Annex A
Heterogeneous C2: When the "C2 Approach" Requires Many C2 Approaches

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A.1 INTRODUCTION

This paper is a contribution to the SAS-085 study on C2 Agility and Requisite Maturity. It addresses heterogeneity of C2 approach, particularly in complex endeavors. As backdrop, we first review briefly the evolution of concepts within SAS-065 and, more recently, within SAS-085.

A.2 BACKGROUND

SAS-065 was originally mandated by NATO-RTO-SAS[1] to develop a generic conceptual model for assessing the evolving "maturity" of NATO's command and control system.[2] The mandate's context was NATO's force transformation initiative to improve the Network Enabled Capability (NEC) of NATO's forces with gradual improvement from the capacity for de-conflicted operations, as prevailed during the Cold War, toward truly coherent operations coping effectively with 21st-century global security challenges. An important element of this was developing convergent national roadmaps (how to get from here to there). These would be based on the Network-Centric Operations Value Chain to arrive at an eventual *homogeneous* collective C2 approach for NATO, one that would be capable of Coherent (Transformed) Operations (Edge C2). This was arguably a "one size fits all" idealization.

Thus, the original concept of the NATO Network Enabled Capability Command and Control Maturity Model (N2C2M2) revolved around (1) improving C2 within *existing organizations*, (2) assisting development of roadmaps for improving the C2 systems of *NATO partners*, (3) the aim of eventually reaching a *homogeneous* collective NATO C2 system for effective joint and combined *military*

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[1] NATO's Research and Technology Organization (RTO) has a panel for Systems Analysis and Studies (SAS), under which efforts such as SAS-065 and SAS-085 are conducted by Technical Teams. Organizational relationships are described at http://www.rto.nato.int/Main.asp?topic=18. SAS-065 was tasked with "The primary goal of SAS-065 is to create an NNEC C2 Maturity Model and use it to explore command and control concepts and issues including exploration of new network enabled command concepts such as collaborative planning and self-synchronization in an NNEC context." http://www.rto.nato.int/ACTIVITY_META.asp?ACT=SAS-065. The objectives for SAS-085 were specified as "To understand and validate the implications of C2 Agility (or a lack of C2 Agility) for NATO missions by improving the breadth and depth of our understanding of C2 Agility; • Match the characteristics of alternative C2 Approaches to situational attributes (e.g. complexity, dynamics) so that Requisite C2 Maturity and its encompassing C2 Agility can be recognized for complex endeavours; • Support the dissemination of this improved understanding through applications involving appropriate military, research and educational institutions. • Update the NATO Code of Best Practice for C2 Assessment, the NATO C2 Conceptual Reference Model and the NATO NEC C2 Maturity Model to reflect the new findings" http://www.rto.nato.int/ACTIVITY_META.asp?ACT=SAS-085

[2] The idea of a maturity model was by analogy to the software maturity model developed by the Software Engineering Institute (SEI) of Carnegie Mellon University.

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operations; and (4) the idea (often implicit) that Edge C2 was the goal. The concept evolved substantially during the SAS-65 and SAS-085 studies.

A number of reasons necessitated the evolution, many of which were discussed with case studies in SAS-065. First, real-world operations involving NATO have often included creating new organizations involving non-NATO partners. Second, a homogeneous C2 approach has not been feasible (or a useful ideal) for non-military aspects of operations such as those in stabilization and reconstruction, or even for military aspects when involving non-NATO partners. Non homogeneity has been even more evident in disaster-response operations in which military forces largely played supporting roles (albeit, critical roles). Finally, it became clear that Edge C2 is sometimes not the best approach and that C2 maturity should be seen as allowing transition among the various C2 approaches (conflicted, de-conflicted, cooperative, collaborative, and edge) so that the best C2 approach for a given context can be adopted.[3]

