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C2 Agility: Next Steps

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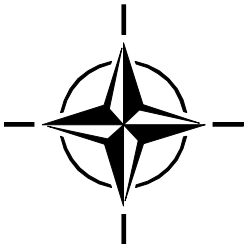
C2 Agility: Next Steps

NATO SAS-104: Final Report



C2 Agility: Next Steps

Executive Summary

This report contains an overview of the work conducted by the NATO SAS-104 from 2014 to 2017. This work followed the NATO SAS-085, which was dedicated to developing and testing Command and Control (C2) Agility theory. The core tenets of C2 Agility, as defined by NATO SAS-085, are:

- Agility is the capability to successfully effect, cope with, and/or exploit changes in circumstances;
- Given the differences between and amongst these mission challenges and the collections of entities needed to meet them, different approaches to C2 are required;
- There will also be times when an entity is engaged in a highly dynamic situation where the mission, and/or the circumstances will change and one's current C2 Approach will no longer be appropriate;
- Thus, entities also need to be able to dynamically transition from their current C2 Approach to a more appropriate one; that is, to manoeuvre in the C2 Approach Space.

The research conducted in NATO SAS-085 showed the potential and possible advantages of adopting C2 Agility through both experiments and case studies. The NATO SAS-104 was created in order to disseminate the knowledge that was created by the NATO SAS-085 and to continue working on remaining research questions, such as assessment of C2 Agility in various domains. The specific objectives of NATO SAS-104 were to (1) improve C2 Agility Awareness in NATO, (2) operationalize C2 Agility concept (bring the C2 Agility Theory into Practice), and, (3) to conduct further C2 Agility research and analysis.

NATO SAS-104 has assembled and collected evidence and research findings as they became known and available. Scientific and military publications that have used theories and concepts developed by NATO SAS-085 have been identified, as well as national research and development initiatives aimed to increase the knowledge about C2 Agility. This report describes eight new case studies on C2 Agility as well as research efforts on selected C2 Agility-related topics to put theory into practice and to develop C2 Agility assessment frameworks. Lastly, throughout the conduct of NATO SAS-104, an extensive body of knowledge was produced addressing theory, concepts, research, experimentation, education and training. It included a total of 3 books, 5 reports, 43 papers, 1 thesis, 4 working documents, 4 workshops, 6 courses to military officers and 6 keynote presentations.

The key findings from NATO SAS-104 can be summarized as follows:

- NATO SAS-104 confirmed the findings of NATO SAS-085 that agile C2 is required in a world characterised by increasing complexity, diverse operational contexts, and varying circumstances. It was also found that awareness of the need for increased agility in general and more C2 Agility in particular has become more widely appreciated;
- NATO SAS-104 found that increasing C2 Agility requires not only adaptations during the conduct of missions but also preparation beforehand to develop and practice a variety of approaches to C2 and the transition from one approach to another (i.e. manoeuvre in the C2 Approach Space);

- NATO SAS-104 concluded that the ability to observe, measure and assess C2 Agility is critical for mission success and that several countries are investing in the development and testing of assessment frameworks, methodologies, and metrics. Such frameworks are needed both for assessing if an entity or a collective of entities have requisite C2 agility, and in order to develop training and exercise programs for improving C2 agility. The ability to assess C2 agility is also needed from a scientific point of view to conduct experiments and studies of the effects of C2 agility;
- C2 Agility concepts have made significant gains in acceptance and organisations in several countries (e.g. GBR, NLD, AUS) are making efforts to translate these ideas into practice. These efforts are described in concept documents, reports, and scientific publications;
- While NATO SAS-104 found that C2 Agility concepts have become more widely understood, the actual adoption of these concepts lags behind. However, C2 Agility concepts and practices have entered the theory-to-practice pipeline in the forms of new concepts and doctrine and can be expected to transit through this pipeline to influence practice in the near future. There is also a need to develop C2 Agility further to better understand how it can be applied in the context of hybrid warfare involving non-kinetics environments such as cyber and information operations, and how C2 in these different arenas can be harmonized.

C2 Agility: Next Steps

Abstract

The Command and Control (C2) Agility Conceptual Model was developed in NATO SAS-085 to provide a principled approach to characterizing C2 Agility and C2 Maturity concepts introduced by NATO SAS-065. NATO SAS-104 was formed to create broader awareness of C2 Agility theory amongst the research and operational communities. Successful transition of C2 Agility theory into practice will improve NATO member nations and coalition partners' ability to be successful in the face of increasing mission uncertainty and complexity for a wide range of operations. The objectives of NATO SAS-104 were to (1) improve C2 Agility Awareness in NATO, (2) operationalize C2 Agility concept (bring the C2 Agility Theory into Practice), and, (3) to conduct further C2 Agility research and analysis. These objectives were achieved through the following interrelated initiatives: 1) dissemination and explanation of C2 Agility concepts and NATO SAS-085 findings and conclusions to the research and operational community, 2) continued evidence gathering through additional case studies and investigation of C2 Agility and 3) research on selected C2 Agility-related topics to put theory into practice and to develop C2 Agility assessment frameworks. NATO SAS-104 has observed that C2 Agility concepts have seen significant acceptance within the research and operational communities; however, the adoption and integration of C2 Agility theory into existing and future capabilities has just begun. The extensive body of knowledge addressing C2 Agility theory, concepts, research, experimentation, education and training that was produced and disseminated to the NATO partners is the contribution of NATO SAS-104 to reduce the existing gap between C2 theory and practice.

Keywords for NATO metadata

- Agility
- Command and control
- C2
- C2 Agility
- C2 Approach
- C2 Manoeuvre
- C2 Theory
- C2 Agility metrics
- C2 Doctrine

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List of Acronyms

IMEF	I Marine Expeditionary Force
AI	Artificial Intelligence
AFRIMS	Armed Forces Research Institute of Medical Sciences
AFSOC	Air Force Special Operations Command
ANFS	Afghan National Security Forces
ARC	Agile Response Capability
ARL	Army Research Laboratory
ASIC	All Source Intelligence Centre
BCT	Brigade Combat Team
C2	Command and Control
C2A	C2 Approach Agility
C2CRM	C2 Conceptual Reference Model
C2IS	C2 Information System
CAN	Canada
C4ISR	C2, Communications, Computer, Intelligence, Surveillance, and Reconnaissance
CCOMC	Comprehensive Crisis and Operations Management Centre
CDME	Collaborative Decision-Making Environments
CJTF	Combined Joint Task Force
COA	Courses of Action
COBP	Code of Best Practice
COP	Common Operational Picture
COPD	Comprehensive Operations Planning Directive

CPA	Coalition Provisional Authority
CSF	Combined Support Force
CSSE	Cyber Security Simulation Environment
DEU	Germany
DNK	Denmark
DRDC	Defence Research and Development Canada
DST	Defence Science and Technology
Dstl	Defence Science and Technology Laboratory
FC2	Future of Command and Control
FFC	Future Force Concept
FFI	Forsvarets forskningsinstitutt (Norwegian Defence Research Establishment)
FSS	Future Sky Safety
GBR	United Kingdom
HQ	Headquarter
HQMM	HQ Maturity Model
IA	Individual Adaptability
IHCM	Improving HQ Coordination Mechanisms
INI	Information Infrastructure
IRA	Irish Republican Army
IST	Information Systems Technology
JCN	Joint Concept Note
JFC	Joint Force Command
JIMP	Joint Interagency Multinational and Public
JSOTF	Joint Special Operations Task Force

LL	Lessons Learned
LNO	Liaison Officer
MiTT	Military Transition Team
MoE	Measure of Effectiveness
MoM	Measures of Merit
N2C2M2	NATO NEC C2 Maturity Model
NATO	North Atlantic Treaty Organization
NATO ACT	NATO Allied Command Transformation
NATO C2CoE	NATO C2 Centre of Excellence
NCW	Network Centric Warfare
NEC	Network Enabled Capability
NGO	None-Governmental Organisations
NLD	Netherlands
NML	NEC Maturity Level
NOR	Norway
OA	Organisational Adaptability
OCHA	Office for Coordination of Humanitarian Affairs
OPP	Operational Planning Process
PA	Project Arrangement
PIRA	Provisional Irish Republican Army
PRT	Portugal
QoI-SAN	Quality of Information- Semantically Adaptive Networks
RTG	Research Task Group
SACT	Supreme Allied Commander Transformation

SAS	System Analysis and Studies
SFAT	Security Assistance Force Teams
SJFHQ	Standing Joint Force HQ
SMARTNet	Semantically Managed Autonomous Resilient Tactical Networks
SOA	Service Oriented Architecture
SWE	Sweden
TEC	Tsunami Evaluation Coalition
UN	United Nations
UNDAC	UN Disaster Assessment and Coordination Team
UNITAF	Unified Task Force
USA	United States of America
WitIA	Warfare in the Information Age

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SAS-104 Membership List

During its 3 years of existence, SAS-104 has had the contribution of the following people:

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CHAPTER 1 – INTRODUCTION

Agility is a commonly used word that each of us has come to understand somewhat differently. This diversity of meanings may be problematic in a scientific context since progress in science requires observation, measurement, and replication. Therefore, some years ago, an international group of researchers convened in an attempt to operationalize the definition and measurement of agility in a military context so it could be systematically studied. This facilitated ensuing research and led to the formation of NATO SAS-065 [1] and SAS-085 [2] research task groups within the System Analysis and Studies (SAS) panel. Both of these groups made significant contributions to the development of Command and Control (C2) Agility Theory and the growing body of empirical evidence that supports a set of agility-related hypotheses.

The impetus and urgency of this interest in understanding and enhancing NATO and member nation agility was a result of:

- A recognition that our organisations, C2 approaches, processes, systems, and endeavours were designed, structured and operated in ways that were maladapted for a world that was increasing complex, dynamic, and uncertain;
- An inability to anticipate circumstances and predict outcomes that was leading to unsatisfactory results with greater frequency; and
- A posit that enhanced C2 Agility could lead to dramatic improvements in military operations.

Thus, agility was seen as an essential survival capability to deal adequately with complexity, dynamics, and uncertainty when addressing 21st century military challenges. C2-related failures have been attributed to many causes but are actually traceable to a systemic inability to adequately deal with complexity, dynamics, and uncertainty: in other words an agility deficit.

1.1 THE NEED FOR AGILITY IN TODAY'S OPERATIONAL CONTEXT

Today's and future operations span across a broad and diversified spectrum of conflict with highly dynamic, volatile and complex characteristics. The capability to manoeuvre between different C2 Approaches required by each kind of situation is critical to operational effectiveness, and sharpens requirements of the skills of individual operators and teams, mission resource management, leadership and decision-making, and overall unit performance.

Tomorrow's forces must be able to operate independently and with little support while still ensuring operational security and mission efficiency without risking excessive resource depletion. Deployed units can be described as "teams of teams", incorporating both human and artificial team members, widely scattered across the whole theatre of operations. They can operate autonomously for certain time periods and in specific areas, but they are mostly forced to coordinate their actions very accurately with one another. The turbulent environment in which these units operate stresses the need for agile capabilities in the broadest sense. This requires agile principles and concepts for C2 along with agile high-performance organisational and capability structures. New technology will offer extensive support to every phase of future military operations in distributed, dynamic mission environments; the potential of prospective high-capacity information collection and processing, artificial intelligence, robots, autonomy, and next-generation human-machine systems are yet to be fully exploited.

For a military force to be successful in future conflicts, highly capable situational understanding is required, with

the abilities of perception and interpretation of a particular situation in order to provide the context, insight and foresight required for effective decision-making, enabling every commander and operator to develop a comprehensive appreciation of the situation. The goal is to keep internal operations at a level of fluidity and flexibility that matches the degree of turmoil in external environments, a principle known as requisite variety [3]. This requires agile principles and concepts for leadership, decision rights and information distribution along with agile high-performance kinetic and non-kinetic capabilities.

Future military, counterterrorism and disaster management operations will often be complex, dynamic and highly interactive endeavours situated in a ”wicked” environment where adopting an approach appropriate for ”tame” problems might be, at least, misleading, and often counterproductive. It is therefore suggested that the first step towards an agile and adaptive force is to recognise and accept the complexity and ”wickedness” of the situation, and let go of the idea that it can be tamed and controlled. This requires a major shift in mindset, at the individual and organisational level, utilizing the new mindset as an enabler of agile and adaptive behaviour; the implementation of new methods, procedures or organisational structures would not be sustainable without this major shift in attitude. This, in turn, requires support from policy and doctrine, an organisational culture based on flexibility, openness to change and tolerance for error (learning culture), and an organisational design that supports and enhances such properties, rather than mortifying them (as is often the case). Agile and adaptive capabilities are valuable assets in any organisation and at any level of command.

