# NATO NEC C2 Maturity Model

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# NATO NEC C2 Maturity Model

CCRP Publication Series

# SAS-065[1]

1. SAS-065 is a NATO research task group operating under the auspices of the SAS Panel. It was formed in 2006 for the purpose of developing a C2 Maturity Model for network-enabled operations. SAS-065's principal products include a detailed description of a NATO NEC Command and Control Maturity Model (N2C2M2) with a User Guide (see section entitled *Applying the NATO NEC C2 Maturity Model*) and a revised C2 Conceptual Reference Model (originally developed by SAS-050). SAS-065 builds on the work of a series of research task groups dating back to 1995 that have explored issues in command and control. These have included RSG-19 and SAS-026, which produced the NATO Code of Best Practice for C2 Assessment, and SAS-050, which produced the C2 Conceptual Reference Model. The members of SAS-065 and the countries and organisations they represent can be found in the *Acknowledgments* section.

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# ACKNOWLEDGMENTS

The development and validation of the NATO NEC Command and Control Maturity Model (N2C2M2) was a major undertaking, requiring serious professional effort from all the members. The chair of SAS-065, Dr. David S. Alberts from the U.S. Department of Defence, and two co-chairs Prof. Reiner Huber of the Universität der Bundeswehr München, Germany, and Prof. James Moffat from the UK Dstl, want to acknowledge the broad and deep professional participation and support for the endeavour. The full membership of SAS-065, along with their national affiliations and organisational homes, is shown in Table *i*.

| Name | Nation | Name of Company / Institute / Firm |
|---|---|---|
| David S. Alberts, Chair | USA | OASD(NII) |
| Reiner Huber, Co-Chair | Germany | Universität der Bundeswehr München, Germany |
| James Moffat, Co-Chair | UK | Defence Science and Technology Laboratory |
| Dave Allen | Canada | Defence Research and Development Canada |
| Anthony Alston | UK | Defence Academy of the United Kingdom |
| Julius Barath | Slovakia | Armed Forces Academy |
| Ulrich Brandenberger | Switzerland | Armasuisse, Science & Technology |
| Ralph Bruehlmann | Switzerland | Armasuisse, Science & Technology |
| Alain Burton | Belgium | Belgian Defense |
| Giovanni Can ice | Italy | CE.SI.VA. - Italian Army M&S Office |
| Mervyn Cheah | Singapore | Singapore Technologies Electronics |
| Lorraine Dodd | UK | Defence Academy of the United Kingdom |
| Petra Eggenhofer | Germany | Universität der Bundeswehr München, Germany |
| Fred van Ettinger | Ne herlands | C2 Centre of Excellence |
| Philip S. E. Farrell | Canada | Defence Research and Development Canada |
| Fernando Freire | Portugal | Military Academy, Portugal |
| Henrik Friman | Sweden | Swedish Defence Research Agency |
| António Grilo | Portugal | INOV/Military Academy, Portugal |
| Anne-Marie Grisogono | Australia | Defence Science and Technology Organization |
| Richard E. Hayes | USA | Evidence Based Research, Inc. |
| Gary Horne | USA | SEED Centre for Data Farming, Naval Postgraduate School |
| Nancy Houston | USA | NATO ACT |
| Tor Langsaeter | Norway | FFI |
| Ulrike Lechner | Germany | Universität der Bundeswehr München, Germany |
| Marco Manso | Portugal | EDISOFT SA |
| Geert Marien | Belgian | C2 Centre of Excellence |
| Jose Martins | Portugal | Military Academy, Portugal |
| Jimmie McEver | USA | Evidence Based Research, Inc. |
| Allen Murashige | USA | HQ USAF/XIW |
| Aga ino Mursia | Italy | Selex Communica ions SPA |
| Paulo Nunes | Portugal | AM/CINAMIL |
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| Bill Piersol | USA | Klett Consulting Group Inc. |
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| João Rocha | Portugal | Military Academy, Portugal |
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| Marco Sebas iani | Italy | CE.SI.VA. - Italian Army M&S Office |
| Sebas ian Schaefer | Germany | Universität der Bundeswehr München, Germany |
| Mink Spaans | Ne herlands | TNO Defence, Security & Safety |
| Klaus Titze | Germany | Universität der Bundeswehr München, Germany |
| Danielle Wynn | USA | Evidence Based Research, Inc. |

Table i: SAS-065 Membership

While some of the work was accomplished during the 12 face-to-face meetings of the Research Task Group, a great deal of effort was required between those formal sessions, often working together in small groups on the Web. Moreover, many individuals put in long hours of professional time during evenings and weekends to complete their assignments and to act as collegial reviewers for the work of others.

Mr. Marco Manso from Edisoft SA in Portugal undertook an important initiative to design experiments focused on the five C2 Approaches identified by the Research Task Group. Mr. Mink Spaans from TNO in the Netherlands also played an important role in leading the development of the *Applications* section of the report. Dr. Richard E. Hayes of EBR in the United States was responsible for integrating the results from the disparate case studies undertaken to validate the N2C2M2. Ms. Petra Eggenhofer from the Universität der Bundeswehr München, Germany, played two very key roles, organising the extended *Glossary* effort and also leading the work to update the *C2 Conceptual Reference Model* originally produced by SAS-050.

Case Studies and Experiments were crucial activities in both developing and validating the N2C2M2. Special thanks to those who led these activities: Prof. Jim Moffat of Dstl in the UK MOD (Hurricane Katrina and UK Current and Future Command Gaming), Prof. Reiner Huber of the Universität der Bundeswehr München, Germany (Indian Ocean Tsunami), Dr. Paul Phister of Air Force Research Laboratory in the U.S. (Pakistan Earthquake), Mr. Bill Piersol assigned to NATO ACT (NATO Operations in Bosnia and Kosovo), Dr. Richard E. Hayes of EBR in the U.S. (Stryker Brigade), and Dr. Ulrike Lechner with the Universität der Bundeswehr München, Germany (Elbe River Flood). However, singling out individuals is only marginally appropriate here for the full membership contributed effectively, with many individuals taking charge of specific analyses and validation case studies. In terms explained in this report, SAS-065 was largely an Edge organisation.

Thanks are also due to the international team of Peer Reviewers who came together in a formal workshop to examine an earlier draft of this report. They are listed below in table *ii*, including a few who were unable to attend the face-to-face meeting, but nevertheless went out of their way to offer constructive criticism and suggestions to improve the product. These people acted in the best traditions of good scholarship, scientific practice, and collegial relations.

Finally, thanks are due to the governments and institutions that nominated and supported the talented group that comprised the SAS-065 membership and peer review group. Special thanks are also due to the governments of Canada, Germany, Italy, the Netherlands, Sweden, Switzerland, the UK, and the United States for hosting meetings of SAS-065.

| **Name** | **Nation** | **Name of Company / Institute / Firm** |
|---|---|---|
| Commander Ian Kennedy Adam | UK | Ministry of Defence |
| Prof. Alex Bordetsky | USA | Naval Postgraduate School |
| Dr. Paul Davis | USA | RAND |
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| COL (GS) Frederic Haas | Switzerland | Swiss Armed Forces, Staff Operational Training |
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| Mr. Wolfgang Jansen | Germany | IABG mbH |
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| LTC (GS) Thomas André Keller | Switzerland | Swiss Armed Forces, AFPS |
| Col John Koivisto | USA | NATO, ACT |
| Major Jose Llanos | Chile | Army of Chile |
| LTC Soenke Marahrens | Germany/ USA | Bundeswehr Centre for Transformation/USJFcom |
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| LTC (GS) Darius Nobs | Switzerland | Swiss Armed Forces, General Staff School |
| Major General William Rajczak | USA | J8, USJFCOM |
| Mr. (Lars) Martin Rantzer | Sweden | Swedish Defence Research Agency |
| Dr. Bard Reitan | Norway | Norwegian Defence Research Establishment |
| Col David Tan | Singapore | Future Systems Directorate Singapore Armed Forces |

Table ii:  SAS-065 Peer Reviewers

# Executive Summary

Two key realities dominate thinking about *command and control* (C2) in the 21st century. The first is the nature of the 21st century military mission space. This space is characterised by its extreme uncertainty. In addition to the high intensity combat operations that are traditionally associated with military operations, the 21st century mission space has expanded to include a wide spectrum of mission challenges, ranging from providing support to multi-agency disaster relief operations to complex coalition efforts within a political-military environment involving a large variety of military and non-military actors; which we describe as *Complex Endeavours*.

The second reality is the ongoing transformation of 21st century militaries, and for that matter, other 21st century institutions and actors from the Industrial Age to the Information Age. With this transformation comes the ability to leverage new information technologies. This has had, and will continue to have, a profound effect on how institutions manage themselves and how they can work with coalition partners.

These fundamental realities put the emphasis on *command and control* (C2), interpreted in its broadest sense to include acquiring, managing, sharing and exploiting information, and supporting individual and collective decision-making. In particular, more mature C2 includes the ability to recognise situational change, and to adopt the C2 approach required to meet that change—which we term *C2 Agility*.

The NATO NEC C2 Maturity Model (N2C2M2) we have developed builds on dearly won insights from the past, but goes beyond them in order that we can exploit Information Age approaches to address these new mission challenges. This way of thinking about C2 is thus entirely compatible with current NATO Allied Command Transformation (ACT) thinking on *Future Capable Forces* which puts the emphasis on Mission Command within federated complex environments and ad hoc coalitions.

This NATO NEC C2 Maturity Model (N2C2M2) was developed by the RTO SAS-065 Research Task Group over a period of about three years. It starts by defining a number of C2 approaches, ranging from *Conflicted C2* to *Edge C2*, that correspond to different regions within the C2 Approach Space shown in Figure ES 1.

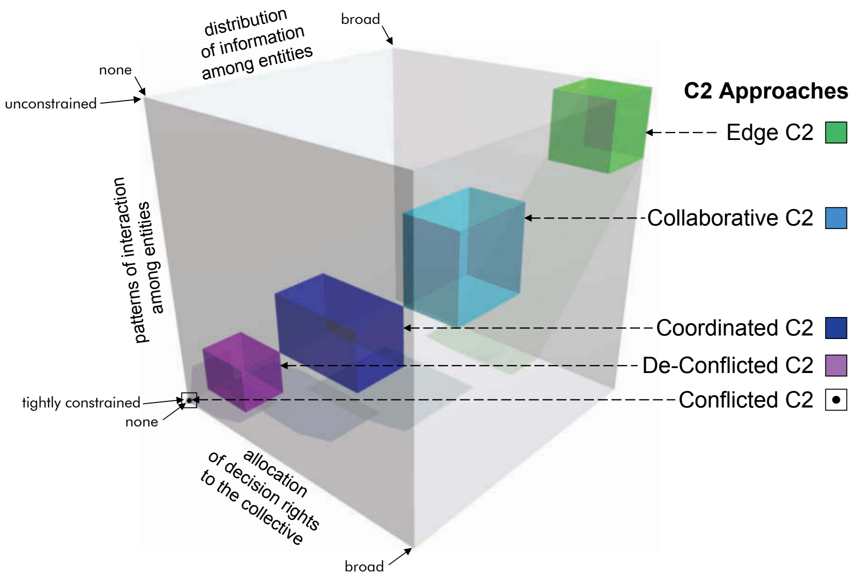


Figure ES 1: C2 Approaches as regions in the C2 Approach Space

The C2 approach space contains the different possible approaches to accomplishing the functions that are associated with command and control. This approach space can be viewed from two perspectives. First, it can be used to think about C2 within existing organisations. Second, it can be used to think about how a disparate set of independent (yet inter-dependent) entities, that is, a collective, can achieve focus and convergence.

SAS-065 concentrated its attention on the second perspective to address C2 for a collective or ad hoc coalition, based on variations in the allocation of decision rights to the collective, patterns of interaction and information sharing behaviours among the entities of the collective, and the distribution of information among these entities.

In Figure ES 1, there is a gap between Conflicted and De-Conflicted C2 and a gap between Collaborative and Edge C2. De-Conflicted, Coordinated, and Collaborative C2 are shown without gaps between them. This is because the exact boundaries between De-Conflicted and Coordinated and between Coordinated and Collaborative are difficult to define precisely. Figure ES 2 below gives a brief description of each of these C2 approaches, in terms of the region they occupy on the C2 approach space (described by the three variables across the top). In Figure ES 2 the relationships among the approaches are depicted by gaps between Conflicted and De-Conflicted and Collaborative and Edge C2, and dashed lines between De-Conflicted, Coordinated, and Collaborative.

| C2 Approach | Allocation of Decision Rights to the Collective | Patterns of Interaction Among Participating Entities | Distribution of Information (Entity Information Positions) |
|---|---|---|---|
| **Edge C2** | Not Explicit, Self- Allocated (Emergent, Tailored, and Dynamic) | Unlimited As Required | All Available and Relevant Information Accessible |
| **Collaborative C2** | Collaborative Process and Shared Plan | Significant Broad | Additional Information Across Collaborative Areas/Functions |
| **Coordinated C2** | Coordination Process and Linked Plans | Limited and Focused | Additional Information About Coordinated Areas/Functions |
| **De-Conflicted C2** | Establish Constraints | Very Limited Sharply Focused | Additional Information About Constraints and Seams |
| **Conflicted C2** | None | None | Organic Information |

Figure ES 2: The different C2 Approaches and how they relate to the C2 Approach Space

As indicated in Figure ES 2, Conflicted C2 stands on its own—it is a situation to be avoided. De-Conflicted C2, Coordinated C2 and Collaborative C2 represent increasingly capable C2 approaches that correspond to greater allocation of decision rights to the collective and increasing levels of information sharing; which increases awareness and shared awareness. Edge C2 then also stands by itself. It is achieved only by the exploitation of a critical level of shared awareness, and shared intent.

These different approaches to collective C2 are key considerations in determining C2 maturity. C2 maturity levels are defined in terms of the specific approaches to C2 that an entity or collection of entities can implement and the ability to recognise which approach is appropriate and adopt the most appropriate approach given the situation. Thus each C2 maturity level is associated with a specific set of C2 capabilities. Furthermore, each higher level of C2 maturity subsumes the capabilities associated with the lower levels. From the collective or coalition perspective there are thus five possible levels of C2 maturity, as shown in Figure ES 3.

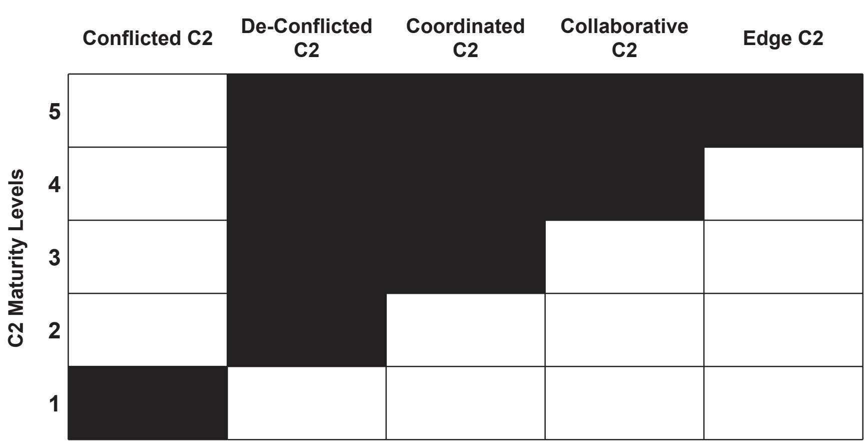


Figure ES 3: Collective C2 Maturity Levels 1 to 5, defined in terms of the different possible C2 Approaches

As indicated in Figure ES 3, collectives or entities that are capable of only Conflicted C2 correspond to Maturity Level 1. Those that can implement De-Conflicted C2 correspond to Maturity Level 2. For Maturity Level 3, an entity or collective must be able to move their C2 approach between De-Conflicted and Coordinated C2 appropriately, as circumstances change. For Maturity Level 4 this approach option space is expanded to include Collaborative C2. Finally, Maturity Level 5 involves the widest set of possible C2 approach options, ranging from De-Conflicted C2 through to Edge C2. Thus in moving from Maturity Level 1 through to Maturity Level 5, the number of options available in matching its C2 approach to the dynamic and complex circumstances it finds itself in is increasingly expanded. In other words, its C2 agility is enhanced.

The number of C2 approaches within each maturity level, as well as the ability to transition between approaches (i.e., C2 agility), are two key components of the NATO NEC C2 Maturity Model (N2C2M2). Together, these components are required to address increasingly demanding and complex operational circumstances. It is thus possible to relate our C2 maturity levels to increasing levels of NATO NNEC operational (or capability) maturity, as shown in Figure ES 4.

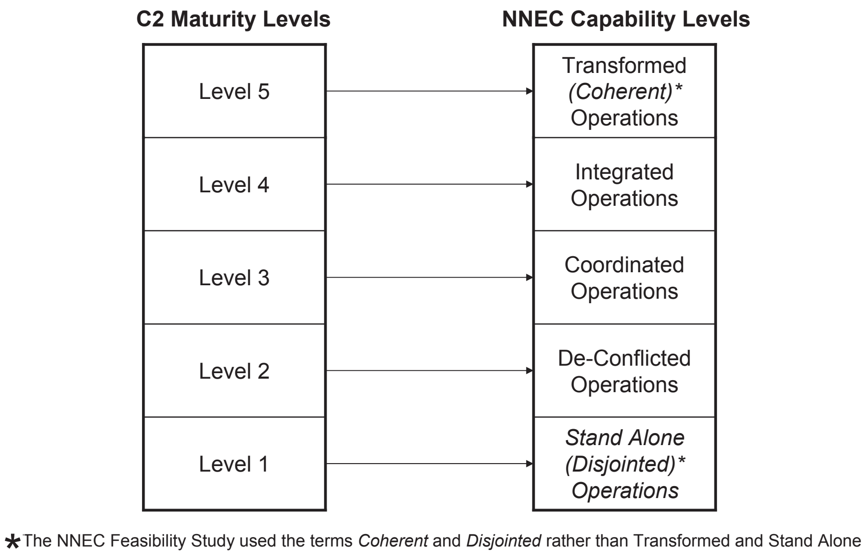


Figure ES 4: Relation between C2 Maturity Levels and NNEC Capability Levels

Understanding these C2 maturity levels, together with the examples provided in the body of the report, and their detailed descriptions, allow an organisation, coalition, and/or nation to assess its current level of C2 maturity and the changes required to transition to a more network-centric C2 approach. Thus, each C2 maturity level provides the set of C2 capabilities required to support the corresponding NNEC capability level.

In constructing the NATO NEC C2 Maturity Model (N2C2M2), we made some initial assumptions about the number of maturity levels required and the detailed indicators or characteristics which distinguish them from one another. In order to validate these descriptions a significant number of case studies, ranging from (at one extreme) multi-agency humanitarian relief operations with military involvement through to (at the other extreme) warfighting within a complex coalition context, were considered. These are brought together in an overarching analysis in the body of this report which shows the need to track not just the whole coalition, but coherent parts of it.

Moreover, in any operational circumstance, it is important to choose the C2 approach required by the operational context. In establishing a strategy for an entity, it is important that an appropriate C2 maturity level is selected; one that will allow the entity to function appropriately in the mix of situations and circumstances that the entity will be involved in over time. Excess maturity (C2 approach options that are not required for the set of circumstances envisioned) comes at a cost, while deficient maturity (not being able to utilise the appropriate approach when it is required) may result in failures to cope successfully. We describe the specific maturity level that fits an entity's mission space as *Requisite C2 Maturity*.

We have also used the results of this extensive case study review to update and enhance the C2 Conceptual Reference Model (C2CRM) and relate it to the N2C2M2.

Having gone through this iterative process of improving our understanding and description of the C2 approaches and C2 maturity levels, we presented our ideas to an authoritative group of peer reviewers drawn from across NATO, PfP and other nations in a special two-day meeting held in Washington, DC; which included cross briefings with NATO ACT activities related to Network Enabled Capability (NEC). Their feedback and suggestions have been taken into account in the final version here presented.

Finally, a number of ways of exploiting the rich set of ideas we have gathered together is described, covering the operational design of a force; strategic planning and roadmapping; and establishing objectives for joint research and experimentation. A number of the NATO nations represented in the RTO SAS-065 Research Task Group are already exploiting the N2C2M2 to support their transformational efforts.

# Chapter 1
# Introduction

## NATO NEC CHALLENGE

NATO has identified Network Enabled Capability (NEC) as a high priority alliance goal. NATO is thus in the process of developing a maturity model related to improving force capability and transformation. Achieving this goal clearly depends on the development of an appropriate approach to NATO Consultation, Command, and Control and the identification of a corresponding Command and Control (C2) Maturity Model.

Within NATO, the Research and Technology Organisation (RTO) sponsors a number of panels including the Studies Analysis and Simulation (SAS) panel. This in turn has a number of research task groups. SAS-065 was chartered in 2006 to develop this C2 Maturity Model.

## SAS-065 GOALS

The primary goal of SAS-065 was to create a NATO NEC C2 Maturity Model (N2C2M2) to facilitate the exploration of network-enabled command and control approaches and capabilities in a coalition context. Thus each C2 maturity level is associated with a specific set of C2 capabilities. Furthermore, each higher level of C2 maturity subsumes the capabilities associated with the lower levels. These NNEC C2 maturity levels are mapped to NNEC transformation maturity levels.

This NATO NEC C2 Maturity Model (N2C2M2) that has been created is an instrument (including metrics) that will enable organisations to orient themselves and measure their current capabilities more specifically, in relation to the C2 aspects of the NNEC vision.

Our secondary goal was to produce a refined version of the C2 Conceptual Reference Model (C2CRM), originally developed by SAS-050.

## SAS-065 SCOPE AND APPROACH

Our effort is focused on C2-related aspects of NNEC. It began with a review of the NNEC Vision and the creation of an initial version of the NNEC C2 Maturity Model. This was used to facilitate discussions with stakeholders (HQ SACT, NC3A, and other interested parties) to help ensure that our understanding of the NNEC vision was comprehensive and that the NNEC C2 Maturity Model envisioned was both relevant and transparent to the wider community.

This initial NNEC C2 Maturity Model was then applied to a range of case studies (see Table 1), that involved a review of the perceived C2 approaches and corresponding levels of C2 maturity of selected forces and coalitions, spanning a wide range of *complex endeavours* from predominantly warfighting (e.g., Bosnia, Kosovo) to predominantly disaster relief (e.g., Tsunami, Pakistan Earthquake, and Katrina). An analysis of experimental data was also used to contribute to the validation effort. The NNEC C2 Maturity Model was refined based on the results of these case studies. Based on this work, we have produced a number of products. A formal peer review of these SAS-065 products was undertaken by experienced analysts, researchers, and operators with relevant expertise.

## SAS-065 PRODUCTS

The following products have been produced by SAS-065:

- NATO NEC C2 Maturity Model description;
- Analysis integrating the case studies;
- Illustrative applications;
- Glossary;
- Updated C2 Conceptual Reference Model (C2CRM);
- Composition of SAS-065.

The NATO countries and organisations represented in this research task group are NATO ACT, Belgium, the C2CoE (C2 Centre of Excellence), Canada, Germany, Italy, Netherlands, Norway, Portugal, Slovakia, United Kingdom, and United States. Contributions have also been made by Australia, Sweden, and Switzerland.

## *History of SAS C2 related Research Groups*

The history of SAS-065 dates back to 1991 when the Ad Hoc Working Group on the Impact of C3I on the Battlefield was formed by Panel 7 (on Defence Applications of Operational Research) of the NATO Defence Research Group (DRG) to assess the state of the art in C2 analysis. Based on the recommendations of the Ad Hoc Working Group, Panel 7 constituted Research Study Group-19 (RSG-19) to address issues of methodology, measures of merit, and tools and analysis. The panel also addressed issues concerned with improving a nation's capability to examine C2 acquisition and decision making. At the October 1995 RSG-19 planning meeting, the group determined that the primary product of RSG-19 was to be a Code of Best Practice (COBP) for assessing C2 to be presented and discussed at a symposium in January 1999. In response to a query by Panel 7, the RSG-19 acknowledged the need for a follow-on group.

In 1998, RSG-19 was re-designated SAS-002 under the aegis of the Studies Analysis and Simulation (SAS) Panel that assumed some of the responsibilities of Panel 7 when NATO reorganised its science and research activities, joining DRG and AGARD into the NATO Research and Technology Organization (RTO). In 1999, the SAS panel approved the formation of a follow-on group, designated SAS-026 to assess, revise, and extend the combat-oriented initial version of the COBP developed by RSG-19 and SAS-002 respectively, to account for C2 in *Operations-Other-Than-War (OOTW)* and their implications, in particular with regard to Human Factors. SAS-026 began its work in January 2000 and submitted the revised NATO COBP for C2 Assessment in November 2002.

Under the designation SAS-051, a lecture tour was organised by RTO to present the COBP to NATO and its member nations. In September/October 2004, five members of the SAS-026 team gave a series of lectures on the steps to be taken to ensure success in C2 assessment and engaging the auditorium in role plays to illustrate responsibilities of and interactions between the actors involved in an assessment. The lectures took place at NATO in Brussels; Farnborough, UK; Brno, Czech Republic; and Ankara, Turkey.

In response to the proposal of an exploratory group following up recommendations made by SAS-026, the SAS Panel authorised the formation of SAS-050 to develop a conceptual model for representing C2 in general, and new network-centric command concepts in particular, as a prerequisite for understanding, exploring, and assessing emerging concepts of operation and transformational capabilities. Beginning in March 2003, SAS-050 finished its work in December 2005. The C2 Conceptual Model consists of a Reference Model, a value view reflecting the value chain from force and C2 characteristics to measures of effectiveness, and a generic C2 process view. The C2 Conceptual Reference Model (C2CRM) contains some 300 variables, and selected subsets of the possible relationships between and among them that were judged to be important to understand C2 and the implications of different approaches to C2. It is considered a point of departure for researchers, analysts, and experimenters engaging in C2-related research, conducting analyses of C2 concepts and capabilities, and designing and conducting experiments.

SAS-065 was chartered in 2006 to create a conceptual C2 maturity model, building on the C2 Conceptual Reference Model of SAS-050, to facilitate the exploration of network-enabled command and control approaches and network-enabled capabilities (NEC) and to identify options for C2 within complex endeavours, i.e., coalitions involving a variety of military and non-military partners each of which may be at different C2 maturity levels and each of which may pursue different C2 approaches.[2]

2. Care has been taken to differentiate between C2 maturity levels and C2 approaches, in full recognition that they both can be described in terms of the C2 Approach Space. Please refer to the Glossary definitions while reading this report to avoid confusion.

# CHAPTER 2

# ORIENTATION

## 21ST CENTURY MISSION CHALLENGES

The challenges faced by NATO and its member nations in the 21st century require the creation of a coalition; a collection of disparate entities who are pursuing related but not identical goals. This *collective* is composed of a number of *contributing entities*, both military and non-military (interagency or whole of government) from the various NATO nations. This coalition will likely include contributions from non-NATO countries and international organisations as well as non-governmental organisations (NGOs) and private voluntary organisations (PVOs). The heterogeneous make-up of the enterprise implies that no single element is *in charge* of the entire endeavour. The interactions between and among these contributing elements need to be considered in terms of the Physical, Information, Cognitive, and Social Domains.[3]

3. Alberts and Hayes, *Understanding Command and Control*, Washington, DC: CCRP, 2006; Alberts and Hayes, *Planning: Complex Endeavors*, Washington, DC: CCRP, 2007.

## COMPLEX ENDEAVOURS

The 21st century mission challenges described above are referred to as *complex endeavours*.[4] The complexity of future endeavours will require greater agility, not only in terms of thought processes, but also in terms of the means to enable the transformation of those processes into action. Past endeavours were defined by a fairly small subset of activities in which military commanders were assured virtual "ownership" of the entirety of the operational environment. The *complex endeavours* of today and tomorrow encompass a more inclusive and broader environment. In some circles this is referred to by the acronym PMESII (Political, Military, Economic, Social, Information, and Infrastructure). Other terms for this are "Hybrid War" and "4 Block War."[5] This broader construct demands greater *agility* on the part of both military and non-military leadership and organisations. Therefore, agility must be an inherent characteristic of the approach to collective command and control that is adopted.

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4. *Complex endeavours* refers to undertakings that are distinguished by one or more of the following characteristics:
   1) The number and diversity of participants is such that
      a. there are multiple interdependent *chains of command*,
      b. the intents and priorities of the participants conflict with one another or their components have significantly different weights, or
      c. the participants' perceptions of the situation differ in important ways; and
   2) The effects space spans multiple domains and there is
      a. a lack of understanding of networked cause and effect relationships,
      b. a resulting inability to accurately predict all of the relevant effects that are likely to arrive from alternative courses of action, and therefore,
      c. a lack of ability to appropriately react to undesirable effects by making timely decisions, developing appropriate plans, and taking the necessary actions.

5. These terms refer to a complex mix of peacekeeping, stability, and warfighting operations.

The low agility of the traditional command processes matched the characteristics of the Industrial Age mission environment, characterised specifically by the familiarity of the mission, the relative linearity of the battlespace, the predictability of actions and effects, and the relatively small rate of change (i.e., modest dynamics). Complex endeavours are more challenging because they may contain multiple phases that span from static to highly dynamic mission environments. This is not to say that there is no place for "traditional" command and control approaches. However, the increasingly volatile, uncertain, complex and ambiguous operational environment, characterised by a more agile and increasingly capable antagonist, requires similarly enabled protagonists. Throughout history, changing environments have lead to the adoption of new practices to augment or replace existing approaches.

Hence, Industrial Age approaches to command and control have proved to be successful in simpler, albeit highly complicated environments where manoeuvre was limited and the concepts of operation employed were based on massed forces to create attrition-based effects. Industrial Age approaches to command and control can prove limiting in this nonlinear, more dynamic, and less predictable environment, just as similar "traditional" approaches are proving suboptimal in the areas of civil and industrial management and governance.

## COMPLEXITY IN THE ENVIRONMENT AND IN THE MISSION

Meeting the challenges we face in the 21st century requires dealing with not only military effects, but also simultaneously social, political, and economic effects. These effects are interrelated (e.g., it is hard to increase economic activity without security). This means that the environment we are trying to influence[6] is less well understood, less predictable, and more dynamic.

This also means that the complex endeavours undertaken in the 21st century by NATO, its member Nations, and others require broad civil-military coalitions. These endeavours are characterised by a high degree of complexity, dynamics, and uncertainty. The variables by which these characteristics may be described and measured include:

- The nature and objectives of the endeavour (combat, peacekeeping, stability, counter-terrorism, humanitarian assistance, disaster relief);
- The number, nature, and diversity of entities comprising the endeavour (friendly, neutral and adversarial actors including the relationships and interactions between them);
- The nature of the military contribution;
- The stability of the environment;
- The predictability of the environment;
- The transparency or uncertainty concerning interactions and variable values;
- The degree to which entities are familiar with the situation and each other;
- The nature of the infrastructure available (ranging from austere to well-developed);
- The degree of clarity and unity of intent (purpose) and strategy;

6. Industrial Age thinkers and practitioners would have used the word *control* here (NATO SAS-050, 2006).

- The nature of the effects space (from one to multidimensional), including interactions between and among the physical, information, cognitive, and social domains.

## COMPLEXITY IN SELF (COLLECTIVE)

In addition to a significantly more complex environment, the nature of *self* is more complex, again because these 21st century complex endeavours require civil-military coalitions or collectives of a wide variety of different organisations. These collectives typically have the following characteristics:

- A large number of entities;
- Entities with significantly different cultures, values, and norms;
- Where trust between and among the entities varies considerably from mistrust to a high degree of trust;
- Entities that speak a variety of different languages;
- Entities that possess a range of information and communications capabilities;
- Entities that approach organisation and management in different ways.

In summary, the opportunity to develop new ways to approach "traditional" command and control was provided by advances in communications, information processing, and networking technologies that combined to enable new, distributed ways of working together. SAS-065 has considered the nature of 21st century mission challenges, the uncertainty of the environment and effects space, and this revolution in information-related technologies as the operational context for the development of the NATO NEC C2 Maturity Model (N2C2M2).

## NATO MISSION SPACE

The problem space that SAS-065 addressed is likely NATO missions. These missions represent a very large variety of situations and circumstance. These include out of area operations, coalitions that extend beyond the core NATO nations, civil-military operations where cooperation with interagency partners is essential, and challenges where effective collaboration with host governments, international organisations, non-governmental organisations, and private industry are important. As they explored the problem space together over time, SAS-065 came to recognise these as "complex endeavours."[7]

The variety of relevant experience covered by the case studies undertaken by SAS-065 includes, as listed in Table 1.

- Combat Organisations (Stryker Brigade Exercises and Operations, WISE Wargames[8]);
- Peace Operations (IFOR in Bosnia and KFOR in Kosovo);
- Small Natural Disasters (Elbe River Flood, Golden Phoenix 07 and Strong Angel III);
- Major Natural Disasters (Katrina, Pakistan Earthquake, Tsunami);
- ELICIT experimentation comparing Hierarchical and Edge organisations.

7. Alberts and Hayes, *Planning: Complex Endeavors*; Alberts, David S "Agility, Focus, and Convergence: The Future of Command and Control." *The International C2 Journal*, 2007. http://www.dodccrp.org/html4/journal_v1n1.html; *Complex endeavours* definition-see footnote 4; Hayes, Richard E. "It's an Endeavor, Not a Force." *The International C2 Journal*, 2007. http://www.dodccrp.org/html4/journal_v1n1.html.
8. WISE—Wargame Infrastructure and Simulation Environment.

| Subject | Focus | Dates |
|---|---|---|
| Combat Organisation: | **Brigade Exercises** | 2005 |
| Combat Organisation: | **Operations (Iraq)** | 2003-2005 |
| WISE Wargames | **C2 Alternatives** | 2006-2007 |
| Peace Operations: | **IFOR in Bosnia** | 1995-1996 |
| Peace Operations: | **KFOR in Kosovo** | 1999-2000 |
| Small Natural Disaster: | **Elbe River Flood** | 2002 |
| Small Natural Disaster: | **Golden Phoenix** | 2007 |
| Small Natural Disaster: | **Strong Angel III** | 2006 |
| Major Natural Disasters: | **Katrina** | 2005 |
| Major Natural Disasters: | **Pakistan Earthquake** | 2005 |
| Major Natural Disasters: | **Tsunami** | 2004 |
| ELICIT Experimentation | **Edge vs. Hierarchy** | 2006-2008 |

Table 1: Case Studies and Experiments

By drawing upon this wide variety of relevant evidence SAS-065 was able to conduct an extensive assessment regarding the clarity, utility, and validity of the NATO NEC C2 Maturity Model. These efforts were all conducted prior to the Peer Review Workshop, which provided an opportunity for additional practitioners and experts to assess the model and make suggestions for its improvement and refinement.

## EVOLUTION OF COMMAND AND CONTROL

The term *command and control* is clearly a product of the Industrial age. The first use of the term as we understand it appears to be by Jomini[9] in *The Art of War*, when he entitles a section of the book, "The Command of Armies and the Supreme Control

9. Baron Antione Henri de Jomini, *The Art of War*. New York, NY: Greenhill Press, 1838. Chapter 2, Article 14. "The Command of Armies and the Supreme Control of Operations." *Precis de l'Art de Guerre*. 1996.

of Operations." It emerges as a term of art around the middle of the last century when President Truman instructs General MacArthur to "take command and control of the forces."[10] Prior to this, *command* was always associated with a commander (an individual) and a headquarters (a management team). Even the idea of a formal staff does not emerge before Gutaavus Adophus (1594-1632) and modern staff structures not until Napoleon Bonaparte.[11] Since the concept of command was traditionally anthropomorphised (interpreted as embodied in a human), the term command became associated with the authority vested in a commander and the study of command involved how particular commanders exercised this authority.

Unfortunately, many official definitions continue to be focused on the authorities associated with command, not on *the what* and *the how* of what needs to be accomplished.[12] Since the term command has become personalised, each commander is expected to have an individual style which is a reflection (an instance) of the art of command. This approach to command fits well with the hierarchical nature of military organisations both in the Industrial Age and in prior ages, when commanders were often royal or political figures representing or being an embodiment of the state.

10. MacArthur, Douglas, *Reminiscences*, McGraw-Hill, New York, 1964.

11. Alberts and Hayes, *Planning: Complex Endeavors*. Chapter 3.

12. Alberts and Hayes, *Command Arrangements for Peace Operations*. Washington DC: CCRP, 1995 pp. 5-6; Alberts and Hayes, *Understanding Command and Control*. Chapter 4; NATO Glossary: http://www.nato.int/docu/glossary/eng/15-main.pdf & http://www.dtic.mil/doctrine/jel/other_pubs/aap_15_04rev1.pdf ; BiSC C2 Plan: Bi Strategic Commands (NATO), the coordinated position of the two Strategic Commands: Allied Command Europe (ACE) and Allied Command Atlantic (ACLANT).

This *commander-centric* view of what is after all a set of functions required for mission success is totally antithetical to the way in which these functions need to be accomplished in 21st century complex endeavours.[13] These civil-military endeavours are necessary because no single entity has the wherewithal to succeed. For a variety of reasons no single entity will be "in command." Hence, a commander-centric view makes no sense.

This reality and the opportunities provided by Information Age concepts and technologies have stimulated calls to rethink command and control.[14] Rethinking command and control does not mean discarding everything we have learned. On the contrary it means revisiting assumptions and building upon what remains valid. Without competent command and control, military operations would never have succeeded in the past, particularly the very large operations that have been undertaken.

Modern command and control organisations trace their origins to Napoleon who is credited with the development of the first modern military headquarters and the associated creation of a "modern" command staff.[15] At this point, the functioning of a command staff became a subject of analysis. Different militaries had different approaches to headquarters organisation and correspondingly different approaches to the way in which intent was expressed and control was exercised.[16]

13. Alberts and Hayes, *Planning: Complex Endeavors*; Hayes. "It's an Endeavor, Not a Force."
14. Alberts, "Agility, Focus, and Convergence: The Future of Command and Control."
15. Alberts and Hayes, *Planning: Complex Endeavors*.
16. Alberts and Hayes, *Command Arrangements for Peace Operations*. pp. 77-125.

It was not until the middle of the century, following Napoleon's staff innovations that the term command and control began to be widely used. This raised the question of what the additional term *control* meant. Several explanations have been provided. One view maintains that the term command referred to what a commander does and the term control was associated with how the "will" of the commander became translated into instructions and promulgated throughout forces by the command staff.[17] This view parses the term *the art and science of command and control* with command being the *art* while control is the *science*.[18] The control (or scientific) aspect of command and control fit well into an Industrial Age perspective that assumed that organisations and situations could be adequately represented as a machine, albeit a complicated one. Given that machines behaved according to a knowable set of rules, results could be controlled scientifically.

This resulted in, until very recently, a bifurcation of inquiry where the study of commanders and their behaviours continued to be a subject for military historians and the study of control became fair game for a variety of scientific disciplines. Two disciplines dominated this academic space. The first was, as seems fitting, Control Theory and the related field of Cybernetics. The second was Decision Making.

17. Bolger, MAJ Daniel P., *Command or Control*, *Military Review*. July 1990. pp. 69-79.
18. Schoffner, LTG Wilson A., *Future Battlefield Dynamics and Complexities Require Timely Relevant Information*. PHALANX: The Bulletin of Military Operations Research. March 1993. pp. 1, 31-35.

Examples of the way the C2 problem was formulated in Control Theory can be found in the classic work by Lawson,[19] Wohl,[20] Levis and Athans,[21] and the development of HEAT (the Headquarters Effectiveness Assessment Tool)[22] and its Army counterpart, ACCES (the Army Command and Control Evaluation System).[23] All these specific approaches evolved from work reported to or building on a significant symposium organised by the Joint Directors of Laboratories in 1989. In essence, they decompose the military process into steps required for controlling a battlespace—monitoring the situation, developing situational awareness and understanding, developing courses of action, decision making that selects among the courses of action, developing and promulgating guidance to implement those decisions, and establishing mechanisms for feedback that allow the cycle to be continuous by monitoring the situation during implementation. They also posit that the purpose of command and control is to (a) reduce uncertainty and (b) gain control over specific parts of the situation (casualty ratios, key terrain, etc.). These approaches proved effective when examin-

19. Lawson, Joel S. Jr. "Naval Tactical C3 Architecture 1985-1995," *Signal*, Vol. 33, No. 10, Aug. 1979, pp. 71-76; Lawson, Joel, S. Jr. "Command Control as a Process" Proc. IEEE Conference on Decision and Control, Albuquerque, N.M., Dec. 1980. Naval Electronic Systems Command, Washington, DC, USA ISSN: 0272-1708, pp. 5-11.
20. Wohl, *Force Management Decision Requirements for Air Force Tactical Command and Control*, 1981.
21. Levis, Alexander and Michael Athans, *The Quest for a C3 Theory: Dreams and Realities*, August 1987.
22. *HEAT User's Manual*. McLean, VA: Defense Systems, Inc., 1984. Headquarters Effectiveness Program Summary Task 002, Prepared for C3 Architecture and Mission Analysis, Planning, and Systems Integration Directorate, Defense Communications Agency. McLean, VA: Defense Systems, Inc., 1983.
23. Hayes, Layton, Ross, and Girdler. *An Evaluation of the Army Command and Control Evaluation System (ACCES) and Recommendations to Enhance the Measurement System*, 1990.

ing Industrial Age conflicts where situations could be decomposed into manageable arenas (e.g., intelligence, logistics, and planning) and where those situations had enough manageable parameters that they could be addressed as relatively closed, engineering type problems.

Examples of how Decision Making was seen as the key to studying C2 included the work of Janis on Groupthink,[24] Klein on Recognition Primed Decision Making (RPD)[25] and Naturalistic Decision Making, Weick on Sensemaking,[26] and theorists who see command as the key issue such as Allard and Pigeau and McCann.[27] These approaches emphasise the nature of the decisions being made and the individuals making them. They place the burden on understanding how people make decisions (from cognitive psychology to theories of learning and knowledge), and the limits of individual cognition. The implication of this school of thought is to focus analyses of C2 inward—on the processes and people involved. This has the natural impact of failing to recognise when situations or adversaries are truly complex and inherently not knowable. Like Control Theory, this classic approach should not be ignored, it represents a part of the understanding needed to analyse command and control. However, complex endeavours require a larger perspective and a broader understanding of what is needed for success. These approaches focus on the individual and well-practiced management processes. However, no one individual or management

24. Janis, Irving. *Groupthink: Psychological Studies of Policy Decisions and Fiascoes*, 1982.
25. Klein. *Sources of Power: How People Make Decisions*, 1998; Klein and Salas. *Linking Expertise and Naturalistic Decision Making*, 2001.
26. Weick and Sutcliffe, *Managing the Unexpected: Assuring High Performance in an Age of Complexity*, 2001.
27. Allard, Kenneth C., *Somalia Operations: Lessons Learned*, Institute for National Strategic Studies, 1995; Pigeau and McCann. "Re-conceptualizing Command and Control." *Canadian Military Journal*, 2002.

team would hope to successfully engage a complex endeavour alone. Complex endeavours necessarily require multiple individuals and teams with a broad range of expertise and capabilities working together toward complementary goals. This is a key challenge of complex endeavours.

During the latter part of the 20th century, technology became an increasingly important consideration. Communications technology became so important that the term command and control or simply C2, became C3 for Command, Control, and Communications. The Information Age dawned and with it the term for C3 evolved to C3I (the *I* for Intelligence) and again to C4I (the fourth *C* for Computers). The study of command and control evolved along with the language. There was an increasing emphasis put on communications-related metrics such as the probability of correct message receipt (PCMR) and measures of information throughput.[28] The focus of research during this period moved from a preoccupation with a commander to a preoccupation with C2 (C3, C3I, C4I) systems. Unfortunately, this remains to be the case today, although there is significant activity beginning to be focused on team, group, and collective behaviours related to accomplishing the functions associated with command and control.

Despite this emerging focus on collective behaviours, the bulk of research and analysis of command and control systems has and continues to be *commander-centric* and the related decision making processes. In the Industrial Age, command was all

28. PCMR, see: Bjorklund, Raymond C., *Dollars and Sense of Command and Control*, NDU Press, 1995; Perry, Walter, David Signori, and John Boon, "A Methodology for Measuring the Quality of Information and Its Impact on Shared Awareness," RAND, 2004; and Headquarters Effectiveness Assessment Tool *"HEAT" User's Manual*, McLean, VA: Defense Systems Inc., 1984.

about the commander. In the Information Age the emphasis shifted to technical systems. However, these systems were conceived, designed, and operated as essentially one-way roads of information to a commander or the command staff. The only decisions considered worthy of attention were those made by a commander or the command staff. This kept the tradition of the *art of command* and a *commander-centric* view in place, driving how communications and information systems and command and control processes were conceived and studied.

21st century mission challenges in the form of complex endeavours and the continued maturation of networking (social, communications, information) concepts, technologies, and services combined to create a schism between the ways in which command and control was conceptualised, studied, and practiced and what was required for success. This disconnect is not limited to the military. Networking capabilities have not only fundamentally changed the economics of information[29] but they have also changed the way individuals and organisations relate to one another. The idea that military institutions in general and command and control in specific should co-evolve with advances in information-related technologies[30] was central to a new theory of warfare, *Network Centric Warfare* (NCW), as it was coined in the United States.[31] NCW suggested a new relationship between those in positions of command and those responsible for the large variety of functions that need to be accomplished in military operations. As a consequence, ideas that foreshadowed the conceptualisation of NCW such as

29. Alberts, Garstka, and Stein. *Network Centric Warfare*. Washington, DC: CCRP, 1999.
30. Alberts, Garstka, Hayes, and Signori. *Understanding Information Age Warfare*. Washington, DC: CCRP, 2001.
31. Alberts et al., Network Centric Warfare; Network Centric Warfare Department of Defense Report to Congress. Washington, DC, 27 July 2001.

information being *freed from the chain of command*[32] *and questions that challenged the existence of a single chain of command,*[33] *set the stage for the lynch pin of NCW, self-synchronisation.*[34] The next step in the process of making the study of command and control less personalised was the change in the term *commander's intent* to *command intent.*[35] This change highlighted both the fact that there are many decision makers (or commanders) in any battlespace or complex endeavour and the fact that no single person is in charge or "in command" during complex endeavours.[36]

While NCW suggested a new way of looking at how to accomplish the functions associated with command and control, many chose to focus on providing the information infrastructure to support network-centric operations, thereby neglecting the need to explore new approaches to command and control. The term NEC, Network Enabled Capability, adopted by NATO and several countries, is aimed at emphasising capability rather than the infrastructure.

The lack of attention on the co-evolution of cognitive and social processes demanded a response. The articulation of a set of Power to the Edge principles and related policies[37] was such a response. Power to the Edge directly addresses the seismic shift

32. Alberts, *The Unintended Consequences of Information Age Technologies*. CCRP, 1996. pp. 15-20, 33-40; Alberts and Hayes, *Power to the Edge*.
33. Mauer, *Coalition Command and Control*, NDU Press, 1994; Allard, *Somalia Operations: Lessons Learned*; Hayes, Margaret and Gary Wheatley. (eds). *Interagency and Political-Military Dimensions of Peace Operations: Haiti—A Case Study*, 1996; Alberts and Hayes, *Command Arrangements for Peace Operations*, pp. 77-125.
34. Alberts et al., *Network Centric Warfare*, pp. 87-114; Alberts et al., *Understanding Information Age Warfare*, Chapter 9.
35. Alberts and Hayes. *Understanding Command and Control*. p. 38.
36. Hayes, "It's an Endeavor, Not a Force"; *complex endeavours* definition, see footnote 4 .
37. Department of Defense, Net-Centric Data Strategy. May 9, 2003.

in relationships that is required to leverage shared awareness to foster self-synchronisation and achieve dramatic improvements in mission effectiveness. *Power to the Edge* thus explains what *NCW* left to the imagination, that is, the "magic" that connects the links in the Network-Centric Value Chain.[38]

From a theoretical and analytic point of view, the emergence of *NCW* and *Power to the Edge* focused attention on a new set of independent variables including but not limited to those variables that specify a particular approach to C2.[39] The idea of a C2 approach space that includes non-traditional approaches to military organisation moves C2 organisation and doctrine from an *assumption* to a *treatment* in the experimentation sense. Without this shift in the conceptual framework, there would be no feasible solution to the problem of civil-military coalition command and control or what is called "collective command and control."[40]

Another development has contributed to the re-conceptualisation of command and control. This development strikes at the assumption that one can optimise C2 or employ a C2 approach that is optimal for the given situation. One cannot and should not think about *optimising* command and control in the 21st century. There is no single approach, no best system design or configuration, no best process for all situations and circumstances. Uncertainty in the mission space and complexity in the environment, the effects space, and the complexity inherent in a collective dominate.[41] Thus, rather than trying to

38. Alberts and Hayes, *Power to the Edge*.
39. Alberts and Hayes, *Understanding Command and Control*. p. 75, figure 11 and p. 82, figure 13; Alberts and Hayes, *Planning: Complex Endeavors*.
40. NATO SAS-065 Research Task Group, *NATO NEC C2 Maturity Model Overview*. Oct 28, 2008. p. 4.
41. Alberts and. Hayes, *Understanding Command and Control*, p. 77, figure 12.

optimise one needs to focus on agility.[42] To engineers and analysts this development creates both a fundamental challenge and an opportunity. The challenge is to rethink an approach and process that assumes a level of understanding that simply is not present in most relevant efforts.

## LANGUAGE

The fundamental changes in the way we need to think about command and control call into question the very language we have used to talk about C2 and, in fact, the term itself.

The term command and control, although used by a number of communities, is primarily associated with military organisations and operations. Therefore, there is a large community that understands this term as it is defined by military organisations. At present, the way that command and control is defined by NATO[43] is based upon traditional military practice, practice that is based upon a number of organisational and doctrinal assumptions that do not hold in the case of complex endeavours. This creates a semantic problem. If one continues to use the term command and control to talk about the way collections of entities could interact and work toward a shared objective, many people will think that these collectives are to be expected to organise and behave as if they were traditional military organisations. This is clearly not the case. In fact, business communities, non-governmental organisations and many interagency partners perceive the term command and control to imply a rigid hierarchy, information flows that move from

42. Alberts, Agility, Focus, and Convergence: The Future of Command and Control.
43. NATO Glossary: http://www.nato.int/docu/glossary/eng/15-main.pdf and http://www.dtic.mil/doctrine/jel/other_pubs/aap_15_04rev1.pdf.

the bottom to the top, and guidance that flows from the top to the bottom as well as centralised decision making. This, of course, represents only one way to accomplish the functions associated with command and control.

To avoid this confusion, we need to think differently about what the term command and control means at a minimum or introduce a different term that refers to the ways in which the functions that are normally associated with the practice of command and control could be accomplished. Continuing to use the term command and control but defining it in non-traditional ways is likely to cause confusion among many readers. Thus, if a new term can be found that captures the intended concepts, this may be preferable.

The term focus and convergence has been suggested,[44] where focus is meant to convey the idea that a collection of entities share an understanding of a situation and some degree of collective purpose and where convergence is meant to refer to the ability of the collective to apply information and resources to make progress and achieve this collective purpose.

Focus and convergence relates to the term command and control in the following manner. Focus and convergence can be achieved by traditional approaches to command and control, but can also be achieved by new approaches to accomplishing the functions associated with command and control. Thus focus and convergence includes but is not limited by the current practice of command and control.

44. Alberts, Agility, Focus, and Convergence: The Future of Command and Control.

The intent of the NATO NEC C2 Maturity Model was clearly not to limit the options to current practice but to describe the full range of possible C2 approaches to achieving focus and convergence of complex endeavours. Thus there will be *C2 maturity levels* that include non-traditional approaches to command and control [or more accurately, new approaches to accomplishing the functions associated with command and control]. As discussed in the next section, properly understood network-centric approaches to command and control involve the ability to readily transition between traditional and non-traditional approaches. However, being able to develop and adopt these approaches is critical to achieving a mature NEC adequate to meet anticipated mission challenges.