As a result, SAS-065 came to view the cube model of C2 approach (Figure 1) in terms of how a set of disparate yet interdependent) entities—that is, a collective of entities undertaking a *complex endeavor* (Alberts and Hayes, 2007)—can achieve focus and convergence by moving entities up or down on the diagonal (from Conflicted at the lower left hand corner to Edge at the upper right hand of the cube) to converge on whatever C2 approach is appropriate in the situation at hand given the maturity / agility of their C2 systems. The SAS-065 studies demonstrated that heterogeneity of C2 approach was the norm and convergence did not necessarily occur over time.
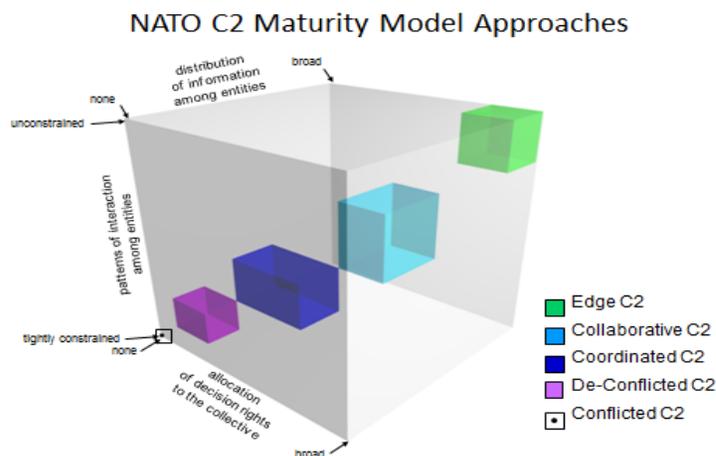
Figure A. 1: NATO C2 Maturity Model Approaches

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[3] The "conflicted" category, originally called Stand Alone (Disjointed) was added by SAS-065.

A.3 HOMOGENEITY OR HETEROGENEITY OF C2 APPROACH?

Turning now to the issues of the current SAS-085 study, a starting point for discussion is recognition that while the C2 approach of a collective in a complex endeavor will—almost by definition—be heterogeneous at the outset for diverse reasons. However, whether the C2 approach *should* evolve to a homogeneous or heterogeneous approach will depend on circumstances. That is, even the ideal will vary with the class of circumstances.

For some classes of complex endeavor, the goal might reasonably be a homogeneous approach to collective C2. The goal might not be feasible initially, but might become so over the course of the endeavor. What homogeneous character the C2 approach should have for best effectiveness would depend on the case and possibly the phase of the endeavor, the class of activities at a given time (e.g., peacekeeping versus counterinsurgent maneuvers, or surveillance versus logistics), or the geographic area.

For other classes of complex endeavor, the collective C2 approach *should* be heterogeneous (even for a particular phase, class of activities, or geography) because of irreconcilable differences in objectives and attitudes, capability differences across collective partners, or both, in which case the question becomes what that heterogeneous approach should be like, with different C2 approaches being taken within different clusters of entities.

The most important factors dictating whether the ideal collective C2 approach would be homogeneous or heterogeneous is whether the partners share objectives and enjoy mutual trust, and whether the differences in capability are small or large (see Figure A.2).   Sections A.4 and A.5 deal, respectively, with these two cases.

Capability Differences	Shared Objectives and Trust		
	Full	Partial	Minimal
Small	Homogeneous	Homogeneous?	Heterogeneous
Large	Homogeneous?	Heterogeneous	Heterogeneous

Figure A. 2: Ideal C2 for Classes of Scenario with Homogeneous or Heterogeneous C2 Approaches

