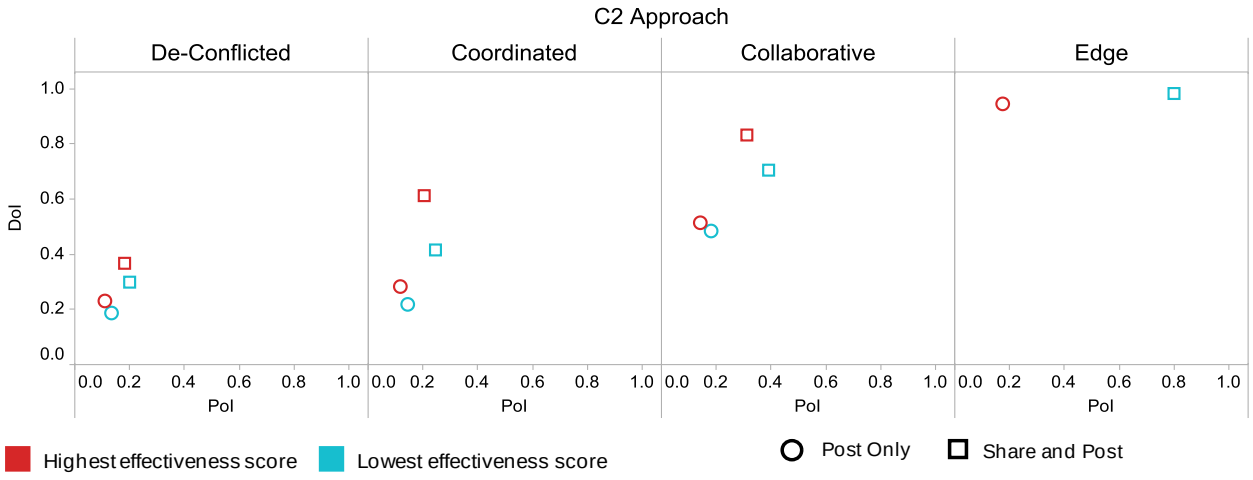
Now that each experimental run has been associated with a given C2 Approach and an observed (calculated) position in the C2 Approach Space has been determined, we can explore the relationships between and among the C2 Approach, positions in C2 Approach Space, effectiveness, and C2 Approach agility. Specifically, we shall look to see if

- within C2 Approach position variation impacts effectiveness
- runs with on-diagonal positions have higher levels of effectiveness than runs with off-diagonal positions
- there is a relationship between the centroid of a C2 Approach region and its agility (C2 Approach Agility is positively correlated with the dimensions of the C2 Approach Space)

Within C2 Approach Position Variations

Figure 10 locates the most (red square) and least (blue square) effective of the observed positions the C2 Approach Space for each C2 Approach and policy variant. For all of the approaches, except for the Edge, the most and least effective scores achieved by the different policy variants were the same. In the case of the Edge, the lowest effectiveness score observed by a Post Only Edge was higher than the lowest score for the Share and Post Edge and the highest score observed for the Post Only Edge was higher than the highest score observed for the Share and Post Edge.

With the exception of the Share and Post Edge C2 Approach, the relative locations follow a pattern where relative effectiveness is associated with higher DoI and lower PoI. The reason for the break in the pattern for the Share and Post Edge is that, as mentioned previously, very dense patterns can create delays and workloads that have adverse mission consequences. The ability of the Post Only variants to achieve the levels of effectiveness they do can be attributed to the elimination of unnecessary interactions and information sharing.



Thus, relative position, within a given C2 Approach, matters. Under some circumstances, it can make the difference between success and failure. This means that 'maneuvering within the region associated with a C2 Approach may obviate the need to change C2 Approaches.

On v. 'Off-Diagonal' Approaches

The NATO NEC C2 Maturity Model portrayal of C2 Approach regions centered along the diagonal of the C2 Approach Space implies the following hypothesis:

C2 Approaches located along the diagonal have a competitive advantage.

SAS-065's diagonal assertion is grounded in the theory of Network Centric Warfare (now referred to as Network Enabled Capability). The seminal Network Centric Warfare literature asserts that in order to take full advantage of the opportunities afforded by communications and information technologies, C2 Approaches need to co-evolve. In the book, Network Centric Warfare, there is a discussion of then prevalent myths, one of which was the "We are already well on the road to NCW."[9] Many at the time thought that simply investing in technology, specifically communications and computers, was sufficient to guarantee the achievement NCW. The authors of NCW argued that

> *"To fully leverage Information Superiority and apply the concepts of NCW to the full range of tasks we in DoD undertake in support of our many mission challenges, two things are required—first, a suitable infostructure and second, coevolved mission capability packages.*[10]

Thus, a suitable infostructure was recognized as necessary, but not sufficient, to achieve a network-enabled force. The coevolution of organization, doctrine, training, and the other components of a mission capability package, later referred to as DOTMLP was seen as essential.