To minimise difficulty for readers who, on the one hand are steeped in military terminology or on the other hand, come from non-military backgrounds and organisations, we have chosen to (1) continue to title the document NATO NEC C2 Maturity Model and use the term *C2 maturity levels*, (2) use the terms *focus and convergence* when we are referring to the ways in which the functions associated with command and control could be accomplished, and (3) add focus and convergence in places when command and control is used, but not in its traditional sense.

## NETWORK ENABLED CAPABILITY

NATO is committed to developing the capability to conduct network enabled operations.[45] The ability to conduct such operations, referred to as NEC[46] or Network Enabled Capability, is considered critical for mission success in the challenging complex civil-military operations that have been described above and will challenge NATO in the 21st century.

The accumulating evidence points to the operational value of NEC.[47] As a result, a number of NATO nations are committed to increasing their levels of Network Enabled Capability. The competitive advantage of NEC derives from a value chain, depicted below (see Figure 1), that begins with a robustly networked force or, in the case of complex endeavours, with a set of participating entities that are connected. If these participating entities are willing and able to share information and to collaborate in the Information and Cognitive Domains, they can create improved information positions (individually and collectively), turn their improved information positions into

45. At their meeting in Nov 2002, in the weeks prior to the Prague Summit, the NATO C3 Board (NC3B) agreed that there was a need to develop a NATO concept to adapt national initiatives such as the U.S. Network-Centric Warfare (NCW) and the U.K. Network-Enabled Capability (NEC) to the NATO context. This NATO concept is referred to as "NATO Network Enabled Capability" (NNEC). In 2003, nine NATO nations launched a two-year feasibility study on Network Enabled Capability. http://www.nato.int/docu/pr/2003/p03-135e.htm (2006).
46. Different nations have different terms for *NEC* such as Network Centric Operations and Network Enabled Operations.
47. Network Centric Warfare Department of Defense Report to Congress (Washington: CCRP, 2001).

improved awareness and understanding,[48] and develop high levels of shared[49] awareness and understanding across a collective. Achieving a significant amount of shared understanding enables a collective to be more agile and span more of the C2 approach space, which is needed to realise higher levels of NEC capability. Higher levels of C2 maturity and NEC capability promise to be both more effective and more agile.

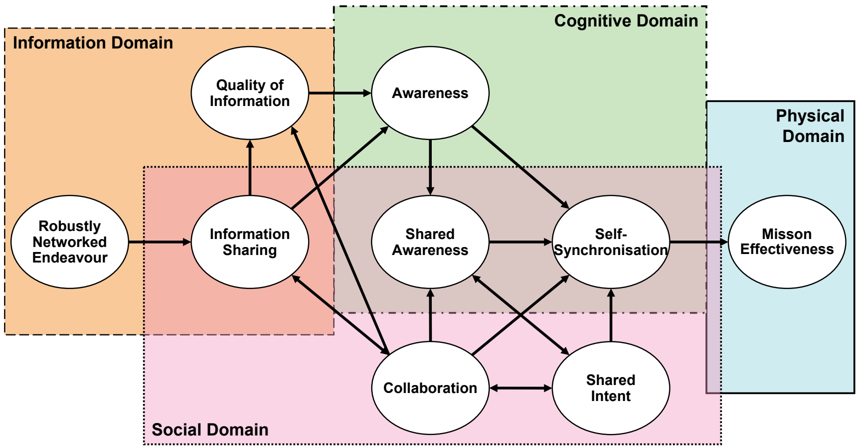


Figure 1: Network Centric Value Chain

48. Awareness and understanding are two different measures. *Awareness* refers to perceptions of a current situation and what it is becoming, while *understanding* goes beyond awareness and includes perceptions of a larger picture including cause and effect as well as temporal dynamics. See *Understanding Command and Control*, Chapter 3.

49. Shared as used in the terms *shared awareness* and *shared understanding* connote entities having similar (but not necessarily exactly the same) perceptions and interpretations of available information. Thus, in order to achieve a useful level of shared awareness and shared understanding, the information shared must include not only situational information but also information that reflects cultural aspects of and experiences relevant to the situation so that entities can better understand the filters and models being employed.

Thus, new network-enabled command and control concepts and capabilities are critical to the success of operations. The need to achieve higher levels of C2 maturity (i.e., the ability to appropriately span the C2 Approach Space) has been recognised at the highest levels of NATO. This need is not simply a reflection of a desire to leverage advancing technology but instead a recognition that more capable C2 approaches are needed to meet mission challenges. Of course, not every mission will require the most capable C2 approaches and sophisticated processes and technologies. Since there are both benefits and costs associated with operating a given C2 approach, there will not be a *one-size-fits-all* solution. Different C2 approaches will be most appropriate for different kinds of missions and circumstances. Thus, the appropriate C2 approach is what is sought, not simply an Edge C2 approach all the time. On the other hand, the highest C2 Maturity Level 5 is always sought because this level contains all possible C2 approaches and the ability to transition between approaches depending on the situation. This idea is supported by a number of case studies.

The new C2 approaches required for NATO's most complex and dynamic missions will differ in fundamental ways from traditional C2 practices. Transforming traditional military organisations into network-enabled ones will require the co-evolution of doctrine, organisation, training, education, materiel, and network-centric approaches to command and control. This will take considerable time and effort. Therefore, it is important to define interim milestones on the road to a more network-centric C2 approach.

NATO has defined five such milestones representing increasing levels of operational capability. Each succeeding level is related to increasing the coherence of the operation or endeavour. These five levels, in increasingly degrees of capability, are:

- Stand alone (Disjointed) operations;
- De-Conflicted operations;
- Coordinated operations;
- Integrated operations;
- Transformed (coherent) operations.

Increasing C2 maturity levels are required to support levels of increasing operational capability. This is described in detail later in this report. These five levels and their relationship to the NEC operational levels are depicted in Figure 3.

## C2 IN THE CONTEXT OF A COMPLEX ENDEAVOUR (COLLECTIVE)

Our emphasis is on the collective rather than the individual entities within the collective. However, the application of the NATO NEC C2 Maturity Model (N2C2M2) that we have adopted is fractal in nature. That is, the structure of the set of entities is basically the same regardless of the scale at which the entities are considered. This is illustrated in Figure 2, where the basic structure consists of entities linked to each other through their interactions. Although the basic structure is the same at each scale or level, the nature of interactions may be qualitatively different. As an example of the differences at the various entity levels, we might consider collectives (the overall coalition and larger group of contributors), organisations (military and civilian), and teams (military units).

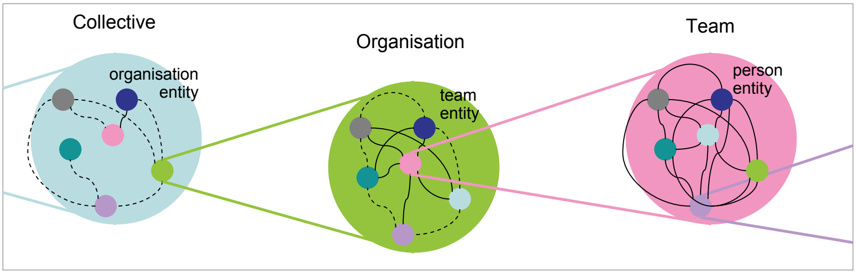


Figure 2: Fractal Nature of Entities with Qualitatively Different Interactions

> ***Collective***—Multiple loosely-coupled organisations may work together if in their best interest, or sometimes for the greater good or a collective purpose. Note that the links may be less robust with less of a central tendency. The organisations bring their specific and complementary capabilities. They may also have different intent as well as different C2 maturity levels. A collective matures primarily by growth (given enough time working together) and less so by deliberate design (legislation, policy, and training).
>
> ***Organisation***—Multiple teams bound by a common vision, a common mission, core values, monetary incentives, business rules, legislation, policy, well-established communication and interaction, and some degree of shared intent required to achieve the mission and realise the vision.
>
> ***Team***—Multiple people work together with high levels of common intent towards a common objective. They train together and develop a common work culture. The team typically consists of a leader and followers who fully understand each other's competencies, authorities, and responsibilities.

Although the N2C2M2 can be applied across a number of organisational levels, how it is applied still depends on the specifics of the entities and the environment in which they operate. We have focused on complex endeavours involving government, non-government, indigenous and international organisations. That is, the case studies we considered covered a wide set of entities working in a variety of environments.

## CONCEPTUAL MODEL

Conceptual models are representations of how we think about something.[50] They are built from concepts. A concept is:

- "A general idea derived or inferred from specific instances or occurrences;
- Something formed in the mind, a thought or notion."[51]

Concepts can be used to capture the essence of sets of concrete objects (for example, tables or chairs) as well as to deal with abstracts sets such as the physical, informational, cognitive, and social domains in the study of command and control.

Models are representations of reality. They can be iconic (physical instantiations that are generally smaller than the object of interest) or conceptual. Iconic models include toys, and physical models of ships or planes used to study alternative designs in artificial environments such as wind tunnels and artificial waterways, which are in themselves, iconic models. Conceptual models are made up of abstractions or concepts, but they must include relationships posited between those concepts or ideas. Indeed, the relationships themselves are also concepts. They might include:

50. Alberts and Hayes, *Understanding Command and Control*, p. 17.
51. American College Dictionary, Third Edition, Boston: Houghton Mifflin Company, 1997.

- A simple statement that two or more concepts are related or influence one another;
- A statement that includes the direction of influence;
- A statement that includes the valence of the relationship;
- A statement that includes the strength of the relationship (which can be ordinal, interval, or ratio in nature);
- Statements about the conditions under which the relationships between the concepts will change or be different.

Given that the concepts in a model can take different values, they become variables when used to explore the model, explain cause and effect within it, or make predictions about it under different circumstances. This is why a conceptual model is considered a vital part of any experiment design.

Conceptual models describe the generic structure of specific categories of problems, systems, or processes in qualitative terms as a guideline for their analysis and assessment in a specific context or application. To this end, generic conceptual models must be instantiated by describing the controllable and uncontrollable variables, and their relationships, that influence the problem solution or performance of systems and processes in the respective specific context. Together with the context-related assumptions and constraints on the variables, and high-level Measures of Merit (MoM), the problem-specific conceptual models provide the basis for a structured qualitative assessment and, if available data permits, also the development of "executable" models.

Executable models specify the conceptual models in terms of mathematical and logical functions and, transformed into computer code, may be used to generate, via computational or simulation experiments, numerate results to support a more comprehensive search for problem solutions than a purely qualitative assessment permits.

## WHAT IS NECESSARY FOR A CONCEPTUAL MODEL TO BE USEFUL FOR RESEARCH AND DEVELOPMENT?

Conceptual models are easy to create. However, research, development, and operational applications require that we demand more than speculation. The dominant quotation on the subject is "all models are wrong, some are useful."[52] To be useful, a conceptual model must have several particular attributes.

- Clearly defined assumptions and limitations;
- Be made up of clearly defined variables;
- Explicitly identify cause and effect;
    - Specify independent variables;
    - Specify controllable and uncontrollable variables;
    - Specify dependent variables;
- Be seen as a valid representation of the phenomenon of interest;
- Be limited to those factors considered essential to the purpose at hand.[53]

52. Box and Draper, 1987, p. 17.
53. Alberts and Hayes, *Understanding Command and Control*, ch. 3.

However, conceptual models are not executable. Rather they provide the ideas needed to develop executable models and simulations. The modellers must add the precision and dynamics needed for those applications.

Properly constructed, "conceptual models represent our current state of understanding and provide a firm foundation to test and improve our understanding."[54] The NATO C2 Conceptual Reference Model (C2CRM) was intended to serve as a point of departure for researchers, analysts, and experimenters. It currently contains more than 300 variables and identifies more than 3000 relationships between and among them. It serves as a checklist to ensure that appropriate attention is given to all the relevant variables and relationships. One product of the SAS-065 work is an update to that model. More importantly, the N2C2M2 focuses attention on those specific variables and relationships that distinguish different levels of C2 maturity and collective C2 maturity.

The N2C2M2 and the C2CRM are not *executable* models capable of generating data to immediately support assessment tasks facing operational and strategic planners in the context of C2 for NEC. Rather, N2C2M2 and the C2CRM are generic conceptual models of C2 systems and processes. Together they support the development of a structured process for the analysis and assessment of C2 problems in the context of NEC, in general, and its implementation in specific scenarios.

## A MATURITY MODEL

A maturity model has the following essential properties:

54. Alberts and Hayes, *Understanding Command and Control*, p. 30.

- It identifies different levels of capability that are achievable;
- It usually assumes that organisations, as they mature, will be able to achieve higher levels of capability;
- Some maturity models map maturity levels to the degree of achievement and/or to the specific characteristics of a number of key variables;
- The maturity levels must be measurable.

A maturity model is like a map, it helps you determine where you are relative to where you want to go. It also identifies places along the way that are intermediate destinations on the journey to maturity and transformation. Typically the highest levels of maturity are desirable for more complex situations.

When planning a journey together with others it is obviously important to first know where you and others who are participating in the journey are located relative to one another. For researchers and analysts is it important to be able to recognise or create, in experiments, the conditions associated with different C2 maturity levels.

## C2 MATURITY

The Network-Centric Maturity Model[55] was designed to suggest a strategy that organisations could adopt to improve network-centric capability with a set of milestones that represented significantly different levels of capability. These milestones were expressed as maturity levels. The network-centric maturity model provided, for the first time, a conceptual tool that could be used to understand and assess the emerging body

55. Alberts et al., *Understanding Information Age Warfare*, p. 241.

of evidence related to the implementation of network-centric concepts. The concept of C2 maturity is thus relatively recent having been introduced less than the decade ago in the book, *Understanding Information Age Warfare* (Alberts, Garstka, Hayes and Signori, 2001). The challenge at hand was to provide a means of evaluating the accumulating body of evidence related to the adoption of network-centric concepts; what in NATO is known as NEC. It was well understood that these concepts could not be fully instantiated in the near term and that a transition strategy would be required. Further, that during this period of transition, organisations should be focused on a series of measurable milestones that were associated with increasing capability to conduct network-enabled operations. Thus, a specific level of C2 maturity is associated with a specific set of capabilities that focus an entity or set of entities and converge on a desired set of outcomes. These are the capabilities formerly included in the set of command and control responsibilities.

A C2 maturity level allows you to choose from one or more C2 approaches together with the ability to transition between the approaches based on an understanding of the situation. The C2 maturity model is a layered framework consisting of five such C2 maturity levels with increasing maturity as the levels increase from one to five.

Thus, C2 maturity in the context of this model, the N2C2M2, equates to a given level of capability to focus attention and effort and converge on desired outcomes in the context of NEC. A higher level of C2 maturity is equated with increased levels of C2 performance and effectiveness as seen from a network-centric perspective.

## C2 APPROACH

A C2 Approach can be defined as a specific region within the C2 approach space. A region defined by specific ranges of these dimensions: *Allocation of Decision Rights*, *Patterns of Interaction*, and *Distribution of Information*. As part of the C2 maturity model, five representative C2 approaches were associated with five specific regions of the C2 approach space. These five C2 approaches are: *Conflicted C2*, *De-Conflicted C2*, *Coordinated C2*, *Collaborative C2*, and *Edge C2*. These regions lie sequentially along the diagonal vector of the C2 approach space, with Conflicted C2 at the origin and Edge C2 towards the farthest end of the C2 approach space. As an entity moves along this diagonal vector (from Conflicted to Edge C2), the approach to C2 is more network-enabled (or network-centric). The Network-Centric Maturity Model[56] referred to more network-centric approaches as being more "mature." Since the N2C2M2 adds other conditions for maturity (recognition of the situation, appropriateness of various C2 approaches, and the ability to transition), to avoid confusion, we have decided to call C2 approaches that are nearer the edge more network-centric, rather than more mature. Thus, a C2 approach is not equivalent to a C2 maturity level; however they are related. The report illustrates the relationship between C2 approaches and C2 maturity levels using a toolkit analogy. That is, each C2 maturity level can be viewed as a toolkit that has a number of C2 approaches in it. For instance, C2 Maturity Level 1 has only Conflicted C2 in it; C2 Maturity Level 2 has only De-Conflicted C2 in it; C2 Maturity Level 3 has De-Conflicted C2 and Coordinated C2 in it; C2 Maturity Level 4 has three C2 approaches in it; and C2 Maturity Level 5 has all 4 approaches in it.

56. Alberts et al., *Understanding Information Age Warfare*.

## AGILITY

Agility is a concept that can apply to entities, systems, and material. Agility is discussed in the context of a force or collection of entities that are participating in a complex endeavour and in the context of the capability of the entity or collective to focus and converge. It is the synergistic combination of robustness, resilience, responsiveness, flexibility, innovation, and adaptation.

## FORCE AGILITY

Given the increased complexity and dynamics of the environment, the effects space, and the collection of entities involved in the endeavour, a corresponding increase in force agility[57] is required for success (Atkinson and Moffat 2005, Alberts and Hayes 2003). Increasing agility requires improving a number of focus and convergence-related capabilities and processes as well as changing intra-entity and inter-entity behaviours. For example, the ability to share information within and among participating entities must be accompanied by changes in information sharing behaviours and policies including a move from decisions to share based on "need to know" to information-sharing decisions based on an understanding of the "need to share." This change in behaviours will result in the enrichment of peer-to-peer (P2P) interactions (e.g., horizontal exchanges and interactions with peer contributing force elements and other actors). The resulting increases in information sharing will improve the quality and accessibility of available information which will, in turn, improve entity awareness and

57. Force agility is all about maintaining an acceptable level of effectiveness in the face of changing circumstances. A more detailed definition of agility is provided in (Atkinson and Moffat, 2005; Alberts and Hayes, 2003).

shared awareness. Peer-to-peer interactions do not replace, but are added to the well-established vertical interactions present in command hierarchies. Such a development will, for many organisations, require a change in culture—both in how information is viewed and how individuals/organisations relate to one another.

## C2 AGILITY (FOCUS AND CONVERGENCE)

Continuing with the toolkit analogy, agility is the ability to select the *right tool for the right job*. A collective is said to be *C2 agile* if they can recognise the dynamic nature of the situation and apply the appropriate C2 approach. Different approaches to C2 involve changes in one or more characteristics of the approach to collective C2 (focus and convergence). This results in approaches that correspond to different degrees of being network-centric being located in different parts of the C2 approach space (Alberts and Hayes 2007).[58] For example, one of the dimensions of the C2 approach space represents the patterns of the interaction between and among participants (in this case the contributing elements and the individuals and groups of individuals including organisations that comprise them). As maturity increases, the nature and frequency of the interactions that take place between and among the entities increase and the focus of these interactions shift from the Information Domain (from sparse to rich exchange of information) to the Cognitive Domain (from low to high degrees of shared awareness and understanding) and then to the Social Domain (from low to high sharing of resources). These are the key "tipping

58. Alberts and Hayes, *Planning: Complex Endeavors*.

points" leading to qualitatively different NNEC C2 maturity levels. *Being able to choose among a larger set of C2 approaches is the essence of C2 agility.*

The net result is that entities have the ability to work more closely together (as appropriate) as the maturity of C2 increases. An increased ability to work together in the Information and Cognitive Domains (to share information and to collaborate) can, if accompanied by an appropriate approach to accomplishing the functions associated with command and control (management and governance), translate into dramatically increased effectiveness and agility. This is, in fact the value proposition that forms the basis for network-centric or network-enabled operations.[59]

## USES OF THE MODEL

There are many potential uses for this maturity model. Among these uses are to help organisations and coalitions:

- understand their current approach to command and control (or management and governance);
- determine their level of C2 maturity;
- determine what they need to do in terms of organisation, doctrine, process, training, and/or materiel investments to develop a capability to operate at a more mature level;
- measure progress;
- understand what is needed to be effective in a greater variety of situations;
- develop a strategic C2 vision;

59. Network Centric Warfare, DoD Report to Congress; Alberts et al., *Understanding Information Age Warfare*.

- create educational and training materials to increase C2 related awareness and competence;
- develop appropriate experiments and/or exercises to enhance their ability to employ various approaches to C2-related awareness and competency;
- understand what C2 approach and level of C2 maturity is appropriate or inappropriate for a given situation;
- develop an associated investment plan and roadmap to develop a capability to conduct network-enabled operations;
- formulate appropriate campaigns of research and experimentation designed to improve our understanding of command and control.

Thus, the N2C2M2 supports a variety of users—from senior management to project managers, from strategic planners to budget analysts, from doctrine developers to commanders in the field, and from educators to researchers to analysts.

We continue, in more detail below, with a discussion of the challenges we face in 21st century operations, explain the reasons why traditional approaches to C2 (management/governance) are increasingly inappropriate, discuss the implications for C2, and document NATO's commitment to leverage the concepts and technologies of the Information Age by developing a capability to conduct network-enabled operations. This introductory section is thus followed by a discussion of what a maturity model is, how C2 maturity levels map to NNEC capabilities, and a description of the NATO NEC C2 Maturity Model (NNEC C2 Maturity Model or N2C2M2) itself; which includes how C2 approaches are related to C2 maturity levels. Since many terms may not be familiar to readers, a *Glossary* is provided at the end of the document.

# Chapter 3
# NNEC C2 Maturity Model

## INTRODUCTION

The NATO NEC C2 Maturity Model (N2C2M2) provides a framework that can be used to assess appropriateness of the C2 approaches and related capabilities possessed by a collection of entities (both military and non-military). The model consists of five C2 maturity levels that are associated with the degree to which an entity or a collective is able to effectively conduct network centric operations.

Operating at a higher level of C2 maturity provides collections of entities (or an entity) with a larger set of C2 approach options from among which to employ. Having options is of little value unless one understands which of the available options is appropriate for the situation at hand. Thus, a maturity level not only involves being able to select from a particular set of C2 approaches but also the ability to recognise the appropriate C2 approach and the ability to transition from one approach to another, as appropriate. This dynamic applies not only to preparing for an endeavour but also during an endeavour as required.

Since increasing command and control capability is not an end unto itself, progress towards NEC requires that links be made between C2 maturity levels and NNEC capability levels. The maturity model establishes these performance-related links.

Knowing where you are is not sufficient for the journey at hand. One also needs a roadmap that shows how to get to the next step along the way. The N2C2M2 helps in this regard by identifying what is needed to move an entity (a nation, or a coalition) from one maturity level to the next.

Thus, the N2C2M2 provides a set of milestones that can be used by NATO as well as nations for C2 and NEC planning (strategic planning for an expected set of mission contexts or planning for a particular mission). It also provides a set of metrics to measure progress toward the achievement of a desired level of C2 maturity which, in turn, is required to achieve a desired level of NNEC operational capability.

### *Mission Context*

NNEC and its associated command and control capabilities need to be analysed and assessed in a realistic context. Given the large uncertainty of the future operational space, including the nature and challenges of complex 21st century civil-military endeavours, agility across this spectrum of future operations provides the context for considering the implications of operating at each of the defined C2 maturity and NNEC levels.

## *Links Between NEC C2 Maturity Levels and NNEC Operational Capability Levels*

The degree of operational coherence (the ability to generate synergy across a set of participants) that can be achieved, as reflected by increased levels of NATO NEC operational capability, will depend upon the nature of the command and control arrangements that exist (both within entities and across a set of entities) and the degree to which the functions associated with C2 are achieved (e.g., shared awareness). Thus, the ability to *command and control*[60] the endeavour determines the operational capability level that can be achieved. The five NEC C2 Maturity Levels and their relationship to the NEC Operational Levels[61] are depicted below in Figure 3. The horizontal arrows imply that a particular level of C2 maturity is adequate to achieve the corresponding NNEC capability level.

60. The word *focus* has been suggested to replace *command* for complex civil-military endeavours; *convergence* has been suggested to replace *control* in environments and situations where *control* is simply not realistic (Alberts, 2007).
61. NNEC Feasibility Study, EAPC(AC/322)N(2006)0002, (2006).

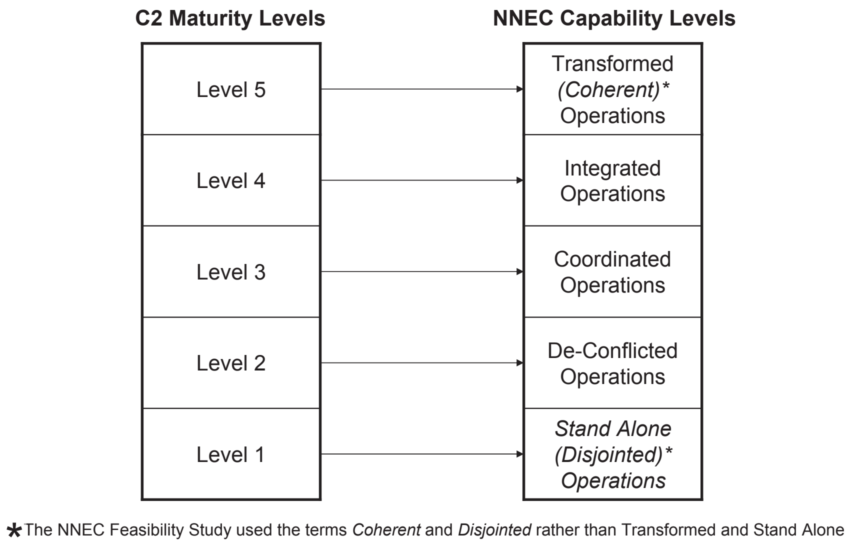


Figure 3: Levels of C2 Maturity and NNEC Capability

## *Outline of the Section*

This section begins with a description of the three dimensional *C2 Approach Space*, the space of all possible C2 approaches. It then indentifies five representative approaches for accomplishing the functions associated with command and control and locates these different approaches in appropriate regions of the C2 Approach Space. Each of these approaches has, in fact, been employed in practice although some have been more extensively employed by military and industrial organisations. The characteristics associated with each of these representative approaches is then described in some detail along with what is required to transition from one approach to another. The section concludes with a discussion of the relative effectiveness of these C2 approaches.

## C2 APPROACH SPACE

The NATO NEC C2 Maturity Model associates the ability to appropriately adopt different sets of representative approaches to accomplishing the functions that are associated with different levels of C2 maturity. Increased C2 maturity corresponds to the ability of an entity to adopt a wider range of approaches to command and control that, in turn, covers a larger portion of the C2 Approach Space. This ability to approach C2 in a variety of ways must be accompanied by an ability to recognise the appropriate approach. The appropriateness of an approach is determined by the nature of the situation and how it is likely to evolve. The entity must also be able to change its C2 approach if necessary in a timely manner. A particular C2 approach differs from other approaches along one or more of three interrelated dimensions.[62] These dimensions are (1) the allocation of decision rights, (2) the patterns of interaction that take place between and among entities, and (3) the distribution of information.

Normally the concept of C2 approach is applied to a single organisation. SAS-065, however, is concerned with complex endeavours[63]. These are endeavours in which there are two or more entities present and where one or more of the following conditions exists: the entities have a degree of common intent; the entities are operating in the same space at the same time; and, the actions taken by an entity can come into conflict with those taken by other entities. The temporal dynamics of the situation and the timeliness requirements associated with a response can vary widely.

62. Alberts and Hayes, *Understanding Command and Control.*

63. See footnote 4.

Therefore, we will interpret the dimensions of C2 approach from the perspective of a *collective*, i.e., the set of entities engaged in a complex endeavour. Thus, while each of the individual entities will have its own C2 approach, the way these entities work together (or fail to work together) is what is of interest. In other words, we are interested in collective C2. Looking at C2 approach from a collective perspective implies the following re-interpretation of the dimensions of a single organisation's C2 approach:

1. ***Allocation of decision rights to the collective***
   In a collection of entities, the allocation of decision rights reflects the actual rights exercised by the entities in a complex endeavour. This allocation can be the result of explicit or implicit laws, regulations, roles, and practices or it can be as a result of emergent behaviour. The allocation of the rights of participating entities to the collective can likewise be explicit, implicit or emergent. An allocation of a right to the collective refers to the degree to which individual entities have given up their respective rights for the benefit of the endeavour as a whole.
2. ***Patterns of interaction among participating entities***
   Patterns of interaction between and among participating entities are a function of their respective abilities and willingness to interact as well as the opportunities they have as a result of the actual occurrence of interactions and collaborations. Interactions are enabled and their quality is enhanced by the ability to have (face-to-face or virtual) meetings, the connectivity of the infostructure, and the degree of interoperability that exists between and among a set of participants (technical, semantic, and cooperability).

3. ***Distribution of information across participating entities***
   The distribution of information across participating entities refers to the extent to which the information needed to accomplish required tasks is available to each participant.

The manner in which decision rights are allocated influences who interacts with whom and the frequency and nature of the interactions that take place between and among endeavour participants. These interactions take place within an entity and between and among individuals in different entities. These three dimensions form a three-dimensional space, as illustrated in Figure 4.

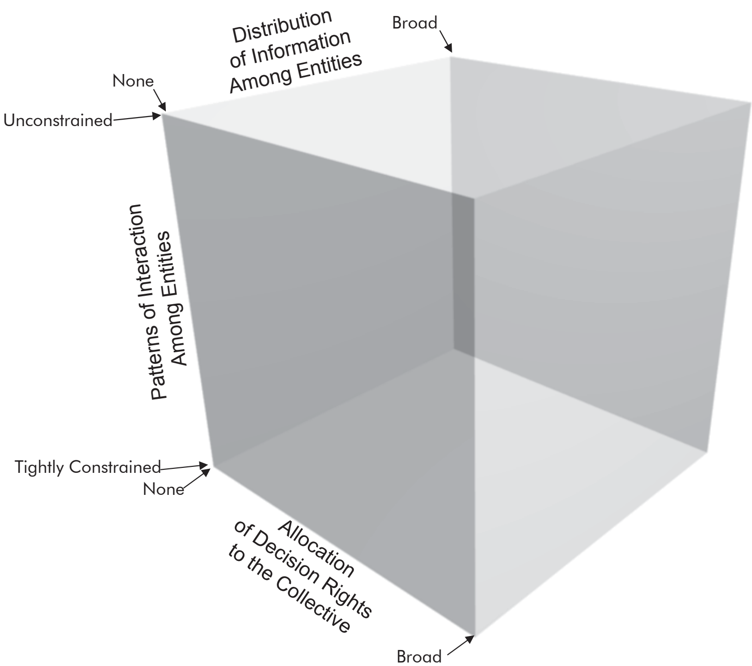


Figure 4: C2 Approach Space and three interrelated dimensions: allocation of decision rights to the collective, patterns of interaction among entities, and distribution of information across entities

Different regions in this space equate to different approaches to collective command and control. Clearly the appropriateness of a particular approach to command and control, as well as the selection of an option or course of action, involves a consideration of responsiveness. In the discussions that follow, it is assumed that the frequency of information sharing, the frequency of interactions and, the allocation of decision rights all match mission requirements.

Furthermore, information sharing and other forms of working together require willingness on the part of the participating entities. Such willingness is assumed in the discussions that follow. As a practical matter, it is possible that entities will agree to operate at a certain level of maturity but not have or have limited willingness to do what is necessary to make the selected approach to command and control work. For the purposes of this discussion we consider this to be a failure to implement.

## C2 APPROACHES

We have grouped C2 approaches into five classes that are described in the following sections. The objectives of each of these C2 approaches and the implications for information sharing, collaboration, and delegations of decision rights are briefly discussed. Note that each entity that is participating in a collective is expected to have its own (internal) approach to command and control, one that may or may not be compatible with the approach adopted (or defaulted into) by the coalition or collective.

## *Conflicted C2*

There is no *collective* objective. The only C2 that exists is that exercised by the individual contributors over their own forces or organisations. 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 (in a C2 sense) between or among the entities. Given that, the only C2 present with Conflicted C2 is the organic C2 within each of the entities (see Figure 5).

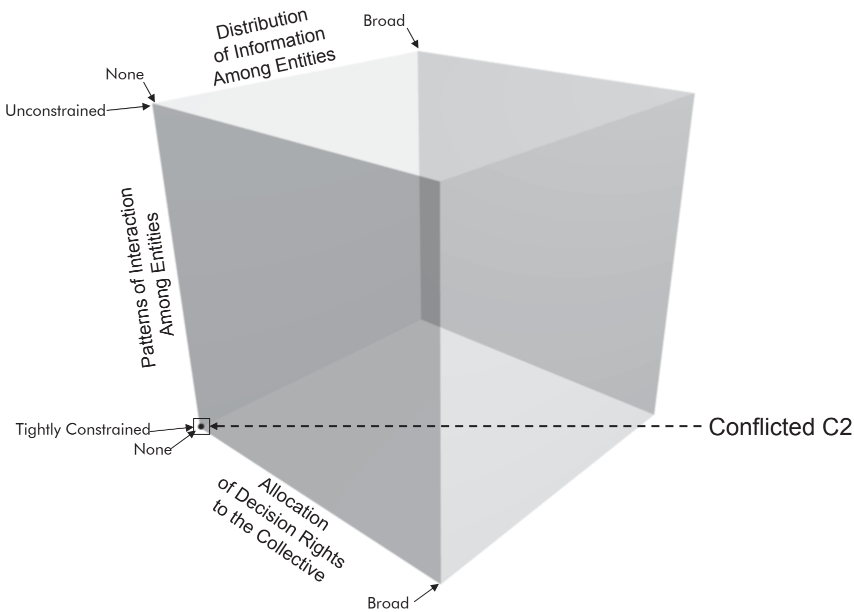


Figure 5: Region of Conflicted C2

In the case of Conflicted C2, all interactions are within individual entities. That is all of the interactions that take place occur between and among individuals within some entity. Thus, a graph of the interactions for the collective of participating entities would show a number of clusters, each corresponding to an individual entity with no links between individuals in different entities; in other words, a set of isolated entity clusters. This is illustrated in Figure 6.

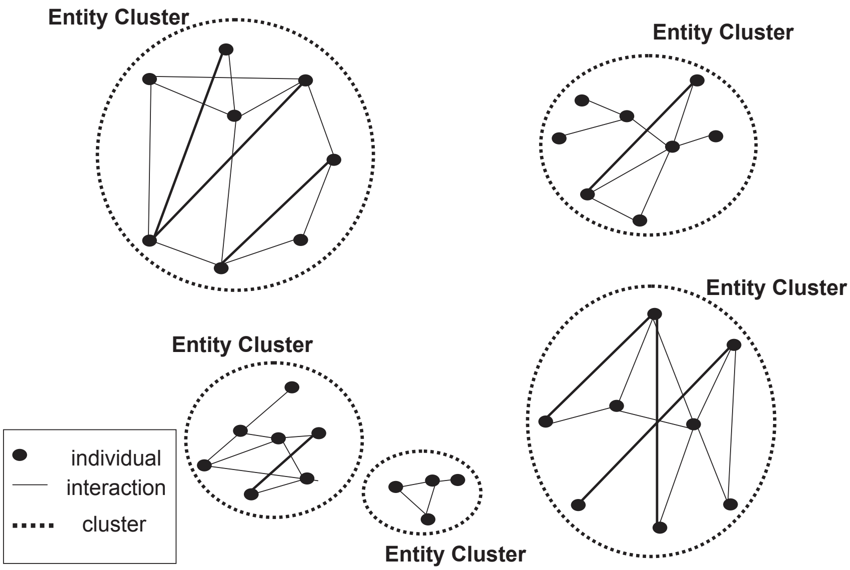


Figure 6: Conflicted C2: Interactions for the Collective of Participating Entities

## *De-Conflicted C2*

The objective of De-Conflicted C2 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 recognise potential conflicts and attempt to resolve them by partitioning across geography, function, echelon, and/or time. This involves limited information sharing and limited interactions.

It requires that entities give up the freedom to operate without any constraints and thus, in effect, agree to delegate those decision rights that are necessary to ensure de-confliction. It also requires that participating entities delegate their rights associated with operating without any constraints. Instead, participating entities agree not to act in a manner that violates any agreed upon constraint. This is the most limited form of collective decision rights in the set of C2 approaches, which includes De-Conflicted, Coordinated, and Collaborative. Given the limited nature of the information exchange and the interactions required, a De-Conflicted C2 approach occupies a small region (locus of points) near the origin of the C2 Approach Space (see Figure 7)

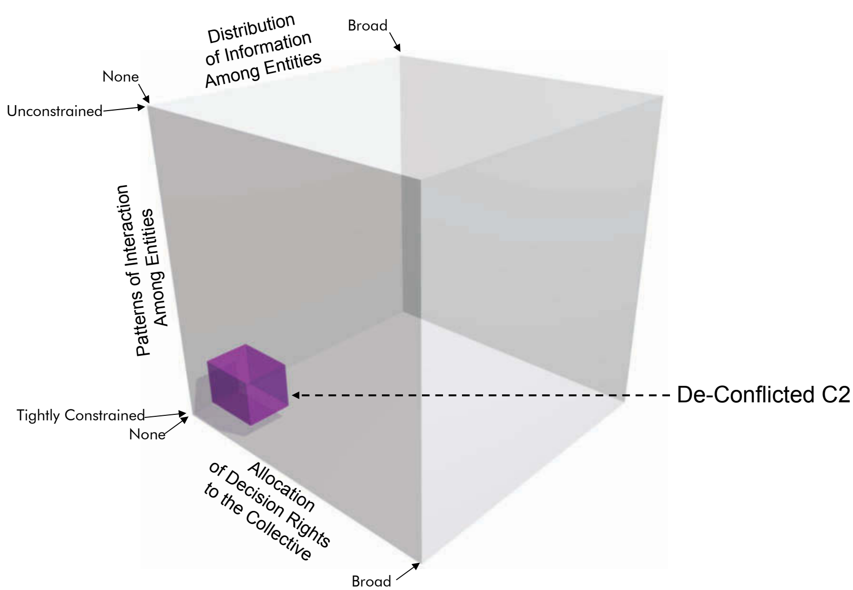


Figure 7: Region of De-Conflicted C2

Depicted in Figure 8, De-Conflicted C2 requires minimal, episodic interactions between and among individual clusters, each of which represents a given participating entity.

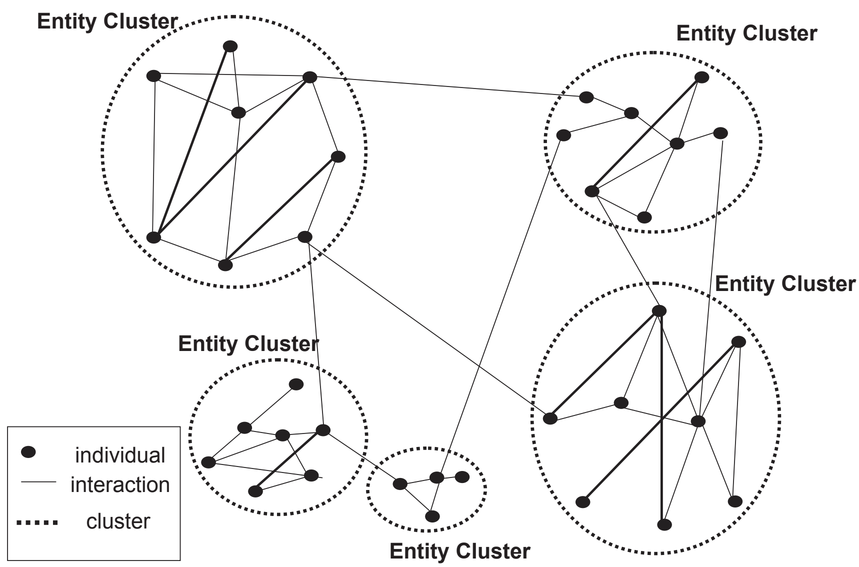


Figure 8: De-Conflicted C2: Interactions for the Collective of Participating Entities

## *Coordinated C2*

The objective of Coordinated C2 is to increase overall effectiveness by (1) seeking mutual support for intent, (2) developing relationships and linkages between and among entity plans and actions to reinforce or enhance effects, (3) some initial pooling of non-organic resources,[64] and (4) increased sharing in the Information Domain to improve the quality of information.

64. *Non-organic resources* refers to resources not *owned* by participants. These include access to bridges and roads, and sharing of higher level ISTAR and logistics.

Coordination involves more than an agreement to modify one's intent, plans, and actions to avoid potential conflicts. It involves development of a degree of common intent and an agreement to link actions in the various plans being developed by the individual entities. This in turn requires a significant amount of information sharing (broader dissemination) and a richer set of interactions, both formal and informal (relative to those required for de-confliction), among those in the various elements that are involved in establishing intent and developing plans. While the interactions required may be quite frequent, they do not approach continuous interaction. A Coordinated C2 approach requires participating entities be constrained by common intent and linked plans. Thus, operating with a Coordinated C2 approach requires the delegation of decision rights to the collective that are associated with the coordination process and the implementation of agreements that are a result of this process.

With a Coordinated C2 approach, more decision rights need to be allocated to the collective. Specifically, the decision of individual entities related to links between and among entities' plans are now collective decisions. Correspondingly, the need for interactions, the amount and frequency of information sharing, and the amount of shared information are all increased. Thus the region of the C2 Approach Space that corresponds to Coordinated C2 occupies a region that extends considerably along the information dissemination and interactions dimensions but only a small distance along the distribution of decision rights dimension (see Figure 9).

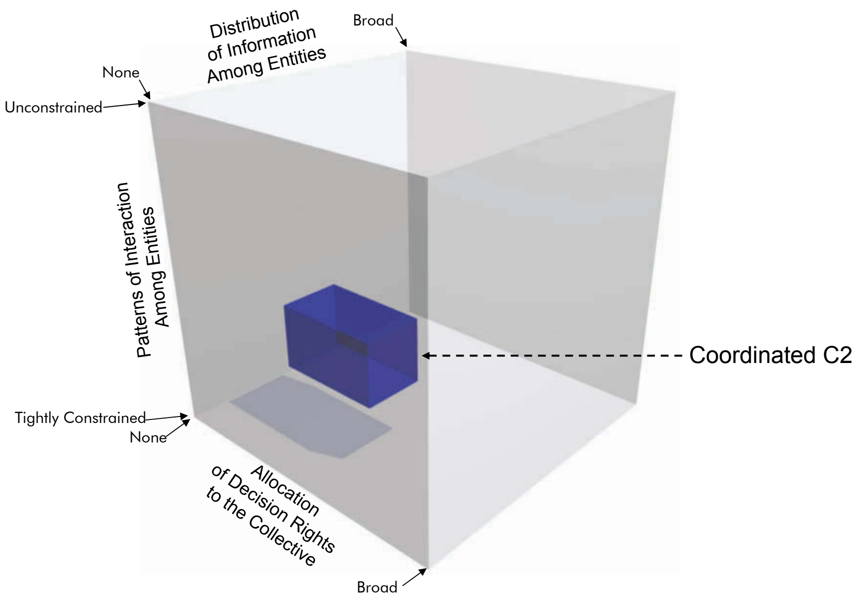


Figure 9: Region of Coordinated C2

In Coordinated C2, some clusters of interactions appear that correspond to tasks that involve two or more individual entities working together. The number of links (interactions) between and among clusters is still limited and although, more frequent and continuous than in the case of De-Conflicted C2, interactions are periodic, not anywhere near continuous (see Figure 10).

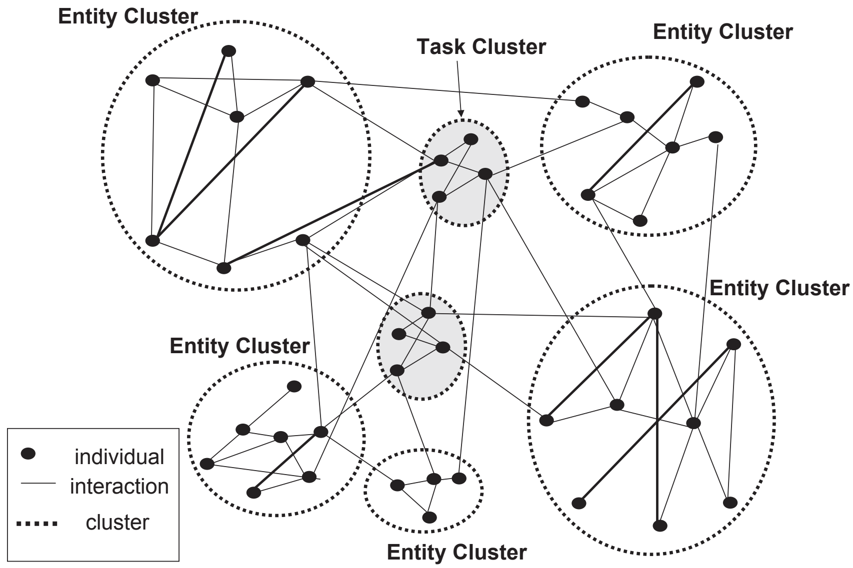


Figure 10: Coordinated C2: Interactions for the Collective of Participating Entities

## *Collaborative C2*

The objective of Collaborative C2 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 resources, (5) some pooling of organic[65] resources, and (6) increasing interactions in the Social Domain to increase shared awareness. This approach to C2 involves more than common intent; it involves the collaborative development of a ***single shared plan***. The intents of the entities/elements are subordinate to common intent. Entities may have other intents as long as they do not conflict with, or detract from, common intent. Similarly, entity plans

65. Organic resources are those *owned* by a participant. They may include vehicles, weapons, and local supplies.

need to be supportive of the single integrated plan. Entities employing a Collaborative C2 approach accept symbiotic relationships and are interdependent. Very frequent interactions, indeed approaching continuous interactions between/among identified individuals/organisations, involving richer and more extensive interchange in both the Information and Cognitive Domains, is required to establish shared understanding and the development of a single shared plan. Collaborative C2 involves a considerable amount of delegation of decision rights to the collective. However, once common intent has been established and an integrated plan has been developed, the collective "delegates" back to the entities—the rights to develop supporting plans and to dynamically adjust these plans collaboratively.

Thus, Collaborative C2 requires that entities accept significant constraints on their plans and actions. This C2 approach corresponds to a region in the C2 approach space that extends across almost the full range of information dissemination and interaction dimensions and along a great deal of the decision rights dimension (see Figure 11).

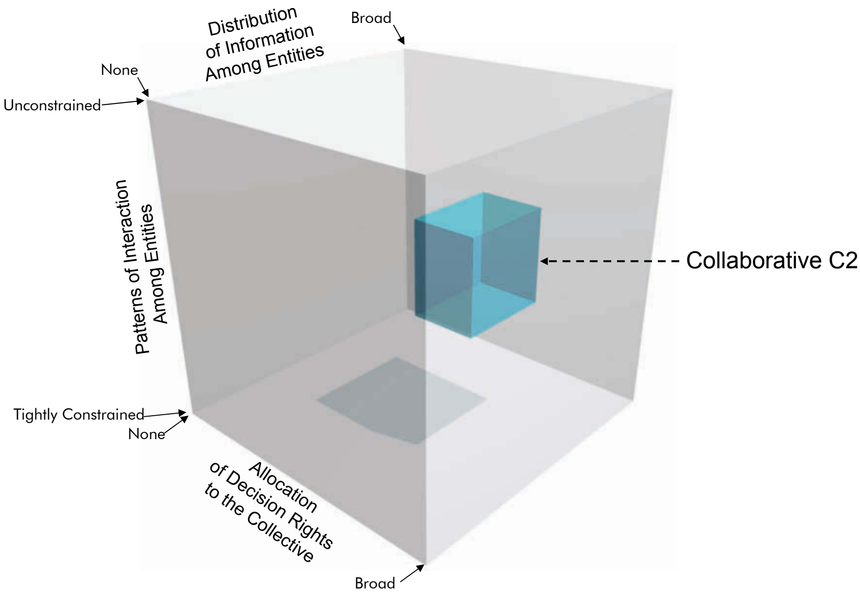


Figure 11: Region of Collaborative C2

Significant task-related clusters of entities working together form and, in fact, begin to compete with entity clusters. Thus, interactions are as much between and among entity clusters and within task-related clusters as they are within entity clusters (see Figure 12). The degree of inter-cluster connectivity increases dramatically and can be characterised as rich and continuous (or near continuous).

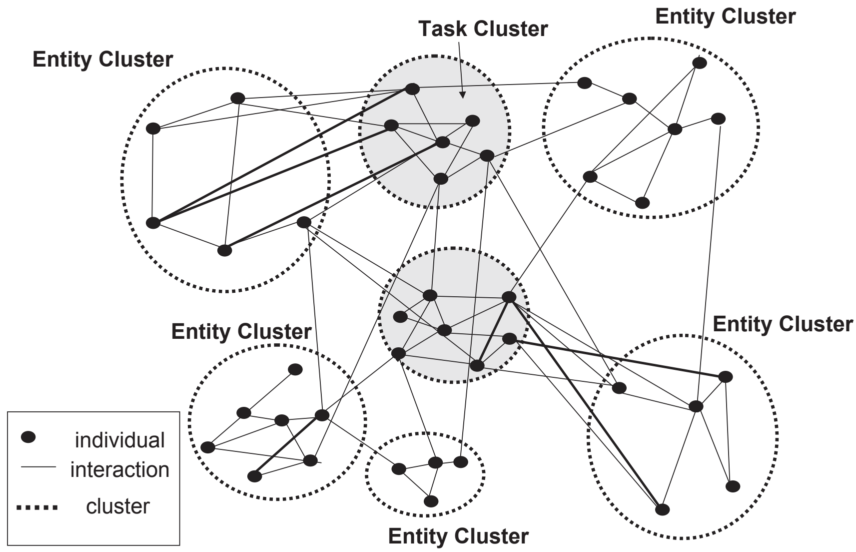


Figure 12: Collaborative C2: Interactions to the Collective Participating Entities

## *Edge C2*

The objective of Edge C2 is to enable the collective to self-synchronise. The ability to self-synchronise requires that a rich, shared understanding exists across the contributing elements. This, in turn, requires a robustly networked collection of entities with widespread and easy access to information, extensive sharing of information, rich and continuous interactions, and the broadest possible distribution of decision rights. Self-synchronisation includes self-organisation. Thus, entities or collections of entities can look and behave as if they are employing other approaches to C2. The key differences are: In Edge C2 the rights to decisions are broadly distributed even when it appears that decisions are being made by a limited set of individuals or entities. This is because other entities maintain their decision rights. In Edge C2, patterns of interaction are dynamic and reflect the confluence of mission and circumstances. The resulting distribution of information is emergent as a function of the emergent decision-related and interaction-related behaviours.

An Edge approach to C2 distinguishes itself from the other C2 approaches by replacing deliberate and formal coordination-collaboration mechanisms with the dynamics of emergence and self-synchronisation. In Edge C2 the entities, enabled by a high degree of shared awareness, widespread access to information, and unconstrained interactions, self-synchronise. In terms of the C2 approach space, an Edge C2 approach allows the collection of entities to operate in a region where collective decision rights can be dynamically allocated by rich and continuous interactions and wide-spread sharing of information (the corner furthest from the origin, see Figure 13), a space previously associated with Edge organisations (Alberts and Hayes 2003).