A.4 C2 FOR COMPLEX ENDEAVORS FOR WHICH HOMOGENEITY OF APPROACH IS AN

APPROPRIATE IDEAL

As mentioned briefly above, complex endeavors are characterized, at least initially, by diverse military and non-military entities with different internal C2 approaches and, sometimes, conflicting objectives, priorities, or perceptions. They are nonetheless connected or networked. Thus, initial collective C2 in complex endeavors/enterprises is by definition heterogeneous. However, depending on the nature and dynamics of the endeavor and the agility of partners' C2, and provided that partners share common objectives and trust each other, the C2 approaches may converge over time[4] toward a homogeneous and appropriate collective C2 approach (Table 1). The collective approach would subsequently adapt to situational changes, but would remain homogeneous across the partners. This seems to be a plausible ideal for some complex endeavors if sufficient time is available for evolution. Another context for the ideal of eventual homogeneous C2 is in NATO defense planning. Huber and Moffat (2011) have proposed also using the "cube model" underlying the N2C2M2 (Figure 1) as a conceptual framework for the evolution of convergent defense planning in Europe, as called for by the recent NATO concept of "Smart Defense." Interestingly, this evolution will itself be a highly complex endeavor involving all European governments and numerous military and industrial stakeholders in Europe and the United States with diverging interests and objectives. In contrast to complex endeavors in the areas of combat operations, peacekeeping and stabilization as well as response to large-scale man-made and natural disasters, time is a controllable factor, at least in principle. This is confirmed by the SAS-085 validation case study on the development and testing of an agile C2 system for the security of the Vancouver Olympics (Farrell, 2010).

A.5 C2 FOR COMPLEX ENDEAVORS THAT REQUIRE HETEROGENEITY OF C2 APPROACH

A.5.1 Initial Observations

In a large class of plausible cases, a homogeneous C2 approach would not be desirable, even with the passage of time. As mentioned earlier, the SAS-065 case studies have shown that heterogeneous and non-converging collective C2 seems to be the norm rather the exception in the early phases of complex endeavors involving coalition combat, peacekeeping, stabilization, and response to large-scale natural or man-made disasters with a high degree of dynamics. More generally, however, and even as a matter of theory, homogeneous collective C2 approaches of participating entities may not even be desirable in many cases for the reasons indicated in Table 1. Because of limitations in trust and differences in capabilities, interactions and information sharing among entities, as well as the allocation of decision rights, may be deliberately limited.

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[4] Such behavior was observed by SAS-065 in studies on two complex endeavors (Katrina and Indian Ocean Tsunami 2004). However, the time spans of the characteristic phases were too short to observe the convergence processes in their entirety, leaving the impression that collective C2 in complex endeavors may be inherently heterogeneous and possibly forced to operate at the lowest common level of C2 maturity of its participating entities.

Collective C2 Maturity and C2 Agility are not easily measured when C2 is heterogeneous. Indeed, the problem of collective C2 boils down to the difficult problem of maximizing effectiveness of the endeavor given the different C2 approaches and operational capabilities of the participating entities for performing the tasks essential for success of the endeavor, and given the constraints to be considered when negotiating a heterogeneous C2 approach for the collective.

Thus, for assessing heterogeneous C2, the conceptual C2 maturity model needs to consider context-dependent considerations that permit, e.g., building task clusters that match capabilities to needs and account for sharing of objectives and degrees of trust. Thus, it is necessary to specify the endeavors in considerable degree, which necessitates use of scenarios in planning. The next section discusses such matters in more detail.

A.5.2 How to Think about C2 Approach Amidst Heterogeneity

A C2 approach for a complex endeavor may be heterogeneous in any of a number of ways:

- Values for the separate dimensions of C2 approach.[5]

- C2 approach for different entity clusters within a collective.

- C2 approaches for different functions or operations (e.g., special-forces operations, logistics, village protection, reconstruction)

- C2 approaches for different phases of the endeavor

- C2 approaches for different geographic areas

Thus, there are at least five different components of heterogeneity.

Because substantial heterogeneity is and will be the norm in complex endeavors, it becomes important to decompose complex endeavors so as to make distinctions. The syntax of narrative for comparing two fictitious complex endeavors might then be as follows:[6]

"Performance in Endeavor A was disappointing to leadership because it was only seldom possible to go beyond de-conflicted operations and, even when it was possible—as in the strike against the insurgent enclave and the evacuation of civilians from the city of Xalan, only two of the coalition partners were able to participate because others lacked the capabilities and/or requisite C2 maturity. This created severe problems because the capable partners lacked local legitimacy and their activities caused negative reactions in significant portions of the local population. Even worse, interactions

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[5] As an example, a C2 approach might involve a great deal of information sharing and patterns of interaction, but with only very circumscribed decision rights because of the potential for tactical-level actions to have adverse strategic effects.