Agile capabilities are currently being studied extensively in a multitude of organisations: Government, military, businesses, healthcare, emergency response, education, and aid organisations to name a few. All of them have in common the need for a strategy and vision for developing these capabilities, with a number of strategic elements:

1) Multiple perspectives and their successful management

- Multifunctional, multiorganisational and multinational interaction towards a common objective;
- Understanding of the situation’s driving forces and of one’s own role in the overall campaign, with all its stakeholders and resources;
- An ability to undertake missions and tasks in all environments, applying methods and procedures for planning and execution in the Endeavour Space;
- Working with temporary coalition partners in joint, interagency, multinational, public, and combined operations.

2) Reliable distributed systems and capabilities

- Systems, where human and artificial team and staff members are a vital part of an “edge organisation”. One capability of special interest is reliable distributed Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR), which requires a high degree of “edge computing”, i.e. local intelligence processing capability to provide data mining, data reduction, and reasoning from massive amounts of data. This requires designing and optimising highly reliable, secure, and power-efficient decision support with edge computing solutions;
- Decision-making and autonomy granted at local levels (edge organisation) necessary to effectively cope with the dynamics of the situation;
- Network-enabled capability enabling information exchange, shared situational awareness and self-synchronisation, when in a collective or coalition environment, to produce intended effects.

3) Adaptation and learning capabilities

- Adaptation in the context of this report includes the ability to perceive, understand and deal with change requirements under time-, risk- and resource-critical conditions. This enables the force to develop during ongoing operations through its mission agility against variations in environment, mission, organisation and resource availability;
- Analysis of performance and conclusions of experiences from ongoing and completed campaigns are translated into action. Unexpected irregular threats and events are tackled through critical thinking, comprehensive analysis, rapid testing and experiments to improve efficiency and shorten the time from discovery to implementation;
- The implementation of C2 Agility, its methods, procedures and organisational structures depend heavily on:
    - Adequate support at the policy level;
    - An organisational culture based on flexibility, openness to change and tolerance for error (learning culture); and
    - An organisational design that supports and enhances C2 Agility.

1.2 BASICS OF C2 AGILITY CONCEPT THEORY

SAS-085 defined agility as the capability to successfully effect, cope with, and/or exploit changes in circumstances [4]. Organisations, processes and individuals that possess agility are able to more effectively and efficiently bring to bear available resources in a timely manner in a variety of missions and circumstances. Systems and equipment that possess agility are able to successfully perform their tasks and function over a wider range of operating conditions.

SAS-085 was formed to improve our understanding of C2 Agility and assess its importance to NATO. SAS-085 accomplished these objectives by articulating the principles of C2 Agility, in the form of a C2 Agility Conceptual Model, substantially validating this model and establishing the importance of improving C2 Agility with empirical evidence obtained from a set of retrospective case studies and simulation-based experiments.

Further, SAS-085 identified a set of next steps towards practical implementation in NATO operations and priorities for increasing the rigor and practicality of methods for measuring and improving C2 Agility. Based on its retrospective case studies and simulation-based experiments, SAS-085 concluded that C2 Agility is a critical capability that should be pursued with urgency by NATO and its member nations, and that C2 Agility Theory has matured to the point where it can support practical efforts to improve operations.

It has been observed that the number of words describing something in a language relates to the importance attached to it. Eskimos reportedly have a large number of words for snow, each of which refers to a different kind of snow, a language that is nuanced enough to convey their reality. While the English language has a fairly large number of words that refer to agility or a lack of agility, dictionary definitions are not particularly useful in de-conflicting the various meanings of these agility-related words nor are they precise enough to guide systematic observation and measurement.

This section presents SAS-085's attempt to develop a language for agility that is complete and precise enough to enable scientific study and broad enough to be applied to many different kinds of 'entities' including organisations, individuals, processes, systems, and equipment as well as the ecosystems that consists of all of these. Understanding the meanings of these agility related terms is necessary to fully appreciate the findings,

conclusions, and recommendations of SAS-104.

Agility, as it is employed here, refers to the capability to operate successfully in what is referred to as an Endeavour Space. Endeavour Spaces are typically multidimensional with each dimension representing an aspect of the mission, task, or operating environment that present difficulties or challenges that if not met, will result in failure. Examples of these dimensions are uncertainty, risk and time pressure. Figure 1 depicts these sources of problem difficulty and the relationships between and amongst them.

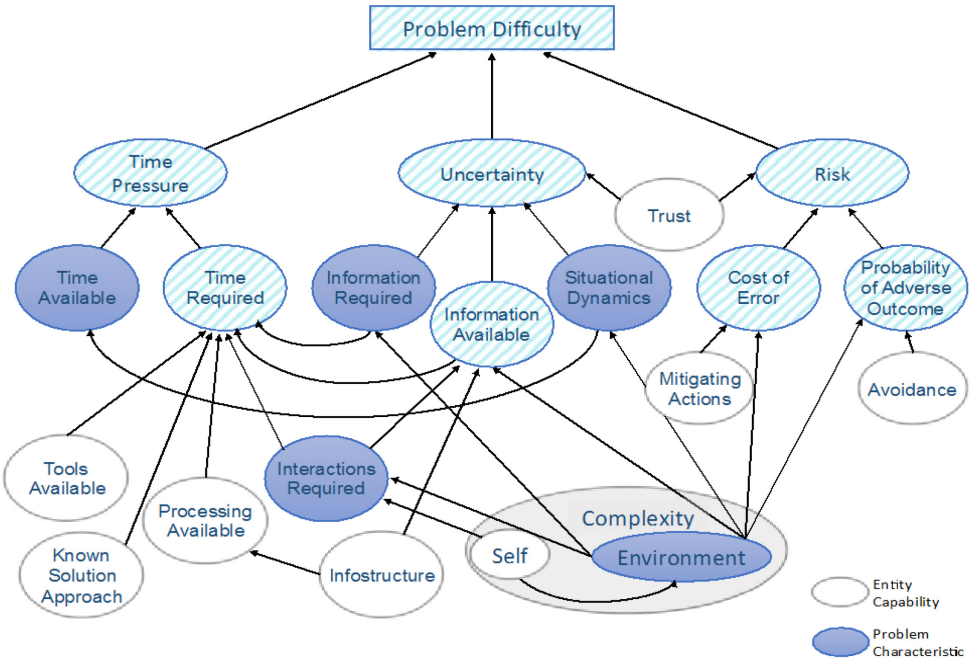

Figure 1: Selected Sources of Problem Difficulty [5]

The greater the region of the Endeavour Space where an entity can successfully operate, the more difficulties the entity can overcome and thus, the more agile the entity will require to be. The measure of agility employed by SAS-085 in its analyses is the proportion of the Endeavour Space where an entity can successfully operate. This measure is meaningful if and only if one constructs an appropriate Endeavour Space, one that reflects the complexity, dynamics, uncertainties, and risk associated with a wide spectrum of military operations. This, in turn, requires thinking about agility as the primary requirement rather than as a nice to have after the fact.

Traditionally, a military's approach to C2 has been designed and built to operate in a well-defined and understood region of this space (not over the entire space). The NATO Network Enabled Capability (NEC) C2 Maturity Model (N2C2M2) developed by the SAS-065 defined five increasingly network-enabled approaches to Collective C2: Conflicted C2, De-Conflicted C2, Coordinated C2, Collaborative C2 and Edge C2. Each one of these C2 Approaches can be categorized by how decision rights are allocated, how entities interact, and how information is distributed. Figure 2 depicts the C2 Approach Space as analysed by SAS-065.

Figure NATO NEC C2 Approaches

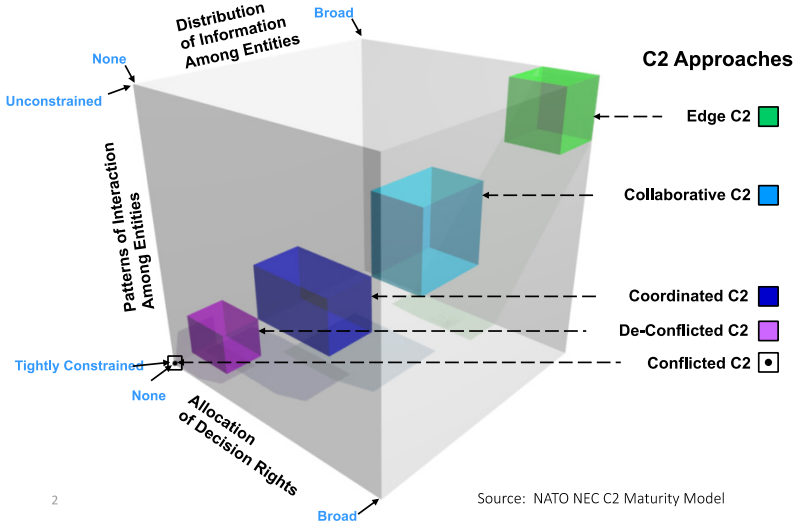

Figure 2: NATO SAS-065 C2 Approach Space [1]

SAS-065 also demonstrated the existence of a relation between the C2 Approach Space and the Endeavor Effectiveness. Building on the findings of SAS-065, SAS-085 demonstrated that, in order to succeed, appropriate C2 approaches should be adopted when facing the challenges posed by a particular mission and set of circumstances located in a specific part of the Endeavour Space [6]. For example, while De-Conflicted C2 may be appropriate for regular day-to-day operations, the complexity associated to situations such as natural disasters will require less constrained patterns of interaction, broaden distribution of information, and more flexible allocation of decision rights. Accordingly, particular missions and sets of circumstances may actually be located in different regions of the Endeavour Space. If the mission or set of circumstances change - so that it is now located in a different region of the Endeavour Space, the adopted C2 Approach might no longer be the most appropriate one and the entities facing the situation might need to adopt a different C2 Approach (see Figure 3).

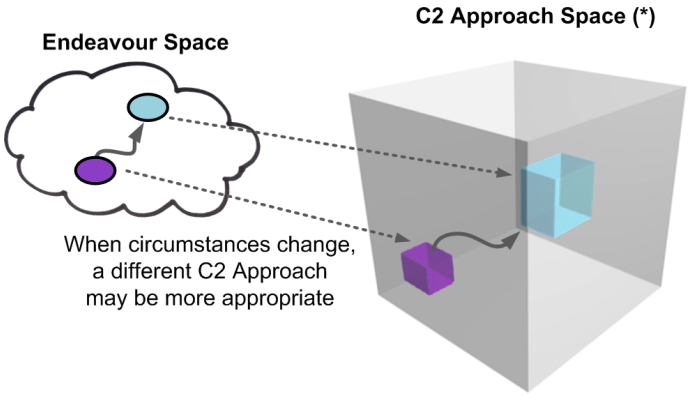

Figure 3: Change of C2 Approach [6]

This ability to change one's C2 Approach dynamically and appropriately as a function of the situation is referred to as C2 Manoeuvre. Figure 4 shows that entities that have more than one C2 Approach in their C2 toolkit can operate successfully in a greater proportion of the Endeavour Space than they would with fewer C2 Approach options. Then, the ability to adopt multiple C2 approaches has the potential to enhance an entity's agility. Accordingly, the capability to recognise the characteristics of a situation as well as to determine and timely adopt an appropriate approach to C2 (i.e. C2 Agility) must be considered a critical enabler of future mission success. Finally, the concept of C2 Maturity level [1], which was developed by SAS-065, relates to the different C2 Approaches that an entity can adopt (Figure 5).

$$\text{C2 Agility} = f(\text{C2 Approach Agility, C2 Maneuver Agility})$$

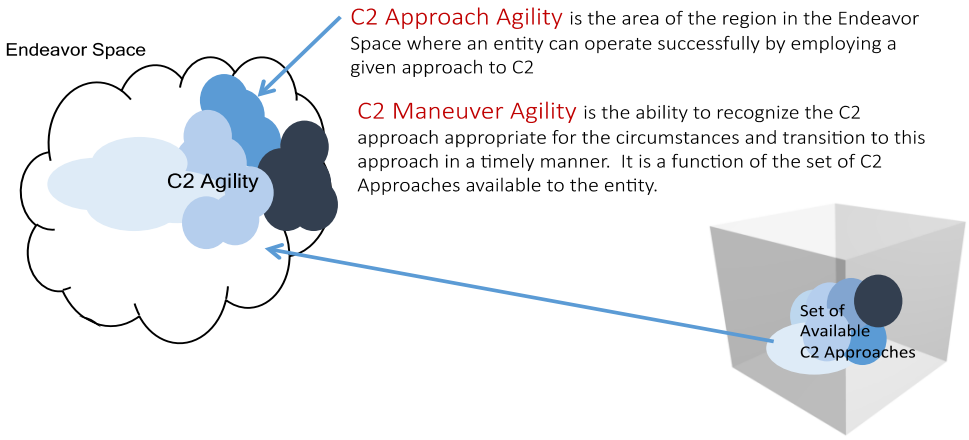

Figure 4: Agility Impact of Having Multiple Approaches to C2 [7]

