

Agile Multi-Domain Command and Control

— Key to Managing Cyber Risk to Mission —

Dr. David S. Alberts

Introduction

Network Centric Warfare and the subsequent development of a ‘robustly networked force’¹ signaled the beginning of an era of increasing dependence on information-related technologies, referred to today as ‘Cyber.’ Cyber capabilities now extend far beyond networking to cyber-enabled capabilities that include both intelligent software and autonomous capabilities built into platforms and weapons systems. It is now hard to imagine any military operation that will not depend upon cyber or cyber-enabled capabilities.

Concurrent with these technology-related developments has been the growing appreciation of the importance of assembling heterogeneous collections of military and civilian entities and the need to find ways to effectively command and control, govern and/or manage these collectives to achieve shared objectives. These operations in multiple domains are quite different from earlier, all military instantiations², placing new demands on C2.

This century has also seen the transformation of Cyber from just an enabler of warfighting to an operational domain of its own alongside of the traditional physical domains of Land, Maritime, Air, and Space. This has stimulated efforts to explore the appropriateness of different approaches to C2 for Cyberspace Operations and how different Cyberspace Operations³ can be effectively integrated with each other as well as kinetic operations.

These major developments are having a profound effect upon our ability to effectively command and control military organizations, particularly when they participate in Complex Endeavors⁴. As a result,

¹ DoD Report to the Congress on Network Centric Warfare, 2001

² Alberts, David S., Multi-Doman Operations: What’s New, What’s Not?, 23rd ICCRTS, 2018.

³ Cyberspace Operations include Defense, Offensive, and Support to other missions

⁴ Alberts, David S. and Richard E. Hayes, Planning Complex Endeavors, CCRP Publication Series, Washington DC, 2007

traditional approaches to command and control may not be up to the task. This paper looks at how we have reached this point and provides a way ahead in the form of a conceptual model of command and control that is more appropriate for today's missions. This model is referred to as an Agile Multi-Domain Command and Control.

A Historical Perspective

The development and adoption of new warfighting technology follows a predictable pattern from initial skepticism that slows its introduction, through a period of co-evolution where strategy, tactics, doctrine and organization are adapted to take advantage of the new technology and, in parallel, the development of a cycle of counter and counter-counter measures that seek to exploit and remedy vulnerabilities.

In the mid-1990s, the Center for Advanced Concepts and Technology at the National Defense University published “Defensive Information Warfare”⁵ which warned that “There is a growing consensus that national prosperity, if not survival, depends upon our ability to effectively leverage information technology. Without being able to defend vital information, information processes, and information systems, such a strategy is doomed to failure.” This is a recognition that Cyber is following the age-old pattern of measure, counter-measure, and counter-counter-measure in the form of a networked-enabled force, attacks on the cyber capabilities of the force, and defensive cyberspace operations.

The 2018 DoD Cyber Strategy⁶ echoes the warning contained in the 1996 National Defense University's publication of “Defensive Information Warfare.” The strategy observed that our adversaries “have expanded strategic competition to include persistent campaigns in and through cyberspace and that poses long-term strategic risk to the Nation as well as our allies and partners.” Among the strategy's objectives are

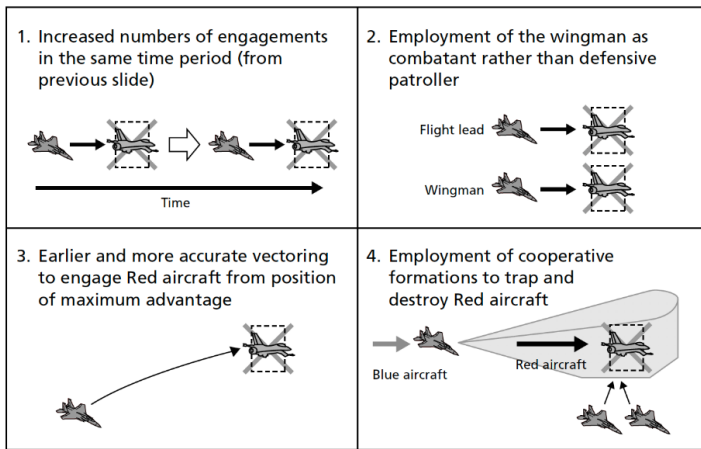
⁵ Alberts, David S., *Defensive Information Warfare*, CCRP Publication Series, Washington DC, 1996

⁶ https://media.defense.gov/2018/Sep/18/2002041658/-1/1/1/CYBER_STRATEGY_SUMMARY_FINAL.PDF.

“Ensuring the Joint force can achieve its missions in a contested cyberspace environment.”

The following air-air combat example illustrates both the warfighting advantage that has been realized as well as the mission risk if this cyber-enabled advantage is successfully countered by an adversary. A study funded by the DoD Office of Force Transformation⁷ found that we were able to increase kill ratios 2 ½ fold, from 3.10 to 8.11 for daytime engagements and from 3.66 to 9.40 for night engagements by taking advantage of the increased shared awareness of the battlespace that could be achieved with Link 16. This increased shared awareness enabled tactics that were not possible using voice communications.

Figure 1 Tactics Enabled by the Increased Shared Awareness provided by LINK 16



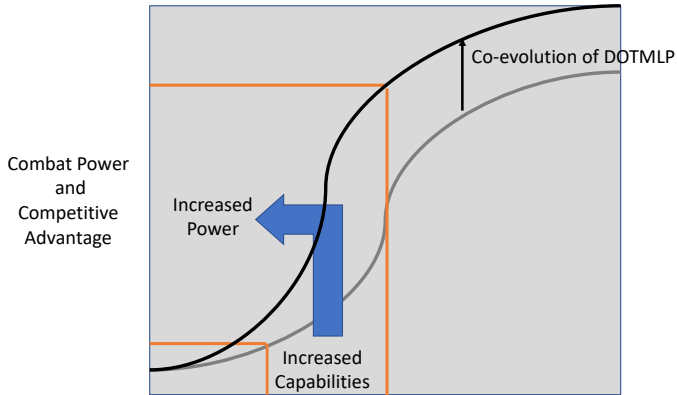
(Source) Network-Centric Operations Case Study -Air-to-Air Combat

with and without Link-16 Example: Mission: Air to Air Combat, Gonzales, D. et. Al, RAND National Defense Research Institute, 2005.