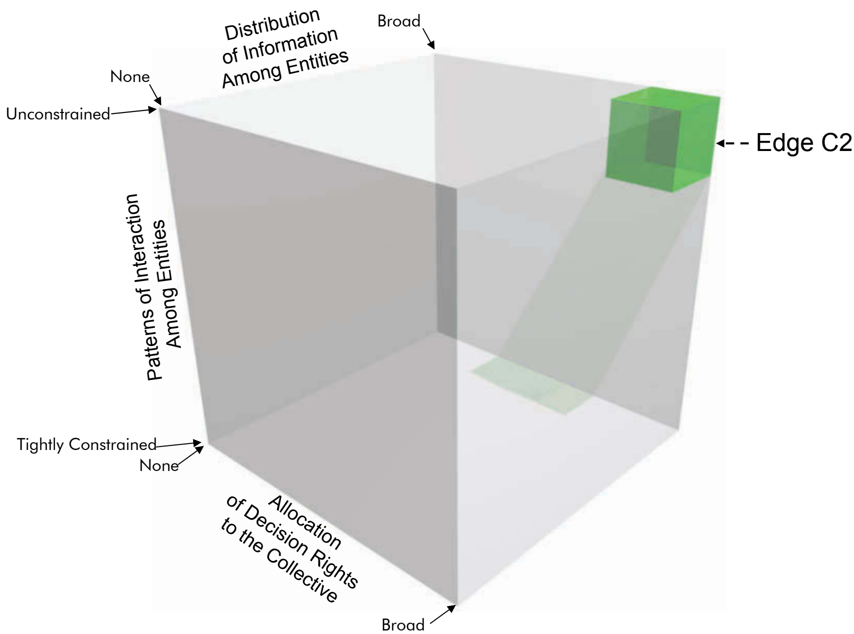


Figure 13: Region of Edge C2

In the case of Edge C2, the clusters of entities related to tasks dominate. These *task-organised* clusters are not static as may be the case in Coordinated or Collaborative C2, but are in fact emergent, being both tailored to the evolving situation and dynamic in response to changes in the endeavour and/or the environment (see Figure 14).

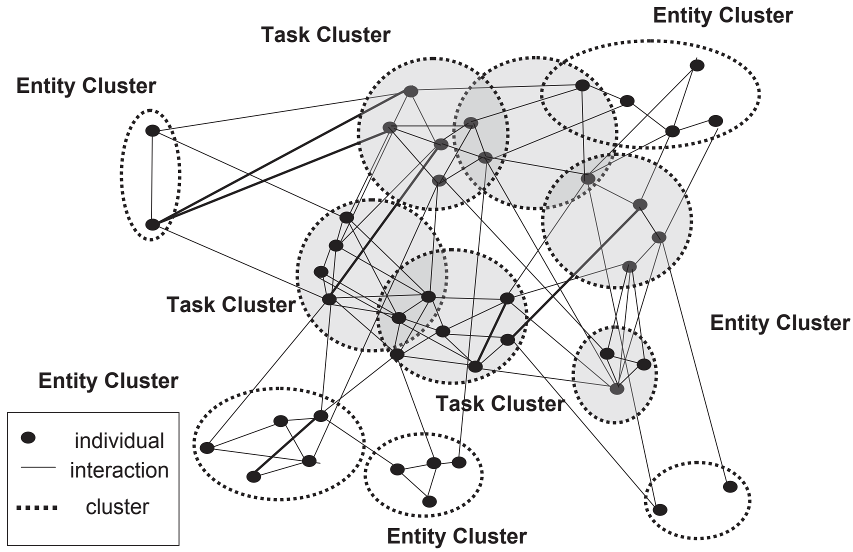


Figure 14: Edge C2: Interactions Between and Among Participating Entities

## C2 APPROACHES AND THE C2 APPROACH SPACE

Figure 15 summarises the attributes of each of the C2 approaches in terms of the region they occupy on the C2 approach space (described by the three variables listed across the top). The relationships among the approaches are depicted by gaps between Conflicted and De-Conflicted C2 and Collaborative and Edge C2. Because the exact boundaries are difficult to precisely define, the boundaries between De-Conflicted, Coordinated, and Collaborative C2 are illustrated by dashed lines (see Figure 15).

| C2 Approach | Allocation of Decision Rights to the Collective | Patterns of Interaction Among Participating Entities | Distribution of Information (Entity Information Positions) |
|---|---|---|---|
| Edge C2 | Not Explicit, Self- Allocated (Emergent, Tailored, and Dynamic) | Unlimited As Required | All Available and Relevant Information Accessible |
| Collaborative C2 | Collaborative Process and Shared Plan | Significant Broad | Additional Information Across Collaborative Areas/Functions |
| Coordinated C2 | Coordination Process and Linked Plans | Limited and Focused | Additional Information About Coordinated Areas/Functions |
| De-Conflicted C2 | Establish Constraints | Very Limited Sharply Focused | Additional Information About Constraints and Seams |
| Conflicted C2 | None | None | Organic Information |

Figure 15: Variables Defining Collective C2 Approach

The first column, the allocation of decision rights reflects the nature and extent of the decision rights held by individual entities that are explicitly ceded or transferred to the collective. This *reallocation* of decision rights may be the result of a pre-existing agreement (as in NATO) or it may be negotiated on-the-fly. The second column reflects interactions among participating entities, including information sharing across the entities (as opposed to within entities) while the third column reflects the way information is distributed. An entity's information position (the extent to which it possesses the information needed) is determined by the information that an entity has received or can access. Given the limited amount of information organic to entities, the ability to develop information positions required to develop adequate awareness depends on interactions as well as information sharing behaviours.

A break between Conflicted C2 and De-Conflicted C2 indicates that there is a qualitative difference between, in effect, no collective C2 and some form of collective C2. The fact that there is no break between De-Conflicted, Coordinated, and Collaborative means that these three approaches differ in the degree of rights allocated to the collective, the nature of inter-entity interactions, information sharing behaviours, and the degree to which the information positions of participating entities differ. Another break, this time between Collaborative C2 and Edge C2, indicates a qualitative difference in the decision rights dimension. Given entities' willingness to allow dynamic distribution of decision rights to the collective in Edge C2, the allocation of decision rights in this C2 approach is an emergent process which results from the peer-to-peer sharing of information, and the dynamic patterns of interaction that occur. This allows for the full sharing of both organic and non-organic resources and the ability to self-synchronise, creating dynamic, task-organised groupings of force as required by the dynamics of the operational context.

As was stated earlier, different classes of command and control approach occupy different regions of the C2 approach space, a three dimensional space with axes[66] that correspond to: allocation of decision rights to the collective, patterns of interaction among the entities, and distribution of information across entities. The five classes of C2 approach are depicted as different regions in the C2 Approach Space (see Figure 16) and are discussed in the following sections.

66. These axes are not independent. In fact, the allocation of decision rights influence the patterns of interactions and both of these in part determine how information is distributed.

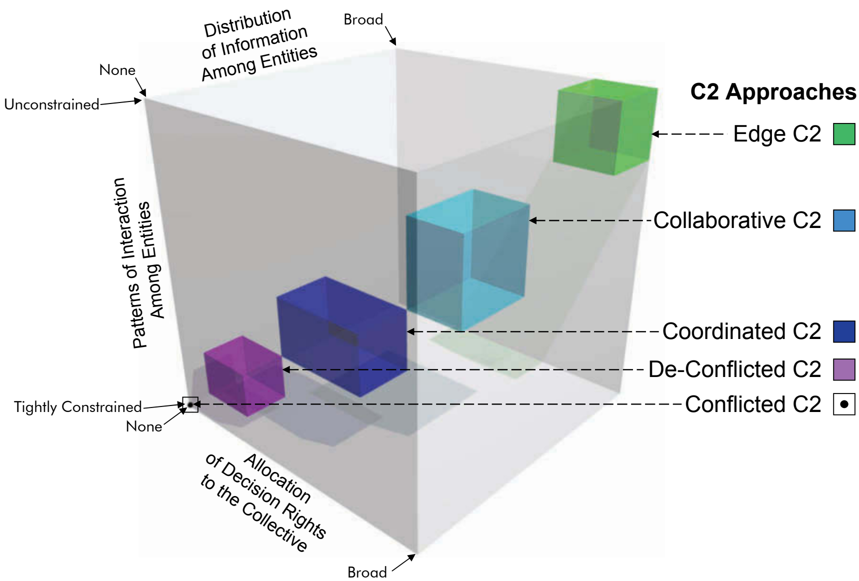


Figure 16: C2 Approaches and the C2 Approach Space

## DISCUSSION OF C2 APPROACHES

This section is devoted to a discussion of some of the implications associated with adopting the different approaches to C2 that correspond to different regions of the C2 Approach Space. This discussion begins with a more detailed look at the patterns of interaction between and among participating entities associated with each of the C2 approaches. These patterns of interaction directly reflect the actual distribution of decision rights and determine, in large part, the way information flows. The resulting distribution of information, together with the patterns of interaction and the allocation of decision rights have an expected impact on the effectiveness of the C2 approach and on C2 agility.

Figure 17 summarises the discussion of the characteristics of the patterns of interaction associated with each of the different approaches to collective C2.

| | | | |
|---|---|---|---|
| **Edge C2** | Endeavour Objective(s) and Tasks | Complete | Tailored and Dynamic |
| **Collaborative C2** | Mixture, Largely Task-Related and Some Entities | Rich | Continuous or Nearly Continuous |
| **Coordinated C2** | Mixture, Largely Entities and Some Task-Related | Limited | Periodic |
| **De-Conflicted C2** | Entity Organisations | Minimal | Episodic |
| **Conflicted C2** | Entity Organisations | None | None |
| **C2 Approach** | **Cluster Attractor** | **Degree of Inter-Cluster Connectivity** | **Frequency/Continuity** |

Figure 17: Characteristics of the Patterns of Interaction by C2 Approach

# C2 APPROACH TRANSITION REQUIREMENTS

The ability to be able to move from regions in the lower left of the C2 approach space to the upper right of the space requires the addition of one or more key capabilities that, in turn, require improvement in the infostructure that supports command and control as well as changes in C2 concepts and processes. This section identifies some of these C2 approach-related requirements.

*From Conflicted to De-Conflicted*

C2 Tasks Required: Identification of potential conflicts and resolution of conflicts by establishing constraints and/or boundaries.

Capabilities Required: Limited communications involving limited individuals and limited information exchanges restricted to constraints and seams (strict Information Exchange Requirements (IER) on a need-to-know basis).

*From De-Conflicted to Coordinated*

C2 Tasks Required: Development of a limited degree of common intent and development of links between and among individual plans and actions.

Capabilities Required: Establishment of a coordination process. Requires sufficient communications, information-related capabilities involving the appropriate individuals, and necessary information exchanges (fixed IERs on a need-to-know basis).

*From Coordinated to Collaborative*

C2 Tasks Required: Development of common intent, shared understanding and trust, development of a single integrated plan, and parallel development of entities' plans that are synchronised with the overall plan.

Capabilities Required: Establishment of a set of collaborative processes, supported by a sufficiently robust and extensively distributed collaborative environment available to all appropriate individuals and organisations. A high degree of interoperability in all domains needs to be achieved in order to develop sufficient levels of shared awareness and understanding (dynamic IERs on a need-to-share basis).

*From Collaborative to Edge*

C2 Tasks Required: Development of shared intent, awareness, and understanding.

Capabilities Required: *Power to the Edge* principles and associated doctrine must be adopted, supported by a robust, secure, ubiquitous, interoperable, info-structure that extends to all participating entities (dynamic IERs on a need-to-share basis).

## C2 EFFECTIVENESS AND C2 ADAPTABILITY AS A FUNCTION OF C2 APPROACH

C2 effectiveness can be calculated or assessed in a number of ways. For the purpose of assessing the ability of a particular approach to command and control to support NNEC, the creation of shared awareness and shared understanding are of critical importance. The NEC Value Chain establishes the link between these two measures and C2 effectiveness. The more network-centric an approach is, the more likely it is to develop shared awareness and shared understanding. As a result, the approach will be more able to cope with changing circumstances.

Figure 18 depicts the measures of C2 effectiveness that are expected to result from employing each of the C2 approaches under consideration.

| | | | |
|---|---|---|---|
| **Edge C2** | Broad, Deep, Tailored and Dynamic | Broad, Deep, Tailored and Dynamic | High |
| **Collaborative C2** | Significant | Significant | Moderate |
| **Coordinated C2** | Limited | Limited | Limited |
| **De-Conflicted C2** | Focused on the Boundaries | None | Extremely Limited |
| **Conflicted C2** | None | None | None |
| **C2 Approach** | **Degree of Shared Awareness** | **Degree of Shared Understanding** | **Adaptability of the Collective C2 Process** |

Figure 18: Measures of C2 Effectiveness

Both shared awareness and shared understanding (across participating entities) are expected to improve as one moves from a Conflicted C2 approach to a De-Conflicted C2 approach and so forth. Edge C2 is expected to result in the highest level of shared awareness and shared understanding. As a result, Edge C2 is expected to also be more effective than other C2 approaches. This should not be taken to suggest that Edge C2 is always the appropriate approach to C2. The appropriate approach to C2 depends on circumstances. Operational effectiveness, not C2 effectiveness needs to be the prime consideration when selecting a C2 approach. Operational effectiveness depends on a number of factors such as the nature and capabilities of endeavour partners, the challenges at hand, and the dynamics of the situation. Decisions regarding what

C2 approaches should be in an entity's toolkit and which one should be selected for a particular endeavour are addressed later in this document.

The ability of C2 to cope with a variety of circumstances and stresses by altering structures and processes (adaptability) is also expected to increase as one moves toward the *edge* corner in the C2 Approach Space as a result of increasing shared awareness and understanding. In addition, the emergent behaviours that accompany an edge approach to command and control are able to be more adaptive because edge organisations can dynamically tailor patterns of interaction in response to changes in the environment more quickly than less network-centric C2 approaches.

# CHAPTER 4

# ENDEAVOUR EFFECTIVENESS

This section looks at the various approaches to C2 in terms of the impact they can be expected to have on mission or endeavour effectiveness.

## ENDEAVOUR EFFECTIVENESS WITH CONFLICTED C2:

It should be kept in mind that when a Conflicted C2 approach is adopted or in place by default, no C2 is being exercised at the endeavour or collective level. Each entity is pursuing its individual intent and taking independent actions. Entities are operating without communicating with or sharing information with each other, or engaging in any C2-related interactions. This means that there is no way to avoid negative cross-impacts between or among participating entities. It also implies that some entity actions will, in all likelihood, lead to adverse interactions—actions that interfere negatively with others. In other words, some of the actions of the independent entities will be in conflict and increase costs, degrade effectiveness, or both.

At times, the actions of one entity may prevent, or make more difficult or more costly, the accomplishment of an intended action of another entity. The net result is that the options available to the individual entities are less than the options available if the individual entities were operating alone in the space. In other words, the total is less than the sum of its parts and, to the degree it is less, there are opportunity costs. There may be some situations where the probability of adverse impacts is low, the consequences few, and the costs of adopting a more capable C2 approach are high. There may also be times where it is not possible (e.g., due to politics or time) to adopt a C2 approach that requires a greater degree of information sharing and collaboration. When the probability of adverse impacts is low, this (non)approach to C2 may be suitable. When politics, time, or capabilities prevent information sharing, Conflicted C2 is just inevitable. For example, in the very early stages of disaster relief (e.g., immediately post-Tsunami) this may be appropriate. But it has been shown both in our case studies and other historical situations that to succeed in these types of situations the C2-related capabilities of the collective or endeavour C2 need to evolve over time.

## ENDEAVOUR EFFECTIVENESS WITH DE-CONFLICTED C2:

Entities that wish to de-conflict must be willing, at a minimum, to accept constraints on their plans or actions. In return they hope to avoid or remove any adverse cross-impacts. Limited peer-to-peer interaction in the Information Domain must be sufficient to dynamically resolve potential cross-impacts. Total effectiveness in situations where a De-Conflicted approach to C2 is taken can approach *the sum of the parts*. The main emphasis of C2 interactions and information flows is still on vertical interaction along ‘stove-piped’ chains of command within each entity.

A De-Conflicted approach to C2 allows partners with different levels of C2-related capability to work together, coexisting in the same operational space. The nature of the constraints imposed will vary, but may include the creation of boundaries (exclusive areas assigned to a given entity) along time, geography, space, function, and/or echelon lines. These boundaries serve to constrain each entity’s option space. Planning is required to establish the initial conditions (the decompositions or boundaries). This may be a lengthy process. Should these boundaries need to be changed, re-planning is generally cumbersome and slow. The boundaries become fault lines and are themselves targets; vulnerabilities to be protected.

This approach to C2 is most appropriate when the situation and the response are stable and decomposable in terms of objectives, geography, space, time, and function (e.g., there are no-cross impacts). Hence the situations that can be effectively handled by de-confliction can be complicated, but not complex.

## ENDEAVOUR EFFECTIVENESS WITH COORDINATED C2:

A Coordinated approach to C2 involves seeking opportunities to generate synergy or symbiosis by linking the plans and action(s) of one entity with those of another. In this manner, actions may reinforce each other in the action spaces or the effects spaces. Alternatively, the entities may, in effect, combine resources to achieve a necessary threshold for effective action or significant effects. Total effectiveness is more than the sum of the effectiveness of individual actions. The option space expands for participating entities. However, planning time may increase as a function of the number and nature of the links between and among plans. A Coordinated approach to C2 may make it possible to form 'task organised' forces or groups with contributions from different entities to simplify interactions across the air, land, and maritime domains, and with other non-military actors. This approach to C2 is appropriate for decomposable problems with limited cross-impacts and limited synergies resulting from working together. Problems may be usefully decomposed by space, time, and/or function.

## ENDEAVOUR EFFECTIVENESS WITH COLLABORATIVE C2:

A Collaborative approach to C2 involves sharing of resources in addition to a requirement for more information sharing and interactions between and among the entities. It envisions going beyond specific and explicit links between and among plans to the collaborative development of a single shared plan that establishes symbiotic relationships. Total effectiveness is significantly more than the sum of the effectiveness of individual actions due to the synergies that are created. The option space is significantly expanded. Entities plan in parallel basing their individual plans on the shared plan. Because of this, planning times may be reduced.

Collaborative C2 may involve the use of *positive control*[67] to allow richer peer-to-peer interactions and collaboration. To a far greater extent than is present in De-Conflicted or Coordinated C2, entities become interdependent. This is made possible as a result of the trust that is developed as a product of creating the necessary shared understanding required to generate a single plan. As a consequence, risk is pooled (like insurance). This approach allows the full implementation of task organised forces and groups across the endeavour. This C2 approach is appropriate for problems that are not fully decomposable in terms of objectives, space, time, echelon, and function, and thus, for which a holistic approach is desirable.

## ENDEAVOUR EFFECTIVENESS WITH EDGE C2:

Edge C2 is about achieving a high degree of shared understanding and the emergence of a common (collective) intent. It requires a rich and continuous set of interactions between and among participants, involving widespread information exchanges to allow the build-up of shared understanding and the ability to self-synchronise. The increased effectiveness that can be achieved may be accompanied by a potential reduction in the total resources required. Furthermore, Edge C2 has inherent C2 agility making it required for situations characterised by high dynamics, uncertainty, and complexity. This is because Edge C2 includes the ability to create dynamic, task-organised activities proactively and as required by the changing operational context.

67. Positive control allows the superior commander (military or civilian) to be informed of such interchange, and to intervene only when he/she can see that such an interchange would not match with higher level, more strategic requirements.

# ENDEAVOUR EFFECTIVENESS AND C2 AGILITY ACROSS C2 APPROACHES

Figure 19 summarises the *return* in terms of endeavour effectiveness that can be expected from operating with the different approaches to C2.

| C2 Approach | Relative Effectiveness | Efficiency, Given Effectiveness | Agility of the Collective C2 Process |
|---|---|---|---|
| **Edge C2** | Tailored and Dynamic Synergies | Highly Efficient | Proactive Across a Broad Range of Conditions |
| **Collaborative C2** | Substantial Synergies Across Collaborative Areas/Functions | Substantial Efficiencies Across Collaborative Areas/Functions | Substantial, Timely and Continuous |
| **Coordinated C2** | Limited Synergies | Limited Efficiencies | Limited to Coordinated Functions/Actions; Slow; Reactive |
| **De-Conflicted C2** | Avoids Costs of Negative Cross-Impacts | Sub-Optimised Use of Resources | Vulnerable at Seams; Rigid from Specialisation |
| **Conflicted C2** | Negative Cross-Impacts | Inefficiency Wasted Resources | Fragile and Vulnerable at the Seams |

Figure 19: Measure of Endeavour Effectiveness

# CHAPTER 5

# COMPONENTS OF C2 MATURITY

C2 Maturity is a function of the:

1. C2 approaches in an entity's C2 toolkit;
2. ability to recognise when each of the tools or C2 approaches in the toolkit are appropriate;
3. ability to adopt or transition to the appropriate C2 approach.

## C2 TOOLKIT

Having more than one way to accomplish the functions associated with command and control has long been a desirable capability for militaries (or for that matter any organisation or collective). The greater the choices available, the better able an entity is to match its operations to the challenges it faces. Theoretically there are a very large number of possible C2 approaches, since each point in the C2 approach space corresponds to a different approach to C2. The N2C2M2 groups C2 approaches of interest into five specific regions: *Conflicted C2*, *De-Conflicted C2*, *Coordinated C2*, *Collaborative C2*, and *Edge C2*.

The N2C2M2 consists of five maturity levels, Level 1 through Level 5. Figure 20 relates each of these C2 maturity levels to the C2 approaches that are in their respective toolkits.

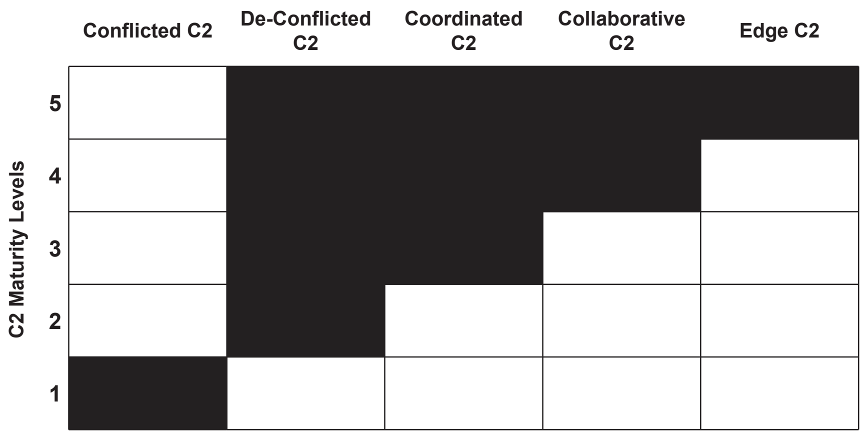


Figure 20: C2 Maturity and C2 Approaches in Toolkit

Entities that are deemed to be at C2 Maturity Level 1 are essentially operating without any Collective C2. As the C2 maturity level increases the entity or collective is capable of employing a greater variety of C2 approaches. Although Edge C2 is shown as being capable of operating with De-Conflicted, Coordinated, or Collaborative C2 approaches, it accomplishes this in a self-synchronising manner. Hence, while the same patterns of behaviour may be observed, these patterns arise from a different set of causes.

## RECOGNITION OF MOST APPROPRIATE C2 APPROACHES

Having the right tools does little good unless an entity understands (1) which tool is appropriate for which situation and (2) is aware of the situation. Thus, as C2 maturity increases, not only are there more tools in one's toolkit, but there is also an ability to recognise a greater variety of circumstances and know the appropriate C2 response (which C2 approach is most appropriate) to each of these situations. This section briefly discusses the characteristics of situations that are of interest in determining an appropriate C2 response.

Situations may range from *simple*, characterised by a modest number of well defined elements, to *complicated,* characterised by a large number of more or less well defined elements with predictable interactions, and onto *complex,* characterised by a large number of partly poorly defined elements and interactions with uncertain outcomes. Situations, in addition to differences by degree of complexity, also differ by the degree to which they are dynamic.

Whether or not a given C2 approach suits the situation at hand depends on the degree to which the situation can be decomposed in terms of objectives, space, time, and functions. Decomposing a situation decreases complexity and reduces dynamics.

De-Conflicted C2 is an option if the situation is fully decomposable and there are no cross-impacts so that solutions can be found piecemeal. Coordinated C2 is an option if the situation is fully decomposable but functional cross-impacts on a limited scale must be expected unless objectives and actions are coordinated to manage those cross-impacts. Collaborative C2 becomes indispensable if the situation is not fully decomposable and cross-impacts on a significant scale must be expected unless actions are linked to exploit the symbiotic effects associated with interdependent actions. Edge C2 is suitable in situations with high dynamics, uncertainty, and complexity.

Complexity, uncertainty, and dynamics are interdependent composite variables that can be measured in terms of the following variables:

- nature or objectives of the operation under consideration (combat, peacekeeping, stability, role of military, counter-terrorism, humanitarian assistance, disaster relief etc);
- number, nature, and diversity of different friendly, neutral, or adversarial actors including the relationships / interactions between them;
- stability and, or predictability of the environment;
- transparency of the situation;
- familiarity with the situation;
- infrastructure (availability, quality);
- clarity, unity of intent (purpose), and strategy;
- nature of effects space (PMESII).

## TRANSITION BETWEEN C2 APPROACHES

Situations are dynamic. The most appropriate C2 approach may not have been selected at the onset of an endeavour. For these reasons it is important that entities are able to transition from one C2 approach to another. This section briefly discusses the issues related to transitioning from a particular C2 approach to another.

## C2 MATURITY LEVEL SUMMARY

The N2C2M2 identifies five levels of C2 maturity. Figure 21 summarises the capabilities associated with each of these five maturity levels in terms of the approaches that are in the toolkit for each of these maturity levels, the ability to recognise or partition the situation space, and the ability to transition between and among tools or C2 approaches. Note that the toolkits associated with higher levels of maturity contain C2 approaches that are more network-centric.


| C2 Maturity Levels | Contents of C2 Toolkit | C2 Approach Decision Requirement | Transition Requirements |
|---|---|---|---|
| **Level 5** | Edge C2<br>Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 | Emergent | Edge C2<br>Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 |
| **Level 4** | Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 | Recognise 3 situa ions and match to appropriate C2 approach | Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 |
| **Level 3** | Coordinated C2<br>De-Conflicted C2 | Recognise 2 situa ions and match to appropriate C2 approach | Coordinated C2<br>De-Conflicted C2 |
| **Level 2** | De-Conflicted C2 | N/A | None |
| **Level 1** | Conflicted C2 | N/A | None |

Figure 21: C2 Maturity Levels and C2 Agility

# Chapter 6
# C2 Maturity and C2 Agility

C2 maturity and C2 agility are not free; more maturity or agility is not always desirable. There are a variety of costs associated with operating at a given level of C2 maturity and thus possessing a given level of C2 agility. These include both costs to individual entities and to the collective as a whole (investment in infostructure, time, and efforts to develop shared awareness and understanding). Therefore, it makes sense for both individual entities and the collective as a whole to operate at the level of C2 maturity required by the situation. The appropriate level of C2 maturity is referred to as requisite C2 maturity[68] and is determined by the capabilities and agility required by the situation.

In other words, if every potential mission could be successfully accomplished by de-confliction, it might not be worth the effort to develop a capability to function at a C2 maturity level equal to Level 3. An organisation or collective possessing the ability to operate at Level 3 may choose a De-Conflicted C2

68. The idea for the term *requisite C2 maturity* and *requisite C2 agility* came from Reiner Huber who led a number of the case studies. The term is analogous to *requisite variety*.

approach if the situation permits. This being said, however, it has become clear from real-world exercises and the case studies that SAS-065 conducted, that the mission challenges faced in the 21st century are indeed complex and dynamic enough to require higher levels of collective C2 maturity. An endeavour is not likely to be successful operating with a De-Conflicted C2 approach when a situation is complex and dynamic to begin with, or when the situation increases in complexity or becomes more dynamic over time. Success, in these situations, requires that a collective must recognise this aspect of the challenge and be able to choose the appropriate C2 approach.

Transitioning from one approach of command and control to another is a significant challenge. An entity or collective may be better off operating at an approach to C2 that provides a "cushion" of capability that would be needed if the situation became more stressful, even though it may initially require greater investments in infostructure and/or training, but by doing so eliminates the need to adapt in real time. Thus, for example, even though operating with an *Edge* approach may not be initially required by the situation, (1) it may be required if the situation deteriorates and (2) it may be easier to stay an *Edge* than (a) to transition to an *Edge* from another C2 approach or (b) to transition from an *Edge* to another C2 approach. At this time, these are all hypotheses which need to be tested.

Edge organisations have the potential to operate with a Coordinated or Collaborative C2 approach. However, operating as an *Edge* will require a greater degree of intra- and inter-entity interoperability than many entities currently possess (particularly inter-entity). It also requires cultural changes for many entities, particularly military organisations. However, NATO is committed to NNEC and, along with this commitment, is on the road to creating an infostructure that will support Edge approaches to command and control.

# Chapter 7
# Model Verification and Validation

## BACKGROUND

The Terms of Reference and Plan of Work for SAS-065 chartered the group to develop a NATO Network Enabled Capability Command and Control Maturity Model (N2C2M2). This effort was informed by the earlier efforts by NC3A to develop a maturity model for NATO Network Enabled Capability (Buckman, 2005)[69] as well as broadly available research on Network Centric Operations. However, this effort was primarily driven by the knowledge and experience of the command and control (C2) experts from 12 nations and two NATO related organisations who comprise the SAS-065 Research Task Group. Based on past experience, these experts decided to undertake a series of efforts, including both case studies and analysis of relevant experiments, in order to validate the initial model. This document describes those efforts and their impact on the C2 maturity model.

69. *NATO Network Enabled Capability Feasibility Study, Executive Summary, Version 2.0*

## PURPOSES

The case studies and analyses of experimental data were undertaken by SAS-065 for three specific reasons:

- Clarity: given the challenging subject of C2 maturity and the number and variety of NATO members, the SAS-065 Research Task Group sought to ensure that the C2 maturity model was clear and easy to understand.
- Applicability: the members of SAS-065 wanted to ensure that their product was actionable, could be applied to *real world* cases and research data, and could be assessed using C2 maturity-related measures and metrics (comparative measurements).
- Validity: the case studies themselves and the effort to integrate the results with the case studies were part of an extended effort to validate the C2 Maturity Model, including assessment of the model's empirical, construct, and expert (or face) validity.

Hence, an effort was made to look at a variety of well-documented cases as well as relevant data from C2 experimentation. These efforts and the dialogue surrounding them resulted in a number of adjustments to the maturity model and the way it is presented. In addition, working with the N2C2M2 in these applications proved to be an important source of insights and logical arguments when SAS-065 began to develop its illustrative applications.

# VERIFICATION AND VALIDATION: CASES AND EXPERIMENTS

These verification and validation cases and experiments were chosen not only because they dealt with missions important to NATO today and in the future, but also because adequate unclassified information was available to make meaningful assessments of the C2 maturity involved. Of course, since all of the analyses were performed after the fact, none of the case studies were an ideal test of the utility of the C2 Maturity Model for either designing a force or planning an assessment. However, SAS-065 believes these validation efforts have provided rich insights into the clarity of the maturity model and potential for applying the model in a variety of ways.

Since those reporting about the events being studied had not developed a data collection plan with C2 maturity in mind and, in most cases, were not tasked to evaluate command and control, the members of SAS-065 were called upon to rely on their experience and exercise their judgment in order to perform assessments. This proved valuable as it caused the Research Task Group to focus on the specific meaning of the maturity levels and to identify the observables that would permit meaningful differentiation between those levels. Even in the case of ELICIT[70] experimentation that had been designed to differentiate between Hierarchy and Edge cases, the analyses required selection of appropriate measures and metrics that could be linked to the maturity levels defined by the N2C2M2.

70. Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust. ELICIT is an online multi-user platform for conducting experiments in information sharing and trust. http://www.dodccrp.org/html4/elicit.html.

The C2 maturity levels relate to different regions of the C2 approach space (Alberts and Hayes, 2006; 2007). Each level of maturity includes the ability to appropriately move within specific regions of the C2 approach space (refer to Figure 16 and Figure 20).

The C2 Approach Space was the guiding concept for the members of SAS-065 as they carried out the case studies. However, one result of these applications was recognition that the three principal axes (*Allocation of Decision Rights, Patterns of Interaction, and Distribution of Information*) needed to be redefined to reflect the collective nature of C2 when conducting complex endeavours. Thus, *Allocation of Decision Rights* was better expressed as *Allocation of Decision Rights to the Collective* because those allocations are the ones that matter for the collective as a whole.

All the case studies completed are included as appendices to this report. Table 1 (above) provides an integrated list of the analyses conducted by SAS-065 members. In some cases the written reports are augmented by briefing materials. All are supported by bibliographies of the sources consulted.

## VALIDATION METHODOLOGY

Validity, which means ensuring that a model or tool is appropriate for the uses or purposes for which it is designed or intended (DoD Directive 5000.59 "DoD Modelling and Simulation (*M&S*) Management," USD (*AT&L* August 8, 2007) was assessed through three lenses.

- Expert Validity (sometimes called Face Validity) – does the model appear credible to those who are knowledgeable in the field?

- Construct Validity – does the model include all the relevant factors? Are all the relevant relationships included?
- Empirical Validity – does the model suggest patterns or relationships that can be observed in the *real world*? Alternatively, does the model behave in a way that reflects observed behaviours?

Each of these issues was explicitly considered both in terms of individual applications and across the SAS-065 project.

The NATO NEC C2 Maturity Model (N2C2M2) case studies[71] followed an inductive process for building a theory. In that process, phases of developing the theory and case study analyses are iterated. The validity of a theory, here the N2C2M2, is ensured by the selection of the cases, the quality of the data collection, and analysis and the iterative process.[72]

The first step in the process was the identification of potentially useful cases. This often originated with a specific member of SAS-065, though some cases were nominated by the group of members from a particular nation. In addition, attention was paid to getting a rich variety of cases that include missions NATO or NATO nations must be prepared to carry out in the foreseeable future. Cases or experiments that dealt with complex endeavours were given priority for further exploration.

71. Case studies are considered a well-established method to build a theory. Traditionally, authors develop theories by combining observations from previous literature, common sense, and experience. However the ties to actual data and *real world* phenomena are considered to be tenuous. One strength of a theory developed in an inductive process from cases following the methods of Yin (2002) or Eisenhardt (1989) is its connection to empirical reality.
72. Eisenhardt, K. M. "Building Theories from Case Study Research." *The Academy of Management Review* 14(4): 532-550, 1989; Yin, R. *Case Study Research: Design and Methods*, 3rd Edition, Sage Publications Inc., 2002.

Nominated cases were typically assigned to one or more members to research the availability of relevant information, both its breadth and depth. In particular, assessments that related to the basics of a C2 approach (allocation of decision rights, patterns of interaction, and distribution of information) were sought. The results of this initial search were then reported back to the group as a whole and, where adequate information was available, a sub-group was formed to pursue the case or experiment.

Work on these cases often required several months. No individual performed a case study independently—all were collaborative efforts. The bulk of the effort was conducted between formal meetings, with heavy reliance on interactions over the internet. During the period when these efforts were underway the formal meetings, which occurred as often as four times per year, were largely devoted to focused discussions about conclusions, reporting the applications to the larger group for constructive criticism, organising new applications, and exploring the implications of the current applications for the N2C2M2.

Once a case was selected and the initial material identified, the work process within the teams completing the applications typically involved initial discussion of how the N2C2M2 applied to the particular case, having two or more people review each relevant source document, and then assigning specific maturity levels for each of the variables for which indicants were available. At the same time, continuous searches were occurring for other relevant sources and materials to consider. Initial codings were then shared with the rest of the sub-group working on the case. Once these were agreed, they were captured in text and graphics that could be used to share them with the Research Task Group as a whole. Large case studies, such as

Hurricane Katrina, stretched over several months and were discussed in some detail at two or more meetings of SAS-065. In the process of developing and analysing the cases, several analysis instruments were crafted by the group to analyse and visualise cases through different lenses. Small groups with several investigators were responsible for compiling and analysing the cases and affiliation to the groups changed in the process. This approach of using groups of investigators with different academic and professional backgrounds and changing group affiliations are a way to ensure creativity in the analysis and model development, to avoid groupthink and to ensure uniform standards in a multi-case analysis. The academic and professional background of the investigators facilitated an interpretation of data to reach the rich findings typically associated with the case study method.

However, the case studies and analyses of experimentation data were never ends in themselves. Their purposes remained to discover and correct potential sources of ambiguity and confusion in the N2C2M2, to ensure the model could be applied by thoughtful analysts to a variety of different types of information and situations, and to validate the arguments underlying the levels of maturity, the variables needed to assess C2 maturity levels, and the factors that differentiate between them. Hence, the Research Task Group carried on a running dialogue, both in the context of specific applications and on a cross-cutting basis, on how the logic and presentation of the N2C2M2 might be improved.

## SEQUENCING OF VALIDATION EFFORTS

A small initial set of case studies were carried out to explore the data requirements and methodology for effective case studies. These included a UK review of several responses to crises reported in the UK literature and an analysis of a US Stryker Brigade exercise in preparation for deployment as a counter-insurgency force. While these were being conducted other members of SAS-065 were exploring source materials for other possible case studies.

After reviewing these initial efforts a working outline for case study reports was developed and implemented in a major effort to assess the response to Hurricane Katrina in the United States. This case was selected as the first for in-depth treatment because it was documented in detail and because it met the definition of a complex endeavour—the kind of civil-military effort considered most challenging. Work was first undertaken by SAS-065 during a face-to-face meeting. This facilitated the group's understanding of the process needed and the type of product required. At the same time, another group also initiated a case study on Tsunami Relief as a cross-check on the work process and products.

With this common experience as a guide, sub-groups were formed to explore the other cases of interest for which adequate unclassified data and information were identified. The case study list grew to include analyses of the German experience responding to the Elbe River Flood, the international community's response to the Tsunami, NATO operations in Bosnia and Kosovo, the response to a major earthquake in Pakistan, analyses of UK wargame experiments that compare different approaches to C2, and analyses of a US Airborne

Division and two Stryker Brigades operating in Iraq. When the results of ELICIT experiments comparing Hierarchical organisations with Edge organisations became available for a number of cases, the research task group used them as a tool for comparing different levels of C2 maturity in a controlled laboratory setting. In addition, the group members developed a set of templates designed to facilitate comparisons between and among the case studies. This template evolved over time as did the C2 Maturity Model and the way it was represented.

This sequencing ensured that the efforts of SAS-065 were not dominated by a single type of application or case. The evolution of the NATO NEC C2 Maturity Model was iterative, which is consistent with the *NATO Code of Best Practice for C2 Assessment*.[73]

## LIMITATIONS

The case studies and analyses of experimentation results provide valuable insights into how the N2C2M2 can be used for force design, assessment of a specific force or endeavour, and how C2 maturity can be incorporated into doctrine, training and other aspects of improved C2 maturity; however they were research efforts, not practical applications in their own right. Those applications would require a different approach and could be designed to ensure data and information availability more directly applicable to the N2C2M2. The decision to generate illustrative applications as a part of this report was a recognition of the need to address these issues.

73. NATO SAS-026, *Code of Best Practice for C2 Assessment*, Washington, DC: CCRP, 2002.

While these efforts were underway some changes were made to the working outline and also to the graphic template used to report results. This means that not all the cases are fully parallel. Since the case studies were never an end in themselves, but rather a tool for validating, learning about and improving the N2C2M2, no effort was made to update the earlier case studies to make them fully compatible with the later ones in terms of either the changed outline or the evolving integration templates. Hence, their reports are generally, but not totally, parallel. That does not limit their value to the overall effort or their utility for others who are interested in the cases themselves and the bibliographies that support them. This report looks across the case studies and extracts key elements of each in order to facilitate comparisons.

We argue that the validity and the wide applicability of the N2C2M2, as outlined in the method of building theories from case studies, is ensured through the selection of cases, the iterative process with alterations of single and multi-case analysis, the triangulation of findings using different data collection and analysis instruments and the analysis by various investigators and groups of investigators with a variety of academic and professional backgrounds over a long period of time with many iterations.

## TYPES OF CASE STUDIES

Each case study (real world operation, exercise, experiment) was identified as including relevant evidence. In many case studies it made sense to look at different phases of the operation; phases in which the nature of the mission, the composition of the endeavour, and the factors determining the C2 approach differed. In addition, most of the applications were also reported in terms of different elements of the endeavour—for example the military and the civilian efforts. This often revealed major differences between the C2 approaches found within particular phases or elements of the overall endeavour. One genuine challenge was determining the logic by which an *overall* C2 approach might best be specified. However, no cases were found where wild mixes of C2 occurred within one phase and element—typically the variables defining C2 approaches were linked and proved to be interdependent and somewhat correlated. Hence the underlying hypothesis, that the C2 approaches adopted within an endeavour or a component of an endeavour generally establishes the level of C2 maturity achieved, was supported by these research efforts.

### *Combat and Exercises*

NATO is currently engaged in combat operations in Afghanistan. The SAS-065 Research Task Group made several efforts to identify rich, unclassified sources that would permit assessment of the C2 approaches of that experience. However, classification issues and the potential for political issues associated with a group of experts providing critical analyses of on-going operations made this topic impractical to pursue.

The United States Army's efforts to develop more advanced digitised C2 systems and approaches provided some well documented cases for analysis. In particular, the ASD/NII Command and Control Research Program (CCRP) and other parts of the U.S. Office of the Secretary of Defence sponsored a series of analyses of the new Stryker Brigades, both in preparing for deployment to Iraq and after those deployments when they assumed challenging counter-insurgency missions. Two carefully developed reports became available during the research task group's period of performance. The first, entitled *Network-Centric Operations Case Study: the Stryker Brigade Combat Team* was published in 2005.[74] It described the Stryker Brigade concept, differentiated Stryker Brigades from the more standard US Army light and mechanised infantry organisations, and compared the exercise performances of Stryker and other units training for counter-insurgency operations. The second, entitled *Networked Forces in Stability Operations*, was published in 2007[75] and compared the performance of the first two Stryker Brigades deployed to Iraq with that of the 101st Airborne Division on similar terrain. Because Stryker Brigades are designed as more mature C2 organisations, including not only different IT equipment, but also very different doctrine, training, and tactics, assessing their performance was considered a valuable element in developing the N2C2M2.

A series of UK wargames[76] were designed and executed in order to compare two different C2 approaches. In one condition, the command and control was organised around traditional geographic distribution of responsibilities, creating a natural hierarchy in which a larger entity (division) worked with components (brigades) each responsible for a specific sector. In the other approach, responsibilities were assigned functionally and cut across geographic regions. Both approaches were staffed with military professionals, demonstrating how they would exploit today's technologies as well as the different opportunities inherent in these C2 approaches.

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74. Gonzales, Johnson, McEver, Leedom, Kingston and Tseng, 2005. ISBN 0-8330-3846-X.
75. Gonzales, Hollywood, Sollinger, McFadden, DeJarnette, Harting, and Temple, *Network Forces In Stability Operations: 101st Airborne Division 3/2 And 1/25 Stryker Brigades In Northern Iraq*, 2007.
76. Lewthwaite, D., P. Pearce, and S. Fellows. "NEC Research Insights from Wargaming." Dstl, UK, 2008.

## *Peace Operations*

NATO's history in both Kosovo and Bosnia were also identified as significant sources for understanding C2 maturity. This was an experience shared by a number of NATO nations, making it important for the purposes of SAS-065. Moreover, some excellent, unclassified material was located that shed light on this experience. The analysis of the Kosovo experience focused on four different perspectives—The Air War, KFOR-UNMIK interactions, KFOR interactions with sector Multinational Brigades, and KFOR interfaces with humanitarian assistance efforts. Similarly, the work on Bosnia (which focused on IFOR) was directed at the relationships between the NATO forces and the other components of that complex endeavour. Analysis of this case study was dominated by three phases of the operation, each characterised by somewhat different approaches to C2.

## *Simple Disaster Responses*

One issue of interest turned out to be the importance of scale—whether relatively large challenges were qualitatively different from those of lesser scope. One of the earliest analyses undertaken was a review of several British responses to disasters (man made and natural).[77] In addition, information was available on two natural disaster simulations, one a major earthquake in Los Angeles (Golden Phoenix 07) and the other (Strong Angel III) a major civil-military relief effort explicitly focused on US Department of Defence linkages to other entities, including state and local governments, first responders from the medical, fire, and medical communities, as well as private industry

77. LN Van Wassenhove, "Blackett Memorial Lecture: Humanitarian Aid Logistics; Supply Chain Management in High Gear." *Journal of the Operational Research Society*, 2006, vol. 57, pp 475-489.

(primarily the communications and utility sectors). In addition, German experience in dealing with major floods on the Elbe River in 2002 also proved very well documented and valuable to the Research Task Group. While useful in their own right, these cases were particularly valuable when compared with larger disasters where the scope of the endeavour was a major challenge.

### *Complex Disaster Responses*

NATO and its member nations are increasingly responding to major natural disasters that have the characteristic of complex endeavours involving a wide variety of actors with quite different capabilities, perspectives and internal C2 approaches. Hence, natural disaster cases were among the most important examined by SAS-065. As noted earlier, the response to Hurricane Katrina, which was well documented, was the first in-depth case study carried out. The response to the Pakistan earthquake in 2005, an endeavour directly involving NATO, proved very helpful. Finally, the response to the 2004 Tsunami in the Pacific was very well documented and enabled good analyses. While a broad analysis across the region impacted by the Tsunami was conducted initially, detailed work on the experience involving the Aceh region was found to be both more feasible and more useful. All three of these large disaster cases were found to have quite different phases in which the C2 approaches were also different. In addition, all three provided situations in which different elements of the overall endeavour (for example, civilian and military efforts) could be analysed independently, giving the Research Task Group greater experience in applying the N2C2M2. Because of the phased nature of these experiences, each of them provided some insight into the relative agility of the C2 approaches that were associated with them.

*Experimentation*

Several members of SAS-065 were involved in experiments using the ELICIT platform,[78] which is designed to allow comparison between different C2 approaches. In particular, all of those using the experimentation platform are required to conduct an initial experiment comparing a hierarchy with an edge organisation in terms of their capability to develop correct and timely shared awareness from a set of widely distributed information elements. The CCRP performed an analysis of 37 experimentation trials (19 edge, 18 hierarchy).[78] The hierarchy runs had characteristics that approximate De-Conflicted C2 and the edge runs correspond to a region of the C2 approach space further along the central diagonal vector (toward Edge C2). Hence, these data were seen as a way of learning whether and how the behaviours under these two sets of conditions would differ as well as whether the two different C2 approaches would provide differences in performance—mission accomplishment.

## REVIEW OF CASE STUDIES AND EXPERIMENTATION ANALYSES

Each case study and the analysis of experimentation results stand on their own. However, there is considerable merit in viewing them through a common lens, which is the purpose of this report. To make the comparisons easier to follow, they have been grouped into the five categories (e.g., Combat Exercises,

78. Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust. http://www.dodccrp.org/html4/elicit.html.

Peace Operations, etc.). The template for the comparison recognises five different levels of C2 maturity as specified in the N2C2M2 in Figure 21.

The comparative template uses the following four groups of factors:

- Variables Defining Collective C2 Approaches (see Figure 15)
  - Allocation of Decision Rights to the Collective
  - Inter-Entity Information Sharing Behaviours (used in these case studies as an indication of *patterns of interaction among the participating entities*)
  - Distribution of Information (Entity Information Positions)
- Required Patterns of Interaction (see Figure 17)
  - Cluster Attractor
  - Degree of Inter-Cluster Connectivity
  - Frequency/Continuity of Interaction
- Measures of C2 Effectiveness (see Figure 18)
  - Degree of Shared Awareness
  - Degree of Shared Understanding
  - Adaptability of the Collective C2 Process
- Measures of Endeavour Effectiveness (see Figure 19)
  - Relative Effectiveness
  - Efficiency, Given Effectiveness
  - Agility of the Collective C2 Process

The least mature, Level 1, means that entities are not capable of any collective C2 (Conflicted C2). At the most mature, Level 5 (Edge C2) entities that can adopt a variety of different approaches to C2 are understood to be qualitatively different from the three middle levels. Those middle levels (De-Conflicted

C2, Coordinated C2 and Collaborative C2) are characterised as a continuum that has been segmented based on their dominant collective C2 approach.

## *Combat Exercises*

The first case study of Stryker Brigade performance reviewed by the SAS-065 group compared the performance of a Standard US Light Infantry Brigade with that of the first Stryker Brigade in a counter-insurgency pre-deployment training exercise. That analysis emphasised the fact that Stryker Brigades differ from more traditional light infantry in more than just C2 capabilities but have substantial advantages in those capabilities. They use Stryker vehicles for greater mobility and have greater intelligence assets including more UAV and an embedded military intelligence company (normally a US Army division level asset). Stryker Brigades also require increased training due to their digitised information systems. They have stronger, more capable C2 systems, including the capability to rely on satellite communications, which give them greater capacity for information sharing, shared awareness, collaboration, and self-synchronisation.

As Figure 22 indicates, the Stryker Brigade consistently showed the attributes of a Collaborative C2 approach, indicating greater C2 maturity. During the exercises under study, standard light infantry organisations have decision rights allocation consistent with De-Conflicted C2, but information sharing behaviours and information distributions consistent with Coordinated C2. Standard US Light Infantry Brigades did perform at Coordinated C2 when considering connectivity between their internal elements, but performed at the De-Conflicted level in terms of the clusters where their activities were centralised (the assigned units, not the functional activities that link their efforts). Moreover, they were impaired by their limited, line-of-sight communications systems combined with doctrine that limited the frequency and continuity of their interactions that were needed to *de-conflict* decision making, plans, and actions. In contrast, because of its digital connectivity the Stryker Brigade showed during these exercises that it had rich and continuous connectivity that could support Edge C2. However, by doctrine and practice its activities tended to cluster around basics or traditional organisations, with functional clusters only created when particular efforts needed to be coordinated. At the same time, the Stryker Brigade did have more connectivity associated with the areas where functional collaboration was possible, another reflection of digital communications enabled by satellite linkages.

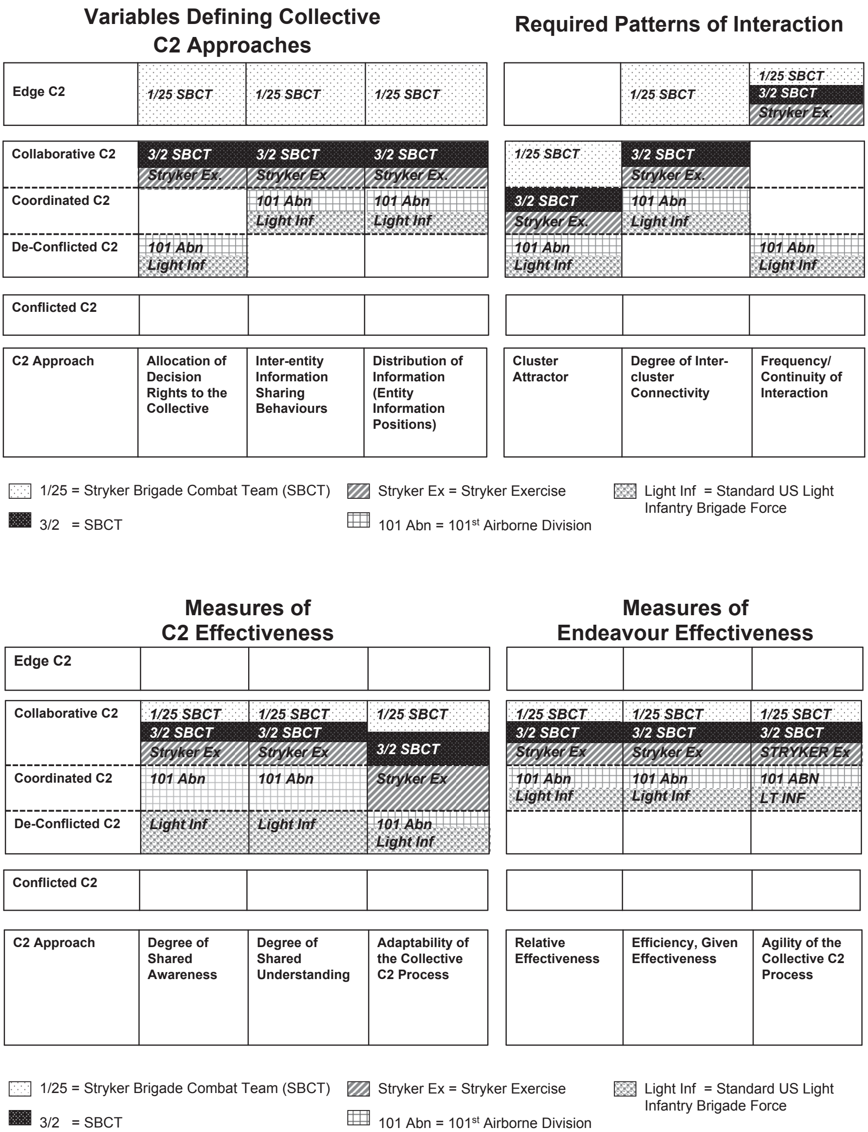


Figure 22: Combat Organisations

In terms of measures of C2 effectiveness, the Standard US Army Light Infantry Brigades were consistently rated as using De-Conflicted C2 approaches, very much in keeping with their doctrine and training. By contrast, for this exercise the Stryker Brigade used its stronger connectivity and greater training to establish shared awareness and shared understanding capable of Collaborative C2. In terms of endeavour effectiveness the Light Infantry Brigades were able to demonstrate Coordinated C2, showing the effectiveness of their professionalism and training. By contrast the Stryker Brigade effectiveness was found to be Collaborative, a reflection of their greater C2 capacity and additional information assets corresponding to a more network-centric C2 approach.