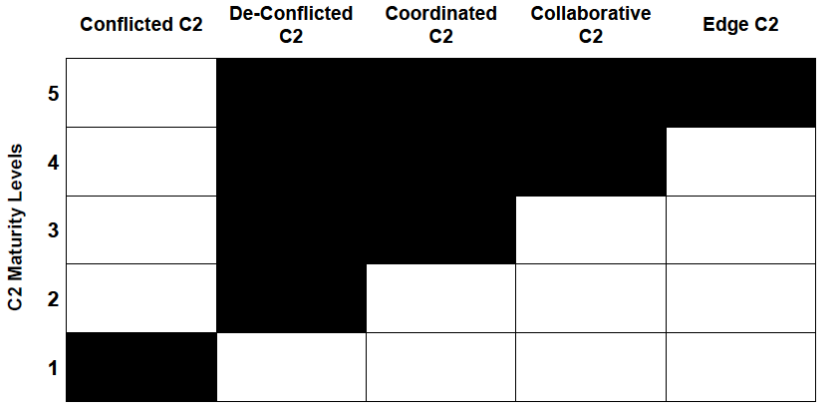

Figure 5: C2 Maturity and C2 Approaches [3]

1.3 AIM AND PURPOSE OF THE REPORT

This report contains an overview of the work conducted by the SAS-104 from 2014 to 2017. This work followed the SAS-085, which showed the potential and possible advantages of adopting C2 Agility through both experiments and case studies. While the work of previous NATO SAS groups (such as SAS-065 and SAS-085) made the scientific as well as the military community sensitive to the agility requirements from the C2 perspective, the operationalization of such a concept remained a challenge for military operations. Accordingly, NATO SAS decided to create the SAS-104 to invest additional efforts to transition the concept of C2 Agility into military reality. The specific objectives of SAS-104 are to:

- Improve C2 Agility Awareness in NATO;
- Operationalize C2 Agility concepts (bringing C2 Agility Theory into Practice); and
- Conduct further C2 Agility research and analysis.

The team of SAS-104, which evolves during its three (3) years of existence, involved the contribution of scientists and military practitioners from Canada (CAN), Denmark (DNK), Germany (DEU), Norway (NOR), Portugal (PRT), Sweden (SWE), Netherlands (NLD), United Kingdom (GBR), the United States of America (USA), NATO C2 Center of Excellence (NATO C2CoE) and NATO Allied Command Transformation (NATO ACT). Leveraging their expertise and national S&T/R&D programs, they spent the last three years exchanging ideas/results and working on mutual subjects of interest to develop evidence-based advice on how to adopt the most appropriate approach of C2 as a function of the mission and circumstances, as well as investigating C2 Agility capabilities facilitating the employment of more than only one approach to C2.

To achieve these objectives, SAS-104 divided its activities into three main areas:

- Dissemination and explanation of C2 Agility concepts;
- Gathering of evidence (e.g., through additional case studies and investigation of C2 Agility in the context of exercises, as feasible) to further validate the C2 Agility concepts; and
- Performing research on selected C2 Agility-related topics.

During the last three years, SAS-104 has assembled and collected evidence and research findings as they became known and available. These contributions to the literature and our body of knowledge have been largely in the form of either additional research into C2 related topics that have implications for Force or C2 Agility, case studies and experiments that have strengthened the empirical basis for the theory or educational and training material for the scientific as well as the military communities.

1.4 STRUCTURE OF THE DOCUMENT

Following the short background and motivation for the need of C2 Agility presented in this introduction, Chapter 2 contains summaries of a number of new case studies performed after SAS-085 to document additional evidence of C2 Agility in real situations. Results of investigations to advance the knowledge of C2 Agility concepts are presented in Chapter 3, while Chapter 4 describes different approaches to assess C2 Agility of organisations. Chapter 5 documents how SAS-104 explained and disseminated the knowledge about C2 Agility. Chapter 6 describes how the work conducted in SAS-085 has contributed to different national and international research efforts, in military as well as civilian contexts. Chapter 7 summaries and concludes the outcome of the various efforts presented in the report.

CHAPTER 2 – DOCUMENTING C2 AGILITY EVIDENCE

The NATO SAS-104 activities included the analysis of real-life situations in order to find out how agility of C2 has been contributing to the overall mission success. The section 2.1 presents eight (8) situations where evidence of C2 Agility was found, as well as an analysis of a small set of lessons learned from a C2 Agility perspective. Section 1.1.1 highlights the main findings of these case studies as well as some thoughts about the approach to take for the analysis of future case studies.

2.1 CASE STUDIES

2.1.1 Nelson at Trafalgar

In the mission Nelson at Trafalgar [2], senior British naval officers were well aware of the limitations of their tactics but had not yet conceived of an alternative that would overcome the limitations of their C2 system which, in turn, limited their tactical options. Nelson had been ruminating for several years on this C2 limitation and how to overcome it in order to bring about decisive action. He knew he needed a different tactical concept for decisive battle and an appropriate C2 Approach that supported it. Nelson's solution to the tactical problem was to try to cut the opponent's line into thirds by approaching perpendicular to it, in two columns, if possible from the windward. One column, which he would lead, would attempt to break the line by crossing in front of the French flagship, while the second, led by his second-in-command, would cross about a third of the way forward from the rear of the enemy's line. This would take the leading third of the combined fleet out of the battle for an extended period since it took a considerable time to turn back and join the fight. The enemy ships in the centre would be outnumbered and subject to rapid defeat at which time the rearmost third could be dispatched. Nelson hoped that by attacking the French flagship directly early, its ability to direct its own fleet would be crippled during its fight for survival. This concept required accepting great physical risk, particularly to the lead ships, but also risked a C2 breakdown in the confusion following the breaking of the enemy's line. Nelson knew this concept for decisive action could not be implemented using the customary centralized C2 from his flagship. His solution to the C2 problem was to organize his force and develop a battle concept so that minimal signalling would be necessary, and to take advantage of the superior experience, skill and initiative of his Captains. He relied on their understanding of his intent.

To ensure that understanding, Nelson had meetings with different groups of his Captains to discuss the new tactical concept and the critical role of individual initiative, while adhering to the overall concept. He wanted to ensure that as the battle developed each Captain would know what to do with his ship to best contribute to success of the concept without the need for signals. He followed up the meetings by putting the concept in writing for distribution to each ship's Captain. Nelson's concept accepted the uncertainties of the battle he intended to fight and his inability to exercise centralized control in the traditional way. He admitted that "nothing is sure in a sea fight beyond all others" and he relied on his Captains' initiative to adjust to circumstances by instructing "no Captain can do very wrong if he places his ship alongside that of the enemy". As a result, Nelson at Trafalgar was an operation with shared intent, an adequate level of shared awareness, and an appropriate approach to C2 which contributed to a successful end state.

2.1.2 1980 USA Hostage Rescue Mission (USA Embassy in Tehran, Iran)

On April 24, 1980, a military operation to rescue the 52 American hostages held in Tehran ended with eight USA servicemen dead and no hostages rescued. This rescue mission could be considered a C2 failure, a failure

that can be traced to a lack of shared intent and awareness. [2]

During the mission, a C-130 transport airplane heading towards Desert One, the designated rendezvous site encountered a large desert dust cloud, not a problem for the airplane, but potential a major threat to the helicopters following at a considerable distance. The pilot of the C-130 did not inform the pilots of the helicopters of this problematic situation because of the dictate of radio silence. While they had a secure satellite radio that could have used to issue a warning, they were not sufficiently familiar with the equipment to make it work. Thus, the helicopters proceeded into the dust where one had to abort because of a suspected equipment failure, two others prematurely landed including the group's leader.

The leader managed to make a secure call to a command centre and was told to proceed to the rendezvous point, but none of the other helicopters could hear this. The other helicopter that had landed prematurely was no longer in visual contact with the leader's helicopter and because of instruments indicating malfunctions made the decision to return to the aircraft carrier with all the spare parts. None of the helicopters were able to talk to those at the rendezvous point and thus were unaware that the landing site was clear. Later the pilot who returned to the carrier indicated that if he had known that he would have proceeded to the rendezvous point with the spare parts. The mission was cancelled after some other missteps and during the retreat one of the helicopters collided with one of the transport planes.

There were additional communication problems that contributed to a lack of shared intent and awareness. For example, the Army Rangers who were guarding the rendezvous site used radios that could not communicate with Delta Force or Air Force personnel, and those at the landing site could not talk to the helicopters. They were also unable to inform ground commanders in a timely manner when necessary.

In addition to these communications problems, there were a number of organisational and structural problems, namely inadequate stovepipes, no unified chain of command, and a lack of trust amongst the component forces that results in the approach to C2 being inappropriate for the nature of the mission, force, and circumstances. The lack of a unified chain of command would not have been a problem if sufficient shared intent and awareness was present. Thus, in this case, every C2-related component that made Trafalgar a success was absent and as a result, the mission failed.

2.1.3 Pakistan Earthquake 2005 and 2015

In 2005, an earthquake measuring 7.6 on the Richter scale hit northern Pakistan on the 8th of October (Annex B). The earthquake epicentre was located 100 km north-northeast of Islamabad, along a fault associated with the Indian subcontinent. In 2015, six months after the devastating earthquake in Nepal, a powerful earthquake once again hit the region. The earthquake occurred at 2:09 pm Pakistan time on the 26th of October 2015. The Pakistan Metrological department reported the magnitude of the earthquake as 8.1 (USA Geological Survey reports it at 7.5). The quake was 196 km (120 miles) deep and centred at 82 km (51 miles) south-east of Feyzabad in a remote area of Afghanistan in the Hindu Kush mountain range.

The purpose of this case study was to compare the October 2005 and October 2015 Pakistan Earthquakes in relation to the NATO NEC C2 Maturity Model (N2C2M2) and to see if lessons learned were applied. To verify the completeness of the considered features, this study also readdressed the list of C2 variables in the NATO C2 Conceptual Reference Model (C2CRM).

While Annex B provides more details on this case study, it is worth mentioning that a key aspect of the analysis conducted comparing the 2005 and 2015 earthquakes, was the ease to determine the C2 Approach categories

using the N2C2M2. Fundamentally, the use of cell phones to assist in the 2015 recovery effort was a good example of C2 Agility. The ability to exploit new technologies allowed a broader C2 Approach, and rapidly implementing this new capability was a good example of transitioning to a higher C2 Maturity level: in this case, transitioning from De-Conflicted C2 to Coordinated C2 in a short period of time.

In conclusion, the difference between the 2005 and 2015 Pakistan Earthquake was the ability of the Pakistan Government to rapidly move from Conflicted C2 to Coordinated C2 over the period of the recovery.

2.1.4 The Initial Response of the Thai Medical System in the 2004 Indian Ocean Tsunami

The Indian Ocean Tsunami of 2004/2005 is believed to have been the deadliest natural disaster in modern history (Annex C). Fanning across the Indian Ocean, the tsunami was triggered by a massive undersea earthquake that occurred on the morning of the 26$^{th\ of}$ September 2004 off the western coast of Northern Sumatra. It flooded coastal areas wiping away local infrastructures and killing over 227,000 and displacing 1.7 million people in 14 countries around the Indian Ocean. An analysis was conducted looking at the initial phase of the tsunami relief operations in Thailand as described in Annex B of the SAS-065 Tsunami report [3] which is based mainly on the information provided by an Israeli medical expert group that studied the operation [2]. The Thai Medical System, supported by Thai military's transportation assets in the initial relief operations were also considered by SAS-065 as an example of a high level of C2 Maturity and Agility.

The complexity of the first response to the tsunami in Thailand was rather modest compared to the complexity of the response in Aceh-Sumatra. In Thailand, based on the Civil Defense Act, the responsibility for relief operations as well as the control of available aid resources were well defined shortly after the tsunami had struck.

In Aceh, many of the local leaders had been killed and the lines of communication destroyed thus leaving it to local people to self-organize search and rescue activities. The military which was left was preoccupied with the Aceh-Sumatra Liberation Front mistrusted national none-governmental organisations (NGOs) which had no capability nor means to coordinate their efforts. Aceh was virtually isolated until a United Nations Disaster Assessment and Coordination Team (UNDAC) arrived two days after the disaster had struck to deploy and coordinate international aid, which, fuelled by the international media, had been arriving in numbers that quickly overwhelmed the UNDAC team's capability. Thus, in terms of the C2 Maturity model, the cooperation amongst the search and rescue/relief efforts of national and international governmental organisations and most NGOs in Aceh changed eventually from initially "conflicted" to "de-conflicted" and "coordinated" after the United Nations' (UN) Office for Coordination of Humanitarian Affairs (OCHA) had established a website in Indonesia to facilitate information-gathering and distribution of the situation and needs assessment [8].