⁷ Network-Centric Operations Case Study – Air-to-Air Combat with and without Link-16 Example: Mission: Air to Air Combat, Gonzales, D. et. Al, RAND National Defense Research Institute, 2005.

Figure 2 depicts the increase in combat power or competitive advantage as a function of both increased capabilities and co-evolved doctrine, organization, DOTMLP⁸.

Figure 2 Combat Power = Increased Capability + Co-evolution



(source) Authors own.

Cyber Risk to Mission

Cyber Risk to Mission is present whenever the cyber or cyber-enabled capabilities upon which a commander depends fail to match operational expectations. Having all of the capabilities desired to plan and execute a mission is not the norm. Successful commanders understand that there will be times when their personnel, materiel, and systems will not be available or will not function as expected when they are most needed. Therefore, they regularly assess the readiness of their Forces, and anticipate, prepare, and plan for situations when their capabilities might be limited. We are just beginning to appreciate and incorporate the threats to cyber capability into our overall risk calculations and operational planning.

A Threat is anything that can cause damage to a capability. Damage includes anything that prevents us from effectively and

⁸ DOTMLPF is an acronym used by the United States Department of Defense. As defined in The Joint Capabilities Integration Development System DOTMLP = doctrine, organization, training, materiel, leadership and education, personnel.

efficiently employing the capability in question. Thus, threats to cyber and cyber-enabled capabilities include events that can destroy, degrade, disrupt, compromise, and thus, deny us the use of our full complement of cyber and cyber-enabled capabilities.

Threats to the availability, functionality, performance, assurance, security of, and/or our confidence in, our cyber capabilities come from many sources, including the following:

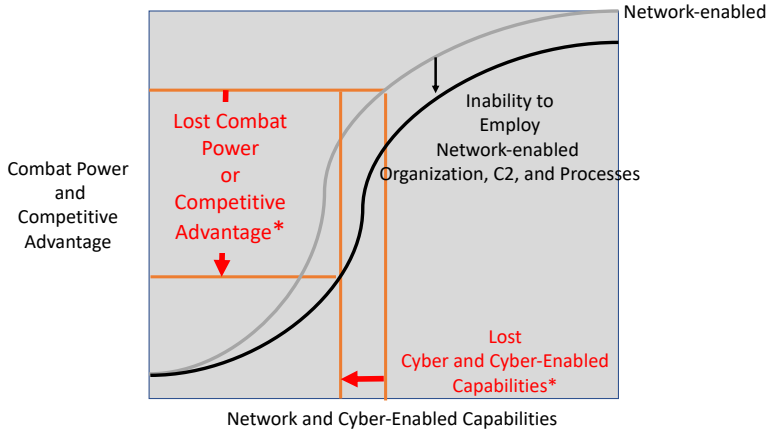
- Adversary actions
- Collateral damage from defending against real or imagined adversary actions
- Characteristics / Complexities of Cyber Capabilities
- Unanticipated behavior of ‘intelligent’ software / decision aids
- Volatility of the Cyber Environment
- Collateral damage from cyberattacks on others
- Mistakes, Accidents, Poor Cyber Hygiene
- Critical infrastructure Damage, Degradation, Disruption, Denial, Destruction

Thus, the sources of cyber risk are varied. Identifying these sources are important as it helps to find ways to avoid or reduce the probability of their occurrence and hence, the probability of damage. Preventing events that would otherwise cause damage and/or reducing the probability of their occurrences is the first line of a layered defense. Good cyber-hygiene, that is, engaging in best cyber security practices, is an example of a preventive measure.

CRM is not about the potential damage to cyber and cyber-enabled capabilities per se; rather, it is about the resulting risk to mission. Cyber Risk to Mission is a function of both the likelihood of damage to cyber and cyber-enabled capabilities and the adverse mission consequences that ultimately can result from the extent and duration of the damage.

As Figure 3 graphically demonstrates, a failure to understand and manage Cyber Risk to Mission will result in our losing the warfighting advantages of a cyber-enabled Force.

Figure 3 Impact of Lost cyber Capabilities



(source) Authors own.

The remainder of this paper is devoted to explaining a new conceptual model featuring the Multi-Domain Command and Control-Harmonization (MDC2-H) Arrangements Space and the role of agile MDC2-H in managing CRM. It begins with an explanation of what a multi-domain approach to command and control is and how various MDC2-H arrangements differ from one another. The paper goes on to explain C2 Agility Theory and why Agile MDC2-H is needed to manage CRM for today’s more challenging missions.

Multi-Domain Command and Control - Harmonization (MDC2-H) ⁹

Not all operations that involve more than one domain require an agile, multi-domain approach to command control. Multi-Domain C2 as this term is used in this paper, is necessary and appropriate for those operations that involve: 1) one or more entities operating in and/or

⁹ This discussion is based upon work in progress by NATO Research Group SAS-143. Their final report is due mid 2022.

creating effects in more than one domain; and 2) the domain operations themselves and/or the effects created by these operations are not totally independent of one another¹⁰.

This lack of operational independence requires that the set of domain operations that comprise the MDO needs to be considered holistically rather than individually as entities have done previously.