The research comparing these two cases also stresses the fact that the Stryker Brigade was able to make qualitatively better decisions and out-perform previous light infantry brigades dramatically in terms of mission accomplishment and loss-exchange ratios during this pre-deployment exercise. The report also stresses, however, that the greater speed, quietness, and mobility of the Stryker Brigade clearly contributed to its better performance. Hence, not all the difference should be attributed to C2 maturity. Overall, Standard US Army Light Infantry would, as described in this case, be rated as achieving Coordinated C2, consistent with its doctrine, training, and communications capability. By contrast, the Stryker Brigade in this exercise would be rated as achieving Collaborative C2.

The second comparative study looked at the performance of the 101st Airborne Division, the 3/2 Stryker Brigade Combat Team (SBCT), which was the unit observed in the exercise reported above and the first unit of its type to deploy to Iraq, and the 1/25 Stryker Brigade Combat Team, (SBCT) which deployed later with upgraded equipment as well as some feedback on the experience of the 3/2 SBCT. These three units were responsible for roughly the same geographic area in Iraq (the 101st area was larger, but included the areas where the other two were employed and, of course, had more assets), although they were present during different periods of time and quite different situations. The report includes considerable discussion of the similarities and differences between the three cases, but concludes there is enough similarity to permit comparative analysis of the command and control involved.

As Figure 22 indicates, the 101st Airborne had a very similar profile to that of Light Infantry Brigades in the counterinsurgency exercises. There were no differences between them in the C2 approach space variables or in the required patterns of interaction. The 101st did generate a higher level of shared information and shared awareness than the Light Infantry Brigades, but not in terms of the adaptability of the collective C2 process. In terms of endeavour effectiveness and efficiency, the two (101st and Standard Light Infantry) were also identical—rated at Coordinated C2. Coordinated was also their overall rating for C2 approach. The parallel findings with respect to the 101st and the standard infantry brigades were seen as positive results for the application of the N2C2M2. These two analyses, conducted a number of months apart and reflecting very different operating environments, focused on units with similar doctrine, training, composition and equipment. Hence, concluding that they were very similar on C2 approach is a strong validating result.

The two Stryker Brigades demonstrated Collaborative and Edge C2 approaches in Iraq. The 3/2 SBCT met the definition of Collaborative C2 on all three factors defining the C2 approach. By contrast, the later deploying 1/25 SBCT was rated as having achieved Edge C2 on these factors, reflecting both its greater connectivity (more of its vehicles were fully networked) and training that benefited from emerging doctrine and lessons reported from the 3/2 experience in the field.

The 3/2 SBCT cluster attractor was rated as Coordinated, consistent with both relevant doctrine when it deployed and its performance during the pre-deployment exercise. The 1/25 was seen as Collaborative, meaning that its working clusters were predominantly functional rather than organised around "home" units. Hence it appears that Stryker Brigades are better prepared to adopt these functionally oriented ways of doing business than more traditional light infantry organisations. Both 3/2 and 1/25 SBCT were seen as having frequency and continuity of interaction consistent with Edge C2, reflecting the value of satellite communications and enhanced bandwidth.

In practice, both the 3/2 and 1/25 SBCT appeared to achieve levels of shared awareness, shared understanding, and the adaptability measure of C2 effectiveness consistent with a Collaborative approach to C2 with respect to collective processes, meaning that they displayed the same C2 approach as the Stryker Brigade during pre-deployment exercises. They were similarly all seen to exhibit a level of effectiveness and efficiency consistent with a Collaborative approach to C2. As a group, therefore, the Stryker Brigades were seen as having achieved a Level 3 C2 maturity, with the potential to operate at a Level 4 maturity.

This finding is also a positive conclusion for the N2C2M2. Organisations with similar IT systems, training, and doctrine were found to be similar in observed C2 approach. Moreover, the greater investments in these organisations were also seen as having resulted in a higher level of C2 maturity, both in exercises and in the field.

Finally, these comparative case studies indicate that the N2C2M2 can be applied to military organisations in the field, provided that their organisations, processes, training, doctrine and experiences are well and thoroughly documented. The N2C2M2 was found to provide clear enough guidance to permit classification of the C2 approach(es) adopted and the level of C2 maturity observed.

### *Peace Operations*

Two peace operations involving NATO were examined in case studies by the members of SAS-065: IFOR in Bosnia from December 1995 through the establishment of SFOR in December, 1996 (peace enforcement) and KFOR in Kosovo from March 1999 through June 2000 (peace imposition). Both were documented in detail in published reports. They were selected because they involved the *real world* issues associated with organising a complex endeavour within NATO.

IFOR (International Force) was the smaller, somewhat less complex of these two NATO efforts. As Figure 23 indicates, the analysis of this case looked at two primary issues, the maturity of the C2 within the NATO military forces involved and challenges associated with the interface between IFOR and the United Nations and other civilian organisations such as non-governmental organisations (NGO). NATO's charter for IFOR was explicitly military—to enforce the Bosnian peace agreement's military elements (separation of forces, cantonment of heavy weapons, etc.). The UN was formally responsible for the civilian elements of the agreement—political, social, and so forth. Other civilian actors worked with and through the UN on those aspects of the endeavour. Hence the charter was fundamentally one of de-confliction between military and civilian functions. Those members of SAS-065 conducting the case study also recognised three temporal phases and a number of functional sub-elements in the operation, which are covered in their report. However, the temporal phases showed no differences except those naturally associated with placing a force in the field and allowing it to become familiar with the environment, so they have not been reported separately here in the integration discussion. Similarly, those performing the case study also looked at several functional sub-elements (e.g., media, EUCOM, NGO) but the patterns over time did not show important differences.

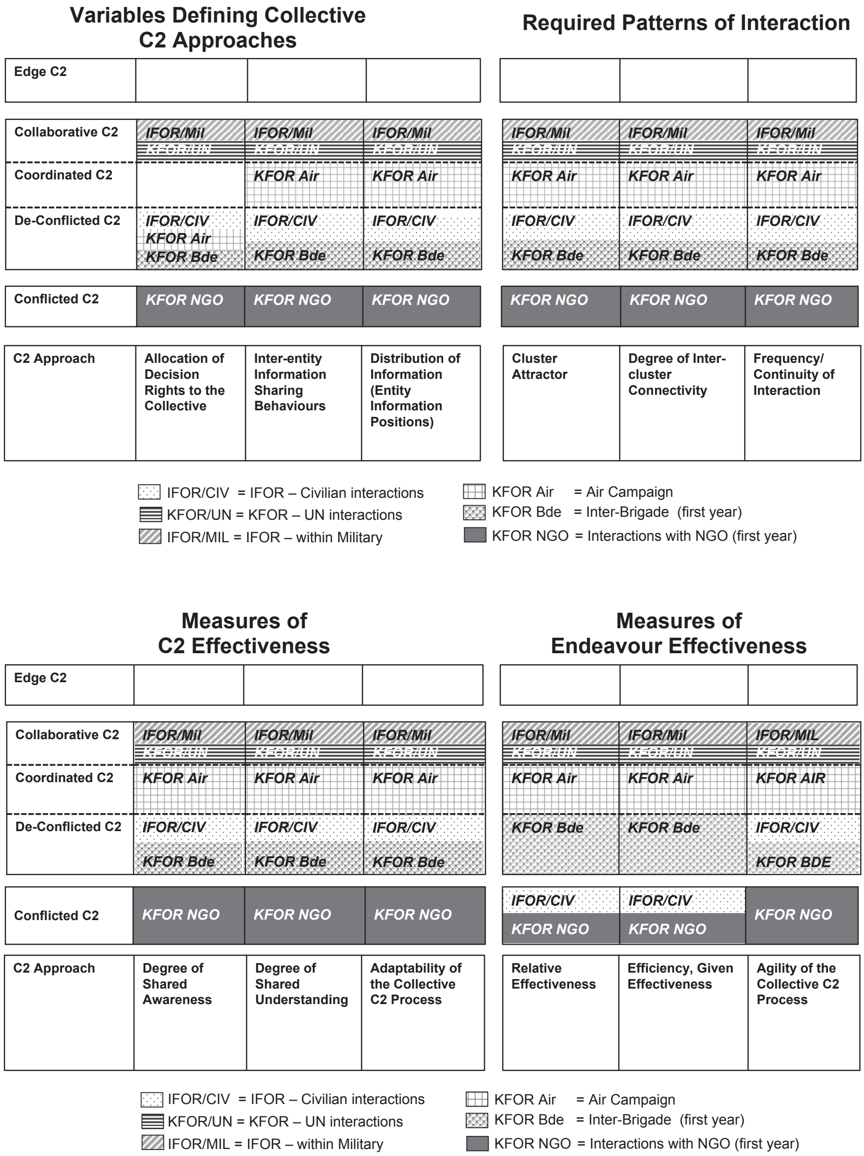


Figure 23: Peace Operations

As Figure 23 indicates, IFOR military command and control was consistently rated as Collaborative across all relevant measures and was ultimately rated as achieving Collaborative C2. This reflects the decades of NATO preparation (standardisation, training, etc.) and working together as well as the relatively small area of operations, which meant that NATO communications systems maintained nearly continuous flows of data and information. By contrast, the interfaces between IFOR and its civilian partners (the UN, NGOs, etc.) were rated as consistently De-Conflicted for variables defining collective C2 approaches: the required patterns of interaction, and the measures of C2 effectiveness. Clear problems emerged however, in terms of relative effectiveness and efficiency in these interfaces. Those could be traced directly to the decision that military and civilian functions should be kept separate and independent, a seam that was repeatedly and effectively attacked by those who wanted to thwart the Bosnia Peace Agreement. In particular the lack of meaningful police presence combined with IFOR's unwillingness to use military forces in a police role consistently undercut the effort. Hence, the overall endeavour (military and civilian together) failed to perform effectively or efficiently despite having the capability to perform with a De-Conflicted C2 approach.

Operations in Kosovo were seen as more complicated and more challenging. Hence describing the case is more complicated. The factor that most limited C2 maturity in KFOR was its interfaces with non-governmental organisations (NGO). These were consistently rated as Conflicted, reflecting the fact that hundreds of NGOs were active in the theatre and no genuinely effective mechanism was created to manage or coordinate their efforts as they related to KFOR. The interfaces between KFOR and the brigades that composed it were consistently rated as

De-Conflicted C2, reflecting established NATO doctrine and practice, but also indicating that they did not rise to the level of Coordinated C2; which would have been possible given their capabilities. As discussed earlier, this meant that little or no synergy was generated between the elements of the force. The relationship that tied KFOR and the NATO forces conducting the air war (Kosovo Air) was somewhat more mature. While the allocation of decision rights reflected NATO doctrine and practice, and were therefore De-Conflicted, the other indicators were consistently seen as reaching a Coordinated C2 approach. Since this was the main thrust of NATO military activity in this peace imposition mission, achieving coordination here was a sign of major efforts by all concerned. Somewhat surprisingly, the SAS-065 group rated KFOR-UN consistently as Collaborative C2. This implies that the experience in Bosnia resulted in recognition of the importance of this interface. Moreover, the charter for KFOR explicitly recognised interdependence between the military and international authorities in this mission.

Examining these two cases provided a strong indication that the charter of a complex endeavour is an important determinant of its C2 maturity—in this case the allocation of decision rights across the collective. These cases also demonstrated that NATO is capable of a relatively high level of C2 maturity, though it does not always rise to the most mature level possible. This was one indication that complex endeavours may *satisfice*—perform at the lowest level of C2 maturity they perceive is needed for mission accomplishment. However, as the IFOR-civilian interfaces indicate, C2 approach cannot overcome structural interdependencies and unwillingness to cooperate. NATO also demonstrated some ability to learn (agility across cases) in improving its interface with the UN between the Bosnian and Kosovo cases.

From the perspective of the N2C2M2 these cases demonstrate that NATO operations can be analysed with respect to C2 approach and evaluated for C2 maturity if adequate access and information are available. The N2C2M2 was applied successfully and found quite consistent patterns among the variables related to each element of the analyses.

### *Simple Disaster Responses*

As noted earlier, SAS-065 chose to examine some relatively small natural disasters (meaning those that could be managed by a single nation with its own assets) in order to assess the possibility that they are qualitatively different from their larger counterparts. Three cases were examined: the Elbe River floods in Germany, Strong Angel III (one of a series of US efforts to examine the processes, technology, and people needed to respond to a disaster), and Golden Phoenix 07, a training event involving first responders and the US military in dealing with a simulated earthquake. See Figure 24.

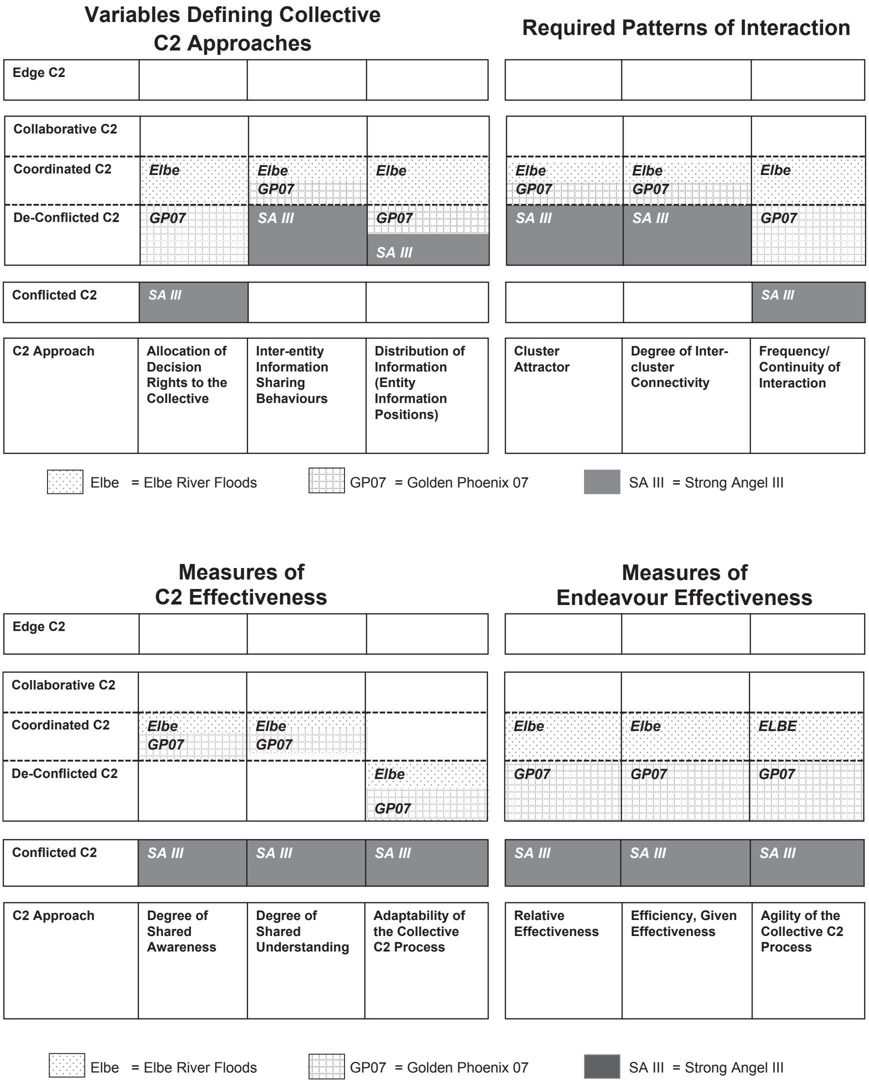


Figure 24: Small Natural Disasters

The Elbe River flood occurred in Germany (Saxony) during 2002. It required an endeavour composed of local, state, and national organisations as well as a number of NGOs.

More than 25,000 volunteers were reported to be involved. The detailed analysis in the case study report examines seven response elements: district authorities, fire departments, State Police, THW[79] (Technical Aid Organisation), Federal Border Police, the German Armed Forces, and NGOs. The German disaster response system has a well prescribed structure that assigns specific roles to all the government players, less so for NGOs. As a consequence, the C2 was consistently scored as Coordinated—all the entities stayed in their lanes but were able to recognise times and functions in which they needed to work together functionally. The single exception was the evaluation of the adaptability of the collective C2 process, which was evaluated as De-Conflicted, indicating the difficulty of altering the command arrangements that had been worked out in detail by the different parts of the bureaucracy. Not visible in the summary provided in Figure 24 is the fact that linkages with the NGOs were consistently rated as Conflicted C2—they had no predetermined way to integrate their command and control into the formal system.

Strong Angel III was a 2006 exercise that simulated a lethal pandemic complicated by a cyber-terrorist attack that involved more than 800 participants. For most purposes this was an effort in developing C2 capabilities on-the-fly under enormous pressure from events. While there was token international presence, the vast majority of the participants were from the United States. Because this was largely a *come as you are* party, little thought had been put into the allocation of decision rights to the collective, setting the stage for Conflicted C2. The

79. THW, a German Federal Agency for Technical Relief (Bundesanstalt Technisches Hilfswerk) is a disaster relief organisation. Its statutory tasks include the provision of technical assistance at home and humanitarian aid abroad. The majority of members are volunteers.

heavy focus on communications led to De-Conflicted information sharing behaviours and required patterns of interaction. However, the lack of agreement of how decision rights would be allocated made the measures of C2 effectiveness and endeavour effectiveness score in the Conflicted C2 range. In essence, the primacy of the allocation of decision rights variable was strongly confirmed here, very much as it was in the charter differences between IFOR and KFOR.

Golden Phoenix 07 was a training event based on a simulated major earthquake in the Los Angeles area. Similar to the Elbe River Flood and Strong Angel III, this event was driven from the bottom up—first responders were the primary actors. However, the Los Angeles area is one of the best prepared within the US, partly because of its considerable experience with natural disasters (wild fires, mud slides, earthquakes) and partly because the state and local authorities have made preparation an important priority.

In Golden Phoenix 07, the allocation of decision rights to the collective was primarily De-Conflicted, reflecting the existing practice within and across first responder communities. This factor also limited the distribution of information and the frequency and continuity of interaction. Some coordinated information sharing behaviours were observed. These centred around specific events requiring cooperation and interdependence, for example, control of rioters that involved US military helicopters for lift, local Special Weapons and Tactics (SWAT) teams as "boots on the ground," fire-fighters, and medical personnel. These incidents also generated some shared awareness and shared understanding at the Coordinated level, but the processes that enabled them were rigid, demonstrating limited adaptability of the collective C2 process. Overall efficiency and effectiveness were seen as consistent with De-Conflicted C2, ultimately constrained by the allocation of decision rights. Overall agility was found to be at a level associated with a De-Conflicted approach to C2.

The primary substantive conclusion arising from the examination of C2 in small natural disasters was that they appear to lack the characteristics of a truly complex endeavour—the variety of actors, a complex structure that cannot be decomposed effectively, dynamics that challenge decision making speed and the need for interdependence beyond the level of coordination. In addition, the willingness of the participants to seek only the level of maturity they believe is required rather than pay the price in time, energy, and resources needed for higher levels of C2 maturity is clear from the analysis in these experiences. From the perspective of the N2C2M2, these cases demonstrated that the information needed to characterise and assess C2 within them can be gathered or gleaned from responsible reporting. These results also tend to support the hypothesis that De-Conflicted or Coordinated C2 approaches are adequate for problems that are decomposable in time, space, or function.

### *Complex Disaster Responses*

Perhaps the most interesting of the case studies conducted were those of major disaster responses truly requiring complex endeavours. As noted earlier, the Hurricane Katrina case study was done first and served as the prototype for the others. The NATO support relief to efforts following the earthquake in Pakistan during 2005 was particularly important because it was heavily military and it involved a highly active and capable host government. Finally, the response to the Pacific Ocean Tsunami, primarily focused on the Indonesian Province of

Aceh, allowed review of a case where the host government sought to control events while also ensuring timely and effective relief. These complex endeavours all changed dramatically over time, forcing consideration of C2 approaches under different circumstances and involving different casts of characteristics. However, this also allowed for more thoughtful analyses of the C2 agility required to manage the changing coalitions and missions.

Hurricane Katrina was analysed primarily from the perspective of national and state actors. The local level efforts varied widely and would be extremely difficult to capture succinctly. Hurricane Katrina Phase 1 was the period of preparation while the storm was well out to sea and perceived as a possible threat. As Figure 25 indicates, except for efficiency, all aspects of Phase 1 were seen as De-Conflicted. That is to say, all the relevant organisations *stayed in their lane*. However, because of their failure to work together considerable duplicative effort was reported, indicating Conflicted C2 in the efficiency arena. Phase 2 was the period during which the threat from Katrina was confirmed, but its scale was not fully understood; the primary activities were warning the population, initial planning, and the beginning of an orderly evacuation. Most C2 related variables reported during Phase 2 were perceived to correspond to Coordinated C2, the exceptions being (a) the tendency for entities to organise their activities in their own organisations and spaces (not around functional areas); (b) their failure to achieve shared understanding of the danger (each organisation made its own assessment); and (c) efficiency, which was impacted by the failure to recognise the need for synergistic actions.

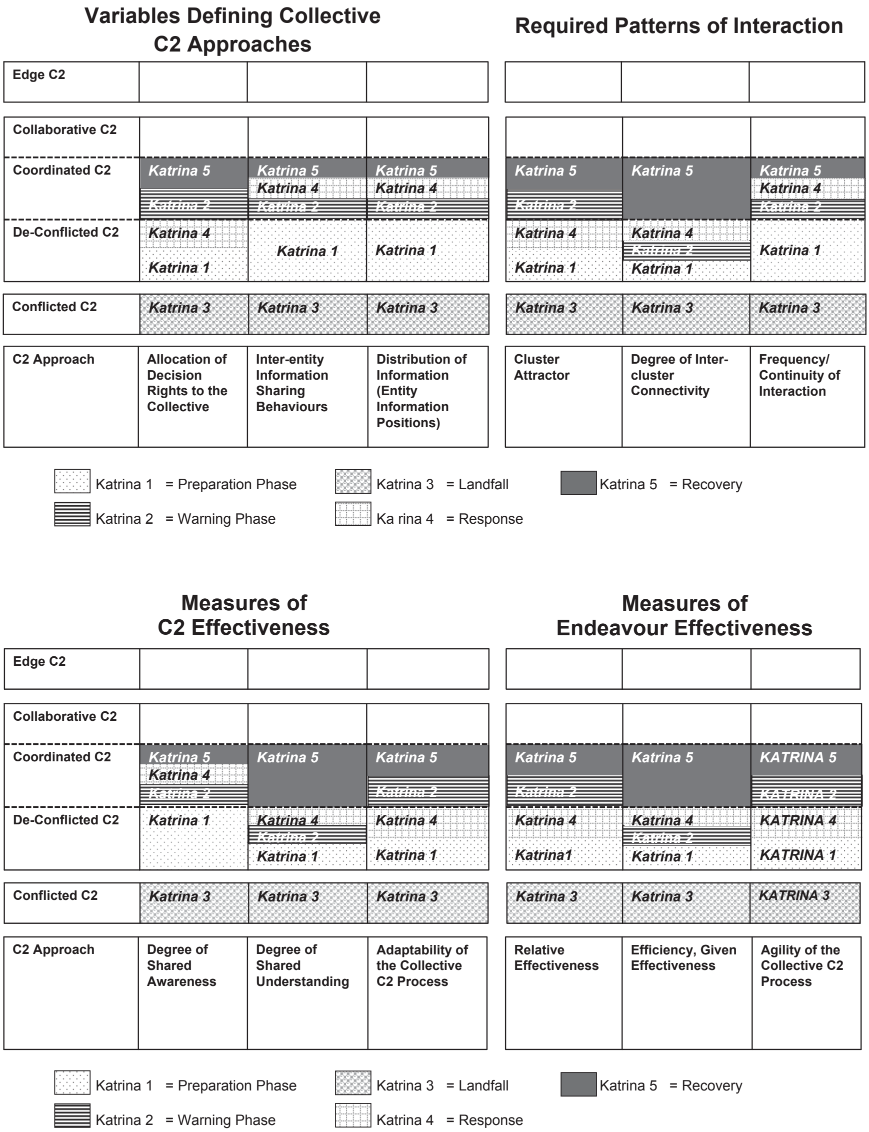


Figure 25: Hurricane Katrina

However, when the storm struck, Phase 3 or Landfall, both the communications infrastructure and the C2 arrangements between and among those responsible collapsed. Effectively, there was no command and control for the endeavour leaving each organisation, and in many cases elements of those organisations, isolated and making the best decisions they could in the absence of shared information and without plans appropriate to the situation. Hence, Phase 3 was perceived to correspond to Conflicted C2 across the board. The response period, Phase 4, really was not up and running until nearly a week after the storm struck. This was built largely on the planning for national disaster management, which had governed the preparation period (Phase 1). As a result, allocation of decision rights to the collective remained almost exclusively De-Conflicted. This was also true for the cluster attractor (organisations dominated to the near exclusion of functionally formed activities), the degree of inter-cluster connectivity, shared understanding, the adaptability of the collective C2 process, and the effectiveness of command and control. The re-established communications systems did move the inter-entity sharing behaviours, distribution of information across entities, frequency and continuity of interactions, and the degree of shared awareness up to the Coordinated C2 level. Phase 5, the recovery period, reflected both learning over time and continuing improved communications infrastructure. Efforts during Phase 5 were seen as achieving Coordinated C2, the level apparently needed for success in such complex endeavours.

Response to the Pakistan earthquake was divided into three phases—Search and Rescue, Relief and Stabilisation, and Reconstruction. While NATO played an important role in this effort the Government of Pakistan was the dominant player, both setting the priorities and organising the effort. The

Pakistan approach was to employ both military and civilian assets (including foreign military and NGOs) and to separate national decision making from local (termed *clusters*).

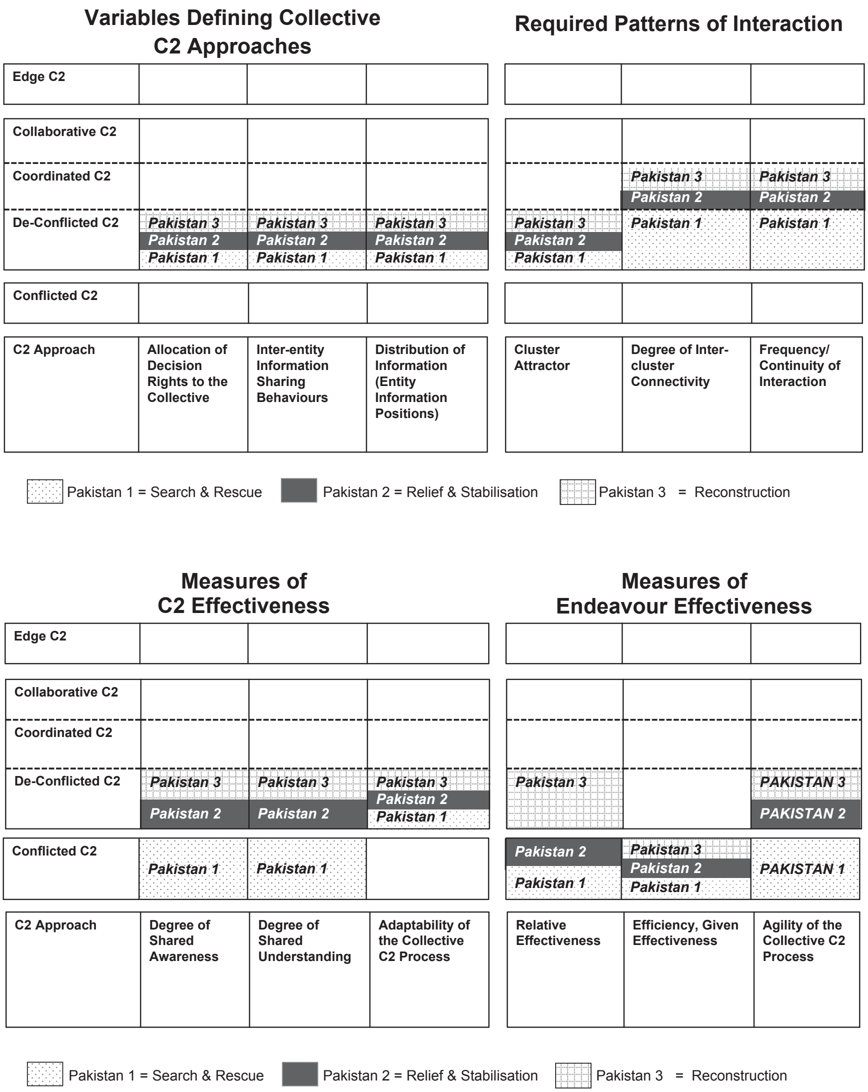


Figure 26: Pakistan Earthquake Response

Pakistan settled on de-confliction as their approach to managing the aftermath of the earthquake. As Figure 26 indicates, in Phase 1 activities (Search and Rescue) all the variables defining collective C2 approaches and required patterns of interaction, as well as the adaptability of the collective C2 process corresponded to De-Conflicted C2. However, the results did not live up to the potential of De-Conflicted C2; as the degree of shared awareness, degree of shared understanding, relative effectiveness, and efficiency were all assessed as a Conflicted C2 approach. In other words, the endeavour lacked a common picture of what had happened and what needed to be done which strongly impacted effectiveness.

Phases 2 (Relief and Stabilisation) and 3 (Reconstruction) had the same C2 approach as Phase 1, De-Conflicted C2, for the variables defining collective C2 approaches and the cluster attractor variable under required patterns of interaction. In other words, the heavily segmented approach that kept military and civilian entities as well as national and local (cluster) entities working independently were still in place. However, improved communications (in many cases specialised and temporary) did allow for Coordinated C2 in terms of frequency/continuity of interaction as well as degree of inter-cluster connectivity. These, in addition to the experience of working together during Phase 1, resulted in improvements in the expected values for measures of C2 effectiveness, thus it was De-Conflicted. However, the potential for achieving more mature C2 was not realised at all during Phase 2, which was judged to be Conflicted for both relative effectiveness and efficiency, given effectiveness. Time and additional experience did improve the assessment of relative effectiveness during Phase 3 to the De-Conflicted level, but efficiency was again rated as Conflicted. The maturity exhibited across the three phases appeared to reach a level associated with De-Conflicted C2.

Once again, the variables defining collective C2 approaches were demonstrated to cast a long shadow—they appear to limit the C2 approaches possible. At the same time, the SAS-065 Research Task Group found that they could apply the N2C2M2 effectively to make sense of the C2 involved in this case.

Tsunami Relief was the largest and most complex of the case studies executed. As with the other complex endeavours, this one involved both civilian and military elements and extended to a large number and variety of foreign actors—military forces, NGOs, and international organisations. Summarising this case required considering six different situations, despite the fact that the SAS-065 analyses ultimately focused primarily on the Aceh Province in Indonesia. In addition, the endeavour changed dramatically across three phases: Search and Rescue, Relief, and Reconstruction. Six different analyses were required to capture the relevant dynamics:

- First Phase Local Authorities (largely isolated efforts);
- First Phase Military (almost exclusively Indonesian);
- First Phase Other (those close enough to participate quickly, including some NGOs);
- Second Phase Military (an emergent coalition including foreign militaries);
- Second Phase Civilians (national authorities, international organisations, and NGOs);
- Third Phase All (foreign militaries had departed).

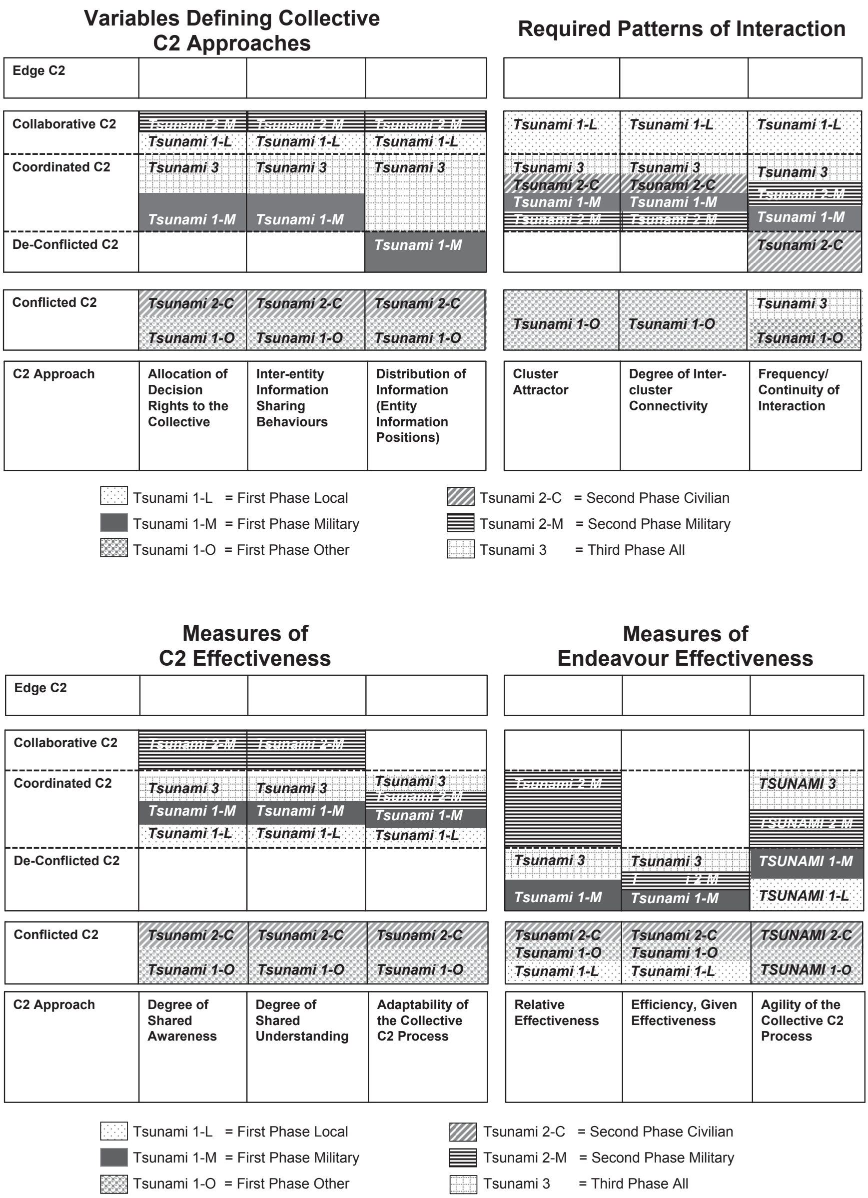


Figure 27: Tsunami Relief

During Phase 1, Search and Rescue, local officials were isolated. Their C2 was heavily influenced by traditional practices, which were Collaborative. Hence, they were seen as achieving Collaborative C2 on all three variables defining the collective C2 approach as well as those describing the required patterns of interaction. However these high levels of maturity are somewhat illusory because they were measured at the level of individual localities, not across the impacted area. Other factors comprising measures of C2 effectiveness were, as a consequence, rated as Coordinated C2, down from the potential maturity established in the more fundamental factors. Moreover, the local leadership lacked the resources to impact the situations strongly so their relative effectiveness and efficiency given effectiveness were seen as ultimately corresponding to Conflicted C2.

During this first phase the Indonesian military were seen as Coordinated on the variables defining collective C2 approaches except for the distribution of information, where their segmentation of the effort led to performance associated with De-Conflicted C2. Moreover, due to limited communications capabilities and traditional military doctrine and training for how to operate, they were perceived by the SAS-065 group as limited to Coordinated C2 in terms of the required patterns of interaction. Not surprisingly, these same factors resulted in Coordinated C2 for all three variables of C2 effectiveness. While their relative effectiveness was seen as holding at Coordinated C2, the efficiency of their C2 approach was rated as De-Conflicted. This reflected an inability to take advantage of potentials for synergy.

Other actors present during Phase 1 (largely NGOs) lacked the preparations and coherence present in the local and Indonesian militaries. They had no capability to organise their efforts, no coherent approach to allocating decision rights, and no reliable means to share information. As a consequence, these other actors were clearly functioning at a level associated with Conflicted C2.

During Phase 2, Relief, independent activity by local councils all but disappeared under the weight of civil authority from the national and regional government and a massive NGO presence. Hence, SAS-065 considered civilian activity as a unit of analysis. However, on the variables defining collective C2 approaches these efforts remained at Conflicted C2. There were efforts to work together, particularly at the functional level (food, housing, etc.) so civilian activity was seen as achieving Coordinated C2 in terms of the degree of inter-cluster activity and the nature of the cluster attractors. However, their interactions were far from continuous and only frequent enough to allow De-Conflicted C2 in practice. Constrained by the low base in variables defining C2 approaches, civilian activity in this phase was plagued by Conflicted C2 in terms of shared awareness and shared understanding. Lacking a coherent approach, they were also seen as Conflicted and unable to find a way to adapt their collective C2 process. This ultimately led to the conclusion that they were also at the level of Conflicted C2 in terms of relative effectiveness and efficiency.

By contrast, the military actors, which now included multinational forces, were able to establish Collaborative C2 across the three variables defining collective C2 approaches. This represented interactions at senior levels. However, their patterns of interaction remained at the Coordinated C2 level—the result of collaborations being implemented in a combination of organisations that largely favoured the home or traditional units. The top level interactions did result in Collaborative C2 ratings on both shared awareness and shared understanding. Overall however, traditional differences between the militaries limited the adaptability of the collective C2 process and the relative effectiveness to the Coordinated C2 approach.

Phase 3, or Reconstruction, was carried out under the leadership of the Indonesian government, with NGOs and international organisations following their lead. Foreign militaries had departed. Virtually all of the variables for this period of time were scored as reaching Coordinated C2. This clearly reflected the experience in prior phases and the opportunity to learn how to work with one another. However, both relative effectiveness and efficiency were seen as De-Conflicted C2, indicating that actions on the ground did not take full advantage of the C2 capability present.

Overall the agility of the collective C2 process exhibited in the military area (effectiveness of changes over phases) was seen as reaching the level of Coordinated C2. The range of agility was constrained by the established doctrine and training of the various militaries involved. While the value of Collaborative C2 was seen in some ways, it could not be carried over to the full suite of C2, both because of relatively weak communications capabilities between the militaries of different nations, and because of an unwillingness or inability to become more interdependent. The civilians involved across the three phases were rated as capable only of De-Conflicted C2 apparently because they had serious problems agreeing on a goal structure that would allow them to implement a more network-centric C2 approach.

*Model Verification and Validation*

The major impact of this case study was a recognition that understanding C2 maturity for a complex endeavour may benefit from, or even require, analyses of the C2 occurring in different sub-elements, whether those are organisational or functional.

## EXPERIMENTATION

SAS-065 sought to take advantage of all the relevant information available to understand C2 maturity. The ELICIT experimentation platform was developed to examine key hypotheses related to the Network Centric Operations Value Chain. It uses a laboratory environment to examine the effect of changes in the C2 approach space (allocation of decision rights, patterns of interaction, and distribution of information) on group capability to solve a knowledge problem http://www.dodccrp.org/html4/elicit.html. Its most basic application is the comparison of classic hierarchies to edge organisations. Members of SAS-065, working with the US Command and Control Research Program (CCRP) carried out a specialised analysis of 37 ELICIT experimentation trials conducted in the US, Portugal, and Singapore over a 3-year period. Table 2 provides a list of the ELICIT trials used in the analyses.

| Edge | | Hierarchy | |
|---|---|---|---|
| Date of Experiment | Experiment Location | Date of Experiment | Experiment Location |
| 10-Jan-07 | Naval Postgraduate School | 24-Jan-07 | Naval Postgraduate School |
| 19-Jan-07 | Naval Postgraduate School | 31-Jan-07 | Naval Postgraduate School |
| 22-Jan-07 | Naval Postgraduate School | 2-Feb-07 | Naval Postgraduate School |
| 26-Jan-07 | Naval Postgraduate School | 6-Feb-07 | Naval Postgraduate School |
| 29-Jan-07 | Naval Postgraduate School | 8-Feb-07 | Naval Postgraduate School |
| 5-Feb-07 | Naval Postgraduate School | 9-Feb-08 | Naval Postgraduate School |
| 7-Feb-07 | Naval Postgraduate School | 13-Feb-07 | Naval Postgraduate School |
| 14-Feb-07 | Naval Postgraduate School | 15-Feb-07 | Naval Postgraduate School |
| 1-Feb-07 | U.S. Military Academy | 3-Mar-07 | U.S. Military Academy |
| 28-Jun-07 | Portugal Military Academy | 26-Jun-07 | Portugal Military Academy |
| 2-Jul-07 | Portugal Military Academy | 4-Jul-07 | Portugal Military Academy |
| 4-Jul-07 | Portugal Military Academy | 4-Sep-07 | Portugal Military Academy |
| 17-Oct-07 | Singapore Military Academy | 24-Jan-08 | U.S. Military Academy |
| 17-Oct-07 | Singapore Military Academy | 17-Oct-07 | Singapore Military Academy |
| 17-Oct-07 | Singapore Military Academy | 17-Oct-07 | Singapore Military Academy |
| 17-Oct-07 | Singapore Military Academy | 17-Oct-07 | Singapore Military Academy |
| 17-Oct-07 | Singapore Military Academy | 17-Oct-07 | Singapore Military Academy |
| 22-Jun-06 | Boston University | 17-Oct-07 | Singapore Military Academy |
| | | 23-Jun-06 | Boston University |

Table 2: ELICIT Experiments Analysed

The hierarchy instantiation was seen as the equivalent of De-Conflicted C2. The edge organisations were seen as the equivalent of a more mature C2 approach, though they did not map specifically to a single C2 approach. However, the difference between the experimentation approaches was strong enough to permit testing the hypothesis that *More Mature Levels of C2 would Perform More Efficiently and More Effectively*.

The results of these analyses are posted at http://www.dodccrp.org/html4/elicit.html. The results of the analysis were clear and unambiguous.

- Edge Organisations were more likely to correctly solve the knowledge problem than Hierarchies;

- Edge Organisations solved the knowledge problem more quickly than Hierarchies;
- Edge Organisations shared information more than Hierarchies;
- Edge Organisations were more efficient than Hierarchies in terms of the experiment person-minutes required to generate correct identification attempts;
- Edge Organisations were generally more efficient than Hierarchies in terms of the number of actions required, on average, to correctly solve the knowledge problem, though the observed difference was only statistically significant at the 80 percent level.

## COMPARATIVE ASSESSMENTS

The members of the SAS-065 Research Task Group were also interested in their ability to make comparisons across the cases. This was an effort to understand whether the factors being considered could be applied consistently and would differentiate levels of maturity appropriately (or find them the same or similar when appropriate). Four such comparisons were made and reported to SAS-065: analytical comparisons between humanitarian operations, Wise Wargame comparison between current and task organised forces, comparison of Elbe River floods to Tsunami Relief, and comparison of Bosnia and Kosovo NATO operations. These later two were comparisons between the findings from case studies conducted by SAS-065.

**Analytical comparisons between humanitarian operations:** Very early in the case study efforts a professional article reviewing and comparing humanitarian relief efforts was identified and offered as a model for how complex endeavours might be analysed.[80] This effort examined its cases through the lens of humanitarian logistics, sometimes defined as "the process of planning, implementing, and controlling the flow and storage of goods and materials as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary's requirements." In another place eerily familiar to those who have worked with network enabled operations, logistics is seen as including, "the planning and preparedness, design, procurement, transportation, inventory, warehousing, distribution and recipient satisfaction. In short, all logistics operations have to be designed in such a way that they get the right goods to the right people at the right time."

The cases examined are (a) the South African food crisis of 2002, (b) the IFRC (a constituent element of the International Red Cross and Red Crescent Societies) response to an earthquake in Gujarat, India in 2001, (c) the UNJLC's (United Nations Joint Logistics Centre) role in responding to Mozambique floods in 2000, (d) the UNJLC's winter season campaign in Afghanistan, and (e) events in Sumatra after the Indian Ocean Tsunami. Comparisons were made across three classical phases—Disaster Preparedness, Disaster Response, and Disaster Management. These three phases were often reported in SAS-065 case studies. This analysis also looked at several factors considered important in determining success: Human Resources, Knowledge Management, Process Management, Resources, and Community. More importantly from the perspective of command and control, the analysis identified three different types of *coordination* in humanitarian relief: coordination by command, coordination by consensus, and coordination

80. Van Wassenhove. "Blackett Memorial Lecture: Humanitarian Aid Logistics; Supply Chain Management in High Gear." *Journal of the Operational Research Society*, 2006.

by default. In addition, the analysis recognised the possibility of *no coordination*. These four categories proved to be quite similar to the five C2 approaches defined by SAS-065.

This comparative analysis also recognised the importance of being alert to the need for change, citing (in their own words) agility (ability to deploy rapidly as needed), adaptability (creating alliances and joint organisations as needed) and alignment (dynamic roles including risk and resource sharing) as desirable characteristics for a humanitarian logistics system. Finally, the analysis recognised lack of trust, both among humanitarian organisations and between them and private organisations as an important barrier to success.

**WISE Wargame Case Study:** The UK conducted a series of WISE (Wargame Infrastructure and Simulation Environment) Wargames in which they sought to compare two different approaches to command and control: (1) traditional hierarchy using geographic de-confliction (Current Case or Baseline) and (2) functional task organisation (Task Group Case or Treatment) with overlapping geographic areas and a relatively flat organisational structure that included resource sharing. In the Task Group Case the Joint Task Force Headquarters (JTFHQ) could arbitrate conflicts (over resources as well as the use of space). This experimentation design was understood by SAS-065 to allow comparison of a traditional approach to C2 (Baseline using Coordinated C2) with a non-traditional approach (Treatment, largely using Collaborative C2, with some aspects achieving Edge C2). The missions assigned and the time available to complete them were identical.

**Variables Defining Collective C2 Approaches**

| | | | |
|---|---|---|---|
| Edge C2 | | *Treatment* | |
| Collaborative C2 | *Treatment* | | *Treatment* |
| Coordinated C2 | *Baseline* | *Baseline* | *Baseline* |
| De-Conflicted C2 | | | |
| Conflicted C2 | | | |
| C2 Approach | Allocation of Decision Rights to the Collective | Inter-entity Information Sharing Behaviours | Distribution of Information (Entity Information Positions) |

**Required Patterns of Interaction**

| | | | |
|---|---|---|---|
| Edge C2 | *Treatment* | | |
| Collaborative C2 | | *Treatment* | *Treatment* |
| Coordinated C2 | *Baseline* | *Baseline* | *Baseline* |
| De-Conflicted C2 | | | |
| Conflicted C2 | | | |
| C2 Approach | Cluster Attractor | Degree of Inter-cluster Connectivity | Frequency/ Continuity of Interaction |

**Baseline** (Traditional Hierarchy using geographic de-confliction)

**Treatment** (Functional Task Organisation)

**Measures of C2 Effectiveness**

| | | | |
|---|---|---|---|
| Edge C2 | *Treatment* | | |
| Collaborative C2 | | *Treatment* | *Treatment* |
| Coordinated C2 | *Baseline* | *Baseline* | *Baseline* |
| De-Conflicted C2 | | | |
| Conflicted C2 | | | |
| C2 Approach | Degree of Shared Awareness | Degree of Shared Understanding | Adaptability of the Collective C2 Process |

**Measures of Endeavour Effectiveness**

| | | | |
|---|---|---|---|
| Edge C2 | | | |
| Collaborative C2 | *Treatment* | *Treatment* | *TREATMENT* |
| Coordinated C2 | *Baseline* | *Baseline* | *BASELINE* |
| De-Conflicted C2 | | | |
| Conflicted C2 | | | |
| C2 Approach | Relative Effectiveness | Efficiency, Given Effectiveness | Agility of the Collective C2 Process |

**Baseline** (Traditional Hierarchy using geographic de-confliction)

**Treatment** (Functional Task Organisation)

Figure 28: WISE Wargames

Both the Baseline and Treatment groups were assessed in qualitative terms, including in-depth interviews of the participants. Quantitative assessments were restricted to measures of performance as the wargame did not permit enough time to assess the success of the campaign.

The Baseline (current case) group was found to be less stressful, undoubtedly because it was more familiar. From the division perspective (the senior headquarters in the wargame), greater positive control was achieved and maintained, meaning in part that there was greater confidence that longer term performance was possible and perspective was being maintained. Communications needs were less, again apparently because the roles, responsibilities, and communications protocols were more familiar, but also because there was no need for peer-to-peer *cross-talk* at the brigade (lower level headquarters). The brigades also focused more on their specific, more tactical responsibilities and showed less interest in the division level (more operational) situation and mission. The effort in the Baseline group was judged to be more risk averse, at least partly because of restraints imposed by the division and the practice of retaining reserves at all levels and throughout the organisation. Finally, the Red Team perceived that Blue was operating at a lower tempo in the Baseline when compared with the Treatment.

The Treatment group (task group case) was seen very different. First there was greater unity of effort and teamwork within the overall command. Secondly, there was greater shared awareness, particularly at the operational level where the efforts of the three task groups had to come together. In addition, the Treatment group was seen as resulting in more pro-active planning and more collaborative planning. However, the Treatment group also showed some challenges. First, this C2 approach appeared to require more joint training in order to ensure the appropriate levels of trust and mutual understanding were available. Second, richer communications tools were required to handle the level of interaction needed to achieve success in this mode. Moreover, planning needs better decision-support tools in order to recognise and deal with the interdependencies inherent in this more network-centric C2 approach. This was reflected in the need to ensure clarity of responsibility of the tasks that arise at the seams between functional task groups, including rear area security and logistics support in this wargame. Finally, the task groups were perceived as being more willing to follow the paths of least resistance (achieve their missions partly by defining them narrowly) and to blur the strong spirit of the *band of brothers* that binds UK forces together in important ways.

Overall, this comparative case study demonstrated both that the N2C2M2 could be applied meaningfully in a rich wargaming setting and also that many of the hypotheses built into it are consistent with efforts involving professional military officers. At the substantive level it also showed the continuing primacy of the variables defining the collective C2 approaches. That is, these key factors drive the C2 approach observed across the other variables of interest.

**Analytical Comparison of Elbe and Tsunami Case Studies:** A specific comparison of the results from examining the C2 approaches used in the Elbe River Flood and Tsunami Relief efforts was undertaken to (a) report on the differences required when dealing with disasters of different scope and (b) to explore an emerging hypothesis about the *requisite* C2 maturity; which argues that the costs of C2 maturity (effort, time, infostructure) are great enough that endeavours will tend to generate only that C2 maturity *required* for success.