The analysis of these case studies led to the following conclusions with regard to the relationship between C2 Maturity and Agility ([8], [2]):

- Entities/components having higher levels of C2 Maturity/Agility are able to adopt a more appropriate C2 Approach than entities/components that have lower levels of C2 Maturity;
- A more complex and dynamic mission and situation requires a higher level of C2 Maturity in order to succeed;
- To be able to adopt Edge C2 in response to a rapidly changing environment, an organisation must be able to rapidly form task clusters of small "hardened" teams by professional competence (i.e. being capable of self-synchronising such as the Thai Medical System);
- The connectivity and performance of supporting systems (organisations/teams) can constrain the adoption of

mature C2 Approaches, and hence, lower the effective maturity of entities.

Indirectly, these conclusions are reflected by the proposals of the Tsunami Evaluation Coalition (TEC) for a radical reform of the international disaster response that includes "de-complexing" large-scale disaster response operations essentially by having nations under risk of natural disasters to develop, to the degree possible, national structures for disaster response management and first response organisations and teams that are, in case of an emergency, reinforced by international capabilities on request to the UN's OCHA only [9].

2.1.5 Malaya-Singapore 1941-42

On the 8th of December 1941 the Imperial Japanese Army (consisting of the 18th and 5th Infantry Division, and the Imperial Guard Division led by General Tomoyuki Yamashita) invaded the Malaya Peninsular in their drive towards Singapore Island (Annex D). The Japanese ground troops had inferior weapons, equipment, and much smaller numbers than compared to the British-Indian Army garrison Singapore, and Malaya (9th and 11th Indian Infantry Division with 12th Indian Brigade in support. It was later reinforced with additional British and Commonwealth troops, all led by Lieutenant-General A. Percival).

The Japanese Army was well aware of its limitations, and consequently they implemented, for the period, a rather unorthodox approach to C2. The objective was to maximise the use of resources to create a bigger impact and increase the overall effect. Japanese Colonel and staff officer Masanobu Tsuji organised the attack forces into small self-contained units with tanks, light fire support and motorized infantry. The lines of communication were limited to the single main road in Malaya, and the plan focused on a single narrow but concentrated breakthrough. The forward unit commanders were given very broad allocations of decision rights. Junior officers could make important tactical decisions upfront and implement the decisions into the tactical plan at once. The different units had unconstrained patterns of interaction and sharing of information was broad. This was made possible by a concentrated use of the main road as the primary line of communication.

The British had a completely different approach to C2. They deployed in rigid lines vertically across the main road and well into the countryside on both flanks. This made the interaction between the units very constrained due to the distances and the difficult terrain. The British had centred their decision-making competence at the top of the Corps headquarters with very little to no allocation of decision rights to the junior leaders.

Consequently, the British-Indian Army suffered a defeat in Northern Malaya at Jitra and Gurun. Japanese success on land could not be stopped and on the 17th of February 1942 Singapore fell to the Imperial Japanese Army. The Japanese had won due to a more suitable approach to C2 given the circumstances.

2.1.6 Burma 1944

After the defeats of the early war, General Bill Slim knew that he had to transform the British-Indian 14th Army if they were to defeat the Japanese Army. General Slim decided to focus on the tactical level of the ground forces, and on C2 at the joint operational level (Annex D). On the tactical level, British and Indian soldiers were trained to make their own tactical decisions in order to respond rapidly and exploit the changing situation of combat. They also trained to cooperate with all arms: infantry, artillery, tanks, local scouts, intelligence units and air support.

On the operational level, General Slim increased the patterns of interaction with unconstrained cooperation between the air and ground element. This enabled new operational concepts such as air-ground fire support, air resupply operations, air-landing operations and air reconnaissance. Intelligence gathering and analysis were also

integrated on all levels.

The rigid lines of battle from World War I were thrown away and the new concept of fighting in a box formation was introduced. The new box concept enabled all units to operate all around 360 degrees. This greatly increased the effective use of resources due to very broad sharing of information and unconstrained patterns of interaction.

These new concepts were put to the test in 1944 during the second Arakan Offensive, the siege of Kohima and the battle at Imphal. The British-Indian 14th Army defeated the Japanese 15th Army and cleared the way for the liberation of Burma the following year.

2.1.7 Operation Banner: Northern Ireland Security Operations 1970's-1990's

When the British Army arrived in Northern Ireland in 1969, it was unprepared for the task ahead (Annex D). The Army had plenty of experience of counterinsurgency tactics from various post-colonial conflicts. However, the British Security Forces could not employ many of the former tactics in Northern Ireland. The terrain, both the human terrain as well as the physical terrain, was vastly different and the British rule of law applied to all operations.

This made the conflict very complex with several fundamental factors radically changing the current operational environment. The conflict was a political conflict requiring a political solution, but with the need for a stable security situation. There were several hostile armed groups on both sides with the Catholic Irish Republican Army (IRA) and the extremely militant Provisional Irish Republican Army (PIRA) as the worst threats. These groups used a mix of tactics from classical insurgency tactics to terrorist bombings and sectarian killings. There were also riots between non-militant Protestants and Catholics, which called for police riot tactics carried out by army units. The British Army also had to cooperate with unusual partners like the Police (they held the legal authority), Special Branch (police intelligence) and newly raised local territorial units, amongst others.

The British Army, together with the police and intelligence, developed radically during the duration of Operation Banner. The most active period was arguably during the 1970's and 1980's, and the British Army tried and adopted many new initiatives while discharging others. Two initiatives stand out as particularly effective:

- The Multiagency cooperation (particularly in the border region);
- Framework operations to target the PIRA's freedom of action. The framework operation included multiple infantry patrols in urban areas to counter hit-and-run attacks and a network of "watchtowers" across the province.

The framework operations and multiagency cooperation required a new approach to C2. Completely unconstrained patterns of interaction between various deployed Army units and between the Army and Police were essential. A broad sharing of information was vital for sharing actionable intelligence before it was obsolete. In order to act in a timely manner against opportunities a very broad allocation of decision rights was necessary.

The combination of the towers, covert observation posts, mobile checkpoints and multiple patrols were part of an effective framework operation. It put the PIRA in a most difficult situation. Due to the framework operations, it required more resources to mount attacks. The security forces had considerably reduced the opportunity to operate freely. Many attacks were prevented, and even if insurgents did attack, they took a great personal risk due to the Security Forces ability to detect and arrest the attacks.

The new concepts were in effect throughout the 1970's and 1980's. A steady decrease in violent attacks followed and in 1998 the Good Friday Agreement (a ceasefire agreement) was signed.

2.1.8 Operation Anaconda, Afghanistan 2002

Operation Anaconda was the USA Armed Forces' first major battle in Afghanistan on March 2nd, 2002 [10], [11]. It was a joint operation with land, air and Special Operations elements in a combined effort to destroy the Taliban and al-Qaeda's ability to wage major operations in Afghanistan, and to kill or capture key al-Qaeda members. The operation succeeded in crippling the ability of al-Qaeda and Taliban to conduct major operations, but failed in the capturing or killing of key al-Qaeda or Taliban members.

The operation has often been highlighted as an example of the high level of professionalism of the USA Armed Forces, but it is also an example of intelligence stove piping and an inappropriate C2 approach.

USA Airborne troops and Special Forces were inserted into the valley and encountered heavy resistance. At the same time, entrenched Taliban and al-Qaeda forces pushed the allied Afghan forces back.

On the first day, the operation ran into several severe problems. There was insufficient air support available, the air force had not appreciated the scale of the mission and Special Forces were conducting missions separate from the overall plan.

The initial C2 Approach was not suited for the mission. This led to the failure of the original plan. The main issues were a constrained pattern of interaction and a limited sharing of information between the component commanders and their respective staffs resulting in the deployment of an understrength ground force with insufficient air support. Once the nature of the heavy fighting became apparent, more air units were allocated together with C2 aircraft.

Broader allocation of decision rights were given to the tactical commanders directly involved in the fighting so they could adjust the force composition and plan according to the current tactical situation on the ground. The adjustment of the C2 Approach, and the force composition during the battle led to a much better integration of air, land and SOF. The decision to strengthen the staff (especially with the airborne C2 platform) and a more "joint" C2 Approach centred around the ground element. This overcame much of the initial C2 Approach issues. The USA force adopted a coordinated C2 Approach between day 2 and day 3. This approach was effective according to the mission demands, leading to a successful outcome (Annex D).

2.1.9 Agile C2 in Crisis Response Work during a Major Forest Fire in Sweden in 2014

This case study was funded by the Swedish Civil Contingencies Agency. The study was presented in a report [12] and is based on an analysis of an emergency response operation where the case study template developed by SAS-085 [6] was used to identify and collect evidence concerning the occurrence of agility and C2 Agility. The firefighting operation during the 2014 Västmanland forest fire [13], [14], [15] was used as the case study example as it involved a multitude of organisations responding to a forest fire that evolved in a rapid and complex way during rather extreme weather conditions in the Swedish context. This situation presented a challenge in terms of C2.

The analysis suggested that the unusual and challenging conditions of the forest fire prevented involved organisations reaching the appropriate C2 Approach during the initial phases of the firefighting operation. The analysis also highlighted the need to be prepared for response operations that are not commonly encountered.

This in turn demanded the ability of firefighters to scale up and create or activate C2 support functions such as a Common Operational Picture (COP) in order to achieve appropriate C2. The COP is an essential component to achieve the right C2 Approach but it was found insufficient or missing in this firefighting operation case study.

Using the SAS-085 case study template proved to be challenging when populating it with data from document sources that were written for purposes other than investigating C2 and C2 Agility. The difficulty was about discriminating facts of interest from the concepts of agility and C2 Agility perspectives. While challenging to do, viewing the handling of the firefighting operation during the forest fire in terms of agility and C2 Agility has been helpful as it has highlighted some limitations of the current approach to large scale firefighting operations.

2.1.10 Analysis of Canadian Armed Forces Lessons Learned

Unclassified Lessons Learned (LL) documents pertaining to six (6) Canadian Armed Forces (CAF) operations (three (3) domestics and three (3) expeditionary) were reviewed [16]. These operations included major events, disaster relief, and combat operations. The analysis of these LLs was conducted in order to highlight instances of manifested or potential agility. The result of this analysis demonstrated a link between operational agility and the dimensions of comprehensive approach, C2, doctrine, communications, training and preparation, and relationships. The implications of these findings for supporting and enabling the commander and staff to perform critical functions of lead, coordinate, plan and organize, direct, and control can be used to help identify key enablers in the development of future capabilities for defence and security organisations to become more efficient and agile. This study concluded that agility can be promoted and enabled when people [17]:

- Feel comfortable and confident in their roles and responsibilities (fostered through training and preparation);
- Know the boundaries within which they can operate (e.g., doctrine, rules of engagements);
- Have an understanding of mission partners and an opportunity to establish relationships with them;
- Have a clear sense of the direction and goal of the mission (commander's intent).

They need to be enabled and supported by the opportunity to be agile, amongst other aspects through a Mission Command philosophy, a climate of trust, and a clear C2 structure with appropriate delegation of authority. This analysis of LL was a good first step towards documenting the rationale behind the concept of operational agility as well as the identification of potential agility enablers.

2.2 MAIN FINDINGS

The review of the case studies confirmed the requirement of our organisations to be more agile in order to face the increasing complexity of possible situations. For example, the Japanese in the Malaya-Singapore case study demonstrated that the use of more suited C2 Approaches to the situation has led to mission success. The 2004 Indian Ocean Tsunami case study has also demonstrated that organisations with higher levels of C2 Maturity are more successful in adopting the most appropriate C2 Approaches to current situations. Moreover, the review of these cases studies showed the importance of integrating new ways of doing things (technologies, processes) in order to increase effectiveness (e.g. the use of cell phones assist in the recovery effort in the Pakistan Earthquake, or the new concept of fighting in a box formation in the Burma case study, or the combination of the towers, covert observation posts, mobile checkpoints and multiple patrols in Operation Banner). The ability to leverage from opportunities is a good example of transitioning to a higher C2 Maturity level, for example using new technology to transition from De-Conflicted C2 to Coordinated C2 in a short period of time. Finally, the need to change the C2 Approach during an operation has also been demonstrated in Operation Anaconda

(Afghanistan), as a leading enabler to a successful mission outcome.