As a result, entities participating in an MDO with these characteristics need to establish appropriate working relationships between and among other entities in order to individually and collectively manage these dependencies. Ignoring these dependencies can prevent synergies and create impediments to achieving desired outcomes.

The need for appropriate working relationships between and among entities may require adaptations to the C2 approach that individually entities traditional adopt.

Mastering the art of MDC2-H will be more important for operations that have or more of the following attributes:

- 1) a heterogeneous set of JIMP actors (Joint, Interagency, Multinational, Public), at least some of whom are independent of each other actors operating in at least two of the three domain categories¹¹
- 2) physical, virtual, and social effects being created in two or more of the domain categories

¹⁰ If no significant dependencies exist between entities operating in the same or different domains, these are, in effect, separate operations and hence do require working relationships between and among the entities and do not require a MDC2-H Arrangement.

¹¹ For the purposes of this paper, three categories of domains are considered: the physical, virtual and social domain. Land, maritime, air and space operations take place in the physical domain. Cyberspace operations take place in the virtual domain. Diplomacy and psychological operations take place in the social domain.

- 3) dependencies between operations and/or activities, whether in the same or different domains, that could interfere with or constrain one another and result in adverse mission impacts
- 4) opportunities for synergies between operations and/or activities provided they are appropriately synchronized¹²
- 5) dependencies between and among effects created by different actors or the same actor in different domains

The interdependencies between and among entities engaged in an MDO make it necessary for these entities to find ways to avoid operational conflicts and/or generate synergies in order to achieve their objectives. To accomplish this, the set of MDO entities need to, in order to be as effective and efficient as they can be, coalesce into and operate *as if* they were an Enterprise¹³ that shares an overall objective in an ecosystem. Given the increasing dependence that entities have on technology in general and cyber-enabled capabilities in particular, this enterprise is, in fact, a Socio-Technical Enterprise¹⁴.

The task of transforming a set of independent actors¹⁵ into an effective enterprise requires some form of collective self-organization and governance that complements the ways that participating entities organize and manage themselves. Since, 21st Century MDO require more than military organizations alone to accomplish their objectives,

¹² Activities are appropriately synchronized when mission constraints are satisfied (e.g. operation A cannot begin before Operation B has concluded) and the measures of mission effectiveness and efficiency are sufficient to deem the MDO a success.

¹³ The term Enterprise is interpreted in some communities as having both some permanence and a formal structure that contributes to the ability of its constitute parts to work together. The MDO Enterprise considered here is simply a collection of entities that choose to work together in some fashion, for some period of time. Some of these entities may, in fact, be part of a larger formal organization or institution while others may belong to another larger organization or be completely independent. The point being is that success will depend upon their working together as if they were an Enterprise.

¹⁴ Socio-technical enterprises are those that delegate significant autonomy and decision rights to non-human intelligent collaborators.

¹⁵ Not all of the actors are necessarily independent thus, there is no single chain of command.

the approach that traditional military organizations and coalitions of military organizations have long employed, namely, Command and Control doctrine, organization, and processes are not necessarily appropriate for the following three reasons:

- C2 is understood to mean that someone must be in charge, and for the MDO Enterprise as a whole this will not be the case
- C2 is not universally seen as the functional equivalent of governance or management arrangements
- C2 is not applicable to some of the possible arrangements between and among all of the participating entities.

Therefore, the term Multi-Domain C2/Harmonization (MDC2-H) to refer to the heterogeneous set of C2-Governance-Management arrangements that shape the behavior of the entities individually, in subsets, and collectively would be more appropriate. Thus, the task of transforming the set of entities into an effective enterprise falls to all the participating entities and the mechanism they employ to achieve this is the MDC2-H Arrangement that is negotiated or emerges from the set of decisions taken by the individual entities. In the case where parents organizations exist, they may dictate, limit (set conditions and establish constraints), and/or support the nature these arrangements. The objective of the adopted MDC2-H Arrangement is to avoid conflicts and enable synergies within, between, and among actors operating in multiple domains, and the effects that these operations or activities create.

Multi-Domain C2-Harmonization Arrangement Space

To systematically explore the appropriateness of different MDC2-H Arrangements, a C2 Approach Space specifically designed for MDO is needed. To accomplish this, we need to take a closer look at not only how different entities manage their own activities when they participate in MDO, but also how they influence and collaborate with each other. This will help us to understand how the working arrangements within

their organizations and the arrangements made other with entities need to be adapted to different Multi Domain Operation challenges and circumstances.

Existing C2 Theory¹⁶ provides a set of C2 approaches to consider as well as a methodology for determining the appropriateness of each of these C2 approaches given the mission and circumstances. The tenets of C2 Agility Theory and much of the empirical C2 research conducted over the past several decades are applicable to some non-military organizations as well; particularly to those that have a hierarchical structure. But these tenets need to be re-examined for these complex MDO.

Applying C2 theory to a single entity engaged in a single domain of operations can be relatively straightforward. However, when multiple entities are involved in a single domain or when multiple domains are involved the theory is still applicable but needs to be extended to include the harmonization arrangements between and among independent actors operating in the same or different domains. Thus, the MDC2-H conceptual framework presented here is based upon an extension and application of the C2 Approach Space.

While initially the C2 Approach Space was developed for a single military organization with a unified chain of command, NATO SAS-065¹⁷ recognized the need to re-conceptualize the C2 Approach Space for the kind of heterogeneous collections of entities that are typical in the MDO considered here.

To call attention to this need, SAS-065 created a “Collective C2 Approach Space” by re-labeling the dimensions of the entity C2 Approach¹⁸. The “allocation of decision rights” was relabeled as “allocation of decision rights between and among the entities”. This was an attempt to look at the collection of entities holistically. In doing so,

¹⁶ NATO Research Group Final Reports of SAS-065, SAS-085

¹⁷ NATO Research Group SAS-065, NATO NEC C2 Maturity Model.