[6] For discussion of such narrative-style discussions and numerous examples, see the case studies in the SAS-065 report.

between military-led and civilian-led activities (including those of non-government organizations) were sometimes in distinct tension, not even de-conflicted.

In contrast, Endeavor B had examples of all classes of C2 approach: when the collective most needed the edge approach, it was able to use it; in most cases, collaboration was effective, and for some purposes simple de-confliction was simple and entirely adequate. Further, both military and civilian elements of the government being supported by the collective were intimately involved in the planning and execution of highly visible and crucial operations. Activities were also de-conflicted with those of non-government organizations. Overall, this case was a success story.
Even in the second, successful case, then, the C2 approach is heterogeneous.

A.6 PREPARING NATO FOR HETEROGENEOUS C2 IN COMPLEX OPERATIONS

As noted above, the collective of complex endeavors will often involve actors with different interests and objectives, with highly varied degrees of trust among different participants, and with large differences in capabilities. This section discusses how NATO may wish to think about preparing for participating in such endeavors. In some such cases, NATO may be playing a dominant role; in others, its role will be supportive or even peripheral. Let us focus here on instances in which NATO plays either a dominant role or, at least, has a major role in planning and managing operations (i.e., a major role in at least major aspects of the endeavor's C2).

Figure A.3 sketches the primary challenge that NATO would face in that instance: working with collective members to define a sound *heterogeneous* C2 approach, one that would modularize the complex endeavor conceptually (e.g., by phase, function, and/or geography) so that partners would take on appropriate functions and enjoy appropriate C2 relationships with other partners so as to achieve the collective's primary objectives without side effects undercutting the endeavor or the collectives' continued viability. As has so often happened in past endeavors, there would be divisions of responsibility, actions to supplement capabilities (including C2 capabilities) of certain collective partners, and arrangements regarding "C2 approach."

For at least the foreseeable future, only a subset of NATO partners (or other subsets of partners) might be expected to use a common high-end C2 approach with high levels of information sharing, distribution of decision rights, and interactions—even for specific functions in specific phases and areas. Which partners could do so, however, might vary across those functions, phases, and areas. Other collective partners will be limited by their capabilities, by disagreements and diversity of some objectives, and by other considerations such as non-government organizations not wanting to work with military forces except as necessary, and vice versa. There will be shortcomings in trust, and for good reason. What, then, would a good heterogeneous C2 approach look like?
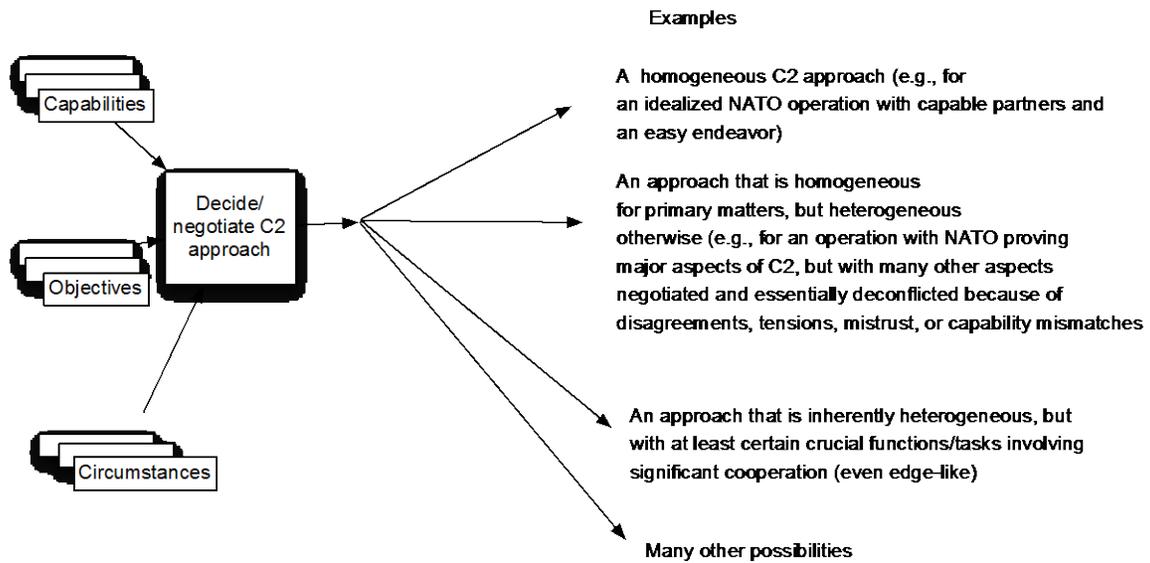
Figure A. 3: Establishing a Heterogeneous C2 Approach at a Given Point of a Specific Endeavor