> *Mission Capability Packages (MCP), as the end products of such a process, would contain concepts of operations, command and force structures, the corresponding doctrine, training and education, technology, and systems with a support infrastructure designed and tailored to accomplish specific missions. An integral part of the MCP concept is the approach proposed to synchronize the insertion of advanced technology with our ability to change the way we fight so that we are able to take advantage of the opportunities afforded by technology.*[11]

[9] Alberts, et all Network Centric Warfare page 9
[10] ibid
[11] Alberts, Mission Capability Packages, NDU Institute for Strategic Studies, see: http://www.dodccrp.org/events/13th_iccrts_2008/CD/library/html/pdf/Alberts_Mission.pdf

That is, there needs to be, among other things, a balance achieved among the three C2 Approach dimensions. The NATO NEC C2 Maturity Model depiction of a set of C2 Approaches positioned along the diagonal of the C2 Approach Space graphically represents instances of approach co-evolution. Thus, these on-diagonal approaches represent those that are co-evolved to support operational concepts that are able to take advantage of the opportunities afforded by technology. In terms of the C2 Approach Space, approaches along the diagonal possess patterns of interaction and distributions of information that efficiently support the allocation of decision rights. That is, individuals are provided access to the individuals and information they need to make the decisions for which they are responsible, in a timely manner. An off-diagonal approach would be one where the pattern of interaction or the distribution of information is either insufficient to support assigned decisions or while able to support required interactions and information flows, supports them inefficiently. Thus, this "diagonal hypothesis" would seem, on its face, to be obvious. In fact, one could ask why any entity would choose to adopt an off-diagonal C2 Approach. To test this hypothesis one needs to compare the performances of a range of C2 Approaches, at different distances from the "diagonal" and compare their agility with respect to an Endeavor Space.

As indicated previously, since Figure 3 does not provide metrics for the dimensions of the Approach Space, the diagonal it presents is just a representation of balanced co-evolution. Thus, once metrics and scales have been defined for each of the dimensions of the C2 Approach Space, there is no guarantee that the C2 Approaches located on the resulting diagonal will be balanced. In fact, there is no reason to believe that C2 Approach balance will be a linear function of any particular set of dimensional metrics.

Assuming that C2 Approaches are designed using theory where theory exists and using empirical evidence where it exists, there is reason to believe that the intended or 'design' position for any given C2 Approach in the C2 Approach Space should outperform other positions within the envelope associated with a particular C2 Approach.

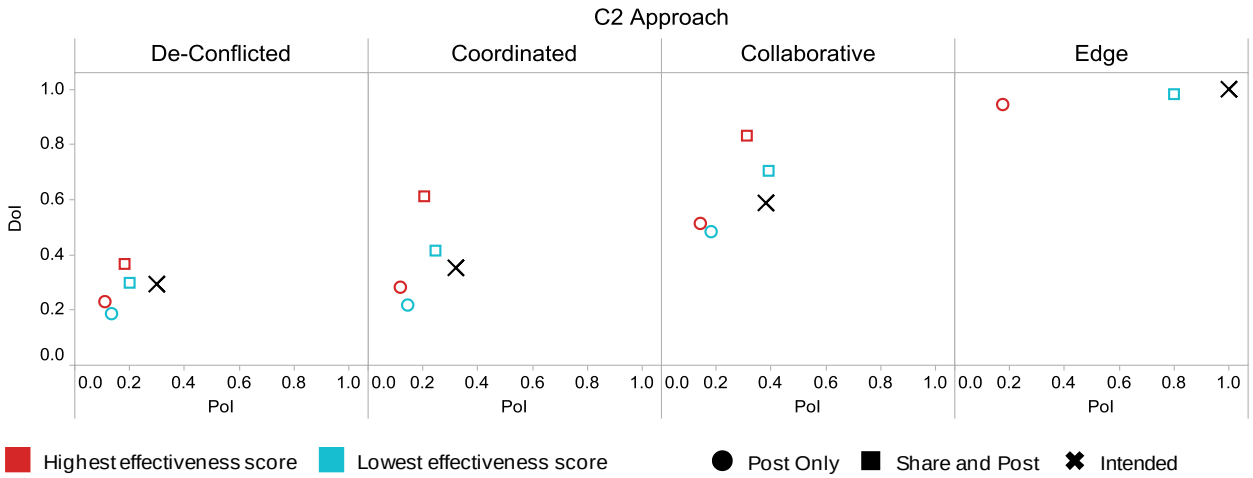


Figure 11 – Intended vs. Most and Lead Effective Positions in C2 Approach Space within C2 Approach Regions

Figure 11 compares the positions observed to be the most and least effective with the intended position (Figure 6) for each C2 Approach.

It is obvious from Figure 11 that the intended positions are not the most effective for any given C2 Approach. However, these intended positions were not based upon a body of empirical evidence, but were based upon general descriptions of these C2 Approaches and assumed that behaviors should strictly conform to that implied from organization charts and SAS-065 descriptions. These results point to a need to develop a greater understanding of the dynamics of these C2 Approaches as a function of mission challenge / circumstances and the need to be more efficient (sophisticated and selective) in interaction and information sharing behaviors. This level of sophistication will ultimately require more education and training to achieve in practice.