¹⁸Entities are composed of individual members who have assigned roles and responsibilities. Individuals may be humans or ‘non-human intelligent collaborators (NIC) as discussed in Chapter 6. The term ‘between entities’ refers to an interaction between 1) a member of one team and a member or another team, 2) a member of one team and a website belonging to another team, and 3) interactions between websites belonging to different teams.

they assumed that a collective could be adequately be described in much the same way as an entity, that is, by associating the collective with a single C2 Approach. Given that many entities are very large and that individual ‘divisions’ or sub-organizations do, in fact, approach C2 differently, this made a lot of sense. While the space they developed and applied provides valuable insights, it does not explicitly focus on:

- 1) the need to distinguish between within Entity C2 and the harmonization arrangements between and among entities as these are not necessarily “C2”.
- 2) differences between entities (military, civilian) and how that impacts their C2, management, or governance options
- 3) differences between domains and the nature of the operations within these domains and how that impact their C2 options
- 4) differences between within-domain and cross-domain harmonization arrangements

Therefore, the MDC2-H Arrangements Space focuses on both within entities approaches and between entity arrangements. The decision to call this the MDC2-H Arrangements Space. (rather than Approach Space) however, places an emphasis on the arrangements between and among entities. This is apt because an MDO can only succeed if proper attention is placed upon these between entity arrangements. Furthermore, this emphasis is needed to encourage entities that have a tendency to focus, first and foremost, only on their own C2 approaches and fail to recognize and consider the need to adapt their preferred approaches for the MDO.

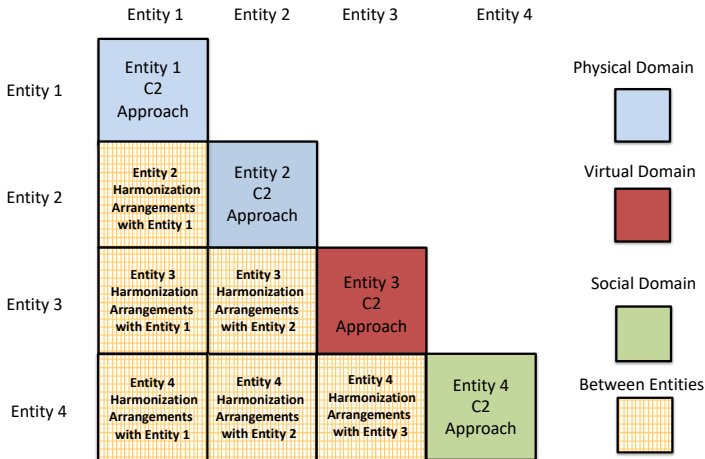
The MDC2-H Arrangements Space, will enable entities to:

- understand the full range of MDC2-H options available to them when they participate in an MDO
- assess the appropriateness of specific options they wish to consider for these operations

- design and conduct experiments and analyses of MDC2-H Arrangements
- identify the characteristics of an observed MDC2-H Arrangement for a case study
- specify an MDC2-H Arrangement for a given MDO (that includes their own ‘C2’ Approach)

Figure 4 depicts the MDC2-H Arrangement Space for an MDO with four participating entities operating in three domain categories (physical, virtual, social). Each cell of the Arrangement Space can take on one of a set of options. When a particular approach or arrangement is selected for each of the cells of this matrix, a particular MDC2-H Arrangement is specified.

Figure 4 MDC2-H Arrangements Space with Reciprocal Harmonization Arrangements

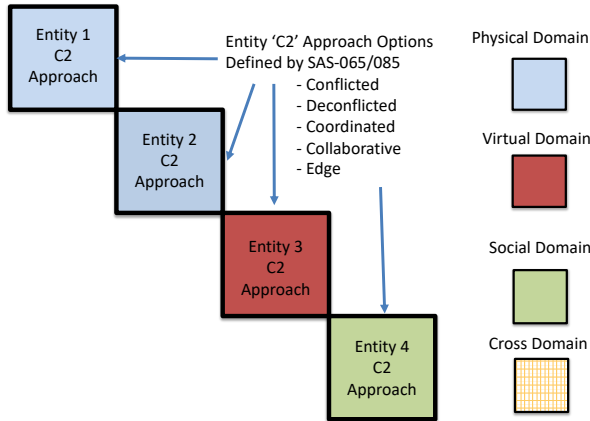


(source) NATO SAS-143 unpublished

A MDC2-H Arrangement is constructed with two basic types of building blocks. One type of building block, depicted in Figure 5, is used to represent the approach each entity adopts to manage its domain

operations, referred to as ‘Entity C2’¹⁹. These blocks comprise the diagonal of the MDC2-H Arrangements Space (matrix).