It was not the function of SAS-085 to answer that question, but it is certainly an SAS-085 function to suggest objectives for NATO C2 planning. It seems clear that, in preparing capabilities for complex endeavors, NATO should want:

- To improve C2 Maturity for as many NATO members as possible so that they could, at least within NATO clusters, move easily among de-conflicted, coordinated, collaborative, and edge approaches.

- To assure that NATO is well equipped and skilled in establishing effective C2 relationships for all of the various partner-groupings, operational functions, and geographic areas involved in an endeavor. That is, NATO should be ready, if circumstances permit, to create or help create an effective web of C2 arrangements within the collective).

- As an essential enabler of the previous item, to have the capability and skill to assure: excellent knowledge of the whole (as in a Comprehensive Approach), the ability to supplement partner C2 capabilities as appropriate, and to constructively influence negotiations affecting C2 quality.

- To be able to reassess, recommend, and implement changes of C2 approach quickly and easily, even within a complex, heterogeneous overall approach.

The last item, of course, requires agility—the primary subject of the emerging SAS-085 report.

Some of the foregoing may appear to be simple and straightforward logic. We note, however, that it

requires: (1) thinking in terms of heterogeneous C2 approaches from the outset; (2) regarding the "lesser" C2 approaches (e.g., de-conflicted) as important and often-desirable building blocks for certain phases, functions, areas, and entity clusters.

To reinforce this point, we note that C2 for a complex endeavor is fundamentally different from what might be appropriate for simpler cases. In particular, because of irreconcilable differences in objectives, capabilities, and values among some collective members, trust will necessarily be limited. That implies that information sharing will be restricted. Also, it will often be necessary for national leaders to retain decision rights on many issues, to include troublesome rules of engagement that require higher-level decisions before various actions are taken that might have undesirable strategic effects (e.g., strikes on a Mosque, return of fire in areas with many civilians and uncertain adversary positions, drone strikes in particularly sensitive areas).[7] Returning to an earlier theme, we believe that the ideal of a C2 approach that moves as far outward as possible, even to the edge, is sustainable only when thinking about particular phases, functions, areas, and partner clusters. It may be crucial to give full information, interaction opportunities, and tactical decision rights to certain special forces on certain missions, but—at the same time—to be maintaining iron-fisted C2 in other aspects of an endeavor.

A.7 REPRESENTING HETEROGENEITY

Since C2 heterogeneity is often fundamental, rather a footnote matter, for discussion of C2 maturity and agility, it is necessary to have graphical ways to depict and discuss heterogeneity. No perfect solution exists because the issue is so multi-dimensional, but we can convey the primary ideas with charts such as Figure A.4, which are available to spreadsheet users as "radar charts;" they are also called spider charts. The "arms" of the chart correspond to the same dimensions as the cube model for C2 maturity: distribution of decision rights, degree of interaction, and information dissemination. These increase as distance from the origin (the center of the chart) increases. Figure A.4 depicts C2 approach separately for NATO members, for those interacting with Ally A, with those interacting with Ally B, and between Allies A and B. A chart like this can be variously used as a characterization of the overall endeavor, a particular phase, or even a specific mission. Such charts can be readily extended to have many dimensions. The cube depiction requires tedious manual construction and does not generalize.