An important aspect that has been identified in the case studies is the need to be prepared for response operations that are not commonly encountered. The forest fire in Sweden in 2014 analysis highlights that requirement in a context where multiple organisations under different chains of command have to contribute together in a context of crisis management. This is in line with the findings of the review of the lessons learned. Additional enablers of agility identified in the review of lessons learned from past operations includes having a good understanding of the boundaries of the operations, of the direction and goal of the mission as well as of the mission partners, which will be facilitated by the establishment of good relationships with those organisations.

Finally, the review of lessons learned is quite clear about the fact that to be agile, people need to have a good awareness of the situation, of the aim to be achieved and of the capacities available (theirs as well as the those of their partners).

As mentioned earlier, filling out different fields of the NATO SAS-085 C2 Agility template (Annex E) was often difficult. This was mainly due to the fact that, since the analysis has been done once the event was over, details were missing in the available post analysis documentation to identify the C2 Approaches being used during the operations. In an effort to facilitate the recording and assessment of C2 Agility of real-life cases, SAS-104 has modified the existing template as presented in Annex F. The information fields to be captured in the template proposed by NATO SAS-085 have been restructured, with the addition of fields to capture information about processes and technologies involved in the case study, as well as insights about potential C2 Agility vignettes. Furthermore, to facilitate the identification of the C2 Approaches in operations, reference information has been added to describe C2 Approaches accordingly to the variables of allocation of decision rights, patterns of interaction, distribution of information as well as on the C2 Tasks and Capabilities associated to each C2 Approach.

Chapter 3 – MOVING C2 AGILITY THEORY INTO PRACTICE

This chapter summarises the work of moving C2 Agility concept and theoretical constructs into practice. Much of this work was developed in a national context as well as in earlier RTGs, particularly SAS-085. While the advances have been made for a specific national or organisational context or scenario, they can quite easily be adopted to support the analysis and implementation of C2 Agility in other situations or contexts.

3.1 C2 BY DESIGN

Military planners are familiar with the concept of Operational Design and Mission Command. These concepts and to a limited extent their practice address the imperative of 'adapting' to changing situations. A major shortfall in the way these concepts are currently understood and applied is the lack of an explicit recognition that, along with plans, the approach to C2 needs to adapt as well. The "C2 by Design" handbook [18] was developed to fill this conceptual and doctrinal gap by providing an understanding of why C2 needs to be designed for specific missions and circumstances and how, within the context of existing practice (e.g. USA JP 5.0) this could be accomplished.

The document contains sections that introduce C2 Agility Theory, demonstrate how the planning process leads to an operational approach that can be leveraged to develop a corresponding and complementary C2 Approach, stress the importance of continuously assessing the appropriateness of the current C2 Approach, and discuss the way ahead to move C2 Agility from theory to practice. Appendices contain historical vignettes and a management tool that can be used by headquarters to ensure that C2 activities adequately support operations.

3.2 INTEGRATION OF C2 AGILITY CONCEPTS IN THE OPERATIONAL PLANNING PROCESS

While some of the concepts associated with C2 Agility are usually being considered during the planning of operations, they are not explicitly mentioned in the NATO Comprehensive Operations Planning Directive (COPD) or national Operational Planning Processes (OPP) such as in Canada. For example, the phase 3 (Operational Estimate/Mission Analysis) of the COPD at the strategic level requires the identification of the different actors contributing to the mission achievement as well as the expected level of interaction between them. The institutionalization of the C2 Agility concept into this step would put some emphasis to understand the different actors in terms of their level of C2 Maturity. The understanding of the C2 Maturity level of each organisation would permit the identification of different C2 Approaches that could be used during the operation. This knowledge can contribute to the optimization for mission success by identifying, for each phase of the mission, the best approach to be used in terms of distribution of information, patterns of interaction and allocation of decision rights. The need to change C2 Approach during the mission should then be considered in advance. The comparison of different Courses of Action (COAs) can also consider their C2 Agility by assessing the flexibility, adaptiveness, responsiveness, versatility, innovativeness and, resilience of each COA.

Finally, the C2 Agility theory has demonstrated the importance for an organisation to self-monitor the efficiency of its C2. To do so, indicators of C2 Agility should assess the efficiency of the distribution of information, the patterns of interaction and the allocation of decision rights. Those indicators should be identified during the Operations Assessment to assess if the C2 Approach in use is effective enough to achieve the commander's intent.

While some planners already consider these different aspects in the conduct of the planning of an operation, it is done in an opportunistic way. Accordingly, it is thought that C2 Agility should be integrated into the COPD as well as into operational doctrine, starting with AJP-5 [19] to formalize and establish the concept.

3.3 ORDERS OF C2 AGILITY AND IMPLICATIONS FOR C2 DECISIONS

The concept of order of C2 Agility is based on what is being adapted in response to changes (and also what types of change). This builds on the principle that agility is about change; however there are lots of different forms of change (corresponding with different forms of time) [20].

- 0-order C2 Agility: change action (react) in response to changes in environmental activity (sense-decide-react);
- 1-order C2 Agility: change course of action (e.g. defensive posture to attack posture) to match/balance environment;
- 2-order C2 Agility: change organisation and begin to adapt/reorganize in response to anticipated organized state of context;
- 3-order C2 Agility: change shape and nature of topology and principles to engage with changing relationships in context.

Different exhibitions of agility (involving the physical, computational, cognitive, social and political facets of the C2 organisations) can be put in perspective of different orders of agility. It was noted that orders of agility would better relate to the degree and form of time defining the feedback than to the levels in the command hierarchy.

Work is being pursued to build a meta-theory that can be used to frame and inform military understanding, planning and decision-making.

3.4 UNITED KINGDOM HEADQUARTER MATURITY MODEL

The NATO Conceptual Model of C2 Agility has been the basis for the development of the GBR HQ Maturity Model (HQMM). Ultimately the GBR seeks to understand what a 'good' HQ looks like, both now and in the future. The HQMM seeks to provide a common framework to develop and maintain HQ competence and effectiveness, and is currently being used as a pilot to assess the maturity of an operational level HQ.

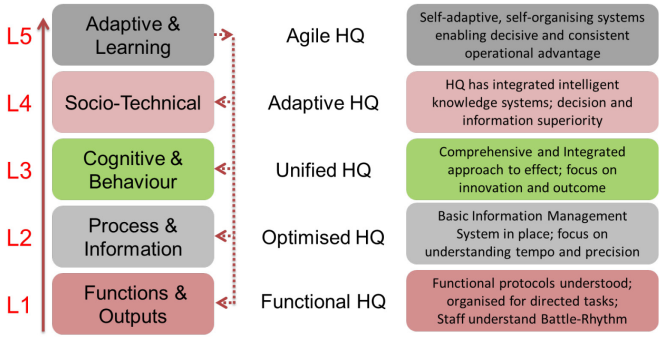

Figure 6: HQ Maturity Model

A maturity model is a performance measurement tool developed originally for the information system functions of commercial companies as part of an approach to improving performance. In this case the HQMM is specifically aimed at capability development and is aspirational in its focus, and it not intended as a tool for certifying whether HQs are operationally capable. Figure 6 shows the HQMM, which has five levels defined as a theoretical continuum along which a HQ may progress demonstrating an increasing level of effectiveness and competence.

The levels 1 to 5 within the maturity model have been developed from the C2 Approach Space model [3]. Version 1.0 has been incorporated into the GBR Joint Concept Note on Future of Command and Control. The GBR Defence Science and Technology Laboratory (Dstl) plans future work to increase the rigor and validity of the tool, and will issue updates in the future; indeed, there has been a recent GBR academic review that has suggested some significant changes to the HQMM; indeed, there has been a recent UK academic review that has suggested some significant changes to the HQMM.

3.5 NETFORCE COMMAND

The phenomenon of adapting C2 Approaches to be able to optimally address the situation at hand and the ability to switch between different approaches to C2 (i.e. C2 Agility), was extensively researched by NATO SAS-085 and SAS-104. An operationalization of Edge C2[1], NetForce, is currently the subject of research in the Dutch research program NetForce Command.[2] In this program, new command concepts including corresponding organisational concepts to explore the implementation of Edge C2 are being developed. NetForce is defined as the total collection of civilian and military capacities, nodes, interacting and collaborating with each other in a technical, social and organisational connected network of capacities and working towards achieving a common objective in an ecosystem. In the most extreme form the nodes in a NetForce synchronise their activities without being ordered to do so, aggregating and disaggregating in accordance with the demands of operational reality.

Hence, a NetForce is not a formal organisation with clear tasks, roles, functions, processes, procedures and structures, but a loose, fluid, temporary, and often, spontaneous coalition of military and civilian nodes.

A NetForce may have different appearances, varying from maximum self-synchronisation to maximum orchestration of the networked coalition. Maximum orchestration resembles the traditional hierarchical organisation. The scale is depicted in the Figure 7. As a consequence of the changing appearance the approach to C2 may change as well. Three typical variants of NetForce (archetype A, B and C) are studied (Figure 7). Archetype A can be placed in the upper right corner of Edge C2. Archetype C moves more towards Collaborative C2, with a lower degree of allocation of decision rights, more constraint patterns of interaction, but still with a broad distribution of information. This research will, amongst others research, provide insight into implications for C2 when operationalizing Edge C2, possibilities to operationalize self-synchronisation and insight into switching between Archetypes and corresponding C2 Approaches. The three NetForce archetypes are explained in more detail in Annex G.

[1] Alberts, Huber, & Moffat (2010) state: 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-synchronization.

[2] The objective of the research program NetForce Command is to develop operational, net-centric concepts for command, leadership, decision making, organization, collaboration, manoeuvre and information management and to aggregate these concepts in an integrated NetForce Command concept that provides the Dutch defense organisation the opportunity to contribute and operate effectively in future operations in a networked environment.

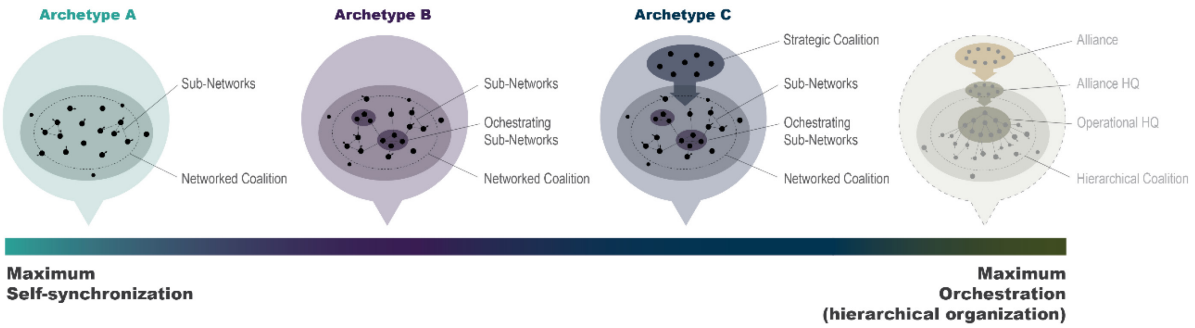

Figure 7: Scale from Maximum Self-synchronisation to Maximum Orchestration [21]

3.6 C2 MANOEUVRE IN CONTESTED ENVIRONMENTS

The USA Army Research Laboratory (ARL) has studied the problem of C2 Agility from the perspective of manoeuvring through several operating topologies in the presence of an adversarial entity attempting to affect the current C2 Approach. Given a finite set of C2 Approaches or network topologies, one is able to characterise resource costs of maintaining C2 links, adding new ones, and measuring the performance when operating at a particular C2 Approach (topology). This work includes network optimisation and game theoretical techniques that study network topology design within a set of policy-compliant topologies. Optimal C2 manoeuvre approaches are identified in response to the resources available to manoeuvre and also the strength of the adversary.

In this scenario, the designer aims to operate the network in an optimal topology within the set of policy compliant topologies with respect to a desired network property. Simultaneously, the adversary counters the designer trying to force operation in a suboptimal topology. Specifically, if the designer and the attacker choose the same link in the current topology to defend/grow and attack, respectively, then the latter is thwarted. However, if the defender does not correctly guess where the attacker is going to attack, and, hence, acts elsewhere, the topology reverts to the best policy-compliant configuration after a successful attack. ARL showed the existence of various mixed strategy equilibria in this game and systematically studied its structural properties. ARL studies the effect of parameters, such as the probability of a successful attack, and characterized the steady state behaviour of the underlying Markov chain. While the intuitive adversarial strategy here is to attack the most important links, the Nash equilibrium strategy is for the designer to defend the most crucial links and for the adversary to focus attack on the lesser crucial links [22]. Decentralized and evolutionary game approaches have also been considered under the overall topic of network protection and network growth games [23], [24], [25], [26], [27], [28], [29], [30]. The result of this ongoing work will provide insights into optimal C2 Approach over the finite-time horizon. This approach will maximize the performance of the organisation while considering costs to maintain or manoeuvre within the C2 Approach space in the presence of an adversary.