Figure 5 Diagonal of the MDC2-H Arrangements Space

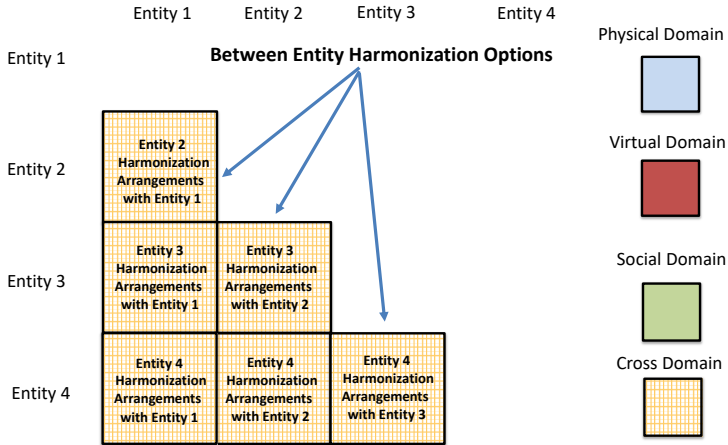


(source) NATO SAS-143 unpublished

The other type of building block, depicted in Figure 6, is used to specify harmonization arrangements between every pair of entities. These types of building blocks populate the remainder of the cells (off diagonal) in the MDC2 Arrangements Space matrix. These may be either with domain or cross-domain. It is important to recognize that an absence of a working relationship between a given pair of entities is a choice. Thus, the between entity arrangement options available (off-diagonal cells) to entities range from ‘none’ to ‘integration’, where two entities choose to operate as one. For MDO operations with n participating entities, the MDC2-H Arrangements Space (assuming harmonization arrangements are reciprocal) there are n blocks on the diagonal and there are $(n^2-n)/2$ off-diagonal blocks. Thus, for MDO that involve many participating entities, the number of possible arrangements grows quite large. Therefore, we will need to look at ways to reduce the choices so that finding an appropriate approach (if not the best approach) is manageable.

¹⁹ ‘C2’ here is a shorthand to include command and control, governance, and management approaches employed by an entity.

Figure 6 Off-Diagonal Options of the MDC2-H Arrangements Space



(source) NATO SAS-143 unpublished

The depiction of the MDC2-H Arrangements Space in Figure 6 assumes that harmonization arrangements are reciprocal. When this is not the case, the MDC2-H Arrangements Space will contain two harmonization arrangements for each pair of entities, the first Entity A → Entity B, the second, Entity A ← Entity B. Each cell in the MDC2-H Arrangements Space represents a set of options.

For the diagonal cells, the possible set of approach options can be found in the C2 Approach Space that has been described and analyzed by a number of NATO research groups. The C2 Approach Space is the subject of the next section. For the off-diagonal cells, the possible set of harmonization arrangement options ranging from ‘none’ to ‘integrated’ will be discussed in the section entitled Harmonization Arrangements.

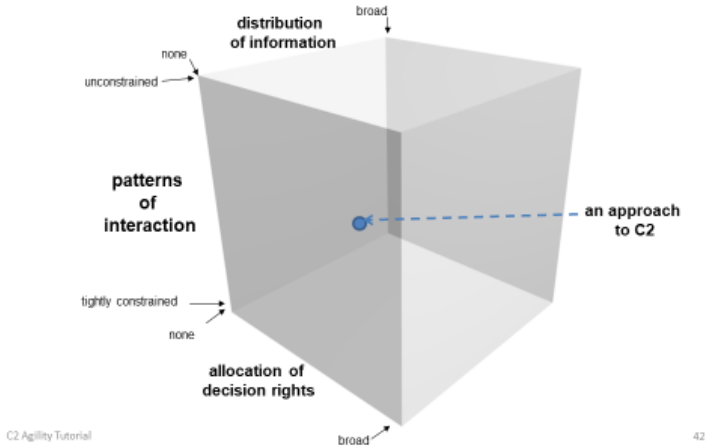
Entity C2 Approach Space²⁰

The concept of the C2 Approach Space, depicted in Figure 7, is based upon considering three aspects of how entities manage themselves. These aspects form the following dimensions: 1) the allocation of decision rights, that is, who in the organization gets to

²⁰ NATO Research Group SAS-050, Exploring New Command and Control Concepts and Capabilities, Final Report, 2006.

make which decisions; 2) the pattern of internal interactions (who interacts with whom both informally and as specified by organizational processes; and, 3) how information is disseminated within the entity.

Figure 7 C2 Approach Space



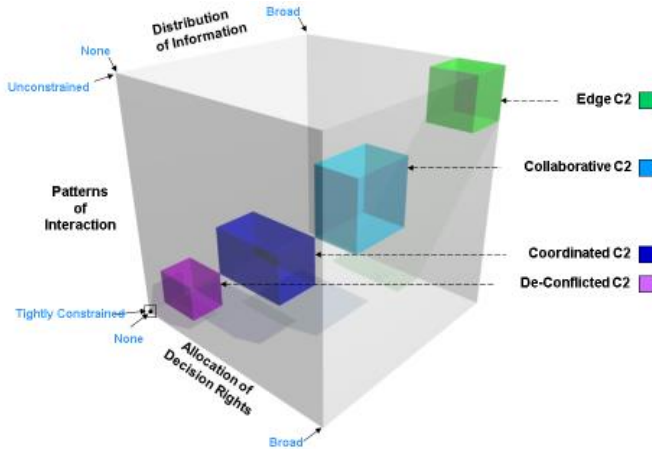
(source) NATO Research Group SAS-050, Exploring New Command and Control Concepts and Capabilities, Final Report, 2006

The concept of the C2 Approach Space can be applied to teams, and organizations that consist of humans as well as non-human entities such as non-human intelligent collaborators (NIC) that take the form of software agents and systems. A particular C2 Approach represents a point or region within the C2 Approach Space.

A considerable amount of research and analysis has involved a set of C2 Approaches that represent approaches that various organizations have employed in a variety of operations and that conceptually fall along the diagonal of the C2 Approach Space, as depicted in Figure 7. As the location of the C2 Approach moves away from the lower left-hand corner of the C2 Approach Space the approaches become more network-enabled, that is, there is increased delegation of decision rights accompanied by less restricted patterns of interactions and wider dissemination of information. Five specific C2 Approaches are depicted in Figure 8. The

NATO NEC C2 Maturity Model²¹ associates increased maturity with an entity’s ability to adopt more network-enabled approaches, from a De-conflicted C2 Approach typical of that of a traditional military hierarchy to an Edge C2 Approach that features emergent behaviors and self-synchronization within an entity.