In Figure A.4, we see that the NATO allies are assumed to operate on the Edge with respect to each other, but that the C2 approaches for NATO relating to Allies A and B are more limited and that the C2 approach relating Allies A and B is extremely limited (perhaps the entities in question want to have nothing to do with each other and have deep mistrust between them).

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[7] Characterizing such restrictions as part of command intent would allow the interpretation that (remaining) decision rights could still be broadly delegated, but that approach seems misleading.
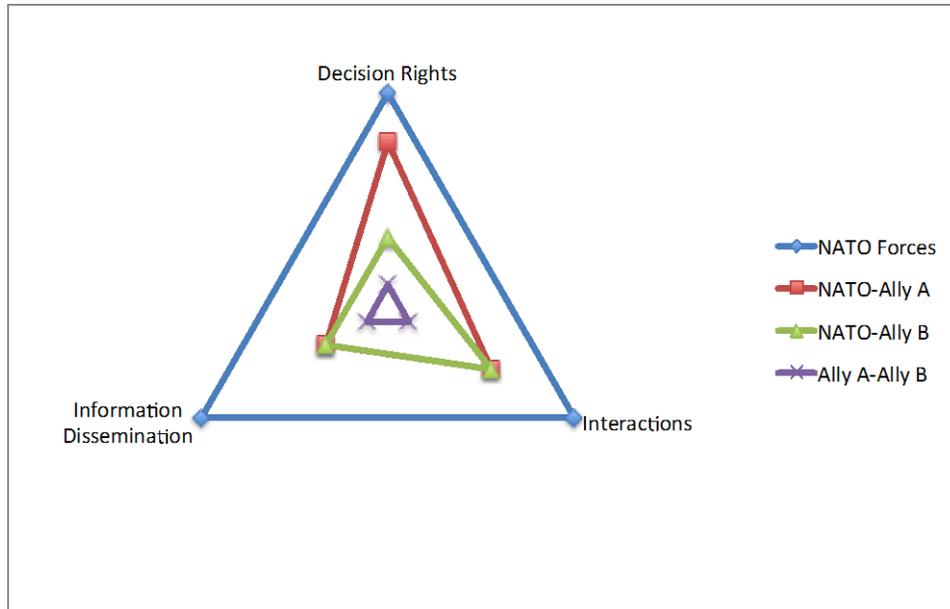
Figure A. 4: Heterogeneity of Approach in a Hypothetical Complex Endeavor