The Elbe River flood was evaluated as relatively low in complexity in contrast with Tsunami Relief, which was seen as highly complex. As noted earlier, the Elbe River flood relief efforts were observed to achieve Coordinated C2, following the processes and procedures developed within Germany and reflecting the variety of actors involved. The effectiveness of the Elbe River efforts were, however, seen as high—relief was provided. While the level of efficiency was seen as more modest, reflecting the loss of synergy available if more mature C2 had been present, the level of C2 maturity observed was clearly adequate to meet the need.

While some aspects of the effort to respond to the 2004 Tsunami were observed to reach the level of Coordinated C2, the same as Elbe Flood relief, that level of C2 maturity was not adequate to achieve effectiveness and was clearly very inefficient. In other words, the level of C2 maturity adequate to manage a relatively small disaster was inadequate to deal with a larger, truly complex situation. SAS-065 concluded that this finding was consistent with the relative maturity hypothesis. First, endeavours are not going to seek as much maturity as they can; instead they will seek a level of maturity adequate to deal with their purposes. Secondly, there is no one C2 approach or level of maturity that is appropriate for all situations.

**Analytical Comparison of Bosnia and Kosovo Case Studies:** As noted above, the NATO operations in Bosnia (IFOR) and Kosovo (KFOR), and particularly their interactions with their international partners in the UN, were observed to have performed at very different levels of C2 maturity. Hence, comparing these efforts and particularly understanding the roots of the differences between them and their effectiveness was undertaken as a useful comparison.

Not surprisingly, the core differences arose from the allocation of decisions rights, not only to the collective, but also between the members of the partnership. In Bosnia the charters of the UN and NATO were sharply differentiated, particularly with respect to police functions. In Kosovo the UN was charged with not only supporting the development of police capability, but also with providing police services necessary for security when and where internationally trained police or police monitors were not available. In both cases the UN and its member nations took considerable time to identify, train, and provide police monitors and trainers. However, in Bosnia NATO forces deliberately and consistently refused to step in and provide police services, even when illegal acts (sometimes perpetrated by local police) were undermining the mission. By contrast, in Kosovo NATO was proactive in ensuring police services were provided, which both controlled and deterred illegal actions. This comparative analysis also made it clear that both NATO and the UN learned valuable lessons from the Bosnia experience and applied them in the later Kosovo operations. The data underlying these analyses are reported in Figure 23.

This analysis confirmed the capacity for using the N2C2M2 as a comparative tool when the cases of interest share mission characteristics. It also demonstrated, once again, that the determinants of C2 maturity are interrelated.

## CONCLUSIONS OF VALIDATION EFFORTS

The case studies, experimentation, and comparative analyses undertaken by SAS-065 had three clear purposes:

- Ensuring the NATO NEC C2 Maturity Model (N2C2M2) was clear and easy to understand;
- Testing and improving the utility of the N2C2M2 by applying it to a variety of situations drawn from *real world* experiences, exercises, and war games; and
- Validating the N2C2M2 by assessing its empirical validity, its construct validity, and its expert (or face) validity.

In addition, SAS-065 sought to learn as much as possible about the process of applying the N2C2M2 in order to create illustrative applications that would be valuable to the community.

### *Clarity*

Ensuring the N2C2M2 was clear and easy to understand was given a great deal of attention. While some basic issues proved easy to communicate, others were found to be more nuanced or more difficult to articulate successfully. The language used in the final version of the C2 Maturity Model is very different in some places from that in its early versions. For example, the most mature level recognised in the model was originally termed *Agile C2*. However, *Agility* was understood to be a variable by which the different levels of C2 could be compared. After much discussion and considering several alternatives, the most mature approach to C2 was ultimately termed *Edge C2*, the language used in the final version. This seemed to create the least confusion of the options examined.

Conducting the case studies, analysing the relevant experiments, and carrying out comparative analyses also made it clear that the original formulation focused on the three dimensions of the C2 approach space (Allocation of Decision Rights, Patterns of Interaction, and Distribution of Information) and made it unnecessarily difficult to discuss the differences between the C2 approaches of a complex endeavour and the C2 approaches of the entities participating in the endeavour, which might be quite different. Hence, the final version of the N2C2M2 uses different language to specify the C2 approaches of an endeavour:

- Allocation of decision rights to the collective;
- Patterns of interaction among the participating entities;
- Distribution of information across participating entities.

At the same time, confusion kept arising between the five different C2 approaches (Conflicted, De-Conflicted, Coordinated, Collaborative and Edge) and the C2 maturity levels. As a result, the C2 maturity levels are articulated in the final N2C2M2 by number (Level 1 replaces Conflicted, Level 2 replaces De-Conflicted, Level 3 replaces Coordinated, Level 4 replaces Collaborative, and Level 5 replaces Edge).

This reformulation focuses the analyst on the complex endeavour level (on collective C2) rather than examining the C2 approaches of the individual entities that make up the collective endeavour. In addition, the fact that decision rights help shape information sharing behaviours and that those two factors (together) help determine the distribution of information also became clear. Hence, the three defining axes for collective C2 maturity levels are not orthogonal to one another. This recognition also means that application of the NATO NEC

C2 Maturity Model (N2C2M2) is best done by first examining decision rights, then looking at patterns of interaction and finally examining the distribution of information.

Any number of minor changes to wording occurred within the model, greatly facilitated by the willingness and ability of the SAS-065 members from different nations and with different backgrounds, experience, and training to work together, read one another's drafts carefully, suggest improvements, and seek mutually agreed formulations. And finally, as previously stated, the decision was made to add a *Glossary* in order to make it easier for those not familiar with the specialised, and sometimes somewhat arcane, language of the international command and control research and development community.

## *Utility and Applicability*

The NATO NEC C2 Maturity Model (N2C2M2) is not an end in itself. To be successful it must be useful to NATO and its member nations as they seek to assess their current C2 capabilities and make decisions about whether and how they might be improved or made more mature. The case studies, analyses of experimentation results, and comparative analyses were ultimately tests of the potential applicability and utility of the N2C2M2. The value of a tool can only be determined by using it, which was one of the primary reasons for devoting so much effort to these activities.

As the C2 maturity model developed and the members of SAS-065 grew more familiar with it, they came to understand the emerging rationale behind it and gained experience in applying it; thus they were able to both appreciate and demonstrate its value and potential. The process was aided by improvements in language and model clarity. Some valuable insights emerged about its application:

- First, C2 maturity changes over time, so applications may need to be segmented in order to focus on coherent patterns. These changes appear to be related primarily to changes in the mission. For example, crisis response and reconstruction levy different requirements and may develop very different command and control capacities and practices. Moreover, C2 maturity may change as a result of the introduction of new entities or the loss of entities in the endeavour. This commonly occurs as the mission changes, but is not necessarily caused by those changes.
- Secondly, C2 maturity typically is different for the endeavour as a whole subset of entities and the individual entities that comprise the endeavour. SAS-065 quickly learned that gaining information and insight into the C2 approaches of the endeavour and of its components often exposed large differences. In a typical example, military entities, whether in a coalition or working at the national level have traditions, doctrine, equipment, and training that determines their C2 approach. However, they are often working within endeavours with civilian partners with quite different traditions, policies, practices, and equipment who have organised their efforts very differently. In most cases the overall endeavour in which these partnerships are brought together has yet a third C2 approach.
- Third, C2 maturity can be seen either as descriptive or prescriptive. When examining current organisations or performing assessments of past experience, or analysing

> the results of an experiment, exercise or wargame, the N2C2M2 is descriptive. In these cases, it captures the essence of the C2 approaches and capabilities observed. However, when used to design a C2 approach, develop a plan for transitioning to a more network-centric approach, or determine the correct C2 approach for a given situation, the N2C2M2 is prescriptive.

While these valuable insights emerged from the efforts of SAS-065, the most general finding with respect to utility and applicability was that the N2C2M2, once clearly understood, could be readily applied to the variety of cases selected for analysis: combat operations, peace operations, disaster relief, experiments, and wargames. Moreover, it was a simple matter to organise the results of the ELICIT experiments to test hypotheses arising from the maturity model and the UK wargames demonstrated the ability to design C2 approaches and evaluate their impact when compared with current practices.

### *Validity*

*Expert (or Face) Validity*: The term *face validity* is often used to assess whether a model appears to make sense to those unfamiliar with it. In the field of command and control, however, this term should be changed to read *expert validity* because the number of knowledgeable individuals is quite small. Understanding this challenging field often requires years of experience and practice.

SAS-065 took every practical opportunity to expose the N2C2M2 to professional audiences and invited a number of experts to review it both during development and at its organised Peer Review Workshop where each nation was asked to identify C2 experts who had not been previously exposed to the ideas to examine the C2 maturity model. Members of the CCRP briefed various developmental versions to a variety of audiences, including experts (analysts and practitioners) from the US, Canada, Portugal, Singapore, as well as international conferences dealing with modelling and simulation, collaboration, and operations research analyses of C2. The ideas were also presented at US military educational institutions, the US Military Academy and the US Naval Postgraduate School. Several members of SAS-065 also asked other analysts from their countries to examine the model.

The overwhelming majority of those experts found the N2C2M2 understandable and the logic underlying it reasonable. Many of their comments dealt with the graphics used to present the N2C2M2 rather than the concepts themselves. Some of their comments dealt with the words used to describe the model and the C2 approach space; which was discussed in the earlier section on *clarity*. The only specific dissent raised was from an analyst who pointed out that the model did not conform to NATO's formal definition of command and control and that some of the language differed from that used by NC3A to describe their NEC Maturity Model. This set of comments was covered in the text of the N2C2M2 where the more traditional approaches were explicitly related to the constructs in the C2 Maturity Model. In addition, the fact that the N2C2M2 focuses on complex endeavours as the challenge of the 21st century and that the C2 Maturity Model notes that more traditional approaches to C2 may be appropriate for less complex situations makes it clear that the N2C2M2 takes these issues into account.

*Construct Validity*: The issues of interest in construct validity are whether all the relevant factors are captured in a model and whether all the appropriate relationships between those factors have been identified and incorporated. In terms of construct validity, the initial NNEC C2 Maturity Model proved to be quite strong. While the specific words needed to accurately and precisely describe the factors, some of the variables were adjusted to make them clearer; however no major new factors were added to the N2C2M2 as a result of case study validation. Given the number and variety of case studies as well as the number and variety of experts involved in conducting them, this result was seen as extremely positive.

The most dramatic development in this arena was the evolution of the dependent variables. The initial argument was that more mature levels of C2 were expected to be required (or at least more effective) when dealing with complex endeavours. This argument was never challenged during case study validation. However, effectiveness was ultimately recognised as a property that might be present at any level of C2 maturity (e.g., De-Conflicted C2 can be effective under certain circumstances). Hence, the variable was re-labelled as *relative effectiveness* and the implied metric focused on performance during a complex endeavour. Secondly, in contrast to earlier C2 assessment practices (e.g., Code of Best Practice for C2 Assessment[81]) the dependent variables were extended to include *Efficiency, Given Effectiveness*. SAS-065 argued that efficiency does not make sense unless effectiveness is established.[82] However, because complex endeavours typically require enormous resources over a con-

81. NATO SAS-026, *NATO Code of Best Practice for C2 Assessment*. Washington, DC: CCRP, 2002.
82. Alberts and Hayes, *Planning: Complex Endeavors*, p.168.

siderable period of time, efficiency (which results in greater residual resources at any point in time during the endeavour) matters more in them than in traditional combat missions.

Indeed, the argument can be made that when the complexity and dynamics of a complex endeavour are both high, excess (or reserve) capacity may be essential to long term success. This argument emerged in SAS-065 discussions of NATO experiences in Afghanistan where it appears that *satisficing* at a lower level of C2 maturity in the early part of that mission may have contributed to the descending spiral that was observed more recently. Of course, more mature C2 is never a goal in itself and a variety of factors (troop strength, host government behaviour, the availability of safe havens, etc.) clearly have contributed to these developments. However, less mature C2 may have meant a failure to fully understand the dynamics of the situation and limited development of effective measures.

The major dependent variable innovation in the N2C2M2 is the recognition that agility is both the single most important measure of effectiveness and that it can only be measured across cases or endeavours. A given endeavour cannot demonstrate agility during an application where the challenge (e.g., recovery from a natural disaster) or adversary remains stable. However, members of SAS-065 were able to identify distinct phases during many of the case studies in which the challenge or adversary changed considerably. For example, dealing with recovery from a natural disaster includes a phase when rescue dominates, one of recovery (when refugees and immediate relief are paramount) and a reconstruction phase. In these instances agility could be examined by making comparisons across the different phases.

Building on this insight, SAS-065 also came to recognise the importance of *requisite maturity* and *requisite agility*. In essence, this argument recognises that the appropriate (and perhaps the necessary) level of C2 maturity is derived, at least partly, from the nature of the situation itself. Complex endeavours, which are inherently dynamic, unfamiliar, and make assessment of cause and effect, temporal dynamics, or other types of predictions very difficult, require (or benefit from) more mature C2. However, SAS-065 also recognised that C2 maturity does not arise simply because it is needed or desirable. The endeavour, including whatever military forces it contains, must also have or develop an appropriate approach to C2 and have the doctrine (or agreed management approach), training, processes, material, and skills to function effectively.

Ultimately the importance of understanding that each level of maturity must include the capability to work with partners who are at lower levels (but above the Conflicted level where working together is impossible) cannot be stressed enough. NATO may be able to raise the level of C2 maturity of its forces quite high, but NATO often finds itself having to deal with partners (interagency, international organisations, host governments, non-governmental organisations of relevant parts of industry) that have much less mature C2 capabilities. In such cases, NATO must be able to work effectively with these disadvantaged partners or it runs serious risk of (a) experiencing Conflicted C2 when dealing with them or (b) having to spend its own (probably military) resources and personnel to perform elements of the mission that do not require military capabilities. For example, if refugee populations must be provided food, water, shelter, and medical support NATO would be better off working with specialised organisations and agencies that can provide those services than tying up military assets to provide them. Hence, NATO forces and the NATO nations engaged in complex endeavours will need the capacity to work with these disadvantaged partners.

In addition, some specific factors were identified in the N2C2M2 that are the consequence of adopting a particular C2 approach or achieving a level of C2 maturity, but that can also occur in other circumstances. For example, more mature C2 clearly leads to different patterns of reliance—dependencies, interdependencies, and symbiotic relationships and synergies all appear to increase as a more network-centric C2 is created. On a related topic, resource sharing also appears to increase at more mature levels of C2, as does collaborative planning. Finally, greater levels of trust are present when higher levels of C2 maturity are present. All these factors are mentioned in the N2C2M2, but they appear to be consequences of adopting different approaches. However, further work may indicate that one or more of them are necessary for greater C2 maturity.

*Empirical Validity*: The most challenging validation issue when working with new ideas and examining future command and control issues is empirical validity—does the model reflect *reality* in a credible way. In a sense, all the work on case studies, experimentation, and comparative analysis were efforts to establish empirical validity. The key question was always, *can the N2C2M2 be used to assess, describe, and recognise causal patterns at work through empirical analyses*? Hence, the fact that these efforts could be carried out provides the first order answer about empirical validity: the N2C2M2 can be successfully applied to a variety of cases.

However, there are also limits to the empirical validity established. When the case studies and comparative analyses were carried out, the members of SAS-065 working with them were familiar with the N2C2M2, potentially leading them to interpret reports and information in its terms. Secondly, none of the case studies performed, except perhaps the Golden Phoenix 07 and WISE wargame analyses, were based on empirical data collected specifically to evaluate C2 approach or C2 maturity. Hence, these analyses relied relatively heavily on inferences by the research teams of SAS-065.

On the other hand, both the WISE wargame and the ELICIT experimentation results were able to examine causal hypotheses about the effect of different levels of C2 maturity and both found results consistent with the N2C2M2 and the propositions that underlie it. Similarly, the consistent findings, across many case studies, that the three core variables defining collective C2 approaches consistently predicted the values for the other major variables in the analyses, implies that the underlying causal model is consistent with the realities reported in the case study sources. Hence, to the extent practical, the N2C2M2 has been found empirically valid. More work on this issue can and should be expected over time within NATO, its member nations, and the relevant research and development communities.

### *Other Insights*

The case studies also provided rich insights on a number of relevant topics which included measurement of the factors captured by the N2C2M2 and the establishment of the appropriate boundaries for applications.

One purpose of the validating case studies was to determine the best approach to measurement so that future applications, whether assessments of particular forces and endeavours or the development of strategies and road maps to improve capabilities, would have a clear grasp of the level of measurement feasible and needed. The case studies were not a perfect tool for this purpose because the material used to conduct them was secondary reporting done for general descriptive and assessment purposes. None of the secondary report authors were specifically interested in the dimensions of the C2 approach space in use, nor were they necessarily aware of the C2 maturity concept. However, the case studies did mean that serious C2 analysts were seeking to assess the levels of C2 maturity present in significant sets of events, many of them involving complex endeavours. Hence, they provide an intelligent starting point for understanding the level of measurement needed and what is feasible.

There are four levels of measurement recognised in the scientific and analytical communities:

- Nominal measurement in which categories can be established, but no natural order exists. Examples include gender, race, civilians versus military, etc.;
- Ordinal measurement is also categorical, but the categories have an inherent order. However, the differences between categories are irregular. Levels of education, for example, can be ranked as primary, secondary, undergraduate, and graduate. In many cases continuums that cannot be accurately partitioned are measured ordinaly. We might, for example, use economic yard-

sticks to recognise impoverished people, poor people, middle income, and upper income, despite the fact that the underlying data is a continuous distribution;

- Interval level measurement means that distances between observations are constant, but zero is not a realistic value. Thermometers, for example, use precise intervals to express differences (ten degrees is always the same value, so the intervals are regular), but because zero is not a meaningful number they cannot be multiplied. Hence, 80 degrees is not twice as hot as 40 degrees;
- Ratio measurement implies not only that the intervals are equal, but also that zero is meaningful. Therefore, the numbers can be multiplied and divided. Hence, distances and volumes are measured at the ratio level.

In an ideal world, the N2C2M2 would be made up of ratio numbers. Hence, the percentage of decision rights allocated to the collective in a Collaborative C2 system would be known in advance; therefore those who design systems and develop forces could work toward that finite goal. Moreover, those C2 systems could be assessed, in part, by looking at the percentage of such rights that were in fact allocated to the collective. However, as the case studies demonstrated, neither our knowledge of the maturity of C2 systems nor our ability to measure the driving factors underlying them is precise enough to support ratio or even interval measurement. Universally the members of SAS-065 conducting validation case studies concluded that ordinal measurement is the correct level of measurement and the most precise possible. Attempting to be more precise proved all but impossible in the case studies. However, the members of SAS-

065 did believe they could design a data collection approach that would be useful for those wishing to apply the N2C2M2. That effort is reflected later in the *Illustrative Applications* section.

Establishing appropriate boundaries also emerged as an important insight from those conducting the case studies. They found that clear specification of the boundaries of the endeavour under study was essential in their applications. For example, as noted earlier, many endeavours change over time, partly in response to changes in the challenges they face and as a result of changes in the endeavour itself: its composition (adding or losing members), its purposes (e.g., from saving lives to dealing with survivors and refugees, to reconstruction in the case of disasters), and/or changes in the info-structure available to support the endeavour. As a consequence, many of the case studies broke their analyses into phases and found different C2 approaches for the different phases.

In addition, many of the larger endeavours were found to be made up of *sub-endeavours* or sets of relatively coherent activities conducted as part of the overall complex endeavour. For example, Tsunami response could be seen as made up of different endeavours in different geographic regions. In some cases these sub-endeavours dealt with specific topics such as medical services or security. Hence, some case studies reported different C2 approaches in different elements of the endeavour. While this effort produced some interesting insights, it also sharpened the need to ensure analyses are properly bounded. Learning that some activities within a larger endeavour are operating at a different level of maturity than the overall endeavour (e.g., the international militaries in the Aceh area of Tsunami relief were operating at a higher level of maturity than the NGO community) is really no different than learning that the different entities that make up a complex endeavour each have their own approach to command and control and are, therefore, operating (internally) at different levels of C2 maturity. This set of findings underscores the fact that future applications to NATO military forces are possible, but will be incomplete if that force is expected to operate as part of a larger endeavour where military activity is not the driving factor such as peace enforcement, counter-insurgency, or disaster relief.

### *Summary*

The case study and analytical work of SAS-065 resulted in great improvement in the clarity, utility, and validity of the N2C2M2. It also helped the authors to broaden and deepen their understanding of the requirements for effective NATO network-enabled command and control.

## INTEGRATION OF VALIDATION CASE STUDIES AND EXPERIMENTS

As noted above, the SAS-065 members who were working on case studies and analyses of experiments often found it easier to decompose the complex endeavours involved and assess the C2 approaches and the level of maturity observed for the components of the endeavour, rather than the endeavour as a whole. Depending on the situation, decomposition of C2 can be in terms of geography, function, time, organisation, or a combination of these elements. In the validation case studies both organisational decomposition and temporal decomposition (the analysis of phases) were used in examining complex endeavours. As also noted, decomposition focuses attention on aspects of the endeavour rather than one collective C2 and the key issues of relative maturity and relative agility. This discussion refocuses the analysis to examine the validation efforts from the collective C2 perspective. To be more precise, the N2C2M2 can be applied to the C2 of a given organisation (internal C2) or to the collective C2 of a set of organisations working together.

The approach used in this section assumes the following:

- when endeavours include different phases they must be examined in terms of each phase if the participants, mission, and relevant situation or circumstances in which the assessment occurs are genuinely different because they are essentially different endeavours;
- that within an endeavour the actors, missions, and conditions remain relatively constant; that the three factors defining the collective C2 approach can be used to identify the relevant C2 approach (thereby assuming that the other factors are subordinate to or can be derived from those three);
- that the level of C2 maturity can be inferred from the range of C2 approaches observed during the endeavour;
- that requisite maturity and requisite agility can only be inferred by looking across the phases of an endeavour or by comparing two or more endeavours involving the same organisation(s) over time.

This requisite maturity (the ability to perform C2 at the levels needed for effectiveness and efficiency) can be inferred from performance within an endeavour, but requisite agility can only be inferred looking across phases or situations. The term *across situations* may include different phases of the same general endeavour where the missions, participants, and circumstances are different enough to consider each phase as a separate endeavour (such as the three phases recognised in responding to the Pakistan Earthquake) or different endeavours carried out by the same or substantially similar organisation. For example, this analysis compares IFOR with KFOR under the assumption that NATO is capable of learning from experience.

Finally, the analysis assumes that any phase or endeavour experiencing Conflicted C2, which corresponds with Maturity Level 1, is unsuccessful in the collective C2 realm. Conflicted C2 must, by definition, be seen as unsuccessful. In particular, it is quite possible that the internal C2 of some organisations within an endeavour would be seen as relatively mature and effective, but the collective C2 of that endeavour would be unsuccessful because it failed to at least de-conflict C2 for the entire endeavour.

### *Collective C2 in Combat Organisations and Exercises*

The integrated results for the combat organisations and exercises used as validation case studies are included in Figure 29. None of these cases were decomposed into phases so their collective C2 focuses on the relationships between the parts of the organisation. Moreover, these cases, as all of the others, need to be understood to deal with the *reported* endeavour, not the true endeavour as it occurred. First, reporting is never complete. Equally important, the sources consulted sometimes fail to capture the full extent of relevant C2 activity. For example, reporting about the three combat forces examined in Iraq (101st Airborne, 3/2 SBCT, and 1/25 SBCT) provided little information about their relationships with host nation military and police or with local authorities because important parts of the relevant evidence could not be included in the *reported* endeavour. The results of the case study analyses for combat organisations and exercises have been ordered to stress changes in C2 approach over time. The first case, Standard US Light Infantry, is drawn from the pre-deployment counter-insurgency exercise used as a basis for comparison with the Stryker Brigade carrying out the same scenario on the same terrain with the same professional opposing force (OPFOR). The dark portion of the relevant column indicates that the collective C2 approach followed was best characterised as Coordinated C2 because two of the three variables defining the collective C2 approach were scored as Coordinated (see Figure 22). However, some aspects of the relevant C2 approach (allocation of decision rights to the collective, cluster attractor, and the three variables focused on the measures of C2 effectiveness) were scored as De-Conflicted C2. Hence the larger oval surrounding the dark symbol, representing the *characteristic mode*, covers both Coordinated and De-Conflicted C2–the full range of C2 approach values recorded for the case.

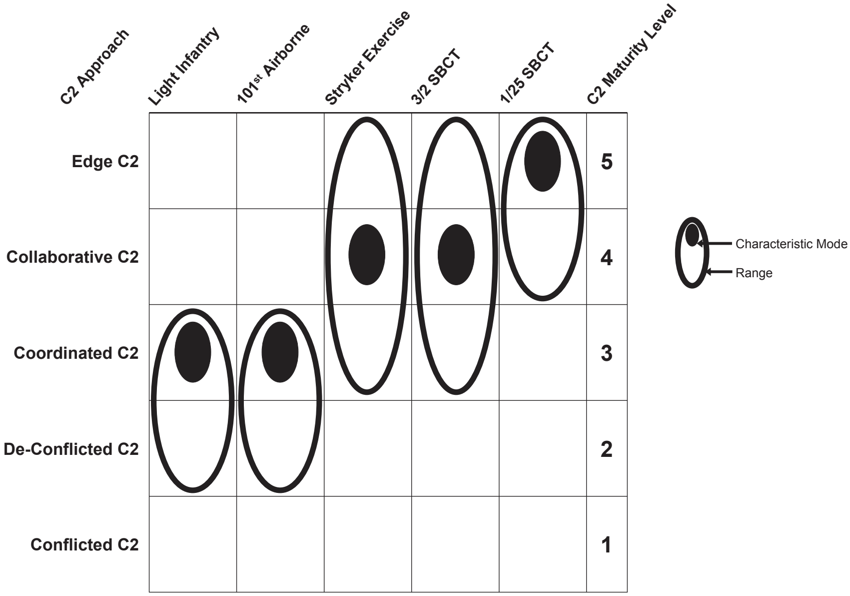


Figure 29: Combat Organisations and Exercises

The same methodology was applied to the other four relevant cases. The 101st Airborne scoring was parallel to the Standard Light Infantry except that two of variables measuring C2 effectiveness (degree of shared awareness and degree of shared understanding) were scored as Coordinated C2 and one factor (frequency and continuity of interaction) was seen as achieving Edge C2 capability. Hence, the same *characteristic mode* (Coordinated C2) and range of relevant C2 approaches are reflected on the graphic.

The next two columns represent the same unit but differ with respect to situation (exercise versus operations) and time. The Stryker Exercise column is actually a pre-deployment analysis of the performance of the 3/2 Stryker Brigade Combat

Team (SBCT). The column labelled 3/2 SBCT is that military organisation after its deployment to Iraq. Hence, there should be little surprise (though perhaps some satisfaction) at seeing the identical collective C2 approach focus (Collaborative C2) and range (from Edge C2 to Coordinated C2). All three of the defining variables were scored as Collaborative C2 for both cases, with only the cluster attractor variable seen as Coordinated and one factor (frequency and continuity of interaction) scored in the Edge C2 category. The Stryker Exercise was seen as less network-centric, as it scored as Coordinated on its adaptability of the C2 process; however, the 3/2 SBCT was seen as Collaborative on the adaptability factor. This difference apparently reflects maturation of the C2 approach as the unit completed its training and entered the *live* counterinsurgency environment. As a practical matter, collaboration tends to become more common when military organisations are freed from training and formal doctrine compliance and asked to perform in challenging operating environments.[83]

The final column on this graphic reports the results from analysing the 1/25 SBCT in Iraq after it replaced the 3/2 SBCT on the same terrain, but in a mission that had evolved. This unit had somewhat better equipment (more satellite communications, more vehicles linked directly to its networks) and the advantage of learning from its predecessor. It was scored as operating primarily with an Edge C2 approach, with some factors (cluster attractor, measures of C2 effectiveness, and measures of endeavour effectiveness) at Collaborative C2. In essence, while it had the technical capacity and general

83. Hughes, Wayne P. Jr. "Fleet Tactics: Theory and Practice" Annapolis MD: Naval Institute Press, 1986; Wentz, *Lessons from Bosnia: The IFOR Experience*, 1998 http://www.dodccrp.org/files/Wentz_Bosnia.pdf; Wentz, *Lessons from Kosovo: The KFOR Experience*, 2002, http://www.dodccrp.org/files/Wentz_Kosovo.pdf.

doctrine to operate as a edge organisation, its efforts were often Collaborative, apparently both because there was no need to operate at the Edge C2 level and because that more mature C2 level remained beyond the training and doctrine of the US Army during this period of time. Hence, it did not reach its full C2 potential. Even so, this case represents extremely mature and capable collective C2 capacity and performance.

Note that the results of the analyses of the 1/25 SBCT case was determined by the methodological decision that the collective C2 approach would be based on the three variables: allocation of decision rights to the collective, patterns of interaction among the participating entities, and the distribution of information across participating entities. Note also that the counter-insurgency assessments in Iraq were focused on the military organisations themselves and did not examine their interagency, host government or NGO relationships, which were not reported in adequate detail in the sources consulted to be included in the analyses.

Finally, from the perspective of assessing collective C2, these five cases indicate that the US forces involved have demonstrated improving C2 maturity over time and substantial C2 agility. The migration from Coordinated to Collaborative to Edge C2 suggests considerable capacity for achieving the higher levels of C2 maturity required for complex endeavours in the 21st century.

## WISE WARGAMES AND COLLECTIVE C2

The first two columns of the next graphic, Figure 30, focus on the *UK WISE wargames* that were created as experiments to examine the performance of fully qualified military professionals using traditional or *baseline* C2 (hierarchical structure with geographic de-confliction) and an alternative or *treatment* C2 (hierarchical with functional task organisation) in a counter-insurgency operation. The traditional, or *baseline* organisation and approach were scored consistently as collective Coordinated C2 in keeping with current UK doctrine, organisation, equipment, and practice. However, the *treatment* or task organisation and approach were characterised as collective Collaborative C2 (two of the three variables defining collective C2 approaches taking that value) with some factors (inter-entity information sharing behaviours, cluster attractor, and degree of shared awareness) scoring at Edge C2. Hence, the *treatment* or task organisation and C2 approach should be understood to be more network-centric. Since this case was limited to military organisations, however, generalising from this evidence to dealing with complex endeavours involving civilian partners would not be valid. That having been said, however, the evidence from these cases is generally consistent with the rest of the assessments, particularly the results of the ELICIT experiments. That is flatter organisations with greater reliance on collaborative processes generate greater collective C2 maturity.

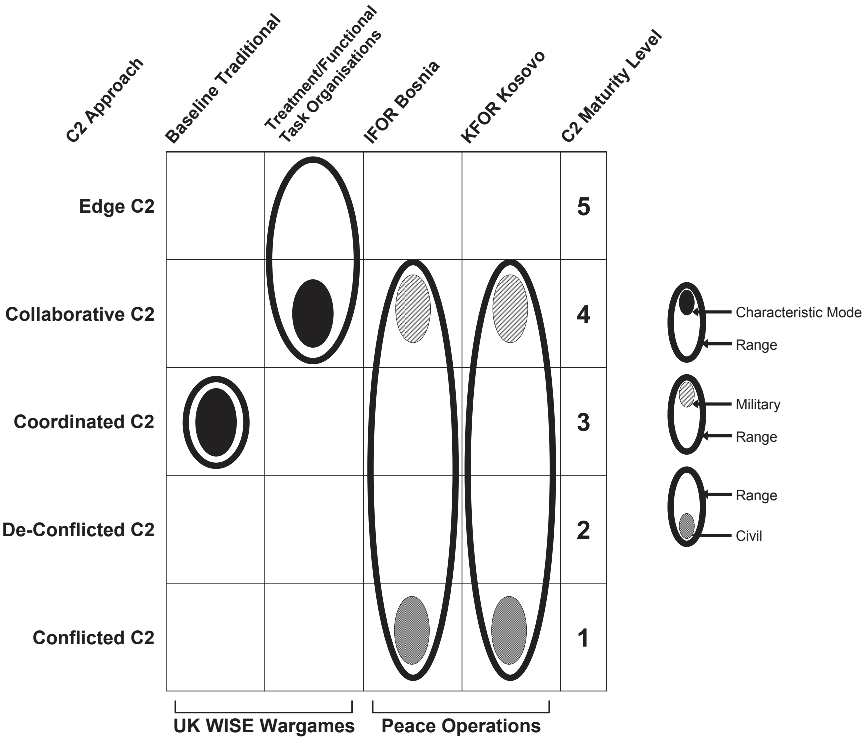


Figure 30: Wargames and Peace Operations

# COLLECTIVE C2 IN PEACE OPERATIONS

For convenience, the NATO peace operations used as validation case studies are also reported in Figure 30, where they occupy the last two columns. The two operations have quite similar summary profiles, but are quite different from the WISE wargames included in the same graphic. The earlier of the two NATO efforts, IFOR in Bosnia, was assessed as using a Collaborative C2 approach in its military aspects (NATO efforts), so that was identified as the *characteristic mode* for the collective C2. However, the SAS-065 analysis of this effort also noted that IFOR's predominant C2 approach when dealing with civilian organisations was best characterised as De-Conflicted C2 and, in terms of relative effectiveness and efficiency given effectiveness the assessment was Conflicted C2. As noted earlier, this occurred because there was a strong effort to de-conflict the military and civilian aspects of the endeavour, which is a practical impossibility when dealing with a complex endeavour. As a consequence, two characteristic modes had to be identified, one for the militaries (NATO) and another for their relationships with civilian authorities. Hence, from the collective C2 perspective, this endeavour would be seen as ineffective and inefficient, despite the fact that some behaviours associated with higher levels of C2 maturity and agility were recorded.

The same profile emerged when the later efforts of KFOR in Kosovo were assessed. Learning from the experience in Bosnia, a serious effort was made to create and maintain a more mature approach when NATO was dealing with the UN in Kosovo. The SAS-065 team rated that aspect of the C2 as Collaborative on all three of the variables defining the collective C2 approaches, so that is shown as one aspect of the *characteristic mode*. However, the overall picture is quite complicated. KFOR Air operations were primarily rated as exhibiting the qualities of Coordinated C2. At the same time, the C2 approach coded for interactions with and among the brigades involved was De-Conflicted. This reflected the dominant doctrinal and organisational arrangements of the times within NATO ground forces.

However, the number of refugees involved made NGOs very much a part of the Kosovo complex endeavour. The SAS-065 assessment of the relationship between those NGOs and the rest of the endeavour, including the NATO forces, was

Conflicted C2. As a consequence, a second *characteristic mode* was also recorded in the Conflicted C2 range. Hence, the variety of C2 approaches involved in KFOR indicated some meaningful agility; however the fact that Conflicted C2 occurred for part of the endeavour, both in this case and in the case of IFOR, indicates that more will need to be done to create and maintain the level of maturity needed for successful C2 in peace operations by NATO in the 21st century.

## COLLECTIVE C2 IN SMALL NATURAL DISASTERS

Three small natural disasters were assessed for C2 maturity in the validation case studies. As noted earlier, all were relatively limited in scope and made fewer demands for collective C2 maturity and agility than the other cases examined. They are integrated in Figure 31. Strong Angel III, designed primarily to encourage and enable the rapid development of communications networks and shared awareness among a variety of participants (military, and civilian) showed the least mature patterns, with allocation of decision rights to the collective being seen as Conflicted, though the other two variables defining collective C2 approaches did rise to De-Conflicted C2. However, all measures of effectiveness were also scored as reflecting a Conflicted C2 approach, underscoring the fundamental importance of the allocation variable. While valuable for learning, the Strong Angel III natural disaster experiment proved to have ineffective and inefficient collective C2.

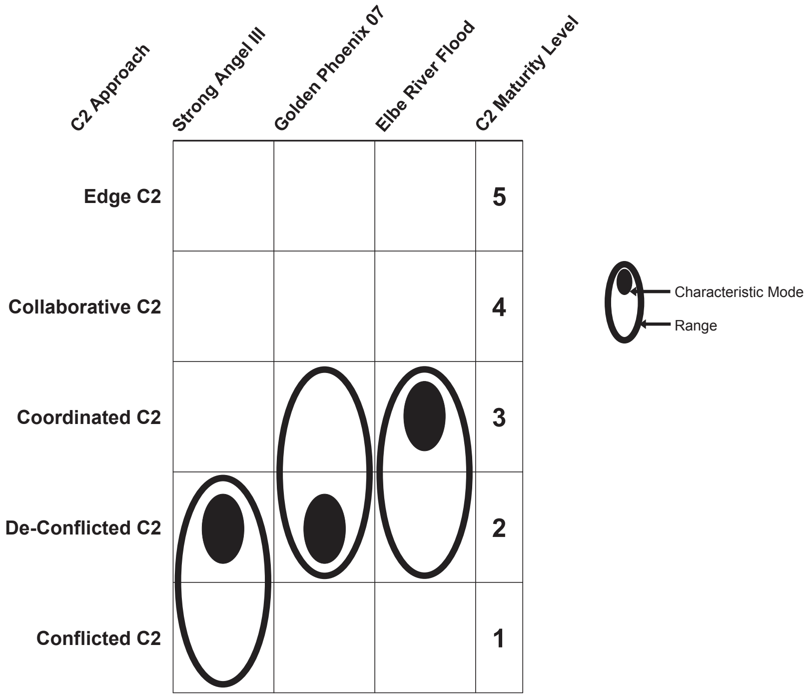


Figure 31: Small Natural Disasters

Golden Phoenix 07, the response to a simulated earthquake, was rated as De-Conflicted on two of the variables defining the collective C2 approach, including the allocation of decision rights to the collective. This training event was not rated below that level on any variable. Inter-entity information sharing behaviours, cluster attractors, degree of inter-cluster connectivity, degree of shared awareness and degree of shared understanding were all rated at the Coordinated C2 level, so some aspects of this endeavour showed the capacity for an improved collective C2 approach, particularly as the event went forward over time. Its C2 approach was scored as adequate to deal with the situation arising from the simulated disaster.

The Elbe River flood had the advantage of (a) a number of prior working relationships among the participants and (b) a relatively intact communications infostructure (which had been destroyed in the Strong Angel III and Golden Phoenix 07 scenarios). This case was scored as using a Coordinated C2 approach, except on the factor involving the adaptability of the collective C2 process. As noted earlier, this apparent inflexibility appears to reflect the fact that a more network-centric C2 approach was not required. Hence, while lessons were learned (or at least recorded), no requirements were identified for greater capability, adaptation, primary work processes or organisations. The Coordinated score for characteristic mode of collective C2 proved adequate to deal with this real world case.

The modest ranges of C2 approaches recorded in these relatively small disasters probably indicates, as noted earlier, that they do not rise to the level of complexity that defines a complex endeavour.

## COLLECTIVE C2 IN COMPLEX DISASTER RESPONSES

Some extremely interesting collective C2 patterns emerge when the three genuine complex disaster responses used to validate the N2C2M2 were examined. To make comparisons easier, each of the three (Hurricane Katrina, Pakistan Earthquake, and Tsunami Relief) have been broken down into roughly equivalent phases: Immediate Impact, Disaster Response, and Recovery. The results of these analyses are shown graphically in Figure 32.

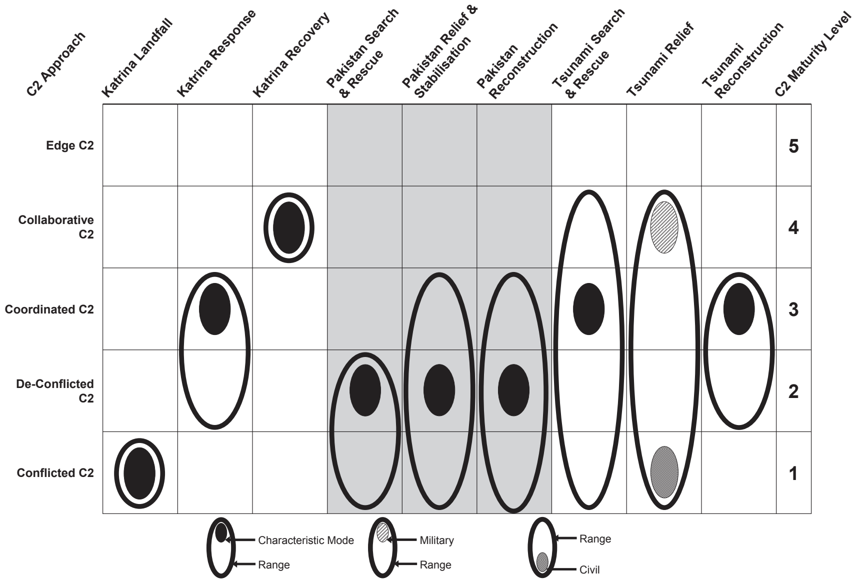


Figure 32: Complex Disaster Responses

The response to Hurricane Katrina has the simplest pattern. First, as in the Strong Angel III and Golden Phoenix 07 scenarios, the communications infostructure that linked the myriad of organisations involved in the response was destroyed by the event itself. Hence, the authoritative descriptions of the opening phase of the operation (termed landfall in the earlier analyses) were scored as Conflicted for collective C2. Once the response phase got underway, however, two of the three variables defining collective C2 approaches were scored as achieving Coordinated C2; though the key factor of allocation of decision rights to the collective was still seen as consistent with De-Conflicted C2. Aided by massive news media coverage and increasingly improved infostructure, this phase was also seen as Coordinated in terms of the frequency/continuity of interaction and degree of shared awareness. However, all other factors (including the three measures of endeavour effectiveness) followed the allocation of decision rights factor, De-Conflicted C2, as the dominant planning and training doctrines of those entities involved. In other words, the collective C2 of the endeavour during this phase was well short of its potential because of the inability to find a way to allocate decision rights within the endeavour.

By contrast, the scores for Phase 3 (Recovery) were concentrated at the Collaborative C2 level. By now the infostructure was restored and structures and processes had returned to their pre-disaster levels. This *return to the familiar* appears to have taken place in the presence of a heightened awareness of the need to work together resulting from the shared experience during the earlier phases. Hence, the pattern from Katrina indicates an ability to change C2 approaches over time and across experience. While the characteristic mode improved across the three phases, the level of C2 maturity was clearly inadequate (lacked requisite maturity) during the first two phases.

The collective C2 response to the Pakistani earthquake was consistently coded as De-Conflicted across all three phases. Moreover, the detailed analyses of all three phases showed some aspects of those operations to have included Conflicted C2. Of course, the earthquake did great damage to the infostructure in the region, so there were major challenges to be overcome during that the first phase (Search and Rescue). In fact, all measures of effectiveness for Phase 1, except adaptability of the C2 process (there were visible improvements occurring even during this early period), were scored as Conflicted C2. As the graphic shows C2 during Phase 2, while still characterised as collectively De-Conflicted and seen as Conflicted on the key measures of relative effectiveness and efficiency, also reached Coordinated C2 for both degree of inter-cluster connectivity and frequency/continuity of interaction. These positive developments were aided by the presence of foreign military forces and the infostructure they brought to help fill the gaps. In Phase 3 (Reconstruction), only the factor of efficiency, given effectiveness, scored as reflecting Conflicted C2. Its profile is similar to Phase 2 except in terms of effectiveness, which was assessed as De-Conflicted rather than Conflicted C2.

As with the review of the Combat Organisations and Exercises, the Pakistan Earthquake response appears to indicate improved maturity over time, though the changes recorded are modest. As in other parts of the assessments, the governments and organisations involved (a) tended to follow their established practices, doctrines, and organisational patterns; and (b) appeared to be seeking to know how much was enough, or perhaps, how little change was needed. However, the fact that some aspects of collective C2 were scored as Conflicted in all three phases means that neither requisite C2 maturity nor requisite C2 agility were achieved.

The final major validation case study, Tsunami Relief, has perhaps the most challenging pattern to read. Collective C2 during Phase 1 (Search and Rescue), was seen as characteristically Coordinated C2 based on the key role of the Indonesian military, although the distribution of information was rated as De-Conflicted, reflecting the host government's reluctance to encourage information sharing given that the impacted area was also a region where guerrillas were operating as well as an established doctrine of De-Conflicted C2. At the same time, the local authorities in the Aceh region were predominantly operating at a Collaborative C2 level, reflecting their traditional decision making practices and their reliance on face-to-face meetings. However, other actors including the civil authorities and NGOs were clearly functioning at a Conflicted C2 level. Hence, Phase 1 has a wide range, including some clear indications of failed C2. At best, however, most participants in the endeavour were able to function at the De-Conflicted level in terms of measures of endeavour effectiveness.

Phase 2, Tsunami Relief, was also a very mixed bag, again reflecting the wide variety of actors present and the complexity of the task. The Indonesian military, working with foreign militaries, functioned during this period at the Collaborative C2 level. This was needed to focus their efforts and improve endeavour effectiveness. However, even for those organisations, patterns of interaction were seen as Coordinated C2, with civilian efforts De-Conflicted and civilian performance largely scored as Conflicted C2. Hence, this phase has no genuine characteristic mode, but rather two very different ones. The inability to find an effective C2 approach across the civilian-military communities reflects many of the same problems seen in Bosnia and Kosovo. However, in this case no effective way to bridge the gap was developed.

Phase 3, Tsunami Reconstruction, was simpler in that the foreign militaries had left and the security threat was seen as diminished. This allowed the government of Indonesia to play a stronger role, including more direct management of NGOs and others involved in providing assistance. However, it also meant a return to *business as usual* in that the urgency was gone, quite similar to reports from Hurricane Katrina. One apparent result of these factors was systematic settling of the C2 approach back to Coordinated C2. While two crucial measures of endeavour effectiveness (relative effectiveness and efficiency, given effectiveness) were scored as achieving only De-Conflicted C2, the rest of the variables of interest all clustered at Coordinated C2.

The Tsunami Relief case study suggests that the relative range of C2 approaches that is appropriate may grow during high stress phases of major complex endeavours, then settle back to less stressful ranges when the emergency is perceived to have passed.

## CONCLUSIONS OF COLLECTIVE C2 ANALYSES OF VALIDATION CASE STUDIES AND EXPERIMENTS

From the perspective of *methodology*, these analyses of collective C2 as seen through the lens of the N2C2M2 indicate that analysts can assess the overall C2 approach, level of C2 maturity, requisite C2 maturity, agility, and requisite C2 agility. C2 approach and level of C2 maturity can be inferred either for individual endeavours or for phases within a larger endeavour that can be seen as individual endeavours because they include different missions, actors, and circumstances.

Inferences about collective C2 maturity and requisite maturity can be made within the context of a single endeavour or a phase that is actually a different endeavour. However, inferences about observed agility can only be made across endeavours or phases. Hence, C2 agility can be seen when comparing military organisations in combat, exercises, wargames, and peace operations. Agility could also be inferred across the phases of the complex disaster responses. In every case, however, the danger of defaulting to Conflicted C2 must be recognised as limiting the observed agility and undercutting requisite agility and requisite maturity. Conflicted C2, as the absence of meaningful collective command and control functionality, is always an indication of inadequacy or C2 failure. This is particularly true when relative effectiveness and efficiency, given effectiveness are rated at the Conflicted C2 level.

From a *substantive* perspective several important conclusions emerge from these analyses. First, there are indications that it is distinctly possible for co-evolution of the capabilities needed to move toward more network-centric C2. Improved infostructure, doctrine, training, and personnel at all levels allow endeavours to become more network-centric over time and (a somewhat larger inference) across cases as they gain experience. This tendency was seen most clearly in military organisations with the opportunity to work together over time and adjust their practices to meet recognised challenges. However, it was also present across phases of complex disaster responses.

Second, there are pressures to improve C2 maturity during high stress situations. These pressures come from the nature of the situation (lives are at risk), from political leaders, from the media, and from the public. However, this conclusion should be understood in the context that this pressure is greatest when the C2 situation is at its worst. For example, when natural disasters destroy the infostructure or a rush to participate brings together widely disparate actors with little or no past experience or agreed approach to the C2 functions. These pressures tend to dissipate when the initial crisis passes. However this may be when the need for collective C2 maturity is greatest because of the multidimensional nature of reconstruction operations, whether as a result of a natural disaster or a military conflict, and the variety of organisations involved in them.

Third, the chasm between military and civilian actors remains a source of serious challenges. Whether the relationships between military and interagency partners, those with international organisations, those with non-governmental organisations, or those with state (or provincial) and local civil authorities are considered, case studies show the greatest likelihood of failed (Conflicted) and Industrial Age (De-Conflicted) collective C2 occurring along the fault lines that define this chasm. The origins of these challenges are legion: lack of trust, lack of interoperability (technical, semantic, and willingness to work together), lack of shared information, lack of collaboration mechanisms, cultural differences (national and professional), and so forth. However, NATO and its member nations need to pay particular attention to these issues and develop greater capacity to deal with them. Otherwise complex endeavours will be more costly and less successful than is possible or desirable.

Fourth, no one should be seeking C2 maturity as an end in itself. Complex endeavours, or more properly, the entities involved in complex endeavours, need to find ways to operate effectively and efficiently in order to accomplish their missions. As a result they must seek to find C2 approaches that work for them, both internally and in terms of collective C2. However, the more the situation resembles a complex 21st century challenge (multi-dimensional, non-linear, unfamiliar, unpredictable, etc.) the greater the need for more network-centric C2 approaches. The more dynamic the situation, the greater the need for C2 agility and the greater the need to achieve some levels of requisite C2 agility and maturity. Put simply, complex endeavours cannot succeed with Industrial Age C2 approaches.

Fifth, greater C2 maturity is not free. It requires infostructure, training, competence, trust, as well as the willingness to share information and surrender decision rights to the collective. Hence, the case studies provide indications that the highest levels of C2 maturity will not always be sought. Indeed, the concepts of requisite C2 agility and requisite C2 maturity are recognition that more is not always better and *real world* organisations may either limit the C2 approaches they are willing to consider or seek to return to less expensive (in resources, trust, information sharing, decision rights, training, etc.) levels of C2 maturity, particularly after the perceived crisis has passed.

These last two points may be particularly important for NATO. As NATO and the NATO nations work to develop NATO NEC C2 Maturity, the absence of immediate pressure and the apparently low dynamics of situations that have not yet erupted into crises, or for which crises appear to be past, may well lead to arguments to *go slow* or develop only limited C2 maturity. However, these capabilities are very difficult to create at the last minute. In particular, the capability to work with civilian partners and non-NATO military partners remain challenges that need more attention, particularly before the advent of a crisis or conflict. Considerable gain in mission accomplishment and efficiency is possible if serious, sustained efforts are made to improve C2 maturity within and among NATO forces and between them and the partners capable of working with them. Similarly, thinking through the requisite agility needed to be effective and efficient in dynamic situations, and preparing for it before the fact, will pay handsome dividends in the long run. The N2C2M2 can be an important tool in those efforts.

# Chapter 8
# Applying the NATO NEC C2 Maturity Model

## INTRODUCTION

The NATO NEC C2 Maturity Model (N2C2M2) provides a framework for determining the C2 approach within the C2 Approach Space that a collective may adopt for a given complex endeavour, or phase within an endeavour. At the same time, it allows the collective to assess their level of C2 maturity that is defined using the same dimensions of the C2 Approach Space. The N2C2M2 can be used in various ways by a number of different communities, including:

- Strategic planners can use the model to determine what C2-related capabilities are needed to face current and future challenges in a variety of different contexts;
- Programmers and budgeters can use the model to support a variety of investment decisions and doctrine development;

- Educators and trainers can use the model to help individuals and organisations better understand the nature of collective command and control and its implications;
- Researchers can use the model to help design experiments, campaigns of experimentation, and exercises;
- Professionals, schools, and colleges/universities can use the model to structure lessons learned and analyses;
- Researchers can use the model to formulate hypotheses and as a framework for conceptual C2 models.