This result presents us with a decision to make regarding what should properly constitute the 'diagonal' in our analysis. A priori, we planned on using the intended positions in the C2 Approach Space, positions we thought would be the centroids of the locus of points associated with a given C2 Approach and those that would result in the best performance. Since this is not the case, defining the 'diagonal' using these points is not consistent with the notion of co-evolved approaches.

On the other hand, we know what positions are associated with the highest levels of effectiveness for each C2 Approach and can assume that if this information were known to practitioners they would choose to operate in this vicinity. Given that for some C2 Approaches and policy variants there are multiple points in the C2 Approach Space that result in equally high effectiveness scores, for the purposes of this analysis we choose to take the average of these positions to use. Furthermore, since effectiveness is a function of C2

Approach and hence of overall position in the C2 Approach Space, the effectiveness comparisons was relative to the best that was achieved by each C2 Approach.

Now we will take a look at the proposition that positions along the diagonal, that is, C2 Approaches that are balanced with respect to the three axis of the C2 Approach Space, are more effective than unbalanced approaches. To seek if the data support such a conclusion, the runs were divided into two groups. The first group was formed by the runs that were equal to or less than a certain distance from the diagonal (.05), the on-diagonal group. The off-diagonal group consisted of the runs that whose positions were observed to be greater than .05 from the diagonal. Figure 12 shows relationship between the average distance from the diagonal and average percent of maximum effectiveness of these two groups. The on-diagonal group is, on average, more than twice as effective (see Figure 13).

Figure 12
Off-diagonal Effectiveness

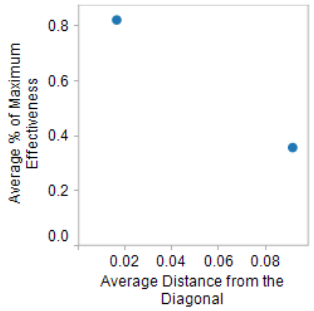


Figure 13
Average % Maximum Effectiveness as a function of On / Off diagonal

	On-Diagonal Group	Off-Diagonal Group
Average % Maximum Effectiveness	0.8235	0.3571
Average Distance from Diagonal	0.0163	0.0916

C2 Approach Agility

This paper concludes with a look at the relative agility of the two variants of the C2 Approaches, approach/variants combinations that occupy somewhat distinct regions within the C2 Approach Space. Figure 14 presents the agility scores associated with each policy variant and C2 Approach for the ELICIT-IDA experiment. [12]

Figure 14

Agility as a function of C2 Approach / Variant

C2 Approaches	All Variants	Post-Only	Share & Post
Hierarchy/De-conflicted	0.054	0.052	0.056
Coordinated	0.102	0.105	0.099
Collaborative	0.292	0.321	0.262
Edge	0.404	0.548	0.259

[12] Results for the other SAS-085 experiments can be found in Bernier, F., Alberts, D. S., Chan, K., Manso, M., Pearce, P., & Bruzzone, A. G. (2013) International Multi-Experimentation Analysis on C2 Agility, In *Proceedings of the 18th ICCRTS*. Alexandria, VA, USA.

As the region occupied by a C2 Approach moves away from the origin of the C2 Approach Space, its agility increases[13]. This is also true when looking at each policy variant separately. However, all but one of the Post Only C2 Approaches variants have higher agility scores than their Share and Post variants while also being located closer to the origin of the C2 Approach Space. This illustrates two points. First, that there are indeed some regions of the C2 Approach Space which appear to outperform other areas. Second, that one must be careful not to over simplify the relationships between C2 Approach position, effectiveness and agility.

Summary

This paper specifically addresses the following position-related hypotheses:

- The C2 Approach Space provides a useful way of characterizing and depicting the differences between and among C2 Approaches.
- The actual positions of a set of C2 Approaches may differ from their intended positions.
- For a given C2 Approach, those closest to the 'diagonal' are more effective.
- The dimensions of the C2 Approach Space are positively correlated to agility.

The analysis findings presented in this paper demonstrates that the C2 Approach Space provides a useful way of characterizing and depicting the differences between and among C2 Approaches and that there are indeed differences that are a result of circumstances that impact intended behaviors. The depiction of the set of increasingly network-enabled C2 Approaches by SAS-085 in the NATO NEC C2 Maturity Model along a diagonal implied that the search for an appropriate C2 Approach should be focus on co-evolved approaches. The findings presented here show that findings position along this 'diagonal' cannot be done by inspection but rather requires analysis of the effectiveness of a large set of points in the C2 Approach Space. However, the SAS-065 thesis that off diagonal approach will not be as effective or efficient is supported here. Finally, the proposition that movement away from the origin, towards the Edge corner does increase agility is supported by the data.

The results reported in this paper are from a single set of experiments (SAS-085 refers to a set of model runs as a scenario). In their final report, the members of SAS-085 will present a series of analysis parallel to those presented here that look across multiple scenarios. Preliminary results indicate that the findings presented here will be supported across this set of experiments.

[13] While there have been a number of experiments that have shown a strong correlation between more network-enabled C2 approaches and Agility scores, there are many variables in play that have not been adequately explored. Thus, readers are cautioned against inferring a simple cause-effect relationship at this time.

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