The C2 approach in this case might be very different in a later phase of the same complex endeavor, which would exhibit the agility to change approach as appropriate. Perhaps the main point here is that while the "average" C2 approach in neither pane of Figure 4 looks advanced, it might be the result of NATO having considerable C2 maturity: the ability to use Edge within NATO when appropriate, the ability to tailor the various C2 relationships consistent with levels of capability, trust, and the like, and the ability to change relationships as circumstances or mission changes within the endeavor.
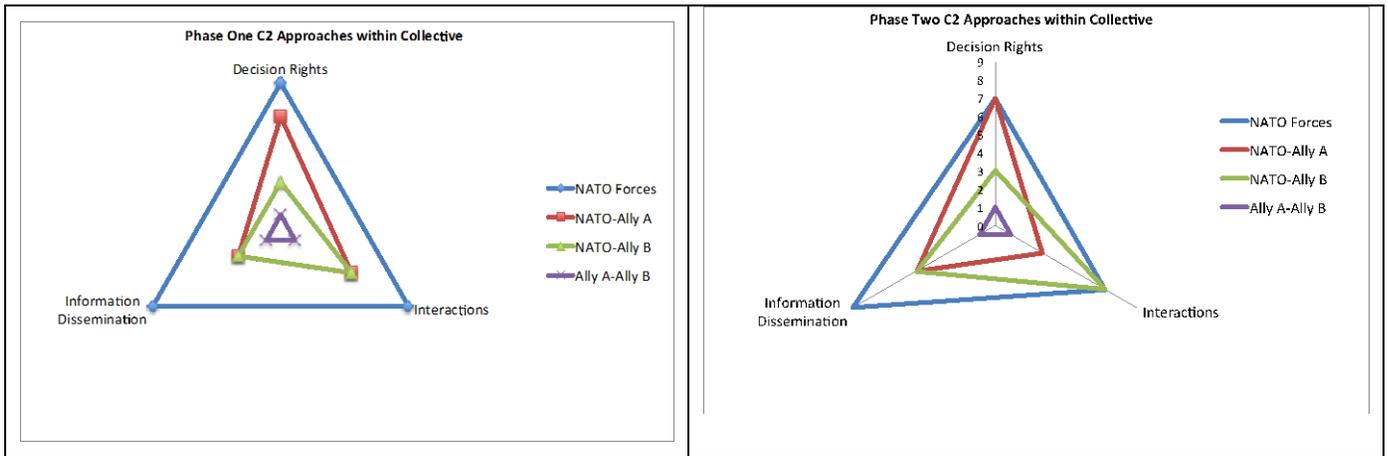
Figure A. 5:

Different C2 Approaches in Different Phases Illustrating Substantial NATO C2 Capabilities and Agility

A.8 REPRESENTING "OVERALL" C2 APPROACH

Describing the C2 approach in a complex endeavor will typically require considerable disaggregation to deal with the differences noted above. That, however, will frequently imply cumbersome detail that is not always appropriate for high-level communication. The question arises, then, as to whether and how to conceive and calculate aggregations or overviews.

A.8.1 Preferred Approach: Avoid Misleading Aggregation

By and large, we favor the approach taken in SAS-065 in connection with case studies. "The" C2 approach in a given case was characterized as within a range of, say, Conflicted to Cooperative, depending on what aspect of the endeavor was being viewed. In Figure 5, for example (Figure 32 of the SAS-065 report), we see examples of three phases in the complex endeavors responding to Hurricane Katrina, the Pakistan Earthquake, and the 2004 Indian-Ocean Tsunami. In nearly all of the phases, a variety of C2 approaches was used. In the figure, the dark ovals indicate overall characterizations, while the larger light ovals indicate the range of C2 approaches used. In the Katrina case, a collaborative C2 approach was feasible in the third phase, after infrastructure had been restored and processes had returned to pre-disaster character.
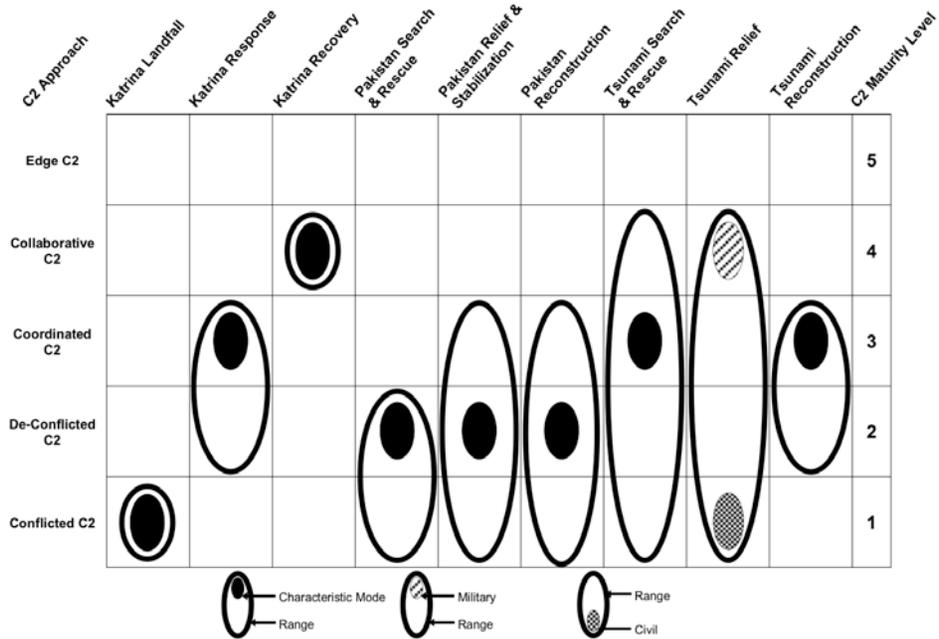
Figure A. 6: Summarizing C2 Approach with Ranges Rather than Points