There is no fixed procedure for the use of the N2C2M2. The purpose of this chapter is to give some examples of suitable areas for application of the model and indications of how it may be applied. These illustrative, model applications will help users to select their own approach.

Three illustrative applications were selected to give users a better idea of the utility and uses of the model. The three illustrative cases presented here (a) clearly benefit from the N2C2M2 and (b) are representative of the potential areas where the N2C2M2 can be applied. It should be noted, however, that many more applications are possible. The selected applications focus on:

- Operational Design;
- Strategic (Defence) Planning;
- C2 Research and Experimentation.

Operational Design is the process of designing the required force for a particular mission. This involves assessing the situation, composing an appropriate force by selecting units from the pool of existing forces, and organising the resulting force; which includes making decisions about a suitable C2 approach.

Strategic Planning is the process aimed at producing a strategic development plan (SDP) that best adapts the defence organisation to possible future operating environments including the range of C2 approaches it is capable of employing and the ability to recognise which of these approaches is appropriate [this equates to C2 maturity]. There is a connection between Operational Design and Strategic Planning. Strategic Planning results in a plan to transform the current pool of forces into the pool to which future Operational Design is applied.

C2 Research and Experimentation is the process of creating and refining existing knowledge about C2. This knowledge constitutes an important part of the basis for constructing an SDP in accordance with the NEC philosophy. C2 Research and Experimentation is thus an important enabler of defence force transformation.

The model may be used in two different ways: (1) as an analysis/assessment tool in the development and refinement of C2 concepts and approaches; and (2) as a conceptual model and tool to facilitate communication among informed stakeholders on C2 related issues. The use of the model in analysis and assessment cases is multifaceted. Most of the chapter is devoted to these types of applications.

21st century missions are characterised by participation of a large number of disparate *entities* that include not only various military units but also civil authorities, multinational and international organisations, non-governmental organisations, contractors, private industry, and private volunteer organisations. The success of such missions is dependent upon effective and agreed C2 arrangements. The N2C2M2 describes, in a relatively simple way, some of the basic requirements for effective

C2 and should be used as an authoritative basis for negotiating C2 arrangements between and among different entities in an endeavour. Similarly the N2C2M2 should be used in an entity's strategic planning process as a means of facilitating communication about C2 issues among the stakeholders in the process: politicians, military, scientific support personnel, etc.

## COMMON APPROACH FOR THE USE OF THE MATURITY MODEL

The N2C2M2 was designed to take advantage of and should be used in conjunction with the NATO Code of Best Practice for C2 Assessment[84] (COBP-C2A) and the C2 Conceptual Reference Model (C2CRM). Their interrelationships are shown in Figure 33.

84. SAS-026, *NATO Code of Best Practice for C2 Assessment*, 2002.

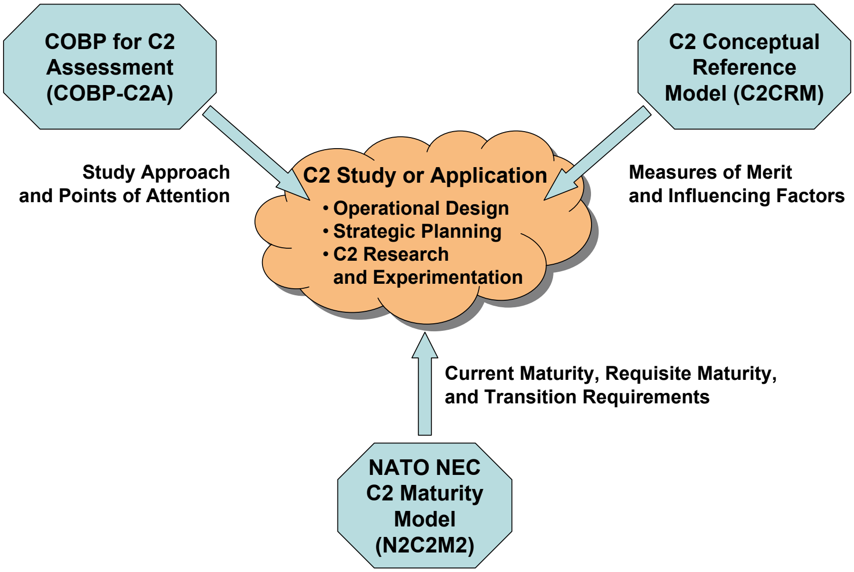


Figure 33: Relation between our application and the NATO NEC C2 Maturity Model (N2C2M2), Code of Best Practice for C2 Assessment (COBP-C2A), and C2 Conceptual Reference Model (C2CRM)

The COBP-C2A will help to identify an appropriate and effective study approach and to specify issues deserving attention. This ensures that the problem will be well formulated, that analysts will have good data collection and analysis plans, select appropriate measures of merit, and pay proper attention to the tools that can support the assessment. The N2C2M2 will help to identify where you are and what you need to do to transform to higher levels of capability. The C2CRM will help to identify the measures of merit, relevant relationships, and the factors of influence.

## *A General C2 Transition Requirement Procedure*

A maturity model is like a roadmap: it lets you know where you are relative to where you want to go. It also identifies places along the way that are intermediate destinations on the journey to transformation. These issues are central to both Operational Design and Strategic Planning. When guiding research these issues need to be addressed in order to identify knowledge gaps needing attention. Analysts need to understand the situation, the required capabilities, the current capabilities, and the transition requirements to move from one C2 approach to another. A general approach to addressing these issues is illustrated in Figure 34.

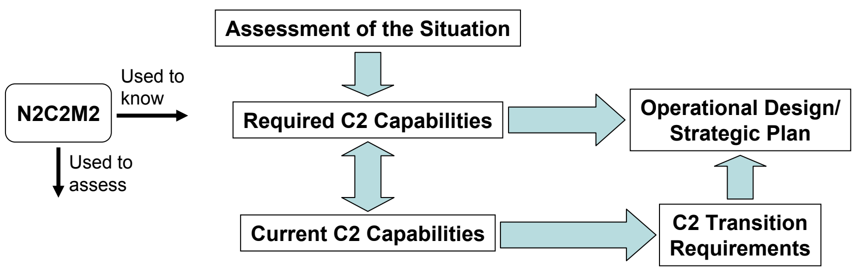


Figure 34: General Approach to Answer Questions Related to C2 Transition by Operational Design/Strategic Planning

The first step is to assess the situation or potential range of situations that are relevant. In particular, it is important to consider the complexity of those situation(s). As discussed earlier, complexity involves variables such as dynamics, non-linearity, interdependencies, lack of predictability, and scope.

Given the complexity anticipated, the N2C2M2 can provide insight into the issues related with the other three boxes in Figure 34. The N2C2M2 can support the process by providing an assessment tool to determine high level C2 capabilities, both in the current setting and the future required setting. In order to determine these high level variables, analysts need to measure (current) or establish desired values for (future) lower level parameters as well as the relation between the lower and higher level parameters. Figure 15, Figure 17, Figure 18, and Figure 19 can be used to structure an assessment of C2 approaches. By assessing where the organisation is or needs to be with respect to the columns in these figures, analysts can determine the current level of maturity and specify what is required to achieve desired future levels. It should be noted that the variables in these figures need to be assessed by more detailed variables, which can be extracted from the C2CRM.

## *The NATO Code of Best Practice for C2 Assessment*

When a C2 assessment study or maturity model application is conducted, the NATO Code of Best Practice for C2 Assessment (*COBP-C2A*) gives guidelines for how to approach this study and how to identify the relevant points of attention for the study. It helps to get a good problem formulation and to choose the right solution strategy. Since the questions in these illustrative applications deal with an assessment of the current and/or required C2 capabilities, the *COBP-C2A* gives good guidance to take into account for all required points of attention. This ensures that the problem will be well formulated, that one has a good data collection plan, pays attention to the tools that can support the assessment, and establishes appropriate measures of merit, etc. Figure 35 shows the general steps that are advised for a C2 assessment study. Note that the process is depicted as an iterative process which is one of the main recommendations from the *COBP-C2A*. Especially in a complex endeavour, where command and control is characterised by complex interdependencies, this is an absolute requirement.

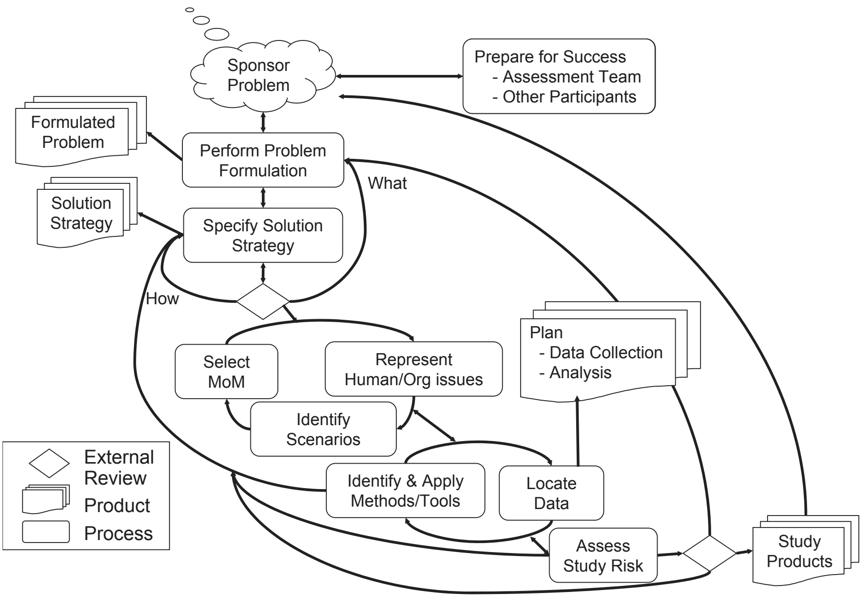


Figure 35: The C2 Assessment Process

The COBP-C2A can be applied to a broad range of studies, varying from acquisition programs to support of operations; however it does not attempt to specifically address the unique properties and constraints associated with each of the many C2-related problem domains.

## *The Command and Control Conceptual Reference Model*

The Command and Control Conceptual Reference Model (C2CRM), developed by NATO SAS-050 and updated by SAS-065, consists of a few hundred variables and a selected subset of the possible relationships between them. The variables are comprised of potential relevant measures of merit (MoM) and influencing factors and, by means of qualitative relations, show the influences between them. The lists of MoM and influencing factors can be considered as suggestions for issues to take into account for a particular study. Of course, not all variables are relevant for all studies; the analyst has to make selections. On the other hand, although the C2CRM consists of more than 300 variables, it could never be complete. Particular studies may involve specific variables that are not all part of the model.

Figure 36 illustrates how the C2CRM can be mapped to the variables in the higher level process and value views. In a similar way, the variables can be mapped to the variables in the N2C2M2.

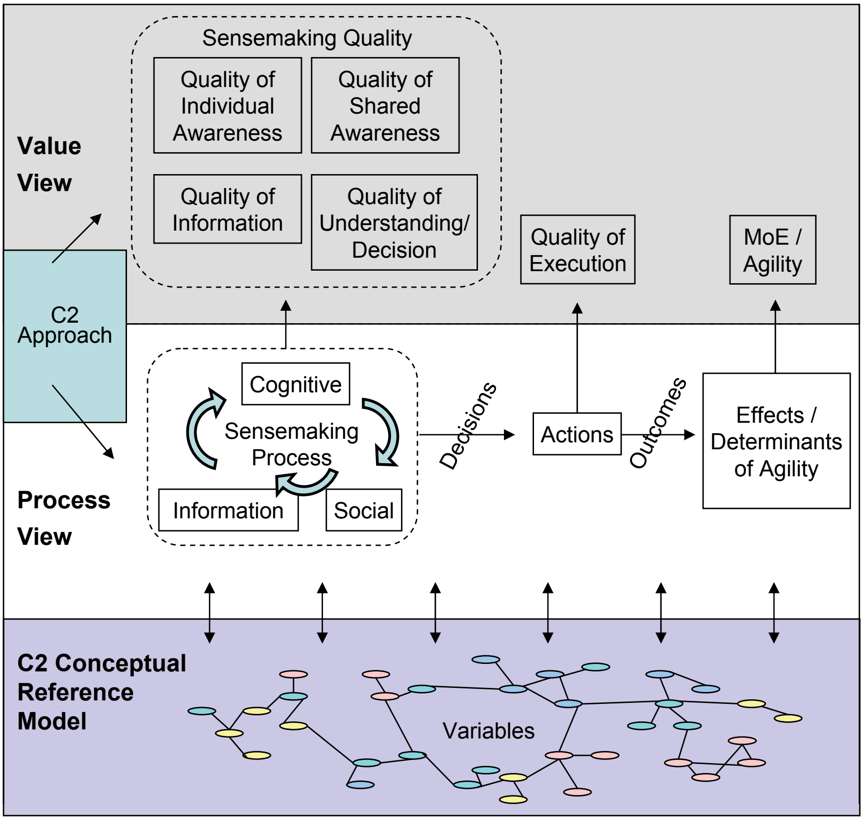


Figure 36: The C2 Conceptual Reference Model (C2CRM)

As described before, the N2C2M2 helps the user assess a particular C2 system and identify the transition requirements to move to higher maturity levels; in fact, it is an extension of the C2CRM. The N2C2M2 adds a number of variables related to C2 approach and C2 maturity. It also relates these additional variables to the variables already included in the C2CRM, which has been updated by SAS-065. Users of the maturity model can get a detailed specification of what is relevant for the current situation and for the transition to the appropriate C2 approach by consulting the C2CRM, when appropriate.

## ILLUSTRATIVE APPLICATION: OPERATIONAL DESIGN

Operational Design is the process of designing the force required for a particular mission. In order to do so, the analyst needs to understand the characteristics of the environment, the relevant actors as well as the relations between them and the mission, the intent and objectives, and the accompanying C2 approach and related capabilities needed to accomplish these objectives. Operational Design considers the anticipated scenarios as well as the available forces and their capabilities. Analysts must look at the C2 of the complex endeavour as a whole. Complex endeavours involve the entire collection of all actors, including the non-military actors (collective C2). Each entity can also look at its own C2 capabilities and requirements.

Relevant Operational Design assessment tasks include:

- Understanding how they currently approach C2 (or management/governance);
- Assessing the (complexity and dynamics of the) situation;
- Understanding what C2 approach is appropriate or inappropriate for a given situation;
- The required C2 maturity levels for the entire endeavour.

In military operations, these are typically the kind of questions that could be faced during the operational planning process. In the development of the different lines of operation that comprise the mission, one could analyse how different C2 approaches might best support the objectives set for those different lines of operations.

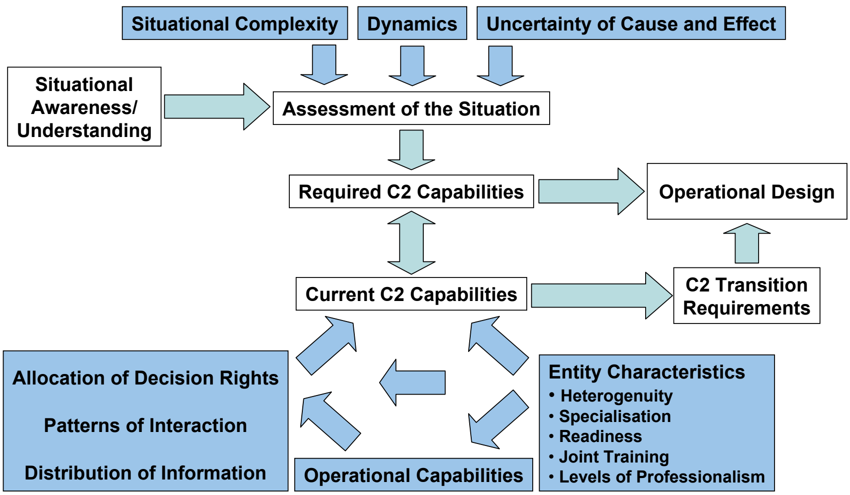


Figure 37: Operational Design and the Influence Factors

The complexity and dynamics of a situation are driven by a number of factors—originating in the mission and the units with their capabilities. Factors to be considered include:

- nature or objectives of the operation under consideration (combat, peacekeeping, stability, role of military, counter-terrorism, humanitarian assistance, disaster relief, etc.);

- number, nature, or diversity of different (friendly, neutral, or adversarial) actors including the relationships and interactions between them;
- stability or predictability of the environment;
- transparency of the situation;
- familiarity with the situation;
- infrastructure (availability, quality);
- clarity, unity of intent (purpose) and strategy;
- nature of effects space (PMESII).

These are obstacles that operational planners typically face. In the development of the different logical lines of operation that comprise the mission, analysts should examine how different C2 approaches can best support the objectives of those responsible for different lines of operations.

By looking at the relevant variables defined in the N2C2M2 as well as the possible C2 relationships between and among the entities participating in the endeavour, analysts can identify the most appropriate C2 approach for the current endeavour and anticipate requisite C2 maturity. As a matter of a fact, the generation of a coalition force supposes that different entities with various capabilities are to be used in the achievement of the mission goals. Those different capabilities offered by each entity, and the requirements of the missions, should lead to different C2 maturity levels used throughout the coalition. These levels may be different from one relationship to another, may vary in function of the mission type, and may evolve over time. It is thus inevitable that the maturity level will not be uniform, but will vary across different participants at any given moment.

During the operational planning cycle, the presence and the role of all active entities in the battlespace must be assessed. The relationship between those external entities and the coalition is also a part of the analysis work to be done. In some operations, such as humanitarian relief or stabilisation and reconstruction, a mutual understanding between the coalition and the external entities (e.g., NGOs, local police, etc.) is necessary for the effective and efficient accomplishment of the mission. That situation may lead to the exchange of information and some form of collaboration between the coalition and those external partners. In that process as well, the use of the N2C2M2 might be helpful in identifying what maturity level is best suited to achieve effective and efficient command and control in the context of the mission and the situation.

Although Operational Design aims at establishing the conditions for effective C2 capabilities, actual maturity is an emerging property that needs to and will adapt as the mission unfolds. The maturity model can play the same role, and the same questions are relevant during this phase. In addition, however, analysts also need to measure progress and ensure that the C2 capability is moving in the desired direction.

In general, the composite variables characterising C2 maturity in the N2C2M2 cannot be measured directly and need to be deduced from more detailed variables. The C2CRM can help point to the specific detailed variables that need to be measured and the data that needs to be collected. After the relevant data have been collected at this detailed level, the variables need to be mapped back to the variables in the N2C2M2. However, the redesign and the novel structures needed to move from one level of maturity to a higher one, as well as the uniqueness of units and missions, make quantitative measures difficult.

The section below uses two case studies to explore the challenges operational designers face today and the contributions of the N2C2M2 for operational design.

## *Elbe River Application*

The Elbe Rive Flood of 2002 is considered one of the worst natural disasters in Germany, particularly in the federal state of Saxony. Unusually heavy rain caused a flooding that started very rapidly in the steep mountains of the *Erzgebirge* and progressed then slower along the river Elbe. The pictures of Dresden and its flooding of the centre of the historic town and the destruction of parts of the city are still vivid in Germany's memory. The report of the *von Kirchbach Commission*[85] reviewed the events linked to the flood, reported the way the relief forces and public administration acted in response, and issued a number of recommendations to improve disaster preparedness.

- The Elbe Flood is a case study examining the collaboration of various relief forces in a natural disaster of an unexpected magnitude, but well within in the scope of typical disaster preparedness scenarios.
- The report concludes that lack of aid material was not one of the most important problems, though there were some shortages and the commission issued recommendations on what material should be acquired for future contingencies, and on its storage.
- In its analysis, the report emphasises the information sharing, communication, and collaboration approaches of the various public institutions and forces. It analyses the danger of long chains of command and slow

85. von Kirchbach: Bericht der Unabhängigen Kommission der Sächsischen Staatsregierung über die Flutkatastrophe, 2002.

processes of information, the danger of an infrastructure partly being damaged, and the difficulties of collaborating with unfamiliar partners. The commission recommends redesigning and tailoring the information flows of, for example, water levels and availability of relief forces as well as aid material. It stresses the ability of the forces to analyse the situation, the need for shared situation awareness, and the value of decentralised decision making, particularly emphasising the principle of subsidiarity—that the central authority should have a subsidiary function, performing only those tasks which cannot be performed effectively by those closer to the situation. The report and this case study stress the importance of an "adequate" design of the information flows, as well as the capabilities for analysis and planning.

- The report stresses the advantages of a joint headquarter of the various forces for situation awareness and coordination, the need for joint planning and, in particular, the need for joint training and joint structures. The commission describes the challenges of integrating units with various levels of professionalism (NGOs, unorganised volunteers, armed forces, fire fighters, technical aid relief workers) in one approach. The report highlights the value of an appropriate design of the C2 structures and the advantages of decentralised decision making. This is strongly in accordance with the N2C2M2 and the concept of requisite maturity.

The report, however, also illustrates the value of hindsight. Any operational planner or designer will normally come up with a better and more detailed plan than the preceding plan or design because of recent *real world* experience. Building structures, decomposition, and modularisation are natural instruments for assessing whether a particular force or endeavour is capable of a task; this tends to recognise the *requisite maturity* for dealing with a class of situations. The case study and the N2C2M2 detail the advantages of alternative C2 approaches and provide guidelines that an operational planner can use to design forces with more appropriate levels of capability. For cases such as the Elbe River flood, this proved to demonstrate the added value of efforts at collaboration and the advantages of a Collaborative C2 approach.

## *Tsunami Application*

The Tsunami of 2004 was one of the worst natural disasters in modern history. It had a devastating impact at the coastlines of a number of countries and brought with it a high count of casualties and left a lot of infrastructure destroyed. The Tsunami and its aftermath, as well as the disaster relief operation, received unprecedented worldwide media attention. The case study documents the numerous relief organisations participating, the various phases of disaster relief, and the major challenges experienced.

- The case of the Tsunami illustrates how numerous aid organisations and relief forces operated in Tsunami-damaged areas to respond to the devastation and its consequences. It was a major challenge to coordinate the relief forces, the incoming stream of material and personnel, and funnel the stream of materials and specialised personnel to the areas with the most urgent needs. Matching those relief capabilities to need on-the-ground was also a major challenge.

- The situation went through the typical phases of disaster relief, with saving lives first, then helping refugees, and finally reconstructing the infrastructure. No centralised, or even previously designed, C2 structure existed for the relief forces. The creation of one was never an option. Centralised planning could not be established, and much of the coordination was done ad hoc and on the spot. Many of the relief organisations were international and specialised for specific roles in disaster relief, which made communication and coordination a challenge.
- The case study captures cases of emerging structures and various levels of maturity of inter-entity coordination. Decision making, allocation of resources, and the information flows were slowly organised. Adequate structures had to be established as well. The case study emphasises the need to be able to establish effective ad hoc C2 systems and the need for agility.

The Tsunami case study illustrates maturity and requisite maturity of entities in an operation of a magnitude and severity for which no single entity has the capacity or training. The entities that join an endeavour (to provide relief and help) are highly specialised and trained to perform specific functions and tasks; though individual capabilities, maturity, and level of professionalism may vary. In theory, such a collection of specialised entities has the potential to deal with any mission—provided the inter-organisational collaboration works in an adequate way with the ability to adapt to needs and integrate new or unknown incoming units, and operate at an international level. This paramount issue is central to the maturity level assessment.

The challenges described in the case studies are, to some extent, typical and recent examples of current missions. These are increasingly characterised by complexity and strong dynamics. Therefore, they require the ability to operate at a higher level of C2 maturity.

Drivers of complexity are:

- Increasing specialisation of the entities as part of a endeavour;
- Increasing internationalisation of missions;
- Heterogeneity, in terms of technology, C2 approach, material, and levels of professionalism;
- Different languages, cultures, and divergent individual intents;
- Decreasing time and possibilities for joint planning and training up front;
- Missions or scenarios of which the entities have a limited, but not necessarily identical, comprehension of the situation;
- Traditional centralised, hierarchical C2 is not an option for various political, social, economic, or pragmatic reasons.

These situations require, and the general public demands, rapid and effective responses. This can only be accomplished by the integration of workflows, processes, and plans. This, in turn, means:

- Considerable information sharing and communication networks can be tailored to the actual scenarios;
- Collaboration;
- Capability for integrated workflows;

- Capability for joint planning;
- Decentralised decision making;
- Synergistic collective actions;
- Reflective capability to adapt the C2 approach and the inter-organisational collaboration approach to changing requirements and scenarios in a seamless way.

Note that much of the complexity of missions is inherent due to the composition of the force and the high pressure from outside (e.g., economic, media). The required maturity and the investments to reach this maturity need to be weighed against the benefits and feasibility of reaching a higher level of maturity. Also, when entities are heterogeneous, the likelihood that entities will operate at different maturity levels is an additional, yet inherent, challenge for the more mature, more professional entities in the collection or collective.

In addition, the requisite maturity of an endeavour might not be constant. Training and mission tailored capabilities allow a unit to use a more efficient, lower level of maturity in a situation; a less trained force may have to use a higher level of maturity with more coordination with partners. Also the requisite level of maturity may decrease (for example, down to De-Conflicted C2) once workflows and geographic or functional borderlines between organisations are established and proven to be effective, since less information sharing and coordination is being required. Also a high level of dynamics, as it is more likely to be in the first phases of a mission, requires a higher level of maturity; whereas later in a mission, when processes and comprehension of the situation have been established, a lower level of maturity eventually suffices.

Note, furthermore, that the requisite C2 maturity may change in the course of a mission.

- Assume a mission is progressing towards a more stable scenario. This will result in an increase in mutual understanding—defining routine processes for information sharing, and functional or geographic de-confliction. Consequently, less information sharing and less coordination may be required. C2 would become less mature which might be sufficient once the situation becomes more stable. In this case, requisite maturity might decrease.
- Assume a mission encounters unexpected dynamics and complexity. Entities that collaborate work out the information sharing infrastructure, processes, and culture and develop more capabilities to act and adapt to a highly-dynamic and complex environment. Here, more C2 maturity will be required.
- The capabilities of the entities for information sharing, processing, collaboration, as well as the design of information sharing and processing may change during a mission resulting in a higher maturity. A knowledge management process that allows entities to learn and reflect facilitates such an increase in capabilities.

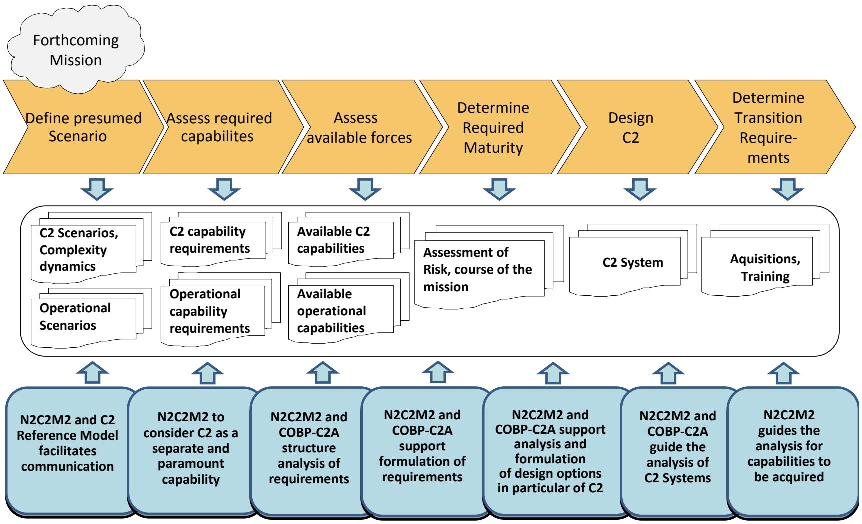


Figure 38: The N2C2M2 in Operational Design

The N2C2M2 serves as a framework by which communication between the parties involved in the design of a force for a forthcoming mission can be facilitated. It supports consideration of C2 as a separate and dominant capability in scenario planning. The N2C2M2 supports the assessment of required capabilities for C2 and the operational entities. Likewise, as a framework together with the COBP-C2A will support the assessment of the C2 and operational capabilities of the available forces. Finally, it supports the assessment of the required maturity for a given scenario and supports the design of the C2 system of a joint force for a forthcoming mission. It guides the analysis of transition requirements and the planning of capability acquisitions or training to be done up front.

## SUMMARY FOR OPERATIONAL DESIGN

The task required for operational planning in an emerging mission is somewhat different from that of a team seeking to assess C2 maturity after the fact. If, for example, a major earthquake were to occur in a developed country and NATO or a neighbouring nation were asked to plan a mission that spanned support to immediate disaster relief (rescue or saving lives) and recovery (assisting refugees, restoring basic services, etc.), the N2M2C2 application would call for the following activities:

- *Define the presumed scenario*. This means making a rapid estimate of the damage, the remaining capabilities of the host government, the number and types of casualties and refugees likely to have resulted from the earthquake, the likely lines of communication and staging areas for the relief effort, the weather, cultural sensitivities, and other factors that define the problem. This will be done in consultation with the host government and experts in disaster relief and recovery. The N2C2M2 will help the operational planners to identify the C2 aspects of the situation that are important, such as the remaining or damaged infostructure as well as the local organisations and their C2 processes, organisations, and systems.
- *Assess requisite capabilities*. Based on the presumed scenario and any new information (as it becomes available), the operational planners will need to assess what is needed to get the job done. This will include not only relief supplies and medical personnel, but also lift, security, specialised expertise (e.g., rescue dogs, listening devices), food, water, shelter, and other means to provide relief and transition from rescue to recovery.

Staging will also need to be considered—what should happen first and what assets can be used to gain timely information about the real needs, etc. In the C2 arena, this means assessing the requisite capabilities for information collection, information sharing, collaboration, and monitoring execution. The N2C2M2 suggests considering C2 as a capability that can be tailored to make effective use of material and personnel in the relief effort.

- *Assess available forces*. The term *forces* has the wrong connotation here. The task certainly includes identifying those military forces that might be involved in the rescue and recovery operations, their experience and level of training for this mission, and relevant communications capability including their capacity to work with civilian partners. However, it also means identifying all the relevant partners: interagency, host government, international organisations, NGOs, private industry, police, fire, medical, and local political authorities as well as the relevant media. In particular, this means to identify the relevant local partners and their networks as they might be able to provide the source of information about and access to the "last mile." From the perspective of C2 this also means assessing their experience, training, and communications capacity for working with one another—understanding the existing C2 maturity. This will require specification of the *natural* or existing networks by which these organisations can carry out C2 functions without additional capabilities.
- *Determine requisite maturity level*. Given the presumed scenario, required C2 capabilities, and available resources, the operational planner will then need to assess the C2 maturity needed. This will be impacted by the

magnitude of the disaster, the dynamics of the situation after the disaster, and its complexity. As previously discussed, when the scope of the problem is limited and the complexity and dynamics are low, a lower level of maturity (i.e., De-Conflicted C2) may be adequate. However, this is unlikely in the event of a major earthquake. Hence, at least Coordinated C2 will be needed. In this case, however, the operational designers recognise that the situation has very real dynamics: strong aftershocks are keeping people highly excited; there are deep cultural cleavages that show signs of boiling over; the lack of clean water threatens major disease outbreaks; and the weather (cold, wet) is making people miserable. At the same time, the complexity is seen as only moderate because the parts of the country not directly affected by the earthquake are still functioning. Hence, the judgment is that Collaborative C2 is the required approach, resulting in Level 4 maturity. The planners also note not all aspects of the endeavour need to be Collaborative, since the security operations require only de-confliction to ensure the military forces and police are not experiencing negative cross-impacts.

- *Design C2*. The task here is to first determine whether the collective can achieve the requisite level of maturity. This issue applies both to the overall collective and to significant subsets of it that may be organised by function. This is the crux of the operational planners' work. They will need to develop at least a notional structure for the endeavour that includes C2 arrangements and plans that not only define the relevant networks (social as well as technical) but also the arrangements for coordination and collaboration mechanisms. These plans will include the existing capabilities identified earlier when the available assets were assessed, but will also include specific additional capabilities needed to ensure the requisite maturity is available. This structure and plans may well differ over time, recognising the different actors that may be present over time and the different tasks that will be performed during phases of the operation. This design should be shared with both experts who understand the mission and with representatives of the participating organisations. This sharing acts as *peer review* for the designers understanding of the structures and capabilities involved in the operation.

- *Determine transition requirements*. This effort itemises what must be done to transform the original C2 capabilities of those participating in the endeavour to achieve the requisite level of maturity. To the extent that this means changing from one level of maturity to another the N2C2M2 transition requirements will provide directly useful guidance. For example, organisations that need to collaborate will require a collaboration mechanism, which might range from getting together around a table in an agreed location to establishing video teleconferencing sites covering those involved. Where more subtle shifts are needed the N2C2M2 description of the required capabilities (e.g., allocation of decision rights to the collective) will be helpful. To take another simple example, the issue of whether patterns of interaction are continuous or nearly continuous is a determining factor for Collaborative C2.

## ILLUSTRATIVE APPLICATION: STRATEGIC PLANNING

A definition of Strategic Planning or long term planning is given by NATO SAS-026: "a process that investigates possible future operating environments and develops a strategic development plan (SDP) to best adapt the defence organisation to those environments given a host of constraints—including financial ones."

Strategic Planning tasks that can be supported by the N2C2M2 model include:

- Developing a strategic C2 vision;
- Understanding what C2 approach and levels of C2 maturity are appropriate or inappropriate for a given set of potential scenarios;
- Developing an associated investment plan and roadmap to develop a capability to conduct network-enabled operations;
- Creating educational and training materials to increase C2 related awareness and competence.

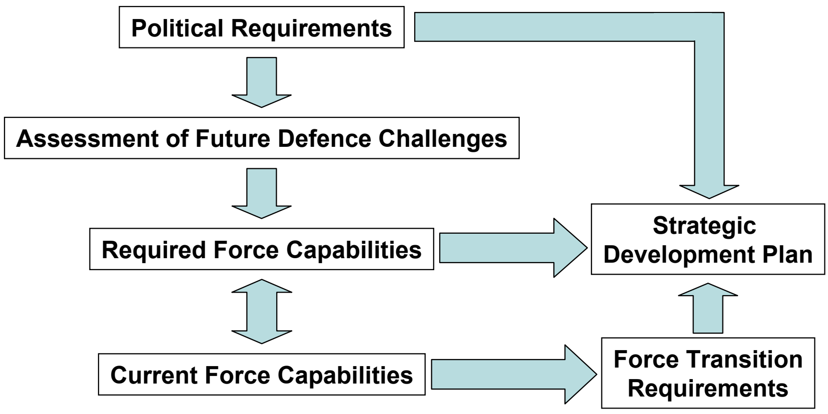


Figure 39: General Approach to Strategic Defence Planning

In very general terms Strategic Planning can be described as in Figure 39. The starting point is the political guidance on the defence ambition of the nation or defence organisation (e.g., NATO). This ambition will normally be made more concrete through the definition of a representative set of planning scenarios. From analysis of these planning scenarios, military capability requirements are deduced. Examples of such requirements can be: surveillance of the sea surface in a particular area over a given time period, air defence, and providing security of a land area. In strategic planning the assessment of *current force capabilities* will have to include force structure elements that potentially may be acquired during the planning period. The process of selecting the most cost-effective force structure elements that satisfy the required force capabilities is a major analysis task. From this analysis, force transition requirements are produced in terms of a SDP. The N2C2M2 will support development of the C2 needed to enable these transition requirements. These transitions, in turn, will make this force effective and efficient, including appropriate linkages to non-defence actors.

Communication between politicians, military, and analysts is a challenge in general throughout this process. The use of the N2C2M2 can help to facilitate the communication on C2-related issues between these parties by focusing attention systematically on key issues and providing a common mental model.

Use of the N2C2M2 can make it possible to work with C2 as a separate capability throughout the planning process. Starting with the planning scenarios, from an assessment of the complexity of the endeavour in each scenario, the N2C2M2 provides a means to identify the C2 maturity level necessary for the endeavour to succeed. This may be accomplished by assessing the *fit* of one's own organisation to the kinds of missions envisioned, and the *fit* of the collection of the organisations constituting the endeavour, including other forces and civilian entities. From these assessments the N2C2M2 may be used to formulate required C2 capabilities.

A process in principle similar to the operational design case should give the C2 transition requirements. In this process the N2C2M2 can be used to aid in the assessment of the C2 capability of specific force structures, formulate a C2 vision, and develop a road map for the transition to the desired C2 capability, with milestones.

Although the process is methodologically similar to operational design, the strategic planning will normally be more difficult to accomplish, since it involves several less-specific scenarios (missions) and a larger pool of less well-specified force component options from which to choose. This is, however, a general complication of strategic planning and is not unique to the C2 part of the problem. As the COBP-C2A makes clear, the critical issue is whether the defence analysts sample the interesting and important part of the mission space.

### *Summary for Strategic Defence Planning*[86]

In summary, the N2C2M2 can support all the main steps in defence planning (see Figure 40).

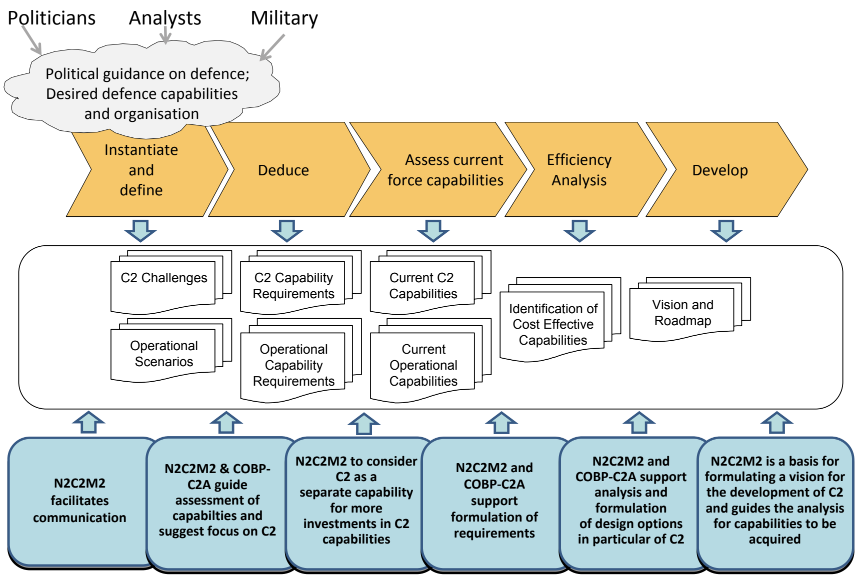


Figure 40: The N2C2M2 and Its Contributions in Strategic Defence Planning

The N2C2M2 facilitates communication between the various stakeholders (politicians, analysts, and military) in the process of developing a political objective for defence planning. The

86. Explicit examples of the use of the N2C2M2 in strategic planning would require a classified discussion. Hence, they were not considered by SAS-065 and are not included here.

assessment of current and required capabilities is supported by the N2C2M2. The model suggests that C2 considerations are paramount and that C2-related capabilities must be considered in investment planning and the acquisition of future capabilities. In the efficiency analysis, the model supports the formulation and analysis of design options and the design of a vision and a roadmap.

## ILLUSTRATIVE APPLICATION: C2 RESEARCH AND EXPERIMENTATION

The third case and final application arena considered includes C2 Research and Development (R&D). Perhaps the area where the value of the model can be realised most immediately across a wide variety of potential situations is the area of research and experimentation. This area has great potential in connecting people from different nations and organisations in understanding pathways toward common goals. In general, the N2C2M2 can be used to help formulate appropriate campaigns of research and experimentation designed to improve our common understanding of command and control. Research and experimentation focused on the activities associated with command and control are important enablers of transformation, allowing for the exploration of new concepts and approaches to C2 in rigorous ways, and permitting systematic and effective investigation of the range of mechanisms that may or may not lead to effectiveness and agility. The N2C2M2 can play an important role in adding value to research and experimentation activities through the description and use of a framework by which to view levels of C2 maturity and the capabilities needed to attain appropriate maturity in operations of varying types. This illustrative application is intended to describe how the N2C2M2 can be used in C2 research and experimentation, and to discuss an example in which the N2C2M2 was used to frame experiments conducted with the ELICIT (**E**xperimental **L**aboratory for **I**nvestigating **C**ollaboration, **I**nformation-Sharing and **T**rust) experimentation platform.[87]

The *Code of Best Practice for Experimentation*[88] *(COBP-E)* discusses experimentation and the role experimentation plays in the processes by which new ideas go from theory to practice. Further, it provides guidance on how effective experimentation campaigns can be conducted. For readers who are considering using the N2C2M2 to inform their own experiments, but who may not be familiar with experimentation processes and activities, the *COBP-E* would be a valuable resource. The guidelines provided by the *COBP-E* will serve as a structure for this application.

## *Uses of the NATO NEC C2 Maturity Model in C2 Research and Experimentation*

The *COBP-E* discusses seven stages of experimentation, shown in Figure 41, *Phases of Experiments*.[89] The NATO NEC C2 Maturity Model (N2C2M2) has its primary application during the planning phases of research and experimentation. It is during these phases that the research questions to be investigated are identified and formulated, and the approaches for eliciting answers to these questions are determined.

87. ELICIT is described in the *ELICIT Overview and Report*: www.dodccrp.org/html4/elicit.html.
88. Alberts, David S., Richard E. Hayes, John Kirzl, Daniel Maxwell, and Dennis K. Leedom, *Code of Best Practice for Experimentation*, (COBP-E) Washington, DC: CCRP Publication Series, 2002.
89. *COBP-E*, Figure 5-1. Phases of Experiments, pg. 62.

The Pre-Experiment phase includes formulation of the experiment to be conducted, the development of a conceptual model for the experiment, and generation of the initial and detailed experimental plans. Researchers review what is known about the subject of study—preferably including a review of the relevant scientific literature, operational knowledge, and insights associated with the study—to ensure a thorough understanding of the issues to be explored and the context for exploration. From this review, explicit descriptions of the propositions, hypotheses, or relationships to be addressed, and the assumptions that will be made should emerge. Furthermore, study leaders will define the independent and dependent variables for the experiment, as well as key intervening variables to be monitored, the constraints on the value of these variables (for the purpose of the experiment), and the experiment control variables—the subset of the independent variables that will be controlled to enable exploration of the effects of the independent variables of interest.

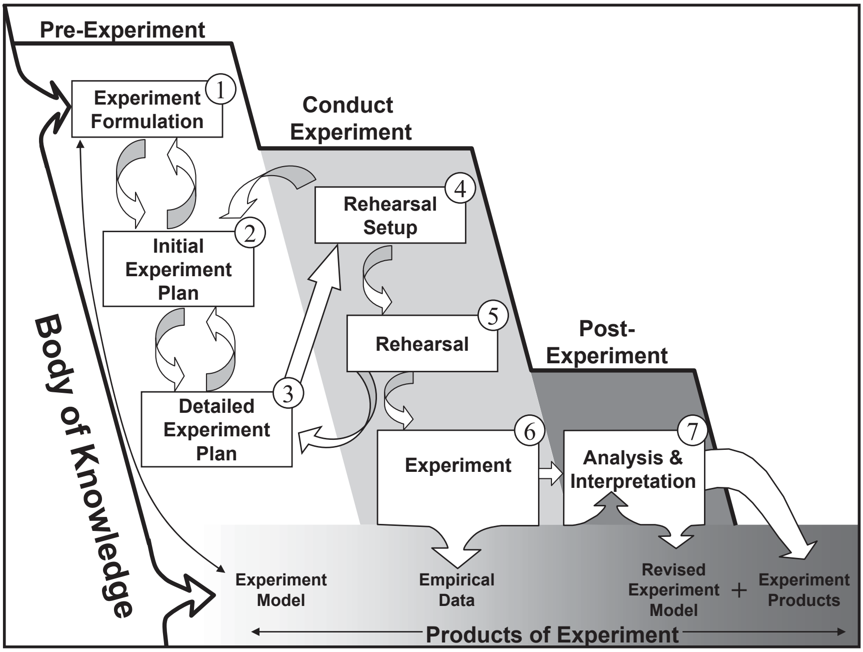


Figure 41: Phases of Experiments [Source: Alberts et al., 2002]

Once this foundational knowledge and delineation of the variables to be a part of the experiment are identified, the COBP-E suggests they be brought together to express a conceptual model for the experiment. This model will illustrate the key concepts and relationships as the subject of the experiment, and provide a framework from which data collection and analysis plans can be structured and developed. With this conceptual model in place the initial plans for the experiment can be developed, then iterated and refined in conjunction with the identified stakeholder community, into detailed preparations for conducting the experiment. This should be done in collaboration with the stakeholder community.

The N2C2M2 can greatly facilitate these processes for experiments related to command and control topics. In particular, the N2C2M2 articulates a clear and wide-ranging vision for a campaign of research and experimentation aimed at improving our ability to achieve mission success and be effective participants in endeavours with higher levels of C2 maturity and a wider range of partners, as will be needed in future operations.

The N2C2M2 can also help researchers identify particular hypotheses associated with the tenets and value chains defined in the N2C2M2, suggesting relationships that need to be explored in focused studies and experiments. The N2C2M2 can facilitate formulating hypotheses to be tested in different contexts, and can be considered a framework to help define C2-related ideas that would benefit from structured testing. Spanning the C2 Approach Space, the N2C2M2 is an important source for questions related to how more effective and more agile C2 can be enabled and the kinds of behaviours and capabilities associated with different levels of C2 maturity. The N2C2M2 framework allows such hypotheses to easily be stated in terms of whether or not changes in independent variables will lead to different levels of C2 maturity and, in conjunction with the C2CRM, suggests observables (metrics, dependent variables) that can be associated with different levels of C2 maturity. More broadly, the N2C2M2 provides a measurement framework for the evaluation of the value of new ideas, systems, and concepts using the common currency of C2 maturity.

In addition to defining dependent and independent variables for exploration, the N2C2M2 suggests relevant *intervening* variables that may influence the relationships between the identified independent variables and dependent variables. It is also helpful in articulating assumptions associated with related C2 experimentation: since the N2C2M2 is a holistic framework, it can guide the definition of the experimentation space and help ensure completeness in its treatment; that is, the full range of relevant factors are parsed into independent variables, dependent variables, and assumptions. Such an ability to think about the broader C2 context helps to ensure the design of experiments exploring particular issues are valid and reliable, in terms of variable selection and treatment. In fact, it is helpful and generally desirable to frame the conceptual model for the experiment in terms of the N2C2M2.

Once the detailed experimental plan is formulated, which includes the data and analysis strategies, the variables need to be operationalised. The N2C2M2 provides criteria for recognising and assessing C2 maturity that can generate insights into the kind and quantity of data that needs to be collected in the experiment, as well as the analyses that must be performed in order to achieve the objectives of the experiment. In addition, the N2C2M2 validation case studies and experiments provide insight into how various N2C2M2 related attributes are recognised and measured in real world settings.

At this point, the intent is not to summarise or repeat the *COBP-E*, but rather to suggest ways in which the N2C2M2 adds value to experimentation efforts that utilise such structured and thoughtful processes. For additional information about experimentation planning and execution, please refer to the *COBP-E*; particularly the material on measurement and metrics (Chapter 7) and data analysis and collection (Chapter 9).

## *Experimentation with NNEC C2 Maturity Model Using ELICIT*

The N2C2M2 was recently employed as the basis for an experiment utilising the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-Sharing, and Trust) experimentation platform. The N2C2M2 played a multifaceted role in the planning of this experimental activity, as the experiment was aimed both at illustrating experimental treatments enabled by the N2C2M2 and validating one of the underlying hypotheses of the N2C2M2, namely that higher levels of C2 maturity lead to greater levels of C2 effectiveness. This section describes the ELICIT experimentation platform, ELICIT-related experiments, and how it was employed to test the N2C2M2 hypothesis described above.

### *ELICIT Background*

ELICIT is an experimentation platform that instruments the actions of a group of participants engaged in a situational awareness problem and enables researchers to study important information sharing and collaborative behaviours. In the ELICIT experiment, participants attempt to identify attributes of an upcoming terrorist attack; in particular, to determine who will conduct the attack, the target of the attack, the country in which the attack will take place, and the time of the attack. Information elements, or *factoids* containing information related to the attack (e.g., "the Grey terrorist group attacks only at night"), are distributed at various times to each participant. Since no participant receives all of the factoids needed to solve the problem from these distributions, the sharing of factoids among the participants is required for success. Thus, ELICIT is a good means by which to study the behaviours associated with this kind of information sharing activity.

The goal of each set of participants is to build situational awareness and identify the *who*, *what*, *where,* and *when* of a pending attack. To accomplish this, participants can share factoids directly with one another. In addition, four community information assets (labelled *websites*) are available to which participants with access can post factoids, and from which others can access the factoids that have been posted to that site. Depending on the experimental configuration, participants can have access to all four websites, only a subset of websites, or no websites. The receiving, sharing, and posting of factoids, as well as the nature of the organisational relationships between and among participants can be constrained intentionally to create various experimental conditions (treatments). However, while it is possible to limit allowed peer-to-peer communications to a subset of those possible, all participants could communicate will all other participants in the trials explored in this application. Readers should note that the only communication possible among participants and between participants and websites in ELICIT is the sharing of a factoid. Free text (or other verbal or written) interaction is not allowed.

ELICIT experimental data includes information regarding the organisational configuration under which the participants operated, and may also include selected information about the participants themselves, as may be relevant to the nature of the experimental questions to which ELICIT is being applied in a particular trial. In past experiments this information included attributes such as nationality, whether the participants were civilians or military personnel, graduate or undergraduate students, and the military leadership scores of U.S. Military Academy subjects.

ELICIT also provides a powerful means for examining the details of a particular trial. Throughout the run, the ELICIT software records every transaction of each participant, including the nature of the transaction, its initiator, the object of the transaction, and the content of the transaction, if applicable. Thus, analysts of ELICIT trials will have access to all factoid distributions, all peer-to-peer sharing events, all web posts, all pulls from websites, and all identification attempts. The resulting data can be explored in practically countless ways, and can yield insight into numerous aspects of information-sharing behaviour.

A typical ELICIT experiment involves 17 participants. In the initial set of trials, from which the data for this use case were extracted, participants were placed into one of two organisational forms, (1) a hierarchical organisation, or (2) an edge organisation. In the hierarchy, sixteen of the participants were assigned to one of four teams with four members each. Each of the four teams in a trial corresponded to one of the *who*, *what*, *where*, *when* areas of the ELICIT problem. The members of each team had access to one website dedicated for their team's use; they could not access the websites of the other teams, and the other teams could not access their website. One member from each team was designated as the team leader. In addition to these 4 teams and their members, one of the participants was assigned the role of *cross-team coordinator*. This participant had access to all four websites, and thus could look across the activity of all four teams. In contrast, the edge organisation had no predefined structure whatsoever. Participants were not assigned to teams or roles, and every participant had access to all four websites. Figure 42, illustrates pure hierarchy and pure edge structures in ELICIT.