3.7 AI TECHNOLOGIES PERTINENT TO COMMAND CENTRES

Data and information coming into an Operational Command Centre has significantly grown over the past five years. It is estimated that 1-5 terabytes of data/information flows into and out of today's Command Centre

within a 24-hour period. The amount of time required for the operational staff to read, digest and act on this information is from hours to days; consequently, the Commander almost always has to make decisions with less than up-to-date information. Technologies supporting agile organisations will require reducing the analysis time and providing a better interface to the Commander. It is believed that the injection of Artificial Intelligence (AI) systems into the Command Centre could provide such support. Fully incorporating pertinent AI systems has the potential to reduce critical timelines to input, analyse, and communicate information (e.g., surveillance, exploitation, real-time feeds, etc.) from hours/days to seconds/minutes. AI can benefit the commander with respect to the "man-machine" interface. By inserting an AI interface between the "computers" and the Commander, this can provide a more natural language interface, which could be easier to "communicate" with. This concept is similar to Star Trek the Next Generation's "Mr. Data" or Apple's "Siri". Imagine the Commander just talking to the "Computer Interface" and having the requested information (with imagery, if required) returned within seconds or minutes? For example, if the Command Centre could capture and embrace the ever-changing C2 enterprise into an agile, intelligent C2 decision infrastructure; then, the Commander would have the capability to seamlessly integrate continuous planning, execution and assessment at all levels of command in near real time. This concept by using the "bubble" charts developed over the course of NATO SAS efforts from 2000-2010 as the underlying systems approach as well as a list of applicable technologies that can be used to inject AI into the Command Centre was presented in the 2016 ICCRTS [31].

3.8 MAIN FINDINGS

This section provides an overview of the research to put C2 Agility concepts into practice. C2 by Design supports military planners to design the best fitting approach to C2 taking the specific mission and circumstances into account. Also some suggestions are provided on how C2 Agility can be integrated in operational planning processes. From the premise that there are different forms of change, induced by the recognition of different forms of time, the C2 Agility theory can be broadened to recognise different orders of agility. The orders of agility may become a useful source of rigor in the design of C2 experiments, the formulation and exercise of simulations and the assessment of C2 capability. The GBR HQ Maturity Model is based upon C2 Agility concepts and seeks to provide a common framework to develop and maintain HQ competence and effectiveness. The NetForce concept provides insights into how to operationalize Edge C2 including challenges and promising concepts to overcome these challenges. Whilst experiencing the operationalization of Edge C2 (e.g. via simulation or gaming) this research will also provide insight into the underlying factors allowing to switch between different NetForce archetypes; in other words, to change the C2 Approach. This section concludes with two examples of technical concepts. The C2 Manoeuvre in contested environments provides insights on how to design and maintain a resilient network infrastructure that maximizes the performance of the organisation while considering costs to maintain C2 Agility. Furthermore AI technologies can be used to deal with the amount of data and information in current Command Centres. The overview provided in this section shows that initial steps are currently being taken to put C2 Agility into practice, however, the majority of work to integrate C2 Agility theory into current operations still lies ahead of us.

CHAPTER 4 – ASSESSING C2 AGILITY

The assessment of C2 Agility is a central and yet challenging issue. While the work of SAS-085 included a number of experiments and case studies, no direct method for the assessment of C2 Agility was developed. Some assessments of C2 Agility in different simulated environments were performed, but these relied on good experimental control, making them less useful for assessments in the field. Additionally, none of these attempts involved human research participants, but was done in agent-based simulations. A primary concern for SAS-104 has therefore been to develop and test methods for assessing C2 Agility in different contexts. As a part of this effort, the participating nations have initiated a number of activities, ranging from in-the-field data collection to simulator-based approaches. These efforts have resulted in several assessment methods, some applicable to field exercises, others useful for experimentation and developmental work. The different national efforts are presented below, consisting of studies from SWE, USA, GBR, and NLD.

4.1 EVALUATING AN ASSESSMENT TOOL INCLUDING C2 AGILITY COMPONENTS FOR THE SWEDISH NAVY

This work is part of a Swedish Defence Research Agency three-year research program, with the aim of developing new, and adapting existing approaches to assess agility in future naval operational C2, including identification of relevant measurable factors reflecting maritime agility and adaptability as well as finding valid and reliable methods for collecting data with respect to personal integrity, workload, security policy and other practical restrictions. In a series of naval exercises, different methodological approaches have been successively explored and developed [32]. The project includes C2 Agility, organisational adaptability and individual adaptability.

An exploratory study of these adaptability traits was undertaken during a naval exercise [33]. The exercise scenario was designed to progressively become more challenging, suggesting decreased performance and adaptability over time. The study objectives were to develop a data collection approach for agility and adaptability traits and to investigate the association between these traits and performance. An assessment instrument, in the form of a survey, was developed. The survey consisted of questions clustered into five themes, two for Organisational Adaptability (OA), one for C2 Approach Agility (C2A), one for Individual Adaptability (IA), and one for perceived performance. All questions were to be answered in a 7-degree Likert scale anchored at “1: not at all” and “7: to a very high degree” unless otherwise noted. Data collected from four command teams were evaluated in terms of response rate and item variation [32].

The results indicate acceptable survey response rates and trends showing a decrease in organisational adaptability and C2 Agility over time while individual adaptability increased. A possible explanation for the difference between individual and organisational trends might be the scenario design. Although the situation got more complex and challenging, the expectations of the different roles might have become clearer. The initial unclear but less threatening situation called for individuals to prepare and a wider set of options. As the situation became clearer individual commanders were able to focus on a few main tasks, associated with their roles, although the organisational level challenge was tougher. Another possible and somewhat overlapping explanation is training effect. As work procedures settles, role tasks become more routine and knowledge of details of the exercise scenario evolves even if the study design tried to address this issue by not collecting data during the first part of the exercise. Yet another possible explanation is respondent bias, as there might be a systematic difference in how one judges the organisational ability compared to how one judges one’s own abilities and challenges.

Although the initial results are promising, the instrument should be tested in other exercises before drawing too strong conclusions about its applicability.

4.2 A USA FRAMEWORK FOR SIMULATION AND MULTI-GENRE NETWORK EXPERIMENTATION TO ASSESS C2 AGILITY

ARL (USA) has developed infrastructure and relevant military scenarios for network emulation and simulation. The Network Science Research Laboratory at USA ARL was originally established to perform network emulation of tactical wireless networks. Recently, this work has expanded to model and test various multi-genre network experiments, which include C2 scenarios. One of such series of experiments has integrated simulation tools such as ELICIT and EMANE to provide the ability to model communications, information and social networks [34], [35]. This allows for experimentation of C2 scenarios and the impact of other network layers on the performance of the organisation. Recent studies [36], [37], [38] have investigated the impact of the network topology on various multigenre network layer measures of performance. Further, the experiments attempt to identify the correlation of these measures of performance. This work relates to a notion of Complex Network Agility [39]. The ARL experimental facility provides capabilities to test, validate and explore various C2 Agility concepts.

4.3 MEASURES OF MERIT

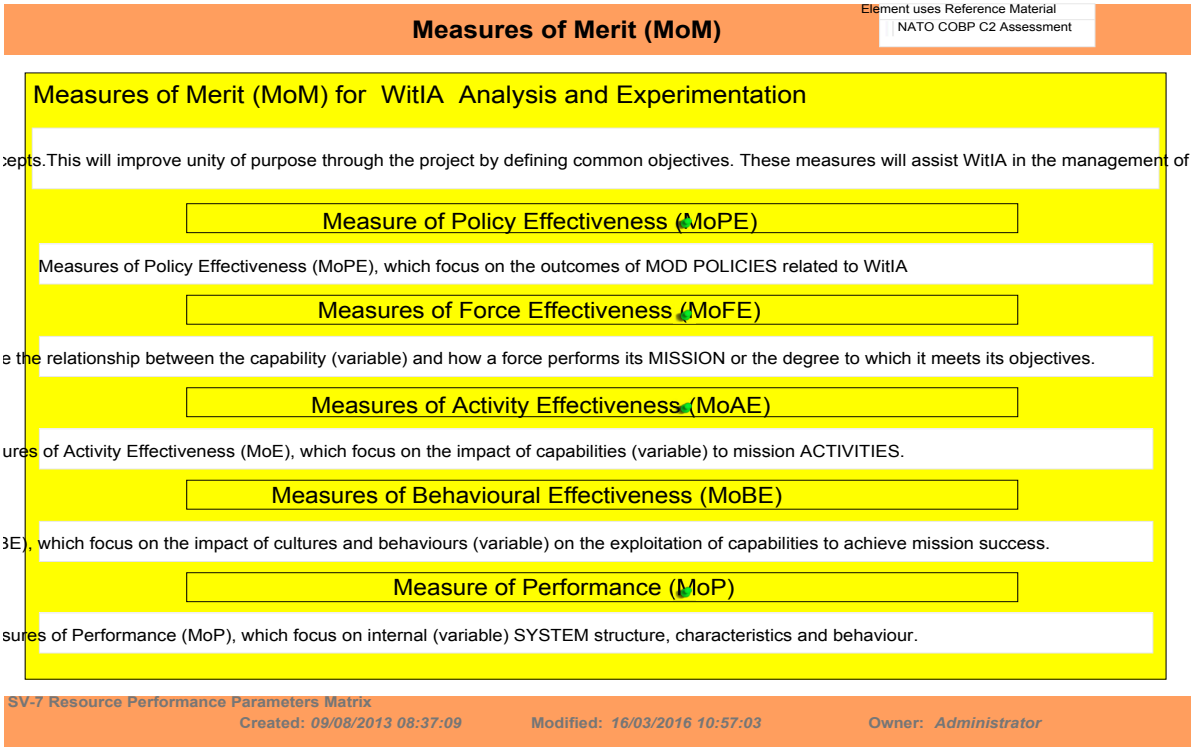

Figure 8: Measures of Merit [40]

The Dstl has developed a set of C2 Measures of Merit (MoM) based on the demands of Agile C2 in order to define and maintain a common set of key performance indicators and metrics to underpin experimentation activities. Many of the agility attributes are behavioural in nature and this was not apparent in the existing NATO Code of Best Practice for C2 Assessment (NATO COBP). The Dstl Warfare in the Information Age (WitIA) work has adapted the MoM to C2 Effectiveness into:

- C2 Activity Effectiveness (MoAE);
- C2 Behavioural Effectiveness (MoBE).

4.4 METRICS BASED ON C2CRM

The Improving HQ Coordination Mechanisms (IHCM) activity is taking observational and other data to assess the capability of the Standing Joint Force HQ (SJFHQ)'s coordination mechanisms (Battle Rhythm, various software packages, etc.) to aid its C2 functions and recommend potential improvements. Part of the work is developing various models and tools which provide insight and quantitative assessment of observations and recommendations. Whilst various traditional tools are available for the assessment of information flows, scheduling, etc. the IHCM work package proposes using the C2 Conceptual Model produced by the NATO SAS-050 group to evaluate less numerically quantifiable metrics and provide an academic basis for measuring the broader impact of improvements in HQ coordination. The final report from NATO SAS 050 [41] provides 309 variables and their linkages and we propose taking these, or a relevant subset, and using them as the basis for a benefits map or systems dynamics simulation. This work is ongoing.

4.5 COLLABORATIVE DECISION-MAKING ENVIRONMENTS (CDME)

Collaborative Decision-Making Environments (CDME) was sponsored by the GBR MOD, managed by Dstl and conducted by QinetiQ and Trimetis. The objective of CDME was to generate evidence and insights about collaboration in a C2 context, including its impact upon operational effectiveness and agility in complex circumstances. The aim of the CDME Experiment (7-9 February 2017) was to develop evidence for the most powerful and practical interventions that could increase effective collaboration (vice coordination) in a C2 context. Seventeen currently serving military officers (at SO1 and SO2 level) participated in the laboratory-based experiment, which used the C3Fire microworld to generate complex and dynamic challenges that could be addressed through collaboration.

Table 1: Collaborative C2 (no commander) vs Collaborative C2 (commander) [42]

Collaborative C2 (no commander)	Collaborative C2 (commander)
Two-level organisation with three teams, each led by a chief and with a distinct goal (lives, protect infrastructure, protect land).	Three-level organisation equivalent to the 'no commander' variant but with an overall commander who is given all three goals.
Command style is 'command by negation' (full mission command).	'Command by negation', as before.
Communications constrained to 'within teams' apart from chiefs, who also have their own radio net.	Communications constrained to 'across command group' (commander and chiefs) and 'across teams'.
Automatic sharing of unit status and fire picture information within, but not across, teams.	Automatic sharing of unit status and fire picture information across teams ('blue force tracker').