Figure 8 NATO NEC C2 Maturity Model Approaches



(source) NATO Research Group SAS-065, NATO NEC C2 MaturityModel, CCRP Publications, Washington, DC, 2010

To complete the specification of a MDC2-H Arrangement, each entity will need to select a Harmonization to employ for each of the relationships it has with other entities. The Harmonization options NATO SAS-143 specified are discussed in the next section.

Harmonization Arrangements²²

The section introduces ²³ the Harmonization arrangements developed by NATO SAS-143. These provide a ‘scale’ or continuum of

²¹ NATO Research Group SAS-065, NATO NEC C2 Maturity Model, CCRP Publications, Washington, DC, 2010.

²² Aletta Eikelboom was instrumental in this effort.

²³ This discussion simply serves to introduce these options. A more detailed discussion and the results of related experiments will appear in the final report of this group scheduled for mid-2022.

ways in which a given pair of entities could work together (or not). Given that MDO will likely involve some participants who have not previously established a way of working together (an arrangement) it should be expected that their relationship will evolve overtime. This does not mean that they will progress to developing very close relationships, rather that they will improve their ability to work together. Their collaboration will be subject to the limitations that one, both, or technological capabilities place on the relationship²⁴.

In the discussion of the different harmonization arrangements below, it is important to note that the entities considered are operating or deployed forces, that is, they are entities that have chosen to participate in the MDO or, have been directed to participate by their parent organization. Entities with ‘parents’ need to be ‘empowered’ to enter into Harmonization Arrangements. The degree to which entities with parents are empowered corresponds to the decision rights that parents delegate to their deployed forces, the information accesses they have, and in selected cases, other forms of support.

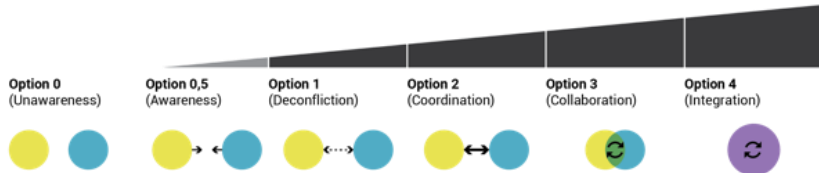
The NetForce program in the Netherlands²⁵ has made important contributions to understanding the richness and dynamics of these arrangements. Three major ideas drawn from NetForce were added to the descriptions of the Harmonization Options. The first is the persistence of the arrangement (temporary v. enduring) considered in NetForce. The second is the extent of “orchestration” that a “parent” organization engages in. While this aspect of harmonization is implicitly captured by the delegation of decision rights to individuals that are member of Task Groups, the NetForce orchestration concept considers this explicitly having identified eight more or less distinct manifestations of orchestration (forms of collective governance). The third involved the dynamics of harmonization that is discussed later in this report.

²⁴ Constraints as to the way one entity can work with another may be determined by an Entity’s ‘parent’ organization or by the leadership of the Entity (or a combination of both).

²⁵ NetForce Command: An Alternative for Command and Control in a Changing World, TNO, 2019.

Entities can work together with or without forming a Task Group. When Task Groups are formed, they have a C2 Approach of their own. This approach can differ from the C2 approach adopted by the entities who are contributing members and the harmonization arrangements between the two entities.

Figure 9 Harmonization Scale



(source) NATO SAS-143 unpublished

The Harmonization Arrangements Scale depicted in Figure 9 represents the ‘closeness’ of the working relationship between any pair of Entities, or when applicable, between an Entity and a Task Group or between two Task Groups. The Harmonization Arrangements Scale has six options, from Option 0 to Option 4. Option 0 covers the situation in which there is no working relationship (in fact, in Option 0 the entities are not even aware of each other) while option 4 represents the integration of two entities, the closest kind of working relationship. There will be, of course, variation within each of these options in reality. *Note that each entity that is participating in a collective (MDO) is expected to have its own (internal) approach to command and control (management or governance), one that may or may not be compatible with the approach adopted (or defaulted into) by the coalition or collective.*

Harmonization Arrangement Option 0: Unawareness

The entities have no awareness of each other. There is no recognition of a shared collective objective. The only C2 that exists is that which is exercised by the individual contributors over their own forces or organization. There is no distribution of information between

or among the entities; all of the decision rights remain within each of the entities, and there are no interactions between or among the entities. In the case of pre-harmonization state, all interactions that occur between and among individuals are within their respective entities. There are no cross-entity interaction.

Harmonization Arrangement Option 0.5: Awareness

Option 0.5 can be seen as a prerequisite for harmonization. To varying degrees the following set of conditions need to be in place in order for two entities to achieve some degree of harmonization. First, there needs to be some knowledge of each other. Second, there needs to be a mutual recognition of and some understanding of their dependency. Third, there needs to be a willingness to modify behavior including a willingness to adopt necessary technology. A modification of behavior does not need to involve any direct interaction with the other entity; it could be simply an adjustment to behavior as a result of awareness. An appropriate analogy could be individuals walking through a crowd. While not actively engaging in coordination, people still mostly avoid bumping into each other as a result of awareness and assumptions about others' intentions.

Harmonization Arrangement Option 1: Deconfliction

The objective of entities that adopt an Option 1 Harmonization Arrangement is the avoidance of adverse cross-impacts between and among the participants by partitioning the problem space. In order for entities to de-conflict their intents, plans, or actions, they need to be able to recognize potential conflicts and attempt to resolve them by partitioning across geography, function, echelon, and/or time. This involves limited information sharing and limited interactions.