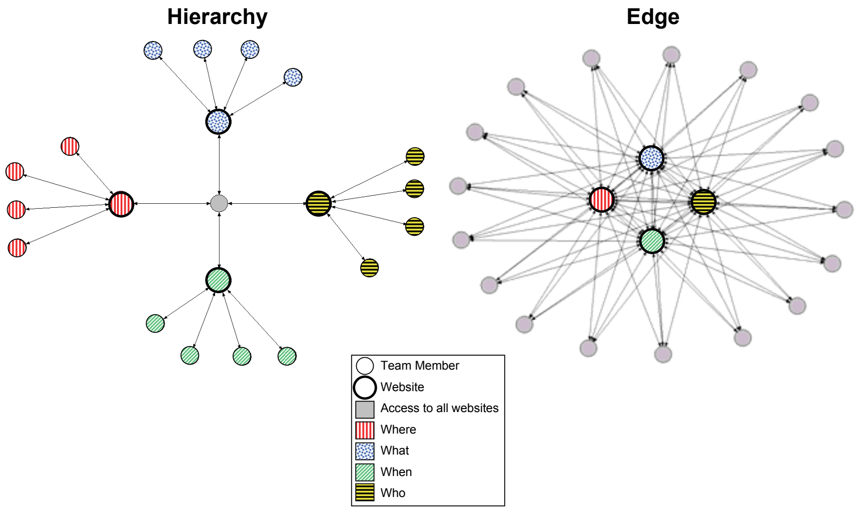


Figure 42: ELICIT Website Access by Organisation Type

The hypotheses explored in this application are derived from these organisational arrangements. Drawing upon the descriptions of C2 maturity levels in the N2C2M2, it was determined that the hierarchical organisations, as instantiated in ELICIT experiments, correspond to De-Conflicted C2. Further, while edge organisations as observed in ELICIT cannot be unambiguously assigned to one or another maturity level of the N2C2M2, it was hypothesised that they correspond to the range of maturity levels that are more mature than De-Conflicted C2 (that is, edge organisations in ELICIT exhibit either Coordinated or Collaborative C2 maturity). This judgment is based on the wider allocation of decision rights in the edge organisation (all participants have equal standing in terms of making identification attempts), and more extensive opportunities for interaction (participants can access all four websites rather than just one). Rather than being left as assertions, these assignments can be verified through the analysis of experimentation data within the context of the N2C2M2; which contains descriptions of the behaviours expected to be associated with each C2 maturity level, in terms of the allocation of decision rights, patterns of interaction, and distribution of information observed.

The core hypotheses to be tested in this experiment explored whether or not organisations operating at higher levels of C2 maturity exhibited higher levels of effectiveness, efficiency, and agility than their less mature counterparts. In the language of this particular experimental set, null hypotheses can be stated as follows:

- H0: Edge organisations exhibit the same levels of effectiveness as Hierarchical organisations in the ELICIT experiment;
- H0: Edge organisations will display the same efficiency as Hierarchical organisations in the ELICIT experiment;
- H0: Edge organisations will display the same effectiveness degradation as Hierarchical organisations in the ELICIT experiment when confronted with more difficult problem sets.

### *Experimental Dataset Used in this Study*

While this application describes a hypothesis-testing experiment employing (and testing) the N2C2M2, the ELICIT trials that provided data came from other experiments conducted by other researchers throughout the international C2 research community. The trials utilised in these analyses include data from experiments conducted at Boston University and the Naval Postgraduate School. Data from 26 trials were studied, with 13 hierarchy trials and 13 edge trials. A total of 442 experimental subjects were involved.

### *The Experimental Conceptual Model and Independent Variables*

Figure 43 illustrates the Conceptual Model developed for the ELICIT-based N2C2M2 hypothesis-testing experiment. The level of C2 maturity of the collective participants, combined with their individual and team characteristics, resulted in the information sharing and collaborative behaviours observed during the trial. These behaviours were also affected by the difficulty of the task (more difficult tasks perhaps requiring more collaboration) and were enabled and constrained by the technical network (instantiated in the ELICIT platform) connecting the participants. The results of these behaviours could then be observed by examination of the various measures of merit. In this experiment, the focus was on measures of merit associated with the quality of information, the quality of shared information, the quality of awareness, and the quality of shared awareness.

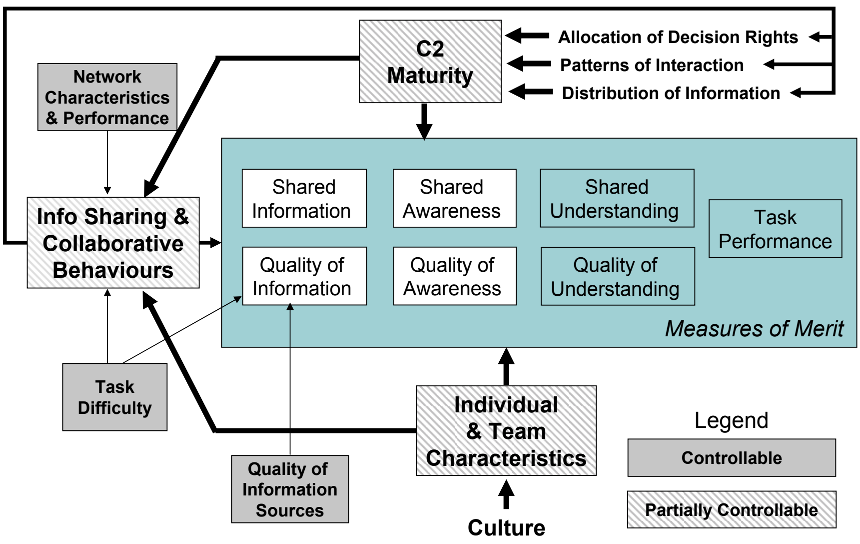


Figure 43: Conceptual Model for ELICIT Based N2C2M2 Hypothesis Testing Experiment

There were a number of other independent variables that were not the focus of the experiment, that nonetheless need to be included in the analyses. Not all of these variables were controlled in the experimental dataset in this study; some are not even controllable in principle. While the connectivity between participants and the group tasks are fully definable as part of the experiment, and some selection of participants can be made to sample from the groups of interest, there are many individual and team/cultural factors that affect how individuals share information, and how they will use that information to solve the ELICIT problem. Because of this, the experiment included a relatively large number of trials, with varied participant backgrounds to help distinguish effects associated with C2 maturity from effects associated with other factors. Additionally, it should be noted that while trials were set up to enable particular C2 approaches (*edge* and *traditional hierarchy* in these trials), through the availability of connectivity and information assets it is the sharing and collaboration *behaviours* that determine the C2 approach and C2 maturity actually exhibited by the trial. Thus, there is actually an influence, not shown in the figure above, from *Information Sharing and Collaborative Behaviours* to *C2 Maturity*.

## *Intervening Variables Illuminating Participant Behaviour*

The N2C2M2 also helped experimenters identify relevant intervening variables associated with information sharing and collaborative behaviours, which in turn help to inform classification of edge and hierarchy trials to C2 maturity levels. Identified intervening variables associated with observed patterns of interaction were drawn from social network analysis metrics, and included such factors as characteristic path length (the length of the path, in terms of "hops," in this case between a pair of participants, averaging overall possible pairs of participants) and connectedness, a measure that captures the tightness of the observed network. Distribution of information was captured in an intervening variable that describes the average number of unique facts to which each participant has access to during various points in the trial. Allocation of decision rights was directly set in the organisational arrangement of each trial. Each of the team leaders was authorised to make identification attempts for his or her own area (the cross-team coordinator was authorised to make identification attempts in all areas). Other guesses, while made and recorded, may be considered unauthorised, and measures of effectiveness can be made relative to authorised identification attempts only to capture this difference in allocation of decision rights between the two classes of trials. [In the edge trials, of course, all participants were authorised to make identification attempts in all areas.]

Other intervening behavioural variables were identified to characterise the sharing behaviours enabling task success. Data from the ELICIT transaction logs were used to determine the levels of peer-to-peer sharing and website posting observed in each trial, measured by the number of sharing and posting actions for participants. In addition, the number of website pulls by participants was also measured. These data allowed comparison of the levels of sharing in De-Conflicted C2 arrangements (the hierarchy trials) and in Coordinated and Collaborative C2 arrangements (the edge trials). Results showed that higher levels of C2 maturity were, indeed, associated with significantly higher levels of sharing.

### *Dependent Variables*

In order to test the major hypotheses of this experiment, it was necessary to identify a set of dependent variables that appropriately represented the concepts of effectiveness and efficiency under study. The objective of the ELICIT experiment is the development of sufficient awareness to allow the experiment participants to identify correctly the components of the ELICIT scenario solution. Dependent variables suggested by the C2CRM that correspond to this objective include the correctness, timeliness, and accuracy elements of the *quality of shared awareness* set of metrics. Correctness was measured by the number of participants authorised to make identification attempts who made at least one correct attempt (expressed relative to the total number of identification-authorised participants, to enable comparison of edge and hierarchical trial results). Timeliness of awareness was measured by calculating the total number of *person-minutes of correctness* in the trial, as follows:

$$Correctness = \sum_i \left( \int_{trial\_time} Level\_of\_correctness_i(t)dt \right)$$

The subscript *i* designates individual participants in a trial, and time, *t*, is expressed in minutes. Accuracy was measured as the ratio of correct identification attempts to total identification attempts.

An organisation's efficiency was measured by calculating its productivity in two respects—use of time and use of allowed actions (sharing, posting, pulling).

To measure the agility of an organisation operating at a given level of maturity, this analysis took advantage of the fact that more than one factoid set was used across the experimental trials conducted. While the initial intent in constructing these factoid sets was that they be isomorphic in terms of the cognitive performance required for solutions, one of the factoid sets has been empirically shown to be more challenging than the others. In measuring agility, the effectiveness of each organisational type, using the standard-difficulty factoid set, was compared with the effectiveness of each type when confronted with the more challenging factoid set. Testing the agility hypothesis involved comparing the degradation in performance caused by the difficult factoid set in the Edge and Hierarchical structures. [Note this approach used the data available to test one aspect of agility that was accessible through those data—the robustness of the C2 approach against problem sets of varying difficulty. A more complete analysis of the agility of Edge and Hierarchical structures would require treatments yielding insight to all aspects of agility—robustness, resilience, responsiveness, flexibility, innovation, and adaptation.[90]]

## *Measures of C2 Effectiveness*

In addition to the overarching measures of C2 effectiveness described above, a number of additional metrics, specifically related to command and control effectiveness, were also extracted and studied. These included the *Quality of Information Position* (the percentage of relevant facts for the assigned task a participant can access as a function of time) and the *Extent of Shared Information* (the average number of participants who have access to each fact as a function of time).

## *Summary of Findings*

Analysis of the behaviour of participants in the Edge and Hierarchical structures supported the assignments of those structures to Coordinated/Collaborative and De-Conflicted levels of C2 maturity, respectively. Edge structures indeed exhibited more mature behaviours than hierarchical ones, in terms of more extensive distribution of information, better quality of information position, a greater extent of shared awareness, and higher levels of information seeking behaviours (in terms of web pulls). Figure 44 shows a plot of a selected distribution of information metric (measured by the average fraction

90. McEver, Jimmie, Danielle M. Martin, and Richard E. Hayes, "Operationalizing C2 Agility: Approaches to Measuring Agility and Command and Control Contexts," Proceedings of the 13th International Command and Control Research and Technology Symposium, CCRP, 2008.

of unique facts to which trial participants have access to over time) illustrating the more widespread information distribution in edge trials in comparison with hierarchy trials.

While it may not be a surprising result that the addition of information sharing capability and more extensive access to information-sharing resources (i.e., the websites) leads to broader distribution of information in the edge trials, such a result will not occur unless the participants in those trials exhibit the behaviour needed to exploit those capabilities. That is, they must interact more broadly and more regularly, leading to more extensive propagation of information. Combined with the more extensive allocation of decision rights in the edge trials, this result verifies our association of edge structures in ELICIT with higher levels of C2 maturity than hierarchical structures.

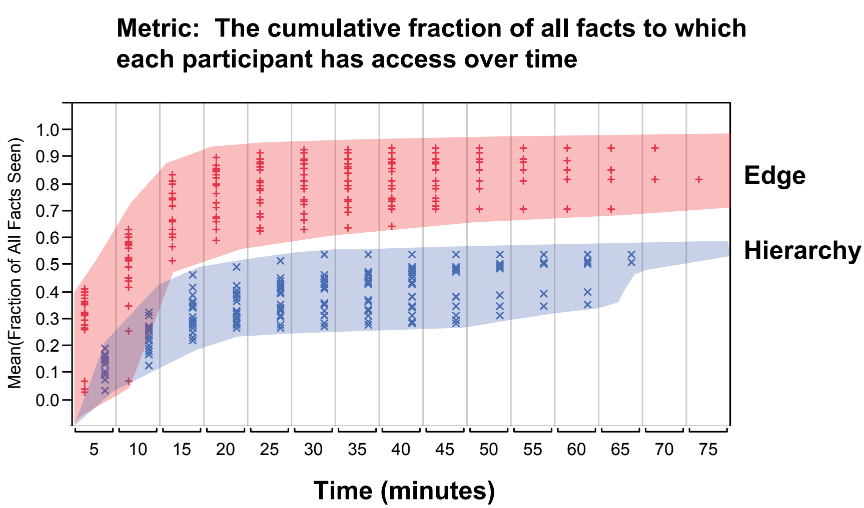


Figure 44: The Cumulative Fraction of all Facts to Which Each Participant has Access to Over Time[91]

91. Figure generated by JMP Statistical Analysis and Visualization Software (Version 7), SAS Institute.

Additional analysis of the ELICIT dataset confirmed that, within the context of the ELICIT environment, higher levels of C2 maturity are associated with higher levels of effectiveness, better efficiency, and more agility. Edge structures, representing Coordinated and Collaborative levels of C2 maturity, were shown to be more effective on the ELICIT problem than hierarchical (De-Conflicted) structures, exhibiting statistically significantly greater levels of correctness, timeliness and accuracy of awareness, and shared awareness. The left portion of Figure 45 shows one measure of effectiveness, the fraction of authorised participants correctly identifying the ELICIT solution. Across the Edge trials, 59% of the participants authorised to make ID attempts (for Edge, this is *all* participants for *all* problem components—*who*, *what*, *where*, and *when*) provided correct solutions. In the Hierarchical trials, only 14% of the authorised participants (the cross team coordinator was authorised for all areas and team leaders were each authorised for the area assigned to their team) provided correct solutions.

Edge structures proved to be generally more efficient than Hierarchical structures in terms of productivity of actions (at the 90 percent level, or 95 percent level in a one-tailed statistical test), productivity of time, and speed (again at the 90 percent/95 percent one-tailed level). The right half of Figure 45 shows one effectiveness measure, the mean productivity of person-minutes in the trial. Edge structures generated almost

6.5 correct solutions for each thousand person-minutes, while Hierarchical structures produced fewer than 2.5 correct solutions with the same level of effort.

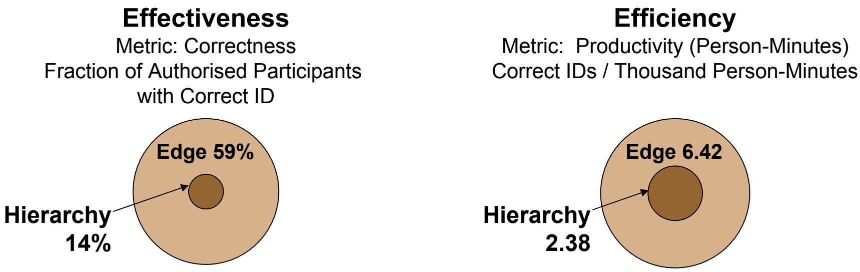


Figure 45: Selected Effectiveness and Efficiency Measures from Edge and Hierarchical ELICIT Trials. Differences are statistically significant at 95% level.

Edge structures were also shown to be more effective in the face of added problem difficulty than their less mature counterparts, degrading in performance less severely when the cognitive complexity of the ELICIT factoid set was increased. Figure 46 illustrates this robustness in terms of the fraction of person-minutes correct[92] resulting from each trial. In Edge structures, the person-minutes correct score for the standard-difficulty factoid set was 15.6%. When using the difficult factoid set, however, this effectiveness score drops to a little more than 1/3 of the original—5.7%. The Hierarchical structures analysed fared even worse, however. The Hierarchical stand-

92. Recall that this score varies from 0 to 1. A score of 0 (zero) indicates no correct solutions, not even partially correct solutions, were generated during the trial. A score of 1 indicates that everyone has the full correct solution from the very start of the trial. A score of 0.25 could mean that no one had any correct solution for ¾ of the trial, at which point everyone generated a fully correct solution … or that no one had any correct solution for ½ the trial, at which point everyone generated a solution for which two areas were correct and two areas were incorrect. There are many associated combinations.

ard-difficulty person-minutes correct score was 4.3%, which fell by an order of magnitude to 0.43% when confronted with the more difficult factoid set. While these results are not statistically significant, they are extremely interesting anecdotally, suggesting further investigation on this point is warranted.

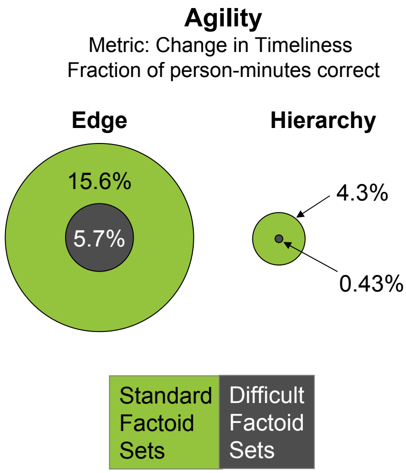


Figure 46: Agility Results for Edge and Hierarchical Trials. Edge performance is degraded less than Hierarchical performance when difficulty of factoid set is increased.

In summary, the data collected and analysed from these experimental trials are consistent with the NATO NEC C2 Maturity Model (N2C2M2) assumptions and hypotheses. Further, the N2C2M2 provided a valuable framework and useful guidance to help structure the experiment and related analysis, and was a rich source of metrics in the planning and execution of the analysis.

# SUMMARY FOR C2 RESEARCH AND EXPERIMENTATION

The contributions of the N2C2M2 to research and experimentation, as shown in Figure 47, are manifold and cover the main steps of an experimentation or research process.[93]

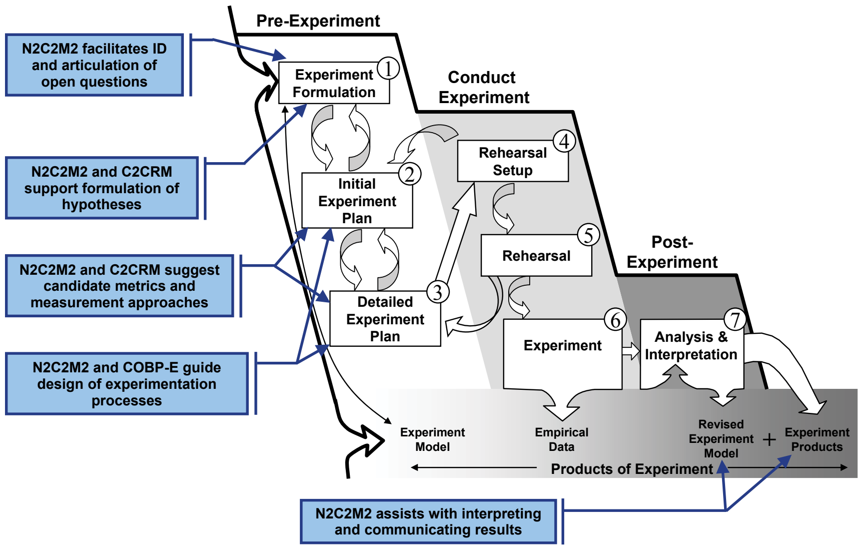


Figure 47: The N2C2M2 for C2 Research and Experimentation

The N2C2M2 is helpful in identification and articulation of open questions that need to be addressed in research and experimentation. The N2C2M2 together with the C2 Conceptual Reference Model (C2CRM) support the formulation of hypotheses, adequate metrics, and measurement approaches. In the development of an experiment design and plan, the N2C2M2 together with Code of Best Practice for Experimentation

93. The *COBP-E* discusses seven stages (*main steps*) of experimentation.

(COBP-E) supports the design of experiments. The N2C2M2 as a reference model supports interpretation of experiment results, relating experiments and research results to the state of the art and the communication to researchers and practitioners.

## CONCLUSIONS ABOUT ILLUSTRATIVE APPLICATIONS

While the N2C2M2 has many potential uses and types of applications, they can all be conceptualised through the lenses of the three classes included here—*Operational Design*, *Strategic Planning*, and *C2 Research and Experimentation*. Those looking into the future and seeking to understand how their C2 capabilities can become more network-centric can use the N2C2M2 to understand where their current capabilities rank, how they differ from the desired maturity level(s), and what factors will need to be changed in order to move in the desired direction. Applied with care, the N2C2M2 will allow those nations, coalitions, and endeavours that want to improve their strategic C2 posture to specify more than just goals—a roadmap and appropriate milestones along the way. However, as the illustrative applications demonstrate, the type of transformational change required for Network Enabled Capability transformation will involve co-evolution of all the components: allocation of decision rights to the collective, enabling patterns of interaction between and among the components of the endeavour or force, and distribution of information across those entities. Moreover, explicit consideration must be made of the partners who might contribute to the goals of the endeavour and how the collective C2 can be organised to allow them to participate effectively.

Those charged with the Operational Design of a force or an endeavour will find the N2C2M2 just as useful, but they will be more focused on the C2 capabilities of the entities that may be involved in the endeavour or operation. The process will be similar—identifying the capabilities of the entities that make up the endeavour, understanding the level of C2 maturity needed for success in the endeavour (including different partners and potentially relevant missions and situations), and specifying what must be done to support the range of C2 approaches needed for effectiveness.

Strategic Planning for C2 must take into account the need for agility—the capability to operate in differing environments, with different partners, and different missions; all potentially changing over time. The difference between operational design and strategic planning is that the entities and their initial capabilities must be dealt with in the near term, with little opportunity for major changes in training, equipment, leadership, or other key factors. Operational design places a premium on the maturity and agility of the most capable entities. They must be able to act as the glue that holds the endeavour together and enable effective participation by all those who can contribute to the endeavour. This will often mean working with "disadvantaged" C2 partners.

Because the state of C2 knowledge remains emergent, C2 Research and Experimentation applications of the N2C2M2 will be extremely important for some time to come. The N2C2M2 provides a rich source of concepts and ideas about C2 in the Information Age and what it will take to assist NATO and NATO nations to achieve effective and efficient Network Enabled Capabilities. However, a great deal still needs to be learned about how these capabilities can be created and maintained in specific contexts—classes of missions, cultural contexts, mixtures of C2 approaches, etc. Moreover, the N2C2M2 also provides an excellent tool for organising existing knowledge and exploring the implications of new insights into command and control.

# GLOSSARY

## ACTIONS

Actions take place in the physical domain. They are triggered by decisions in the cognitive domain (Alberts et al., 2001, p. 21). (C2 Primitive)

See also *Physical Domain*

## ACTOR

Any individual, group, organisation, or any other entity interacting with the environment that is capable of influencing the environment and, in turn, is capable of being influenced by the environment. Actors may be part of friendly, neutral, or adversarial actions or operations within/towards the endeavour.

See also *Entity*

## AGILE

The term *agile* can be used to describe each component of an organisation's mission capability packages (MCPs) or an organisation that can instantiate many MCPs. The use of the word *agile* is appropriate when the characteristics of a model corresponds to many if not all of the dimensions of agility that are defined in *Power to the Edge* (see Alberts and Hayes, 2003) and included in the NCO Conceptual Framework as well as the NATO C2 Conceptual Models (Alberts and Hayes, 2003, pp. 123-159).

## AGILE C2

Agile C2 is the ability to recognise which C2 Approaches are appropriate for the situations (e.g., mission, operating environment, and set of coalition partners or contributing entities) and dynamic transition to these (Alberts and Hayes, 2007, p. 172).

See also *C2 Approach*

## AGILE C2 SYSTEM

An agile C2 system is able "to operate in a complex, multiple-axis (several synergistic efforts simultaneously and continuously) operation with a coherence that is maintained over time. […] it moves the force toward a capability to engage in effective self-synchronization" (Alberts and Hayes, 2003, p. 147). A C2 System is agile if it is capable of supporting the appropriate C2 approach and transition to that approach.

See also *C2 Approach* and *Self-Synchronisation*

## AGILITY

Agility is the synergistic combination of robustness, resilience, responsiveness, flexibility, innovation, and adaptation.

## ALLOCATION OF DECISION RIGHTS

One of the three dimensions of the C2 Approach Space. "Decision rights belong to the individuals or organizations accepted (whether by law, regulation, practice, role, merit, or force of personality) as authoritative sources on the choices related to a particular topic under some specific set of circumstances or conditions. The allocation of decision rights is their distribution within the international community, a society, an enterprise, or an organization" such as "a military, a coalition, an interagency effort, or an international effort including military elements. There can be different distributions of those rights across functions, echelons, time, or circumstances." (Alberts and Hayes, 2006, p. 83)

See also *C2 Approach Space* and *C2 Approach Dimensions*

## AWARENESS

"Awareness relates to a situation and, as such, is the result of a complex interaction between prior knowledge (and beliefs) and current perceptions of reality" (Alberts et al., 2001, p. 18) and "focuses on what is known about past and present situations." (ibid., p. 19). (C2 Primitive)

## C2

**Command and Control**

See also *Command and Control*

## C2 AGILITY

The agility of the collective C2 process. Its essence is the ability to choose among a number of C2 Approaches, including the adoption of a C2 Approach that is at a lower level than the C2 Approach that has been in use so far and, if required, the use of different C2 Approaches when collaborating with different organisations. C2 Agility includes the ability to create dynamic task-organised groupings of force proactively, and as required by the changing operational context. C2 agility is connected with C2 maturity in that increasing levels of C2 maturity translate into increasing C2 agility.

See also C2 *Approach* and *C2 Maturity*

## C2 APPROACH

The way an organisation or entity accomplishes the functions associated with command and control, i.e., how the allocation of decision rights is organised, and how the patterns of interaction and the distribution of information are established. A C2 approach can be thought of a specified region in the C2 Approach Space. The N2C2M2 describes five C2 Approaches to accomplish the functions associated with command and control. These are:

- Conflicted C2
- De-Conflicted C2
- Coordinated C2
- Collaborative C2
- Edge C2

See also *C2 Approach Space*, *Conflicted C2*, *De-Conflicted C2*, *Coordinated C2*, *Collaborative C2*, and *Edge C2*

## C2 APPROACH DIMENSIONS

The three dimensions constituting the C2 Approach Space. These are:

- Allocation of Decision Rights
- Patterns of Interaction
- Distribution of Information

See also *C2 Approach Space*, *Allocation of Decision Rights*, *Patterns of Interaction*, and *Distribution of Information*

## C2 APPROACH SPACE

The space defined by (the) three C2 approach dimensions, as illustrated in Figure 4. It describes possible approaches to accomplishing the functions associated with C2. It is described by means of the following three major axes (or dimensions of command and control):

- Allocation of Decision Rights
- Patterns of Interaction
- Distribution of Information

(Alberts and Hayes, 2006, p. 75)

See also *C2 Approach Dimensions*, *Allocation of Decision Rights*, *Patterns of Interaction*, and *Distribution of Information*

## C2 CAPABILIY

The ability to execute a course of action associated with the functions of command and control (based on "capability" definition of DoD Dictionary of Military and Associated Terms).

See also *Command and Control*

## C2 CONCEPTUAL REFERENCE MODEL (C2CRM)

The Command and Control Conceptual Reference Model (C2CRM) was developed by NATO SAS-050; it consists of a few hundred variables and relations between them. The variables are comprised of potential relevant measures of merit (MoM) and influencing factors and, by means of qualitative relations, show the influences between them. The lists of MoM and influencing factors can be considered as suggestions for issues to take into account for a particular study.

See also *NATO C2 Conceptual Reference Model*

## C2 DOMAINS

C2 Domains characterise the fundamental capabilities of a network-centric enterprise. Four domains exist: Physical, Information, Cognitive, and Social (Alberts and Hayes, 2003).

See also *Physical Domain*, *Information Domain*, *Cognitive Domain*, and *Social Domain*

## C2 EFFECTIVENESS

C2 effectiveness is the degree to which a specified purpose is accomplished, or an intended or expected result is produced on the basis of a specified C2 Approach. It depends on the C2 Approach employed and the requirements of the situation at hand.

See also *C2 Approach* and *Effectiveness*

## C2 EFFICIENCY

The amount of C2 resources expended relative to a specified outcome (e.g., completion of the assigned military mission in a specified quality). Provided that the output (mission accomplishment) is the same, fewer resources consumed means higher efficiency.

See also *Efficiency* and *C2 Effectiveness*

## C2 MATURITY

C2 Maturity is a relatively recent concept (Alberts et al., 2001). C2 Maturity refers to the ability to utilise the C2 Approach Space, with increasing levels of maturity being available along with the ability to operate in a larger portion of the space, in an appropriate fashion.

See also *C2 Approach Space* and *C2 Maturity Levels*

## C2 MATURITY LEVELS

C2 Maturity Levels are associated with the degree to which a collective or entity is able to conduct network-centric operations (NNEC capability levels). C2 Maturity Levels are defined in terms of specific regions of the C2 Approach Space. The N2C2M2 defines five levels of C2 Maturity:

- Level 1: Capability to operate only at Conflicted C2;
- Level 2: Capability to operate at De-Conflicted C2;
- Level 3: Capability to operate at De-Conflicted and Coordinated C2;
- Level 4: Capability to operate at De-Conflicted, Coordinated, and Collaborative C2;
- Level 5: Capability to operate at De-Conflicted, Coordinated, Collaborative, and Edge C2.

## C2 PROBLEM SPACE

The space spanned by the three dimensions *rate of change* (static versus dynamic), *degree of familiarity* (known versus unknown), and *strength of information position* (informed versus uninformed) that describe characteristics of a problem at hand. For any position within this problem space there is an appropriate type of C2 Approach (described by a specified position in the C2 Approach Space). The three dimensions can be described as follows:

- *Rate of change* represents the speed with which the situation (e.g., political, social, economic operating environment, and methods of warfare employed) changes.
- *Degree of familiarity* refers to the extent to which the nature of the problem (e.g., location, extent of information requirements, required patterns of interaction) is known.

- *Strength of information position* refers to "the extent to which the decision making is informed or uninformed." (Alberts and Hayes, 2006). As explained in *Understanding Information Age Warfare*, (Alberts et al., 2001) the information position of an organisation is the degree to which it is able to fulfil its information requirements.

The three dimensions of the C2 problem space are not necessarily orthogonal (Alberts and Hayes, 2006, pp. 76-79).

See also C2 *Approach* and *C2 Approach Space*

## C2 RESEARCH AND EXPERIMENTATION

Activities aimed at generating insights into C2-related questions. Experimentation is, in the narrower sense of the word, the performance of "a test made to determine the efficacy of something previously untried," "to examine the validity of an hypothesis," or "to demonstrate a known truth." These three meanings differentiate the three major roles [i.e., discovery, hypothesis testing, and demonstration] "that DoD organisations have assigned to experimentation." (Alberts and Hayes, 2002, pg. 19). An experiment always generates empirical data that are subsequently interpreted. The term *research* is broader in a sense that it includes not only experimentation, but also other types of activities such as historical research, modelling, etc.

## C2 SYSTEM

The facilities, equipment, communications, procedures, and personnel essential to a commander for planning, directing, and controlling operations of assigned and attached forces pursuant to the missions assigned (DoD Dictionary of Military and Assoc. Terms).

In the *Headquarters Effectiveness Assessment Tool* (HEAT), the C2 system is understood as an adaptive control system, with the purpose to bring or keep the operational environment within some desired boundaries (Alberts and Hayes, 2006, pg. 165).

See also *Command and Control*

## CLUSTER

A cluster is a group of nodes (individuals, entities, or things) having a large proportion of mutual connections, i.e., number of links and reciprocations within the group's nodes are denser than with outside nodes (Kadushin, 2004).

## CLUSTER ATTRACTOR

A factor that causes clusters to form. Examples of cluster attractors are group membership and tasks.

See also *Cluster*, *Entity Cluster*, and *Task Cluster*

## COGNITIVE DOMAIN

The cognitive domain is the space where understanding develops (Atkinson and Moffat, 2005). The perceptions and understanding of what this information states and means exists in the cognitive domain. Also in the cognitive domain are the mental models, preconceptions, biases, and values that serve to influence how information is interpreted and understood, as well as the nature of the responses that may be considered (Alberts and Hayes, 2003).

See also *C2 Domains*

## COLLABORATION

"Collaboration is a process that takes place between two or more entities. Collaboration always implies working together toward a common purpose. This distinguishes it from simply sharing data, information, knowledge, or awareness" (Alberts et al., 2001, pp. 27-28). (C2 Primitive)

## COLLABORATIVE C2

One of the five C2 Approaches described in the N2C2M2, basically characterised by the collaborative development of a single shared plan. Collaborative C2 involves a considerable amount of delegation of decision rights to the collective; it aims at developing synergies by negotiating and establishing collective intent as well as a shared plan, establishing or reconfiguring roles, coupling actions, rich sharing of non-organic resources, some pooling of organic resources, and increasing interactions in the Cognitive Domain to increase shared awareness.

See also *C2 Approach* and *Cognitive Domain*

**COLLECTIVE**

Multiple, loosely-coupled organisations that may work together if in their best interest, or sometimes for the greater good or a collective purpose. Note that the links may be less robust with less of a central tendency. The organisations bring their specific and complimentary capabilities. They may also have different intent as well as different C2 maturity levels. A collective matures by growth (given enough time working together) and less so by deliberate design (legislation, policy, and training).

**COLLECTIVE C2**

Functions of command and control, as accomplished by a collection of entities.

See also *Collective*

**COLLECTIVE ENDEAVOUR**

An endeavour that involves a large number of disparate entities whose activities are related to a broad range of effects, including not only (and very often not primarily) military, but also social, economic, political, and informational factors (Alberts and Hayes, 2007, pp. 9-11). Therefore, a collective endeavour refers to the activities of the involved entities as a whole and is thus characterised by a single, rather than several different C2 Approaches.

**COMMAND (a functional perspective)**

Command is equated with the establishment or emergence of a set of initial conditions, including the rules or mechanisms by which these conditions are adjusted dynamically (Alberts and Hayes, 2007, p. 29). Command functions include: establishing the goal or objective (the intent); determining roles, responsibilities, and relationships; establishing rules and constraints; and monitoring and assessing the situation and progress (Alberts and Hayes, 2006, p. 154).

**COMMAND (a human perspective)**

The creative expression of human will necessary to accomplish the mission. The function of command is to invent novel solutions to mission problems, to provide conditions for starting, changing, and terminating control, and to be the source of diligent purposefulness (Pigeau and McCann, 2002, p. 56).

**COMMAND (a military perspective)**

The exercise of lawful authority (NATO, U.S., and Slovakia quote).

**COMMAND AND CONTROL (C2) (Traditional)**

From a traditional perspective, command and control refers to "the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission […]" (Defense Technical Information Center, 2008). "The concept embraces the continuous acquisition, fusion, review, representation, analysis, and assessment of information on the situation; issuing the commander's plan; tasking of forces; operational planning; organizing and maintaining cooperation by all forces and all forms of support; organizing command and control; preparing subordinate command and control bodies and forces for combat operations; supervising and assisting subordinate commanders, staffs and forces; the direct leadership of troops during performance of their combat missions." (NATO Glossary, 2008). Beyond these classical definitions, the essence of C2 is defined by three key factors, i.e., the three dimensions of the C2 Approach Space. Whereas Command and Control are separate functions they are interrelated. Their elements span all domains of warfare, i.e., physical, information, cognitive, and social (Alberts and Hayes, 2006). C2, at the enterprise level, shapes the force (or the enterprise) determining the purpose of the organisation, its priorities, and ultimately the capabilities it has. Thus, C2 at the enterprise level determines what is possible. C2 at the mission level is about employing the assets of an organisation—its people, systems, materiel, and its relationships with others—in the pursuit of mission-specific goals and objectives (intent) (NATO SAS-050 Research Task Group, 2006).

See also *Command*, *Control*, and *Focus and Convergence*

## COMMAND INTENT

Part of the process of making the study of command and control less personalised was changing the term *commander's intent to command intent*. This change highlighted both the fact that there are many decision makers (or commanders) in any battlespace or complex endeavour and the fact that no single person is in charge or *in command* during complex endeavours. (Alberts and Hayes, 2006)

**COMMANDER**

A person with the decision rights associated with the command functions.

**COMMANDER'S INTENT**

A concise expression of the purpose of the operation and the desired end state. It may also include the commander's assessment of the adversary commander's intent and an assessment of *where* and *how much* risk is acceptable during the operation (DoD Dictionary of Military and Associated Terms).

**COMPLEX ENDEAVOURS**

The term describes "undertakings that have one or more of the following characteristics:

1. The number and diversity of the participants is such that
   a. There are multiple interdependent chains of command;
   b. The objective functions of the participants conflict with one another or their components have significantly different weights; or
   c. The participants' perceptions of the situation differ in important ways; and
2. The effects space spans multiple domains and there is

a. A lack of understanding of networked cause and effect relationships; and
b. An inability to predict effects that are likely to arise from alternative courses of action."

(Alberts and Hayes, 2007, p. 4)

The actors within an endeavour "may have a variety of different relationships with one another and may be working toward somewhat different goals or purposes. Indeed, their ability to work in concert may depend on the fact that their goals and objectives, while not identical, are not mutually exclusive." (Hayes, 2007, p. 146).

## COMPLEXITY

Complexity refers to a bundle of attributes of a system that involves variables such as dynamics, non-linearity, interdependencies, lack of predictability, and scope. Key properties of complexity are (Moffat, 2003, p. 42-43):

- Non-linear interaction: This can give rise to surprising and non-intuitive behaviour, on the basis of simple local co-evolution.
- Decentralised control: Emergent behaviour is generated through local co-evolution.
- Self-organisation: The ability to evolve over time without the need for guidance from outside the system.
- Non-equilibrium order: The order (e.g., the space and time correlations) inherent in an open, dissipative system far from equilibrium.
- Adaptation: Clusters or avalanches of local interaction are constantly being created and dissolved across the system.

- Collectivist dynamics: The ability of elements to locally influence each other, and for these effects to ripple through the system, allows continual feedback between the evolving states of the elements of the system.

See also *Complicatedness* and *Situational Complexity*

**COMPLICATEDNESS**

The attribute of a system that is, similarly to a complex system, characterised by a large number of degrees of freedom. However, in a complicated system the interactions of its components are locally linear (while they are locally non-linear in a complex system), i.e., they are locally independent, and their effect is additive (the effect is the *sum of the parts*). Compared to complexity, complicatedness of a situation refers to the degree to which the situation can be partitioned into a number of components and interactions without losing anything in the process (e.g., The *whole* is or *equals* the *sum* of *the parts*). Complicated things require much more effort to analyse, but they are amenable to analysis.

*Simple-Complicated* can be a scale where the closer one is to "simple," the easier it is; that is, less knowledge and effort are required. What moves you up the scale is the increase in the numbers and diversity of the participants, the number of different ways they could interact (cooperative, collaborative, independent, neutral, friendly, unfriendly, or hostile,) and the number and diversity of the variables that populate the effects space (physical, informational, cognitive, social).

*Simple-Complex* is not a scale. The terms *simple* and *complex* are qualitatively different ideas. Complex things are not amenable to deductive analysis alone. Making progress requires the ability to both analyse and synthesise.

See also *Complexity*

## CONCEPTUAL MODEL

A model is a simplified representation of reality; a conceptual model can be defined as a representation of how something is perceived or thought of, hence of a current state of understanding (Alberts and Hayes, 2006). It is based on concepts—general ideas derived from specific instances (American College Dictionary, 1997), including relationships between the concepts it consists of. These relationships are again concepts.

## CONFLICTED C2

One of the five C2 approaches described in the N2C2M2, basically characterised by individual contributors exercising C2 only over their own forces. Hence, there is no collective objective, or any information distribution or other kinds of interaction between the entities.

See also *C2 Approach*

## CONTROL (as an independent variable)

Control refers to "those structures and processes devised by command to enable it and to manage risk" [...] The function of control is to enable the creative expression of will and to manage the mission problem in order to minimize the risk of not achieving a satisfactory solution." (Pigeau and McCann, 2002, p. 56)

**CONTROL (a functional perspective)**

An emergent property that is a function of initial conditions, including those established by command (Alberts and Hayes, 2007, p. 29).

**CONTROLLABLE VARIABLE**

A controllable variable in an experiment is an independent (input) variable that is deliberately varied in order to assess its effects in dependent (output) variables.

If an extraneous factor that is not deliberately treated as an input variable, but is likely to affect the experiment can be kept constant, so as to minimise its effects on the outcome (it is then referred to as *control variable*), it is, strictly speaking, also a controllable variable.

See also *Uncontrollable Variable*

**COORDINATED C2**

One of the five C2 approaches described in the N2C2M2, basically characterised by: seeking mutual support for intent; developing relationships and links between and among entity plans and actions to reinforce or enhance effects; some initial pooling of non-organic resources; and increased sharing in the Information Domain. Coordinated C2 involves the development of a degree of common intent and an agreement to link actions in the various plans being developed by the individual entities.

See also *C2 Approach* and *Information Domain*

**COORDINATED OPERATIONS**

One of the NNEC Maturity Levels; corresponds to Coordinated C2 in the N2C2M2.

See also *NNEC Operational Capability Model* and *Coordinated C2*

**CORRECTNESS**

In ELICIT experimentation, correctness refers to a performance measure. In the experimentation efforts described in this report, it was measured by the number of ELICIT participants who made at least one correct attempt, expressed relative to the total number of identification-authorised participants.

See also *ELICIT*

**CROSS-TEAM COORDINATOR**

In the Hierarchy trials of the ELICIT experimentation, four teams are formed. One member from each team is designated as the team leader and one of the participants is assigned the role of cross-team coordinator—who can look across the activity of all four teams.

See also *ELICIT*

## CULTURE

A set of basic beliefs, values, attitudes, goals, and practices that characterises and is shared by a collective, such as a group, institution, organisation, or nation.

## DECISIONS

Decisions are *choices* among alternatives. Choices to do nothing are *decisions*. Decisions occur in the cognitive domain. They "are acted upon and/or conveyed via the information domain for others to act upon, resulting in or influencing actions in the physical domain and/or other decisions" (Alberts et al., 2001, p. 20).

See also *Physical Domain*

## DE-CONFLICTED C2

One of the five C2 approaches described in the N2C2M2, basically characterised by the entities partitioning the problem space in order to avoid adverse cross-impacts. This requires limited information sharing and limited interactions between the entities.

See also *C2 Approach*

## DE-CONFLICTED OPERATIONS

One of the NNEC Maturity Levels; corresponds to De-Conflicted C2 in the N2C2M2.

See also *NNEC Operational Capability Model*

## DEPENDENT VARIABLE

A dependent variable in an experiment is a variable that is expected to be affected by the variation of (an) independent variable(s), i.e., its value is expected to depend on the value of the independent variable(s).

## DISJOINTED OPERATIONS

See *Stand-Alone Operations*

## DISTRIBUTION OF INFORMATION

The way information flows and is disseminated in the *real world* because of informal relationships, linkages, and sources. As one of the three dimensions of the C2 Approach Space, it "[…] refers to a key result of the C2 processes within military organization, coalition, or international effort […] involving military forces and civilian organizations […]. [It] is impacted by the distribution of decision rights (which includes who makes the choices about information distribution processes and the creation of the infrastructure by which information is shared and collaboration is carried out, as well as who is entitled to what information) and the patterns of interaction (who is able to acquire what information). […] The concept also includes the richness element in network-centric thinking. Richness focuses on the breadth, depth, and quality (correctness, completeness, currency, consistency, etc.) of the information that is available" (Alberts and Hayes, 2006, pg. 108-109).

See also *C2 Approach Space*

## DYNAMICS

Pattern or history of growth, change, and development (Random House, Inc., 2009). Dynamics may characterise the operational environment as well as command and control. Accordingly, dynamics of command and control approach may signify the extent to which fundamental dimensions of command and control approach change across purpose and/or time (NATO SAS-050 Research Task Group, 2006).

## EDGE C2

One of the five C2 approaches described in the N2C2M2, basically characterised by a robustly networked collection of entities having widespread and easy access to information, sharing information extensively, interacting in a rich and continuous fashion, and having the broadest possible distribution of decision rights. The objective of Edge C2 is to enable the collective to self-synchronise.

See also *C2 Approach*, *Self-Synchronisation*, and *Collective*

## EDGE ORGANISATION

In ELICIT experimentation, an edge organisation is a configuration of the participants that have no predefined structure. Participants are not assigned to teams or roles, and every participant has access to all information sources.

See also *ELICIT* and *Hierarchical Organisation/Hierarchy*

## EFFECTIVENESS

Being effective means being adequate to accomplish a purpose; producing the intended or expected result (Random House Unabridged Dictionary, 2006).

See also *C2 Effectiveness*

## EFFICIENCY

The ratio of the effective or useful output to the total input in any system (The American Heritage® Dictionary of the English Language, 2006). As such, it is a function of both effectiveness and cost (e.g., time, resources, money, etc.).

See also *C2 Efficiency* and *Effectiveness*

## ELICIT

Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust. ELICIT is an online multi-user platform for conducting experiments in information-sharing and trust. It instruments the actions of a group of participants engaged in a situational awareness problem and enables researchers to study information sharing and collaborative behaviours. Participants attempt to identify attributes of an upcoming terrorist attack; in particular, *who* will conduct the attack, *what* is the target of the attack, the country *where* the attack will take place, and *when* [the time] the attack will occur. Information elements (factoids) containing information related to the attack are distributed at various times to each participant. Since no participant receives all of the factoids needed to solve the problem (from these distributions), the sharing of factoids among the participants is required for success.

See also *Correctness*, *Cross-Team Coordinator*, and *Factoid*

**ENDEAVOUR**

In the context of C2 and Complex Endeavours, it is used to characterise a large number of disparate entities whose activities are related to a broad range of effects, including not only (and very often not primarily) military, but also social, economic, political, and informational factors (Alberts and Hayes, 2007, pp. 9-11).

Endeavours have a purpose or set of related purposes. They seek to have their members and the other relevant entities synchronise their efforts, arrange them purposefully in time and space, in order to generate effects consistent with those purposes.

The term *endeavour* was suggested as a replacement to the term *force*, since the latter is often used within a military contexts, implying a tightly coupled set of actors or direct actions that alter the operating environment (e.g., kinetic strength and impact) (Hayes, 2007).

**ENDEAVOUR EFFECTIVENESS**

Endeavour effectiveness is the ability to effectively accomplish an endeavour; producing the intended or expected result. This includes, but is not limited to, its purpose.

See also *Endeavour* and *Effectiveness*

**ENTITY (COMPLEX ENDEAVOURS)**

The term *entity* is used as a more generic definition to refer to an individual or any size team, group, or organisation (NATO SAS-065 Research Task Group, 2008).

**ENTITY CLUSTER**

The gathering of individual actors within a specified entity. An isolated entity cluster represents such a gathering of individuals within an entity which does not interact with any other entities (NATO SAS-065 Research Task Group, 2008).

See also *Cluster*

**EXTENT OF SHARED INFORMATION**

In ELICIT experimentation, *Extent of Shared Information* refers to the average number of participants who have access to each fact as a function of time.

See also *ELICIT*

**FACTOID**

In ELICIT experimentation, a factoid is an information element (usually 1 sentence in length) containing information related to a fictitious terrorist attack—the details of which participants are tasked to determine. Dozens of factoids are distributed at various times to the participants during an ELICIT experimentation trial.

See also *ELICIT*

**FAMILIARITY**

Being familiar with a situation, operational environment, task, procedure, other individuals, etc., means having encountered it or them before, or having knowledge of it or them (based on the definition of *Situational Familiarity* of NATO SAS-050 Research Task Group).

**FOCUS AND CONVERGENCE**

Together with *agility*, *focus* and *convergence* are two of the key terms that form the core of a new conceptual foundation of future command and control: whereas "focus provides the context and defines the purposes of the endeavour," the term convergence refers to "the goal-seeking process that guides actions and effect" (Alberts, 2007, p. 3). The notion of *focus and convergence* is suggested to replace that of *command and control* with a view to future approaches in complex endeavours. The combined term *focus and convergence* indicates that these two functions are interdependent, based on a set of dynamic interactions between them.

See also *Command*, *Control*, and *Command and Control*

**FORCE AGILITY**

Force agility is an attribute of a total force (e.g., JTF) in terms of a mission capability packages (MCPs), or a force that can instantiate many MCPs. Force agility can be thought of as being able to utilise many, if not all, of the dimensions of agility that are defined in *Power to the Edge* (see Alberts and Hayes,

2003) and are included in the NCO Conceptual Framework and the NATO C2 Conceptual Models (Alberts and Hayes, 2003, pp. 123-159).

See also *Agility*

**HETEROGENEITY**

Differences within a group or collective that may refer to aspects as varied as culture, language, demographical attributes, educational background, level of professionalism, materiel, technology, C2 approach, etc.

**HIERARCHICAL ORGANISATION / HIERARCHY**

In ELICIT experimentation, the hierarchical organisation is a configuration of the participants where all participants, except one, are assigned to one of four teams. Each of the four teams in a trial correspond to one of the four aspects of the ELICIT problem (identification of the details of a fictitious terrorist attack). The members of each team have access to a specified portion of the overall information provided (i.e., information distribution is limited). One member from each team is designated as the team leader. In addition, one of the participants is assigned the role of *cross-team coordinator* and can look across the activity of all four teams.

See also *ELICIT*, *Cross-Team Coordinator,* and *Edge Organisation*

## INDEPENDENT VARIABLE

In an experiment, an independent (input) variable is a variable that is expected to exert an effect on dependent (output) variable(s). Those that are deliberately varied in the experiment are called *controllable variables*.

See also *Controllable Variable* and *Dependent Variable*

## INFORMATION

The result of putting individual observations (sensor returns or data items) into some meaningful context (Alberts and Hayes, 2006). (C2 Primitive)

## INFORMATION DOMAIN

The information domain is the space of all information sharing (Atkinson and Moffat, 2005). The information collected, posted, pulled, displayed, processed, and stored exists in the information domain (Alberts and Hayes, 2003).

See also *C2 Domains*

## INFORMATION EXCHANGE REQUIREMENTS (IERs)

Information Exchange Requirements are statements that define a specific category of information that needs to be communicated between two parties or organisations. Most commonly, IERs are used to define information exchange needs between data processing systems at two or more C2 nodes. Often IER statements are expanded to include additional parameters such as the bandwidth size, how frequently the information is exchanged, and the media over which it will be transmitted. The expanded versions of the IERs are used in modelling and simulation activities to determine or confirm the media bandwidth needed under various scenarios. (Beckner, 2000). The engineers designing C2 systems spent a great deal of time developing IERs that specified who needed access to what information and under what circumstances (Alberts and Hayes, 2006)

## INFORMATION SHARING

Interactions that take place between two or more entities in the information domain. These could be between humans, databases, or programs such as planning or fire control applications (Alberts et al., 2001).

See also *Entity*

## INFOSTRUCTURE

The term *infostructure* has been used since the mid-1980s to refer collectively to the information applications and processes that are required for an information age economy of the 21st century, or a portion of it, to function. The term also has had specific application towards installations necessary for defence. Perhaps because of the word's technical sound, people now use *infostructure* to refer to any process, application, substructure, or underlying system.

## INTEGRATED OPERATIONS

One of the NNEC Maturity Levels; corresponds to Collaborative C2 in the N2C2M2.

See also *NNEC Operational Capability Model* and *Collaborative C2*

## INTENT

The concept of Intent is a statement of purpose. It may be expressed in a variety of forms and degrees of specificity (e.g., goals and objectives; see Alberts and Hayes, 2007, pp. 29-30).

## INTERVENING VARIABLE

"Intervening variables in experiments are equivalent to the remaining data, algorithms, and logic in a model that either provide context for the model, or describe some relevant cause-and-effect relationship among independent and dependent variables" (Alberts and Hayes, 2002, p. 326).

See also *Dependent Variable* and *Independent Variable*

## LEVEL 1 MATURITY

Level 1 Maturity is one, the least mature, of the C2 Maturity Levels. It refers to the *capability* to operate only at Conflicted C2.

See also *C2 Maturity* and *C2 Maturity Levels*

## LEVEL 2 MATURITY

Level 2 Maturity is one of the C2 Maturity Levels. It refers to the *capability* to operate at De-Conflicted C2.