The two contrasting cases in Section 3.1 were written in this same spirit. Such narrative summaries depend heavily on the subjective judgment (and integrity) of the narrator, but are arguably the most meaningful way to proceed. That said, the following paragraphs address aggregation.

Despite the virtues of *not* aggregating, what follows discusses how aggregations can be calculated— but only with a mixture of objective and subjective reasoning.

A.8.2 When Aggregation Is Necessary

We did not attempt to develop a "correct" formula for calculating the aggregate or overall C2 approach for a given historical case or future operation. Clearly, however, there will be requests for formulas to assist in developing metrics of capability and performance and allocating resources.

When efforts are made to develop such formulas, it will be essential to recognize that an overall "value" for C2 approach should probably not be seen as any simple average. Decision theory and experience tells us that it is often necessary to use nonlinear formulations and to consult experts in highly structured discussions. Naïve use of even *weighted* sums often proves seriously misleading. Further, it is often necessary to have iterative discussions with decision makers so that any metrics

developed reflect the intended values, including degree of risk-aversion. Aggregation is not merely a "mathematical" exercise.[8]

Resolving such matters would be an appropriate topic for future work, but is beyond the scope of this study. Nonetheless, Figure A.7 illustrates some of the issues. To do so, it considers four different complex endeavors with different characters. It assumes that the C2 approach of Figure 5 applies in all of them. It then asks how the "overall C2 approach" might be evaluated in the four scenarios. The results vary substantially because the evaluations reflect scenario character. In the first scenario, NATO is assumed to dominate the endeavor. In the second, NATO and Ally A carry most of the burden. In the third, NATO is merely supporting Ally A, which is the dominant entity. In the last scenario, it is assumed that all of the partners play critical roles. Our primary point here is merely to recognize that aggregate measures will be needed and that establishing the most sound analytic approach for calculating them will require time and effort. *In the meantime, the best approach is—as in SAS-065—to avoid aggregations and instead to show the range of C2-approach scores that applied in a given case study or that would apply in a hypothetical scenario.*
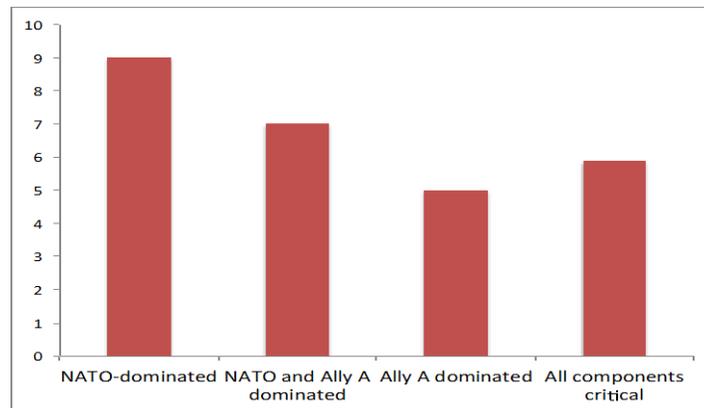

Figure A. 7: Illustrative Evaluations of Aggregate C2 Approach for Four Scenarios

IN WHICH THE C2 APPROACH IS THE SAME

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[8] The importance of nonlinear evaluations is discussed in Davis (2002), a RAND primer on capabilities-based planning and documentation of a related tool for portfolio analysis (Davis and Dreyer, 2009).

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