Opting for an Option 1 Harmonization arrangement requires that entities give up total freedom to operate. Participating entities agree not to act in a manner that violates any agreed upon constraint made for the benefit of the entities individually and collectively. This is the most limited form of 'collective decision rights' in the set of Harmonization Arrangement options considered here and involves minimal, episodic

interactions; just those interactions necessary to understand potential conflicts and agree to some constraints on their behavior. In this case, the interaction shown involves each entity's designated decision maker. No other interactions between entities are involved.

An Option 1 Harmonization Arrangement could be adopted each with entities adopting the same or different approaches to command and control, management or governance. If we consider Hierarchy, Coordinated, Collaborative and Edge as the set of possible entity C2 approaches, this amounts to 16 possible configurations for any two entities working together at a given Harmonization Option²⁶.

Harmonization Arrangement Option 2: Coordination

The objective of entities that adopt an Option 2 Harmonization Arrangement is to develop, for some aspect of their respective operations, a degree of mutual intent and an agreement to shape or adjust their respective plans and operations in order to enhance their capabilities and the effects they are able to create. To achieve this level of integration, each entity requires timely awareness of the other's relevant plans and actions, an understanding of how these plans and actions can impact each other, and frequent enough interactions to ensure that things are still on track. It also involves the willingness to make appropriate modifications in their plans and processes.

The acceptance of these constraints and/or modifications to their operations amount to delegating decision rights to the collective. In an Option 2 Harmonization Arrangement, entities each still have their own plan. However, they are willing and able to continue to adjust their plans as necessary to avoid conflicts and generate synergies as the situation evolves. The 'closeness' with which the individuals who are responsible for keeping an aspect of a plan aligned can vary. In an Option 2 Harmonization Arrangement, they remain more involved with their respective entity and their cross-entity interactions do not dominate their activities. An Option 2 Harmonization Arrangement may involve material support to each other. To achieve this level of

²⁶ The number 16 is based upon there being 4 C2 Approach Options available to each of the two Entities.

integration requires an acceptance of some mutual dependencies (risk) and a measure of trust.

Opting for this level of integration requires a significant amount of information sharing (broader dissemination) and a richer set of interactions, both formal and informal (relative to those required for Option 1), among those in the various elements that are involved in aligning intents, adjusting/aligning plans, and those implementing the plans. While the interactions required may be quite frequent, they do not approach continuous interaction.

Harmonization Arrangement Option 3: Collaboration

The objective of entities that adopt an Option 3 Harmonization is to develop significant synergies by (1) negotiating and establishing collective intent and a shared plan, (2) establishing or reconfiguring roles, (3) coupling actions, (4) rich sharing of non-organic resources²⁷, (5) some pooling of organic resources, that is those owned by a participant. They may include vehicles, weapons, and local supplies), and (6) increasing interactions to increase shared awareness.

Option 3 involves developing synergies and close relationships between the entities, more than common intent as with an Option 2. This closer relationship is often characterized by the establishment of a Task Group, a temporary composition of members of both entities who will collaboratively develop a shared plan to address a specific operation or ‘problem’ in the endeavor space. Once an integrated plan has been developed, the entities retain the rights to develop supporting plans and to dynamically adjust these plans collaboratively as long as they are supportive of the integrated plan. Entities may also develop ‘individual’ plans for their own operations, as long as they do not interfere with the mutual plan. Entities may have other intents as long as they do not conflict with, or detract from, common intent.

²⁷ Organic resources are those that belong to the entity employing them while non-organic resources are those that are not owned by the entity employing them. As an example, Entity 1 provides track data or satcom bandwidth with Entity 2. For Entity 1 these are organic resources while for Entity 2 these are non-organic resources.

Entities employing an Option 3 Harmonization Arrangement accept mutual interdependence and a symbiotic relationship. The development of an Option 3 Harmonization Arrangement is facilitated by mutual appreciation of each other's culture, organization, processes, and respective limitations. An effective Option 3 Harmonization arrangement is presumed to require that each entity adopt at least a Collaborative C2 Approach.

A Task Group, comparable to subnetworks in NetForce²⁸ that persist for the duration of the operation, differs from the existence of cross-entity interactions between and among a set of individuals in three important ways. First, the interactions between and among members of a Task Group are persistent. Second, the individuals in a Task Group work more closely with one another than they do with members of their entity (while the task group is in existence). And most importantly, task-related decision rights are delegated from the entities that participate in the Task Group to the Task Group. Overall the balance of interactions within and between entities become more equal as the number and size of Task Group(s) grow.

Membership in a Task Group can come with different rules of engagement. These rules are established by the participating entities and define the decision rights (some of which may be conditional), set constraints on information sharing and for working with members of the Task Group from other entities, and establish reporting requirements for members back to their originating entities. It should be noted that simply delegating a decision right does not ensure that this right will be exercised. A host of factors will determine how comfortable a Task Group member will be in exercising delegated rights and working with members from other entities. These include home organization culture, 'hardness'²⁹ of the Task Group, training, and the specifics of the situation.

²⁸ Ibid NetForce

²⁹ The term hardness, when used in the context of a team, refers to the degree to which they have developed cohesion and learned to function effectively and efficiently.

A Task Group can develop its ‘own’ C2 approach. This may vary from Hierarchy to Edge. However, one can assume that the C2 Approach adopted by the Task Group will not be less ‘networked’ than the C2 Approach of the entities from which they come. Thus, if the entities that have formed the Task Group have adopted a Collaborative C2 Approach, it can be assumed the Task Group will adopt at least a Collaborative C2 Approach.