The CDME Experiment served to explore the impact of behavioural interventions, C2 structures/arrangements the level of challenge upon collaborative performance and effectiveness. Two C2 structural variants were developed for the experiment. Both map onto the SAS-085 definitions of Collaborative C2 yet differed slightly with respect to the three dimensions of the C2 Approach Space (see Table 1, Figure 9 and Figure 10). Different variants were developed to enable the experiment team to explore the impact of C2 structures and arrangements upon performance and effectiveness.

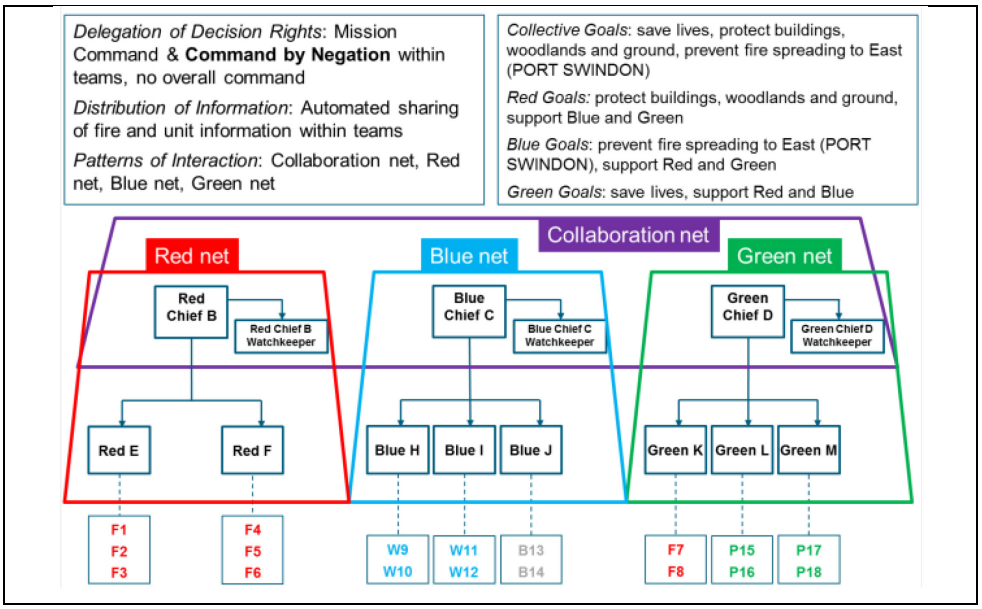

Figure 9: Collaborative C2, No Commander [42]

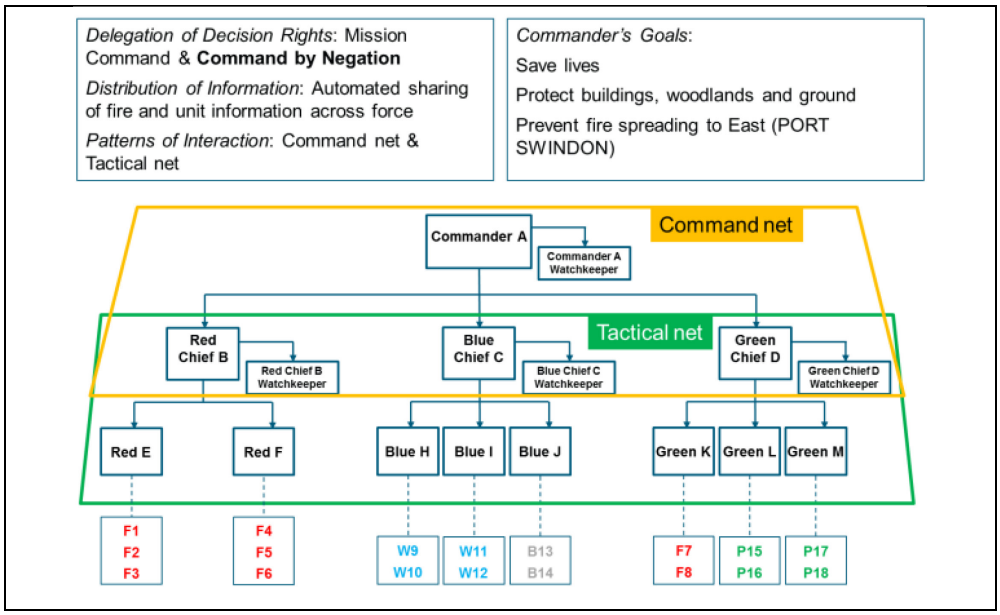

Figure 10: Collaborative C2, Commander [42]

The table below illustrates the experiment design. Note that C2 structural variants were adjusted alongside the two other key independent variables and the primary focus of the experiment was the impact of the behavioural interventions[3]. For the purposes of this discussion, Dstl was particularly interested in changes in effectiveness between Games 2 and 3; and between Games 5 and 6.

Table 2: CDME Experiment Design

Game (Condition)	C2 Structural Variant	Behavioural Intervention	Level of C3Fire Challenge
Training Game 4	Collaborative C2 (no commander)	None	Low
Game 1	Collaborative C2 (no commander)	None	Medium
Game 2	Collaborative C2 (no commander)	SFOR	Medium
Game 3	Collaborative C2 (commander)	SUCI	Medium
Game 4	Collaborative C2 (commander)	MTE	High
Game 5	Collaborative C2 (commander)	ANO	High
Game 6	Collaborative C2 (no commander)	None	Medium

Participants generally increased their performance throughout the series of games through innovation and learning. The number of distinct tactics developed per game started high and generally decreased as good tactics became normal practice. Performance did not always translate into effectiveness because the level of the challenge was increased (to drive collaboration). The table below summarizes results against five key Measure Of Effectiveness (MOEs) for those CDME Experiment games corresponding to the 'switch' between C2 variants.

Table 3: Summary MOEs by Selected Games

Game	C2 Structural Variant	Number of lives lost	Number of hospitals & schools destroyed	Number of houses destroyed	Area of ground lost	Fire Threat to neighbouring area
…		…	…	…	…	…
Game 2	Collaborative C2 (no commander)	0	0	17 (28.8%)	364 (21.7%)	0
Game 3	Collaborative C2 (commander)	0	0	6 (10.5%)	119 (7.1%)	0
…		…	…	…	…	…
Game 5	Collaborative C2 (commander)	13	0	3 (5.3%)	727 (43.2%)	1 (2.4%)
Game 6	Collaborative C2 (no commander)	24	0	24 (42.1%)	938 (55.8%)	1 (2.4%)

[3] The four interventions were Shared Frames of Reference (SFOR), Situation Understanding and Command Intent (SUCI), Making Thinking Explicit (MTI) and Anticipating Needs of Others (ANO).

Effectiveness, according to decreases in these measures, either remained the same or increased when the 'commander' variant was substituted for the 'no commander' variant between Games 2 and 3. This result suggests that the 'commander' variant, which afforded *greater freedoms* for patterns of interaction and provided *greater automated information sharing* (see Figure above), led to greater effectiveness *for the same level of challenge*. Observations of collaborative behaviours during the experiment indicated, however, that gains in effectiveness were also due to learning and innovation in tactics. Further, the relative and cumulative impact of the different behavioural interventions cannot be ruled out.

Effectiveness remained the same or decreased when the C2 structures reverted back to the 'no commander' (Game 5 to Game 6) even when the level of the challenge was also decreased. One possible explanation, corroborated by observations of collaborative behaviour during Game 6, is that participants were overconfident that the tactics they had developed for the more challenging games (under the 'commander' C2 variant) would be appropriate for the 'no commander' variant.

In summary:

- C2 'commander' structures that afford greater freedoms for patterns of interaction, and provide greater automated information sharing, are more effective; yet
- Effectiveness results from a wide range of factors, both structural and non-structural (e.g. degree of challenge, behavioural interventions and learning).

4.6 NETFORCE FRAMEWORK

In order to support a structured approach to knowledge development for concepts that support NetForce, a framework was developed [43]. This NetForce framework can be used to: 1) structure knowledge gained from desk research and literature reviews; 2) analyse real-world cases in order to identify weaknesses and threats; and 3) support the development and evaluation of new (NetForce) sub-concepts, like C2 Agility.

The NetForce framework (see Figure 11) consists of seven elements that need to be considered when analysing, developing and evaluating concepts. These seven elements are: 1) trends, 2) challenges, 3) objectives, 4) concepts, 5) contexts, including boundary conditions, 6) requirements, including preconditions, and 7) effects, including (potential) strengths and weaknesses.

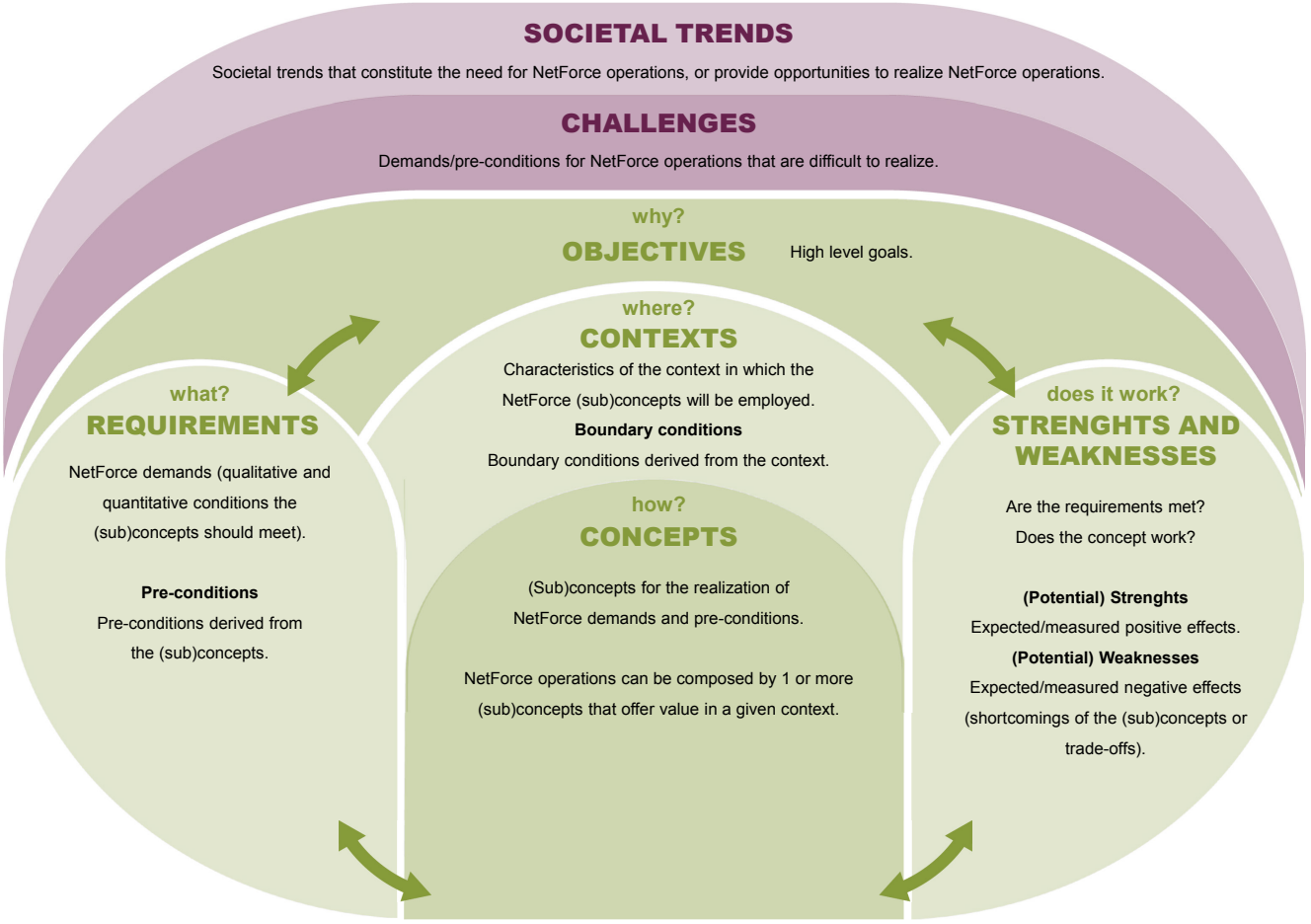

Figure 11: The NetForce framework [44]

To evaluate and assess new/existing concepts, this concept should be described in detail regarding the elements of the framework. Once the framework is filled, it becomes possible to identify 'paths or relations' through the framework to identify relations between e.g. objectives, requirements, (sub-)concepts and effects. Multiple hypotheses can be generated as to which aspects of a concept (e.g. aspects of C2 Agility) deliver the intended effects and fulfill intended objectives and which fail to do so. This will help to generate knowledge and creative solutions as to which concepts are potential promising approaches and how to evaluate and assess whether they actually are.