See also *C2 Maturity* and *C2 Maturity Levels*

## LEVEL 3 MATURITY

Level 3 Maturity is one of the C2 Maturity Levels. It refers to the *capability* to operate at De-Conflicted and Coordinated C2 and to flexibly to change between these two C2 approaches, as required by the circumstances (situation characteristics and capabilities of allied entities).

See also *C2 Maturity*, *C2 Maturity Levels,* and *Level 2 Maturity*

## LEVEL 4 MATURITY

Level 4 Maturity is one of the C2 Maturity Levels. It refers to the *capability* to operate at De-Conflicted, Coordinated, and Collaborative C2 and to flexibly change between these three C2 approaches as required by the circumstances (situation characteristics and capabilities of allied entities).

See also *C2 Maturity*, *C2 Maturity Levels*, *Level 2 Maturity*, and *Level 3 Maturity*

## LEVEL 5 MATURITY

Level 5 Maturity is one, the most mature, of the C2 Maturity Levels. It refers to the *capability* to operate at De-Conflicted, Coordinated, Collaborative, and Edge C2 and to flexibly change between these four C2 approaches as required by the circumstances (situation characteristics and capabilities of allied entities).

See also *C2 Maturity*, *C2 Maturity Levels*, *Level 2 Maturity*, *Level 3 Maturity*, and *Level 4 Maturity*

**MANAGEMENT AND GOVERNANCE**

These terms are used in the civilian and business domains in order to define the way enterprises (or organisations) define and implement authority, processes, and interactions (*governance*) and their practice and manner of managing resources and assets, including workers (*management*), in order to accomplish their functions and goals.

In the context of the N2C2M2, the term *Management and Governance* is used as the civilian synonym to *Command and Control* (military).

See also *Command and Control (A Military Perspective)*

**MATURITY LEVEL**

See *Maturity Model*

**MATURITY MODEL (M2)**

A maturity model defines improvement approaches, by means of increasing levels of maturity (i.e., maturity levels), which may be achievable by organisations (or departments). It is usually assumed that increasing maturity results in the ability to achieve higher levels of capability and performance (NATO SAS-065 Research Task Group, 2008).

Maturity models have become popular this last decade, given their usefulness for developing strategic roadmaps, guiding transformation, assessing performance, processing improvement, and as a benchmarking tool.

See also *C2 Maturity*

## MEASURES OF MERIT

The term *Measures of Merit* (MoM) refers to the degree or grade of excellence, expressed in terms of performance or effectiveness. *Measures of Merit* comprise *Measures of Effectiveness* (MOE) that are also referred to as measures of impact of the state of the command and control (NATO SAS-050 Research Task Group, 2006), Measures of Efficiency, and Measures of Agility.

## N2C2M2

The NATO NEC (Network-Enabled Capability) Command and Control Maturity Model. The N2C2M2 was developed specifically for operations that can be characterised as *Complex Endeavours*. Nevertheless, the N2C2M2 can be applied to the lesser included cases of more *traditional* operations.

## NATO C2 CONCEPTUAL REFERENCE MODEL

A conceptual model of command and control intended to serve as a point of departure for researchers, analysts, and experimenters engaging in C2-related research, conducting analyses of C2 concepts and capabilities, and designing and conducting experiments. It serves as a checklist to ensure that adequate attention is afforded to important variables and relationships. The definitions and accompanied measures provided are meant to be tested in practice and built upon.

The Reference Model contains over 300 variables and a selected subset of the possible relationships among them that were felt to be important in order to understand C2 and the implications of different approaches to C2. It was developed by the SAS-050 (see NATO SAS-050 Research Task Group, 2006) and revised by the SAS-065 Research Task Group in 2009.

See also *Conceptual Model* and *C2 Conceptual Reference Model*

**NATO CODE OF BEST PRACTICE FOR C2 ASSESSMENT**

The NATO Code of Best Practice for C2 Assessment (COBP-C2A) offers broad guidance on the assessment of C2 for the purposes of supporting a wide variety of decision-makers and the conduct of C2 research. For the proper evaluation of C2 issues, dimensional parameters, measures of performance, measures of C2 effectiveness, and measures of force and policy effectiveness were distinguished and linked. The COBP was organised into four themes:

- Study dynamics, problem formulation, and the development of a solution strategy;
- In depth identification and discussion of the essential elements of assessment: measures of merit, scenarios, human and organisational issues, data, and tools;
- Risk and uncertainty;

- Range of assessment products.

The COPB-C2A was developed by the NATO SAS-026, based on previous SAS-002 work (see NATO Code of Best Practice for C2 Assessment, 2002).

## NATO MISSION SPACE

The spectrum of all possible missions NATO may be involved in, including counter-terror operations, peacekeeping operations, humanitarian interventions, and military operations to support democracy, counter-insurgency operations, military support to beleaguered countries, anti-piracy operations, disaster relief operations, assistance to civilian authorities following attacks by cyber warriors on infrastructure or in the event of natural disasters, etc. (Source: ACT, *Future World Scenarios: Supporting Paper to the Long Term Requirements Study*, April 2006).

See also *Operations Other Than War (OOTW)*

## NCW TENETS

The tenets of Network Centric Warfare are (Alberts et al., 1999; Alberts and Hayes, 2007):

- Robustly networking an enterprise leads to widespread information sharing and collaboration;
- Increased sharing and collaboration improve both individual and shared awareness;
- Shared awareness and collaboration improve decisions and, in the presence of edge approaches to command and control, enable self-synchronisation;

- The result is dramatic improvement in mission or enterprise effectiveness and agility.

Networking forces are the basis of this theoretical foundation (where the human is the central point), which evolves into shared awareness and self-synchronisation. When using an *Edge C2 Approach*, this will then help to improve decisions, resulting in an increase in effectiveness and agility.

## NETWORK CENTRIC OPERATIONS (NCO)

When network-centric concepts are applied to operations other than war, we use the term *Network Centric Operations*. At the operational level, Network Centric Operations provide commanders with the capability to generate precise warfighting effects at an unprecedented operational tempo, creating conditions for the rapid lockout of adversary courses of action (NCW DoD Report to Congress, 2001).

## NETWORK-CENTRIC WARFARE (NCW)

NCW represents a powerful set of warfighting concepts and associated military capabilities that allow warfighters to take full advantage of all available information and bring all available assets to bear in a rapid and flexible manner. NCW focuses on the combat power that can be generated from the effective linking or networking of the warfighting enterprise. It is characterised by the ability of geographically dispersed forces (consisting of entities) to create a high level of shared battlespace awareness that can be exploited via self-synchronisation and other network-centric operations to achieve commanders' intent (Alberts et al., 1999; Alberts et al., 2002).

NCW is about human and organisational behaviour. It is based on adopting a new way of thinking—network-centric thinking—and applying it to military operations. NCW supports speed of command—the conversion of superior information position to action. NCW is transparent to mission, force size, and geography (Alberts et al., 1999, p. 88; Alberts et al., 2002).

## NETWORK ENABLED CAPABILITY (NEC)

NEC refers to the coherent integration of sensors, decision-makers, weapon systems and support capabilities to achieve the desired effect. […] The bottom line is that it will mean better-informed decisions and more timely actions leading to more precise effects (UK Ministry of Defence, 2005).

## NETWORK ENABLED COMMAND AND CONTROL

Command and control co-evolved to work with network enabled capabilities.

See also *Command and Control* and *Network Enabled Capability*

## NETWORK ENABLED OPERATIONS

Network Enabled Operations (traditionally referred to as Network Centric Operations, NCO) was introduced to emphasise that the principles of Network Centric Warfare (NCW) and Network Enabled Capabilities (NEC) are applicable to various kinds of operations in many arenas. The NCO concept "involves a number of interrelated concepts that form an intellectual basis for the Defense Information Transformation […], which is about human and organisational behaviour...is based on adopting a new way of thinking—network-centric thinking—and applying it to military operations...focuses on the power that can be generated from the effective linking or networking of the enterprise." (Alberts and Hayes, 2007, p. 24; see also Alberts et al., 1999, p. 88).

See also *Network-Centric Warfare* and *Network Enabled Capability*

**NNEC**

NATO C3 Board (NC3B) agreed that there was a need to develop a NATO concept to adapt national initiatives such as the U.S. Network-Centric Warfare and the U.K. Network Enabled Capability to the NATO context. This NATO concept is referred to as "NATO Network Enabled Capability (NNEC)" (Buckman, 2005).

See also *Network-Centric Warfare* and *Network Enabled Capability*

**NNEC OPERATIONAL CAPABILITY MODEL**

NATO has defined milestones on the road to a fully mature NEC, representing increasing levels of operational capability. Each succeeding level is related to increasing the coherence of the operation or endeavour. The N2C2M2 maturity levels correspond to and support these five levels:

Table Glossary 1

*The NNEC Feasibility Study used the terms *Coherent* and *Disjointed* rather than *Transformed* and *Stand Alone*.

See also *NNEC* and *C2 Maturity Levels*

## NON-ORGANIC RESOURCES

Non-organic resources are those resources that are not *owned* by participants. These include access to bridges and roads, and sharing of higher level ISTAR (Intelligence, Surveillance, Target Acquisition, and Reconnaissance). (NATO SAS-065 Research Task Group, 2008).

See also *Organic Resources*

## OPERATIONAL CAPABILITY

The ability to execute a course of action associated with a strategic, operational, tactical, service, training, or administrative military mission (based on definitions of *capability* and *operation* in the DoD Dictionary of Military and Associated Terms).

See also *NNEC Operational Capability Model*

## OPERATIONAL DESIGN

The conception and construction of the framework that underpins a campaign or major operation plan, and its subsequent execution (DoD Dictionary of Military and Associated Terms).

## OPERATIONS OTHER THAN WAR (OOTW)

OOTW consists of raids, Network Enabled Operations (NEO), peace enforcement, humanitarian assistance, peacekeeping, and nation assistance. OOTW encompass a wide range of activities where military forces perform actions used for purposes other than the large-scale combat operations usually associated with war (GlobalSecurity, 2009).

The U.S. Army Field Manual 100-5 defines OOTW as "military activities during peacetime and conflict that do not necessarily involve armed clashes between two organized forces" (Headquarters Department of the Army, 1993, p. Glossary-6). They "range from support to US, state, and local governments, disaster relief, nation assistance, and drug interdiction to peacekeeping, support for insurgencies and counterinsurgencies, noncombatant evacuation, and peace enforcement." (ibid., pg. 13-0).

## OPPORTUNITY COSTS

The costs in terms of foregone alternatives; the value of the next best alternative forgone as the result of making a decision and selecting one specific option.

## OPTIMISATION

The procedure or procedures used to make a system or design as effective or functional as possible, especially the mathematical techniques involved. (The American Heritage® Dictionary of the English Language, 2006).

The approaches to optimising systems are varied and depend on the type of system involved, but the goal of all optimisation procedures is to obtain the best results possible (again, in some defined sense) subject to restrictions or constraints that are imposed.

System models used in optimisation are classified in various ways, such as linear versus nonlinear, static versus dynamic, deterministic versus stochastic, or time-invariant versus time-varying. In forming a model for use with optimisation, all of the important aspects of the problem should be included, so that they will be taken into account in the solution. (McGraw-Hill Concise Encyclopaedia of Engineering, 2002).

## OPTION SPACE

The total of alternative actions an entity can choose from. In the context of the N2C2M2, the option space is assumed to increase with increasing C2 maturity (capability), giving an entity an increasing number of options for acting in a particular situation.

## ORGANIC RESOURCES

Organic resources are those *owned* by a participant. They may include vehicles, weapons, and local supplies (NATO SAS-065 Research Task Group, 2008).

See also *Non-Organic Resources*

## ORGANISATION

The term organisation refers to a structure, such as a group of persons, with the following characteristics (The American Heritage® Dictionary of the English Language, 2000):

- Its elements are "organised for a particular purpose;"
- Its elements carry out varied "functions that contribute to the whole and to collective functions;" and
- It provides individuals with a structure to "cooperate systematically to conduct business."

In the context of the N2C2M2, an organisation comprises multiple teams bound by a common vision, a common mission, core values, and monetary incentives (typically), business rules, legislation, policy, well-established communication and interaction, and some degree of common shared intent required to achieve the mission and realise the vision.

## PATTERNS OF INTERACTION

For Information Age networks, *Patterns of Interaction* is a C2 key dimension defined by means of three key elements:

- Reach (the number and variety of participants);
- Richness (the quality of the contents); and
- Quality of interactions enabled.

Understanding *Patterns of Interaction* requires focusing on more than just connectivity needs. It requires analysing:

- Level of interoperability achieved (more than technical interoperability, including also semantic interoperability and *cooperability* or willingness to interact and desire to communicate clearly);
- Range of media across which these interactions occur (e.g., voice, email, video conferencing and whiteboards);
- Collaborations (working together toward a common purpose); and
- Digital connectivity.

Information Age *Patterns of Interaction* are social networks enabled by whatever mechanisms are available (e.g., courier, telephone, videoconference, LAN, WAN, WWW) which mainly depend on cooperability, i.e., the willingness to work together and collaborate when appropriate (Alberts et al., 2001; Alberts and Hayes, 2006).

See also *C2 Approach Space*

## PEER-TO-PEER (P2P)

Peer-to-peer (P2P) interactions take place among individuals at equal positions within an organisation or group. P2P communication or networking refers to participants sharing a portion of their own resources that are provided directly to other participants without intermediaries.

## PHYSICAL DOMAIN

The physical domain is the physical world (Atkinson and Moffat, 2005). C2 sensors, systems, platforms, and facilities exist in the physical domain (Alberts and Hayes, 2003).

See also C2 *Domains*

## POSITIVE CONTROL

Positive control allows the superior commander (military or civilian) to be informed of richer peer-to-peer interactions and collaboration interchanges, and to intervene only when he or she can see that such an interchange would not match with higher level, more strategic requirements (Alberts and Hayes, 2007, p. 175).

See also *Commander*

## POWER TO THE EDGE

An approach to designing C2 concepts, organisations, and systems as to meet requirements of the complex endeavours faced currently and in the future. It "involves the empowerment of individuals at the edge of an organisation (where the organisation interacts with its operating environment to have an impact or effect on that environment) or, in the case of systems, edge devices. Empowerment involves expanding access to information and the elimination of unnecessary constraints. […] Moving *power* to the *edge* implies adoption of an edge organisation, with greatly enhanced peer-to-peer interactions. Edge organisations also move senior personnel into roles that place them at the *edge*. They often reduce the need for middle managers whose role is to manage constraints and control measures. Command and control become unbundled. Commanders become responsible for creating initial conditions that make success more likely and exercise control by: creating congruent command intent across the enterprise; allocating resources dynamically; and establishing rules of engagement and other control mechanisms that the fighting forces implement themselves." (Alberts and Hayes, 2003, p. 5).

See also *Command and Control* and *Commander*

## PROCESS VIEW

The C2 Conceptual Model consists of a Reference Model, a *value view* reflecting the value chain from force and C2 characteristics to measures of effectiveness, and a generic C2 process view. A *process view* can be instantiated in multiple ways, depending on the chosen subset of variables and relationships that represent a specific C2 Approach and process.

See also *C2 Conceptual Model*, *C2 Approach*, and *Value View*

## QUALITY OF INFORMATION

Quality of Information is a Measure of Merit of the product of the Information Domain. In the C2CRM, Quality of Information is a composite variable, thus consisting of a number of more directly measurable variables (e.g., Information Accuracy, Information Completeness). The Quality of Information is influenced by the distribution of information, collaboration processes, and information sources (NATO SAS-050 Research Task Group, 2006).

See also *Information Domain*, *Measures of Merit*, and *NATO C2 Conceptual Reference Model*

## QUALITY OF INFORMATION POSITION

In ELICIT experimentation, the percentage of relevant facts for the assigned task that a participant can access as a function of time.

See also *ELICIT*

## RELATIVE EFFECTIVENESS

The effectiveness of an endeavour under the given circumstances based on the recognition that effectiveness might be present at any C2 approach (e.g., De-Conflicted C2 can be effective under certain circumstances). Hence, the metric *relative effectiveness* focuses on performance during a complex endeavour. It is one of the *Measures of Endeavour Effectiveness*.

See also *Effectiveness*

## REQUISITE C2 AGILITY

C2 Agility is not free, nor is more agility always desirable. There are a variety of costs associated with operating at a given level of C2 maturity. Therefore, it makes sense for both individual entities and the collective as a whole to operate at the level of C2 maturity required by the situation. The appropriate level of C2 maturity is referred to as Requisite C2 Agility.

See also *Requisite C2 Maturity* and *Requisite Variety*

## REQUISITE C2 MATURITY

The ability to perform C2 at the levels needed for effectiveness and efficiency. It can be inferred from performance within an endeavour. What is sought is not simply the highest maturity level that is achievable, but the appropriate and sufficient maturity level for a given situation.

See also *Requisite C2 Agility* and *Requisite Variety*

## REQUISITE VARIETY

A term coined by Ashby (1958) states "the variety in the control system must be equal to or larger than the variety of the perturbations in order to maintain stability." In other words, to properly control a complex system, the variety of the control system, i.e., the number of accessible states which it can occupy, must match the variety of the complex system that is to be controlled. This means that control system itself has to be complex (Moffat, 2002). The *Law of Requisite Variety* has inspired the invention of the terms *Requisite C2 Agility* and *Requisite C2 Maturity*.

See also *Requisite C2 Agility* and *Requisite C2 Maturity*

## RESEARCH AND TECHNOLOGY ORGANISATION (RTO)

A NATO organisation that promotes and conducts co-operative scientific research (e.g., SAS Panel activities) and exchange of technical information amongst 28 NATO nations and 38 NATO partners. RTO is the single focus in NATO for Defence Research and Technology activities. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers.

See also *Studies, Analysis, and Simulation (SAS)*

## ROBUST NETWORK

A robust network is a network typology in which all nodes are connected (network average path length is one). This network has no structure holes (i.e., no risk of nodes being isolated) and, therefore, its structural cohesion is high (i.e., no risk of network collapse) which makes it highly resilient to node or link failures.

## SELF-ORGANISATION (a complexity theory view)

Self-organisation refers to the phenomenon that "systems with a large number of degrees of freedom can produce extended ordered structure, without the need for guidance from outside the system" (Atkinson and Moffat, 2005, p. 36). Interpreted in terms of an Information Age force structure, it refers to the phenomenon that "local co-evolution induces long-range order" (Atkinson and Moffat, 2005, p. 40). Among the key requirements or facilitators of self-organisation are trust between the involved individuals and the delegation of authority to lower levels of command.

## SELF-SYNCHRONISATION

Self-synchronisation, as a mode of interaction between two or more entities based on highly decentralised C2, refers to the phenomenon of "units linking up with other units, which are either local in a physical sense or local through an information grid or intranet" (Atkinson and Moffat, 2005, p. 41). According to Alberts and Hayes (2003, p. 36), the notion of self-synchronisation is consistent with that of self-coordination used elsewhere in place of self-synchronisation, defined as the effort to "increase freedom of low level forces to operate near-autonomously and re-task themselves through exploitation of shared awareness and commander's intent" (Rumsfeld, 2003). Among the requirements of self-synchronisation are clear and consistent understandings of command intent, high quality information and shared situational awareness, competence at all levels of the force, increased allocation of decision rights, and understanding of the situation, as well as the capabilities and behaviours of appropriate levels of the group; which is based on factors such as training, competence, willingness to be interdependent and trust in the information, subordinates, superiors, peers, and equipment. Key elements of self-synchronisation are "two or more robustly networked entities, shared awareness, a rule set, and a value-adding interaction. The combination of a rule set and shared awareness enables the entities to operate in the absence of traditional hierarchical mechanisms for command and control. The rule set describes the desired outcome in various operational situations. Shared awareness provides a mechanism for communicating the ongoing dynamics of the operational situation and triggering the desired value-adding interaction" (Alberts et al., 1999, pp. 175-176). (C2 Primitive)

See also *Entity*, *Intent*, and *Shared Awareness*

## SENSEMAKING

A cognitive process that involves the construction and further development of mental models, situational awareness and understanding, and ultimately leads to decision-making. This process is often informed by social interaction as well as enabling the evolution of shared situational awareness and understanding (cf. NATO SAS-050 Research Task Group, 2006).

See also *Situation(al) Awareness* and *Situation(al) Understanding*

**SHARED AWARENESS**

Shared awareness exists when two or more entities are able to develop a similar awareness of a situation (Alberts et al., 2001). (C2 Primitive)

See also *Situation(al) Awareness*

**SHARED INFORMATION**

Shared information is the available information that is accessible by two or more members (Alberts and Hayes, 2006). (C2 Primitive)

**SHARED INTENT**

A statement of purpose that is shared among entities, i.e., the individual entities' intents are identical.

See also *Intent* and *Entity*

**SHARED UNDERSTANDING**

Shared understanding exists when two or more entities are able to develop a similar understanding of a situation (Alberts et al., 2001). (C2 Primitive)

See also *Situation(al) Understanding*

## SITUATION(AL) AWARENESS

Describes the awareness of a situation that exists in all or part of the battlespace at a particular point in time (Alberts et al., 2001, pp. 120-125). It deals with what people know about the current and the emerging situation to include perceptions of cause and effect and the temporal dynamics of the situation and endeavour (Alberts and Hayes, 2007, p. 162). Situation(al) awareness includes awareness of intent (purpose, considerations, and constraints). "Awareness of intent, like all forms of awareness, is a *perception*, not a knowledge, of intent (Alberts and Hayes, 2007, p. 32)."

See also *Situation(al) Understanding*

## SITUATIONAL COMPLEXITY

In general, a situation is complex if it cannot be broken into a number of components and interactions without losing something in the process, i.e., that "the whole is more than the sum of its parts." More specifically, situational complexity in the context of C2 refers to a state in which an operational situation is characterised by a high number and diversity of friendly, neutral, and adversarial actors and relationships and interactions between them. This is often accompanied by high dynamics (frequent and fast change of the operational environment) and uncertainty (e.g., lack of transparency, unfamiliarity with the situation, and uncertainty about environment, objectives, and outcomes).

See also *Complexity*

## SITUATION(AL) UNDERSTANDING

Situation awareness plus an appreciation of temporal dynamics and likelihood of feeling states. Understanding is required for planning since (1) planners can only impact future events and (2) successful planning is informed by a grasp of the effects that can be expected (Alberts and Hayes, 2007, p. 162).

See also *Situation(al) Awareness*

## SOCIAL DOMAIN

The social domain is where people share (or otherwise) more deeply held beliefs. History and culture, social and institutional structure, economics, and government and politics have the most influence in the social domain (Atkinson and Moffat, 2005). C2 processes and the interactions between and among individuals and entities that fundamentally define organisations and doctrine exist in the social domain (Alberts and Hayes, 2003).

See also *C2 Domains*

## STAND-ALONE OPERATIONS

One (the lowest) of the NNEC Maturity Levels; corresponds to Conflicted C2 in the N2C2M2.

See also *NNEC Operational Capability Model* and *Conflicted C2*

## STRATEGIC PLANNING

A process that investigates possible future operating environments and develops a force structure development plan (SDP) to best adapt the defence organisation to possible future operating environments, including the range of C2 approaches it is capable of employing and the ability to recognise which of these approaches is appropriate. Strategic Planning tasks include: developing a strategic C2 vision, understanding what C2 approach and levels of C2 maturity are appropriate for potential scenarios, developing an investment plan and roadmap to develop capabilities, and creating educational and training materials to increase C2 related awareness and competence. Strategic Planning results in a plan to transform the current pool of forces into the pool to which future Operational Design is applied.

See also *C2 Approach and Operational Design*

## STRUCTURE DEVELOPMENT PLAN (SDP)

In the process of strategic planning, a force structure development plan is produced that best adapts the defence organisation to possible future operating environments.

See also *Strategic Planning*

**STUDIES, ANALYSIS, AND SIMULATION (SAS)**

Studies, Analysis, and Simulation is a technical panel of the RTO conducting studies and analyses of an operational and technological nature and promotes the exchange and development of methods and tools for operational analysis, as applied to defence problems.

See also *Research and Technology Organisation (RTO)*

*SAS-026*

A Research Task Group (formerly referred to as a *study group*) in the Studies Analysis and Simulation (SAS) Panel of the RTO that was formed in 2000 to assess, revise, and extend the combat-oriented initial version of the COBP—developed by the study groups RSG-19 and SAS-002, to account for C2 in Operations Other Than War (OOTW) and their implications, in particular with regard to Human Factors. SAS-026 submitted the revised NATO COBP for C2 Assessment (COBP-C2A) in 2002.

See also *NATO Code of Best Practice for C2 Assessment* and *Operations Other Than War (OOTW)*

## *SAS-050*

The SAS-050 Research Task Group (formerly referred to as a *study group*) developed a conceptual model for representing C2 in general, and new network-centric command concepts in particular, as a prerequisite for understanding, exploring, and assessing emerging concepts of operation and transformational capabilities.

See also *NATO C2 Conceptual Reference Model*

## *SAS-065*

The SAS-065 Research Task Group created a revised C2 Conceptual Reference Model (C2CRM), building on the conceptual model developed by SAS-050, to facilitate the exploration of network-enabled command and control approaches and network-enabled capabilities, and to identify options for C2 within complex endeavours (i.e., coalitions involving a variety of military and non-military partners each of which may be at different C2 maturity levels and each of which may pursue different C2 approaches).

See also *Complex Endeavours, NATO C2 Conceptual Reference Model*, and *N2C2M2*

## SUPREME ALLIED COMMANDER TRANSFORMATION (SACT)

SACT is one of NATO's two strategic commanders and the commanding officer of Allied Command Transformation, ACT.

See also *NATO* and *ACT*

**SYNCHRONISATION**

Synchronisation is the purposeful arrangement of things or effects in time and space. Synchronisation takes place in the physical domain (reality) (Alberts et al., 2001). (C2 Primitive)

See also *Physical Domain* and *Self-Synchronisation*

**TASK CLUSTER**

The gathering of individual actors from the same or different specified entities who work together on or within the same specified task. These clusters may be static in Coordinated or Collaborative C2, but are emergent in Edge C2, i.e., they are both tailored to the evolving situation and dynamics in response to changes in the endeavour and/or the environment.

See also *Cluster* and *Entity Cluster*

**TEAM**

Multiple people work together with high levels of common intent towards a common objective. They train together and develop a common work culture. The team typically consists of a leader and followers who fully understand each other's competencies, authorities, and responsibilities.

**TRANSFORMED OPERATIONS**

One (the highest) of the NNEC Maturity Levels; corresponds to Edge C2 in the N2C2M2.

See also *NNEC Operational Capability Model* and *Edge C2*

## TRANSITION REQUIREMENTS

The changes required in an entity's entire setup in order to move from a current C2 maturity level to another—including: doctrine, organisation, structure, processes, material, level of training and education, and its way of coordinating with the other entities involved in the same endeavour.

## UNCONTROLLABLE VARIABLE

An uncontrollable variable in an experiment is a variable that is likely to exert some influence on the dependent variable(s) or on the hypothesised relationship between independent and dependent variables. However, neither is its effect of primary interest, nor are its values deliberately varied or held constant in the experiment.

See also *Controllable Variable*, *Dependent Variable*, and *Independent Variable*

## UNDERSTANDING

Understanding involves having a sufficient level of knowledge to be able to draw inferences about the possible consequences of the situation, as well as sufficient awareness of the situation to predict future patterns (Alberts et al., 2001). (C2 Primitive)

See also *Situation(al) Awareness* and *Situation(al) Understanding*

**VALIDATION**

The process of establishing evidence that provides a high degree of assurance that a product (e.g., a model or tool) is appropriate for the uses or purposes for which it is designed or intended (DoD Directive 5000.59 "DoD Modelling and Simulation (M&S) Management," USD (AT&L August 8, 2007).

See also *Verification*

**VALIDITY**

The appropriateness of a model or tool for the uses or purposes for which it is designed or intended.

See also *Verification*

*CONSTRUCT VALIDITY*

In general, the term refers to the degree to which there is evidence about whether a particular operationalisation of a construct adequately represents what is intended by theoretical account of the construct being measured.

Specifically applied to the case of the N2C2M2, construct validity refers to the degree to which the model includes (i.e., identified and incorporated) all the relevant factors and relevant relationships between those factors.

## *EMPIRICAL VALIDITY*

In general, empirical validity (also referred to as *statistical* or *predictive* validity) describes how closely a measure corresponds with an external criterion measured in other contexts. It defines the relevance of a measure in terms of its observed correlation with some other measure of interest.

Specifically applied to the case of the N2C2M2, empirical validity refers to the extent to which the model suggests patterns or relationships that can be observed in the real world and the extent to which it behaves in a way that reflects observed behaviours.

## *EXPERT VALIDITY*

Expert validity (also referred to as *face validity*) is an estimate of the extent to which a model appears to adequately reflect the underlying construct, i.e., the extent to which the model appears credible to those (experts) who are knowledgeable in the field.

# **VALUE VIEW**

The C2 Conceptual Model consists of a Reference Model, a generic C2 process view and a value view reflecting the value chain from force and C2 characteristics to measures of effectiveness. The value view contains a subset of variables from the Reference Model and the relationships among them that collectively form a value chain for C2. Each of the variables is a measure of quality, performance, effectiveness, or value.

See also *C2 Conceptual Model*, *C2 Approach*, and *Process View*

## VERIFICATION

Process used to evaluate whether or not a product (e.g., a model or tool), service, or system complies with a regulation, specification, or conditions imposed at the start of the development phase.

Verification and validation is the process of checking that a product (e.g., a model or tool), service, or system meets specifications and fulfils its intended purpose.

See also *Validation*

# ACRONYMS

**ACCES**

Army Command and Control Evaluation System

**ACE**

Allied Command Europe

**ACLANT**

Allied Command Atlantic

**ACT**

Allied Command Transformation

**AGARD**

Advisory Group for Aerospace Research and Development

**BiSC**

Bi Strategic Commands

**C2**

Command and Control

**C2CRM**

Command and Control or C2 Conceptual Reference Model

**C2CoE**

Command and Control Centre of Excellence

**C2M2**

Command and Control Maturity Model

**C3**

Command, Control, and Communications

**C3I**

Command, Control, Communications, and Intelligence

**C4I**

Command, Control, Communications, Computers, and Intelligence

**CCRP**

Command and Control Research Program

**COBP**

Code of Best Practice

**COBP-C2A**

Code of Best Practice for C2 Assessment

**COBP-E**

Code of Best Practice for Experimentation

**DRG**

Defence Research Group

**ELICIT**

Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust

**EUCOM**

United Nations European Command

**HEAT**

Headquarters Effectiveness Assessment Tool

**HQ**

Headquarters

**IERs**

Information Exchange Requirements

**IFOR**

International Force

**IFRC**

International Federation of Red Cross and Red Crescent Societies

**ISTAR**

Intelligence, Surveillance, Target Acquisition, and Reconnaissance

**JTFHQ**

Joint Task Force Headquarters

**KFOR**

Kosovo Force

**M2**

Maturity Model

**MCP**

Mission Capability Package

**MoE**

Measures of Effectiveness

**MoM**

Measures of Merit

**N2C2M2**

NATO Network Enabled Capability Command and Control Maturity Model

**NATO**

North Atlantic Treaty Organisation

**NC3A**

NATO Consultation, Command, and Control Agency

**NC3B**

NATO Consultation, Command, and Control Board

**NCO**

Network Centric Operations

**NCSA**

NATO Communication and Information Systems Services Agency

**NCW**

Network Centric Warfare

**NEC**

Network Enabled Capability

**NEO**

Network Enabled Operations

**NGO**

Non Governmental Organisation

**NNEC**

NATO Network Enabled Capability

**OOTW**

Operations Other Than War

**OPFOR**

Opposing Force

**P2P**

Peer-to-Peer

**PCMR**

Probability of Correct Message Receipt (a communications-related metric)

**PfP**

Partnership for Peace

**PMESII**

Political, Military, Economic, Social, Infrastructure, Information

**PVO**

Private Voluntary Organisation

**R&D**

Research and Development

**RPD**

Recognition Primed Decision Making

**RTO**

Research and Technology Organisation

**SACT**

Supreme Allied Commander Transformation

**SAS**

Studies, Analysis, and Simulation

**SBCT**

Stryker Brigade Combat Team

**SDP**

Structure Development Plan

**SFOR**

Stabilisation Force

**SWAT**

Special Weapons and Tactics

**UAV**

Unmanned Aerial Vehicle

**UN**

United Nations

**UNJLC**

United Nations Joint Logistics Centre

**UNMIK**

United Nations Mission in Kosovo

**WISE**

Wargame Infrastructure and Simulation Environment

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# V

# Catalog of CCRP Publications

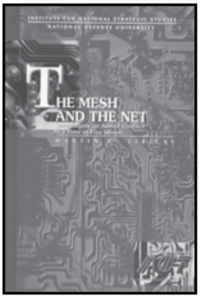
## Coalition Command and Control

*(Maurer, 1994)*


Peace operations differ in significant ways from traditional combat missions. As a result of these unique characteristics, command arrangements become far more complex. The stress on command and control arrangements and systems is further exacerbated by the mission's increased political sensitivity.

## The Mesh and the Net

*(Libicki, 1994)*

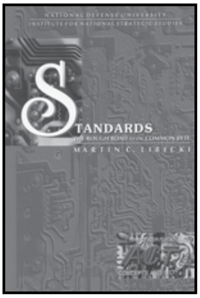



Considers the continuous revolution in information technology as it can be applied to warfare in terms of capturing more information (mesh) and how people and their machines can be connected (net).

## Command Arrangements for Peace Operations

*(Alberts & Hayes, 1995)*

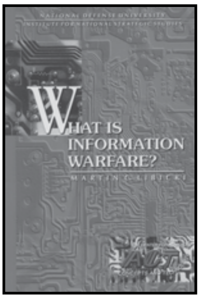

By almost any measure, the U.S. experience shows that traditional C2 concepts, approaches, and doctrine are not particularly well suited for peace operations. This book (1) explores the reasons for this, (2) examines alternative command arrangement approaches, and (3) describes the attributes of effective command arrangements.




## Standards: The Rough Road to the Common Byte

*(Libicki, 1995)*

The inability of computers to "talk" to one another is a major problem, especially for today's high technology military forces. This study by the Center for Advanced Command Concepts and Technology looks at the growing but confusing body of information technology standards.




## What Is Information Warfare?

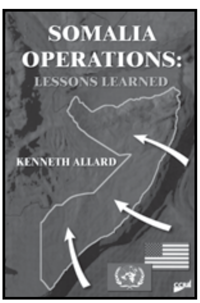
*(Libicki, 1995)*

Is Information Warfare a nascent, perhaps embryonic art, or simply the newest version of a time-honored feature of warfare? Is it a new form of conflict that owes its existence to the burgeoning global information infrastructure, or an old one whose origin lies in the wetware of the human brain but has been given new life by the Information Age?


## Operations Other Than War

*(Alberts & Hayes, 1995)*

This report documents the fourth in a series of workshops and roundtables organized by the INSS Center for Advanced Concepts and Technology (ACT). The workshop sought insights into the process of determining what technologies are required for OOTW. The group also examined the complexities of introducing relevant technologies and devices.



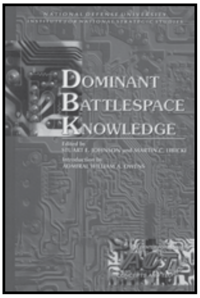

## Somalia Operations: Lessons Learned

*(Allard, 1995)*

This book is Colonel Allard's examination of the challenges and the successes of the U.S. peacekeeping mission to Somalia in 1992-1994. Key topics include planning, deployment, conduct of operations, and support.

## Dominant Battlespace Knowledge

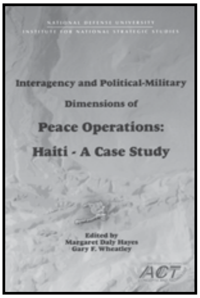
*(Johnson & Libicki, 1996)*




The papers collected here address the most critical aspects of that problem—to wit: If the United States develops the means to acquire dominant battlespace knowledge, how might that affect the way it goes to war, the circumstances under which force can and will be used, the purposes for its employment, and the resulting alterations of the global geomilitary environment?

## Interagency and Political-Military Dimensions of Peace Operations: Haiti - A Case Study

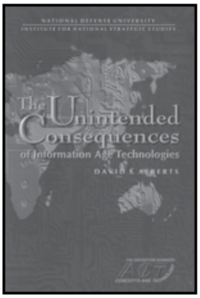
*(Hayes & Wheatley, 1996)*



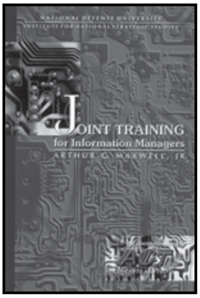

This report documents the fifth in a series of workshops and roundtables organized by the INSS Center for Advanced Concepts and Technology (ACT). Widely regarded as an operation that "went right," Haiti offered an opportunity to explore interagency relations in an operation close to home that had high visibility and a greater degree of interagency civilian-military coordination and planning than the other operations examined to date.

## The Unintended Consequences of the Information Age

*(Alberts, 1996)*



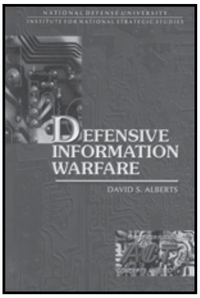

The purpose of this analysis is to identify a strategy for introducing and using Information Age technologies that accomplishes two things: first, the identification and avoidance of adverse unintended consequences associated with the introduction and utilization of information technologies; and second, the ability to recognize and capitalize on unexpected opportunities.




## Joint Training for Information Managers

*(Maxwell, 1996)*

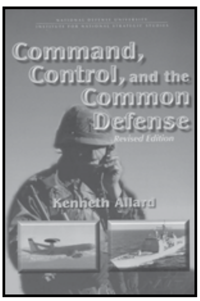
This book proposes new ideas about joint training for information managers over Command, Control, Communications, Computers, and Intelligence (C4I) tactical and strategic levels. It suggests a new way to approach the training of future communicators.




## Defensive Information Warfare

*(Alberts, 1996)*

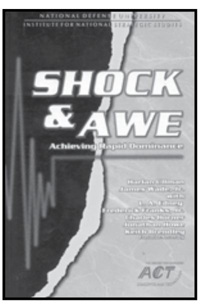
This overview of defensive information warfare is the result of an effort, undertaken at the request of the Deputy Secretary of Defense, to provide background material to participants in a series of interagency meetings to explore the nature of the problem and to identify areas of potential collaboration.




## Command, Control, and the Common Defense

*(Allard, 1996)*

The author provides an unparalleled basis for assessing where we are and were we must go if we are to solve the joint and combined command and control challenges facing the U.S. military as it transitions into the 21st century.



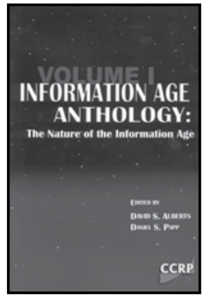

## Shock & Awe: Achieving Rapid Dominance

*(Ullman & Wade, 1996)*

The purpose of this book is to explore alternative concepts for structuring mission capability packages around which future U. S. military forces might be configured.

## Information Age Anthology: Volume I

*(Alberts & Papp, 1997)*




In this volume, we examine some of the broader issues of the Information Age: what the it is; how it affects commerce, business, and service; what it means for the government and the military; and how it affects international actors and the international system.

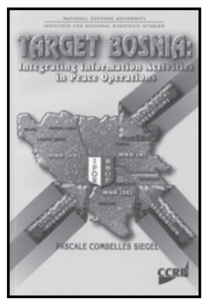
## Complexity, Global Politics, and National Security

*(Alberts & Czerwinski, 1997)*


The charge given by the President of the NDU and RAND leadership was threefold: (1) push the envelope; (2) emphasize the policy and strategic dimensions of national defense with the implications for complexity theory; and (3) get the best talent available in academe.

## Target Bosnia: Integrating Information Activities in Peace Operations

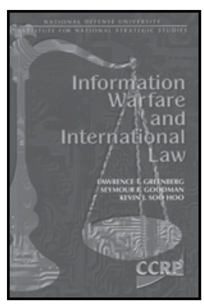
*(Siegel, 1998)*



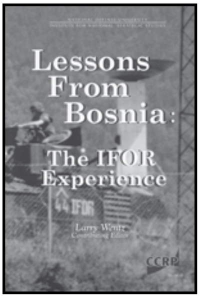

This book examines the place of PI and PSYOP in peace operations through the prism of NATO operations in Bosnia-Herzegovina.

## Information Warfare and International Law

*(Greenberg, Goodman, & Soo Hoo, 1998)*



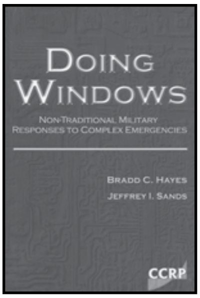

The authors have surfaced and explored some profound issues that will shape the legal context within which information warfare may be waged and national information power exerted in the coming years.




**Lessons From Bosnia: The IFOR Experience**

*(Wentz, 1998)*

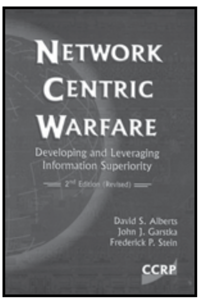
This book tells the story of the challenges faced and innovative actions taken by NATO and U.S. personnel to ensure that IFOR and Operation Joint Endeavor were military successes.




**Doing Windows: Non-Traditional Military Responses to Complex Emergencies**

*(Hayes & Sands, 1999)*

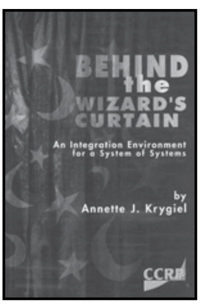
This book examines how military operations can support the long-term objective of achieving civil stability and durable peace in states embroiled in complex emergencies.




**Network Centric Warfare**

*(Alberts, Garstka, & Stein, 1999)*

It is hoped that this book will contribute to the preparations for NCW in two ways. First, by articulating the nature of the characteristics of Network Centric Warfare. Second, by suggesting a process for developing mission capability packages designed to transform NCW concepts into operational capabilities.



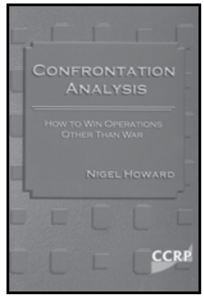

**Behind the Wizard's Curtain**

*(Krygiel, 1999)*

There is still much to do and more to learn and understand about developing and fielding an effective and durable infostructure as a foundation for the 21st century. Without successfully fielding systems of systems, we will not be able to implement emerging concepts in adaptive and agile C2, nor reap the benefits of NCW.

## Confrontation Analysis: How to Win Operations Other Than War

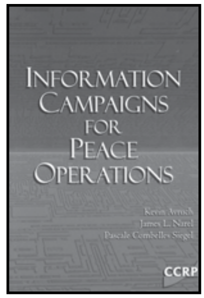
*(Howard, 1999)*




A peace operations campaign should be seen as a linked sequence of confrontations. The objective in each confrontation is to bring about certain "compliant" behavior on the part of other parties, until the campaign objective is reached.

## Information Campaigns for Peace Operations

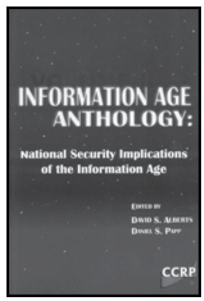
*(Avruch, Narel, & Siegel, 2000)*




In its broadest sense, this report asks whether the notion of struggles for control over information identifiable in situations of conflict also has relevance for situations of third-party conflict management for peace operations.

## Information Age Anthology: Volume II

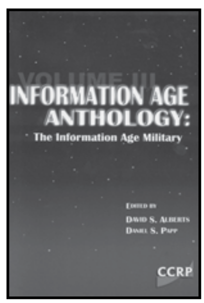
*(Alberts & Papp, 2000)*



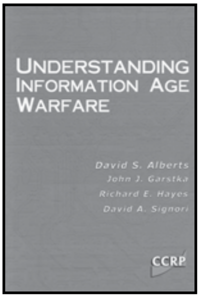

Is the Information Age bringing with it new challenges and threats, and if so, what are they? What dangers will these challenges and threats present? From where will they come? Is information warfare a reality?

## Information Age Anthology: Volume III

*(Alberts & Papp, 2001)*




In what ways will wars and the military that fight them be different in the Information Age than in earlier ages? What will this mean for the U.S. military? In this third volume of the Information Age Anthology, we turn finally to the task of exploring answers to these simply stated, but vexing questions that provided the impetus for the first two volumes of the Information Age Anthology.




## Understanding Information Age Warfare

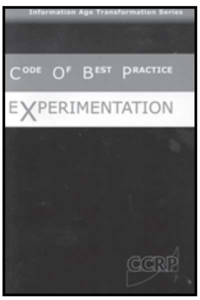
*(Alberts, Garstka, Hayes, & Signori, 2001)*

This book presents an alternative to the deterministic and linear strategies of the planning modernization that are now an artifact of the Industrial Age. The approach being advocated here begins with the premise that adaptation to the Information Age centers around the ability of an organization or an individual to utilize information.


## Information Age Transformation

*(Alberts, 2002)*

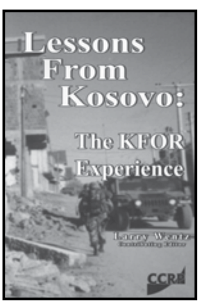
This book is the first in a new series of CCRP books that will focus on the Information Age transformation of the Department of Defense. Accordingly, it deals with the issues associated with a very large governmental institution, a set of formidable impediments, both internal and external, and the nature of the changes being brought about by Information Age concepts and technologies.




## Code of Best Practice for Experimentation

*(CCRP, 2002)*

Experimentation is the lynch pin in the DoD's strategy for transformation. Without a properly focused, well-balanced, rigorously designed, and expertly conducted program of experimentation, the DoD will not be able to take full advantage of the opportunities that Information Age concepts and technologies offer.



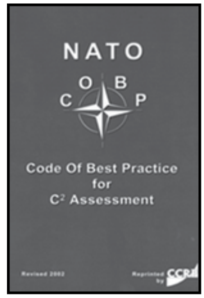

## Lessons From Kosovo: The KFOR Experience

*(Wentz, 2002)*

Kosovo offered another unique opportunity for CCRP to conduct additional coalition C4ISR-focused research in the areas of coalition command and control, civil-military cooperation, information assurance, C4ISR interoperability, and information operations.

## NATO Code of Best Practice for C2 Assessment

*(NATO SAS-026, 2002)*




To the extent that they can be achieved, significantly reduced levels of fog and friction offer an opportunity for the military to develop new concepts of operations, new organisational forms, and new approaches to command and control, as well as to the processes that support it. Analysts will be increasingly called upon to work in this new conceptual dimension in order to examine the impact of new information-related capabilities coupled with new ways of organising and operating.

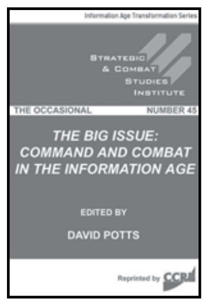
## Effects Based Operations

*(Smith, 2003)*

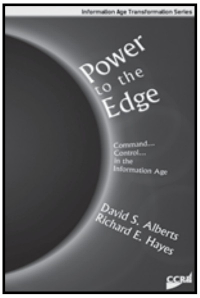

This third book of the Information Age Transformation Series speaks directly to what we are trying to accomplish on the "fields of battle" and argues for changes in the way we decide what effects we want to achieve and what means we will use to achieve them.

## The Big Issue

*(Potts, 2003)*



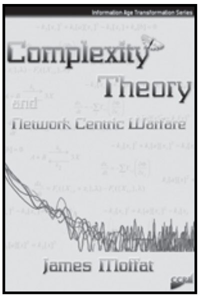

This Occasional considers command and combat in the Information Age. It is an issue that takes us into the realms of the unknown. Defence thinkers everywhere are searching forward for the science and alchemy that will deliver operational success.




**Power to the Edge: Command…Control… in the Information Age**

*(Alberts & Hayes, 2003)*

*Power to the Edge* articulates the principles being used to provide the ubiquitous network that people will trust and use, populate with information, and use to develop shared awareness, collaborate, and synchronize actions.




**Complexity Theory and Network Centric Warfare**

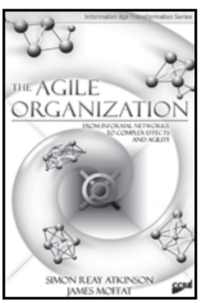
*(Moffat, 2003)*

Professor Moffat articulates the mathematical models that demonstrate the relationship between warfare and the emergent behaviour of complex natural systems, and calculate and assess the likely outcomes.


**Campaigns of Experimentation: Pathways to Innovation and Transformation**

*(Alberts & Hayes, 2005)*

In this follow-on to the Code of Best Practice for Experimentation, the concept of a campaign of experimentation is explored in detail. Key issues of discussion include planning, execution, achieving synergy, and avoiding common errors and pitfalls.



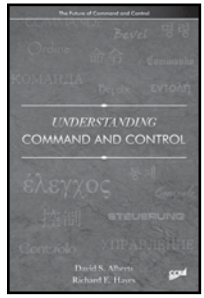

**The Agile Organization**

*(Atkinson & Moffat, 2005)*

This book contains observations, anecdotes, and historical vignettes illustrating how organizations and networks function and how the connections in nature, society, the sciences, and the military can be understood in order to create an agile organization.

### Understanding Command and Control

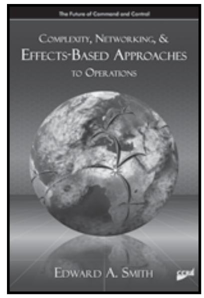
*(Alberts & Hayes, 2006)*




This is the first in a new series of books that will explore the future of Command and Control, including the definition of the words themselves. This book begins at the beginning: focusing on the problem(s) that Command and Control was designed (and has evolved) to solve.

### Complexity, Networking, and Effects-Based Approaches to Operations

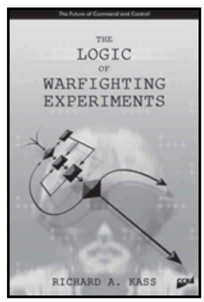
*(Smith, 2006)*




Ed Smith recounts his naval experiences and the complex problems he encountered that convinced him of the need for effects-based approaches and the improved infostructure needed to support them.

### The Logic of Warfighting Experiments

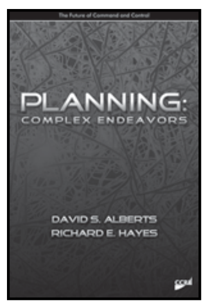
*(Kass, 2006)*




Experimentation has proven itself in science and technology, yielding dramatic advances. Robust experimentation methods from the sciences can be adapted and applied to military experimentation and will provide the foundation for continual advancement in military effectiveness.

### Planning: Complex Endeavors

*(Alberts & Hayes, 2007)*

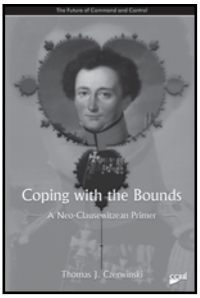



The purpose of this book is to present and explain an approach to planning that is appropriate for complex endeavors at a level of detail sufficient to formulate and conduct a campaign of experimentation to test, refine, and ultimately implement a new approach or set of approaches to planning.


## The International C2 Journal

*Established 2006*

The International C2 Journal is one of the latest CCRP endeavors. This internationally directed and peer reviewed publication presents articles written by authors from all over the world in many diverse fields of Command and Control such as systems, human factors, experimentation, and operations.




## Coping with the Bounds

*(Czerwinski, 2008)*

Originally published by NDU in 1998, the theme of this work is that conventional, or linear, analysis alone is not sufficient to cope with today's and tomorrow's problems, just as it was not capable of solving yesterday's. Its aim is to convince us to augment our efforts with nonlinear insights, and its hope is to provide a basic understanding of what that involves.