Harmonization Arrangement Option 4: Integration

The objective of entities that adopt an Option 4 Harmonization Arrangement is to enable the entities to operate as an integrated and agile entity³⁰. Meaning the entities themselves no longer exist from an organizational perspective. The integration can be seen as an ‘new’ (temporary) organization comparable to a large Task Group. The integrated organization will develop their intent, plans etc. as if it is ‘one’. Sufficient decision rights must be delegated by entities to the Collective to enable agile behaviors in accordance with the demands of the mission and circumstances.

An Option 4 Harmonization Arrangement differs from other Harmonization options in the variety and fluidity of its approach to C2. Sets of entities that have adopted an Option 4 Arrangement can either explicitly position themselves anywhere in the C2 Approach Space including “at the Edge” where they are able to self-synchronize. Thus, an observer of an Option 4 Harmonization Arrangement could see the entities take on a number of different organizational forms and dynamically adjust their working relationships as required by the dynamics of the operation.

Thus, while the entities operating at Option 4 could simply agree (for a limit time and purpose) to form a single chain of command and operate as a traditional hierarchy, or for that matter any other C2 approach, the most interesting and perhaps the most practical approach for an Option 4 Harmonization Arrangement is create the conditions

³⁰ An agile entity is one that is able to change C2 Approaches appropriately as the mission and circumstances change. This is discussed in detail in The Agility Advantage and in the SAS-085 Final Report.

necessary for self-synchronization. The ability of two entities to self-synchronize will be a function of the nature of the MDO and the degree that entities have established common intent and achieved a rich, shared understanding.

This does not imply that self-synchronization cannot occur in other Harmonization Options. However, in these other options, this self-synchronization is limited to entities and Task Groups that have adopted an Edge C2 Approach. Previous NATO Research Groups and a considerable body of C2 Literature addresses the C2 of ‘integrated’ enterprises (e.g. NATO). However, these tend not be inclusive enough for the kinds of MDO this paper addresses which will arrangements that feature *self-organization and self-synchronization* enabling by the ability to develop appropriate levels of shared understanding and the delegation of decision rights to enable act to be taken when appropriate. Thus, an Option 4 Arrangement distinguishes itself from the other Harmonization Arrangements by its ability to replace deliberate and formal coordination-collaboration mechanisms with the dynamics of emergence and self-synchronization. Although, for the ‘original’ entities all C2 Approaches are possible an effective Option 4 Harmonization Arrangement requires each deployed entity to have adopted an Edge C2 Approach for the duration of the arrangement. Achieving this level of harmonization requires entities to put the Endeavor first and be willing to give up their “freedoms” in favor of the collective. Parenting organizations must acknowledge the fact that they are handing over control of one or more of their resources with only limited say in how they may be employed.

Agile Command and Control³¹

Now that the ‘command and control’ options available to entities participating in an MDO have been identified, it remains to introduce agility into the discussion. The need for agile C2 (agile MDC2-H in the case of these MDO) has been well articulated. A growing body of evidence supports the importance of enhancing the agility of

³¹ For a comprehensive treatment of agility and C2 agility see: Alberts, David S., *The Agility Advantage*, CCRP Publication Series, Washington, DC 2011.

organizations faced with dynamic situations characterized by complexity and uncertainty. The increasing likelihood that military organizations will be operating in highly contested cyber environments only increases the importance of C2 Agility.

Agility is the capability that enables entities to succeed and remain successful despite unanticipated events and rapid changes in circumstances that would otherwise threaten success. C2 Agility involves understanding the appropriateness of the C2 approach options it has available and 1) selecting the most appropriate approach for the mission and circumstances, 2) recognizing when the mission or circumstances have changed (e.g. a loss of cyber capability), 3) assessing whether the current C2 approach remains the best fit for the circumstances, and 4) if necessary transition to a more appropriate option.

The agility of an individual entity, a MDC2-H Arrangement, a process, a system, or an individual can be measured by looking at the situations where they can function successfully and compare these to the set of situations of interest. The larger this set of situations where they are successful, the more agility the entity possesses. Each MDC2-H Arrangement is capable of functioning effectively for a particular set of missions and circumstances. When entities have the ability to ‘maneuver’ in the MDC2-H Arrangements space (e.g. change their own C2 Approach and/or adopt a different harmonization option) they can increase the set of missions and circumstances in which they will be successful.

Agile MDC2-H and CRM

Arguably CRM will be significant in almost every MDO militaries will participate in the future. In fact, a loss of cyber and cyber-enabled capabilities can be reasonably expected to occur. The question is whether or not the entities, individually and collectively, will be able to effectively manage this risk.

C2 depends heavily upon cyber capabilities to facilitate the access to information and interactions within and across entities and thus, can be expected to be adversely impacted. It is possible, even probable, that

their ability to employ the MDC2-H Arrangement they have adopted may no longer be adequately supported by cyber. Different approaches to MDC2-H require different levels of connectivity and performance. The more C2 Agility the individual entities possess, the greater their ability to have high quality cyber awareness, and develop shared cyber awareness, the more Agile will their MDC2-H be. More Agile MDC2-H will translate into being able to find a way to remain successful despite a loss of cyber and cyber-enabled capability – in other words, the better able they will be in managing CRM.

This discussion would not be complete without mention of three important trends, namely increasing utilization of automation, intelligent software and autonomy. The automation of a variety of C2-related tasks also has been prevalent for some time. Yet, there has not been a clear recognition of what this increased automation means in terms of the constraints it places on commanders and C2 systems. These constraints may be, under certain circumstances, impediments to agility and therefore to mission accomplishment. In other words, the very cyber capabilities that are under attack may limit the responses we need to take to manage CRM. The emergence of autonomous systems is a more recent development. From a C2 perspective, as is the case with automation, the design and operation of ‘autonomous’ systems involve delegations of decision rights; however, the impacts and consequences of these delegations are currently not well understood. Automation, the employment of intelligent software and autonomy all need to be far better understood.