The framework has been applied in a case study of the 2008 terrorist attacks on Mumbai [43], as well as a case study on the introduction of community policing in the Netherlands.

4.7 MAIN FINDINGS

During the course of SAS-104, several attempts to create assessment instruments and frameworks for C2 Agility have been made by the participating nations. The Swedish efforts have led to a query-based assessment instrument tailored for naval conditions. The instrument has been field-tested at a major naval exercise and is judged to be a mature prototype at this stage. It is applicable for staff or command post work and reflects individual as well as organisational adaptability.

The USA (ARL) developed a framework for assessing C2 Agility in simulation and multi-genre network experimentation. This allows for experimentation of C2 scenarios and the impact of other network layers on the performance of the organisation. The experimental facility hosted by the ARL provides capabilities to test, validate and explore various C2 Agility concepts, with a specific focus on different network configurations.

GBR has worked on three different concepts, Measures of Merit (MoM), Measures based on the C2CRM, and Collaborative Decision-Making Environments (CDME). The Measures of Merit are being further developed by the WitIA work in an effort to support analysis and experimentation. The C2CRM has been proposed as a tool to find opportunities for improvements in the C2 functions, and especially coordination of these functions, of the Standing Joint Force HQ. Lastly, the GBR has utilized the C3Fire microworld as a tool for studying the performance of different C2 Approaches. The microworld allowed the researchers to compare performance of different organisational configurations facing scenarios of varying difficulty. In summary, the GBR has worked both with assessments that can be used to assess aspects of C2 Agility in actual staff work, and with performance of different C2 Approaches in a simulated environment.

The NetForce project in the Netherlands developed a framework based on seven elements that should be considered when analysing, developing and evaluating concepts related to C2 Approaches. The NetForce framework can be applied at several levels of detail - the main challenge is to unravel the complex, intertwined relations between objectives, requirements, (sub-)concepts and (potential) strengths and weaknesses. An initial version of the framework has been tested in two case studies. Currently, the NetForce framework is still being developed, specifically the mapping of concepts and how they relate to each other.

The work conducted during SAS-104 has created several promising ways of assessing C2 Agility in different domains. A large part of the instruments and frameworks have been presented in different scientific publications, in the form of reports, conference papers, and journal articles that are enumerated in Annex A. In terms of maturity, most of the assessment approaches need further validation, especially the approaches aiming to be used outside strictly experimental environments. Development of the assessment approaches is thus an ongoing process.

CHAPTER 5 – SHARING KNOWLEDGE ABOUT C2 AGILITY

During the time life of the project, SAS-104 has put an extended effort to share the knowledge that has been developed on the C2 Agility concept. Annex A gives an overview of the material that has been produced to better explain and disseminate C2 Agility knowledge. Effectively, a total of 3 books, 5 reports, 1 thesis, 4 working papers, 43 conference/journal papers were developed and published between 2013 and 2017. Furthermore, 6 keynote presentations describing the concept of C2 Agility have been presented to formal events such as NATO TIDE Sprints, Dstl C2 Symposium (GBR) and conferences (International Command and Control Research & Technology Symposium as well as NATO Operations Research and Analysis Conference). Furthermore, SAS-104 has contributed to the material and the presentation of 4 workshops/panels that were conducted with military operators and defence scientists from different counties (CAN, GBR, SWE, USA, etc.). Finally, 6 course materials were developed and presented in different military curriculum (CAN, DEN, GBR).

While all the products identified in the previous paragraph contribute to the documentation and dissemination of the C2 Agility knowledge, they are not the best mean to introduce the concept of C2 Agility in a few minutes. Consequently, SAS-104 has developed a C2 Agility Brochure, a C2 Agility Booklet as well as an Elevator Pitch which allow giving an idea of what C2 Agility is about. Furthermore, since illustrations of real-life case are often a lot more meaningful to a military audience than the description of a concept, a set of vignettes illustrating the link between C2 Agility and mission success have been developed. An overview of these vignettes is presented in the next section.

5.1 C2 AGILITY VIGNETTES

The “C2 by Design” handbook [18] was developed to help commanders and their staffs become successful practitioners of C2 Agility. The central point of the handbook is that a unique and tailored C2 Approach can and should be associated with every operational approach, and that a significant change in circumstances can and probably should necessitate a change to the C2 Approach. Appendix A to this handbook includes nine historical vignettes. Seven describe successful operations that depended on C2 Agility. Two describe operational failures that can be attributed, at least in part, to a lack of C2 Agility.

The vignettes were included in the handbook for four reasons. First, they illustrate that even before C2 Theory was articulated, C2 Agility has been manifested throughout history. Second, they are real-world examples of what C2 Agility looks like in practice. Third, they reinforce and support the logic of C2 Agility Theory. Fourth, they are easily remembered stories from which C2 Agility lessons learned can be drawn and applied in the future. The nine vignettes include:

- Nelson’s Victory at Trafalgar, 1805
- Battle of Britain, 1940
- UNITAF (Unified Task Force) in Somalia, 1993
- Joint Special Operations Task Force in Iraq, 2012
- Unity of Effort in Security Force Assistance Operations, 2001
- Brigade Counterinsurgency Assault, 2005
- The Battle of the Frontiers, 1914

- Joint Special Operations Air Component – Haiti, 2010
- Combined Joint Task Force 7 and the Coalition Provisional Authority – Iraq, 2003

Summaries from these vignettes, which were taken from the "C2 by Design" book **[2]**, follow.

5.1.1 Nelson's Victory at Trafalgar

"Nelson's ruminations (deep thinking) about how to achieve the objective of decisively defeating the combined French/Spanish fleets was akin to the design process. He understood the problem was not the opposing fleet as much as the standard approach to battle, which made decisive outcomes unlikely. His operational (in this case "tactical") approach was to abandon convention by adopting a radically different concept for manoeuvring his fleet. Once initiated, this approach to manoeuvre could not be executed successfully using the 'normal' C2 methods. Instead, Nelson conceived of C2 not dependent on signals from the command ship, but rather relying on command through intent."

5.1.2 Battle of Britain

"In order to achieve the overarching purpose of avoiding a ground invasion of Britain, the RAF devised a new operational approach for air defense. It also implemented a corresponding C2 Approach to allow varying degrees of centralized control over its newly created integrated air defense system. The C2 Approach was evident in a variety of newly created C2 activities, including reports provided to the Operations Center from radar facilities, ground observers, and radio intercepts; as well as developing predictions about where the attacking Germans were going to strike and passing them to subordinate units. The C2 Approach was also evident in the procedures used to determine which component of the air defense system would respond to an attack. C2 Agility enabled authority to be exercised as needed according to the circumstances, so that air controllers could vector aircraft towards incoming enemy aircraft, and then, when fighters were in visual contact, they could assume control of the engagement."

5.1.3 UNITAF (Unified Task Force) in Somalia

"By early January 1993, less than a month after entering Somalia from a cold start, I Marine Expeditionary Force (IMEF)/ Unified Task Force (UNITAF) had adapted its C2 Approach to align it with its operational approach and the realities of its environment, mission, and organisation. It had shed the C2 structure that was not needed and created a new structure that was needed. Further, it had incorporated coalition members of varying capabilities and had established relationships tailored to the entities involved (and to their various degrees of subordination). Upon recognising the need to establish linkages (relationships) and, if possible, communities of interest, with all the relevant external actors, including the clans that were the underlying cause of the crisis, it established those links. This led to the beginnings of a shared understanding of what was to happen (providing focus) and the necessary cooperation of all actors needed to achieve the limited objectives (enabling convergence). In summary, despite an extremely austere and initially hostile environment, IMEF's C2 Agility yielded an effective UNITAF in a very short time."

5.1.4 Joint Special Operations Task Force in Iraq

"General McChrystal realized he needed a new operational approach in order to defeat the enemy's network. His description of the changes to his C2 Approach illustrates the importance of thinking about C2 in a systematic way. This is because changes in one dimension often create the need to change in another dimension. In essence decentralization was needed to accelerate the pace of operations. But to achieve decentralization, collaboration

needed to improve and information flows needed to accelerate. This example also illustrates how the activities associated with a C2 Approach can morph and grow, one step often leading to another. For example, the linkages amongst all parties were at first linear, resulting in gaps or "blinks" in shared awareness. Over time, it became clear that merely establishing linkages was not sufficient, if the amount of information passed along the links was minimized. It was only by changing their activities, in this case by widely sharing the drone video, that shared awareness started to develop, which in turn led to even more intelligence-sharing with combat teams. Further, by continually assessing the results, and measuring how the increased C2 activity led to increases in operational tempo, precision and success, the Joint Special Operations Task Force (JSOTF) could definitively conclude that it was on the right track."

5.1.5 Unity of Effort in Security Force Assistance Operations

"In order to enable ground forces to build the capacity and capability of Iraqi and Afghan security forces, the Army created new types of units, the Military Transition Teams (MiTTs) and Security Assistance Force Teams (SFATs), but the operational approach and C2 Approach were not changed commensurately. This led to the friction Colonel Lillibridge had experienced in Iraq, where the lack of clarity on how to interact with battlespace owners, coupled with the seniority of the MiTT leadership, led them to exert authorities that were at cross-purposes with other units. Therefore, the Brigade Combat Team (BCT) devised an operational approach that maximized interaction between SFATs and the Afghan National Security Forces (ANSF), while enabling the BCT to take the lead for all other operational tasks and to participate in all combat operations. The new C2 Approach was tailored to support this operational approach in several key respects. First, it assigned authority to the battlespace owners for all missions, and gave them control over enablers provided by the coalition. Second, it restricted the authority of the SFATs, thereby removing conflict over who was in charge between them and the battlespace owners. Lastly, the C2 activities continually reinforced and supported the C2 Approach; for example, by commanders reiterating the ground rules as they circulated around the battlefield, and SFATs participating in operations only when their Afghan partner was present."

5.1.6 Brigade Counterinsurgency Assault, 2005

"The mission success of TF 3-504 was the result of the two differing operational approaches, and supporting C2 Approaches, that were chosen, effectively leveraging the aggressive actions and initiative of USA airborne infantry. Successfully transitioning from an assault operation based on companies to a distributed operation conducted by squads required a major change in the C2 Approach at a critical juncture. Prior planning enabled the task force to transition from a tightly controlled C2 Approach to one that allowed for decentralized decision-making and initiative. As authority was pushed down to the squad level, higher-level commanders retained authority over critical resources that could be directed to specific squads as needed. In addition, information (graphics and building numbers) was widely distributed, and flexible means were developed for adjusting decision rights, including prearranged firing rules and moveable boundaries between units, that helped prevent friendly-fire incidents. As a result, USA forces maintained a rapid operating tempo, achieving decisive outcomes while preventing the insurgents from exercising initiative."

5.1.7 The Battle of the Frontiers, 1914

"A C2 Approach optimized for mission-type orders given to each army was insufficient to support the operational approach that evolved, which required close coordination. And, lacking a C2 assessment process, German forces were unable to recognise this shortcoming in advance, or to adapt their C2 Approach to the conditions they encountered . Through careful analysis of the C2 implications of the Schlieffen Plan, they might have identified the desired information flows across armies, the expected collaboration between adjacent units,

and the need for decision rights to be assigned to an echelon with adequate situational awareness. This would have led them to select a different C2 Approach. Then, they could have noted, perhaps in an exercise, that their activities did not match the approach; for example, because one unit's alterations to a planned manoeuvring were not communicated to other units, or because decisions were not reached in a timely manner. In addition, since the approach required changes to communication linkages amongst German army headquarters and armies, it would have been reasonable to assess whether those linkages were in place and effective.

The above analysis points to the need to ensure C2 Agility in advance of an operation. This is because mistakes will certainly be made, unexpected events will occur, and circumstances will change. One of the most quoted axioms along these lines, that "no plan survives first contact with the enemy," is attributed to von Moltke, the Elder (1800-1891), who was the uncle of the senior German commander in this battle. Given this insight, it is reasonable to assess whether the German headquarters and field commanders were sufficiently agile in the face of change. Collective agility was required because the situation was complex and thus could not be decomposed into independent parts. In fact, individual agility in the absence of shared awareness was a cause of the ultimate German failure in the Battle of the Frontiers."

5.1.8 Joint Special Operations Air Component, Haiti

"Though specifically organized, trained and equipped to respond globally to emerging combat crises, the Air Commandos of the 1st Special Operations Group demonstrated exceptional agility throughout their support of the 2010 Haiti earthquake international relief effort. Despite limited connectivity and a fragmented group of international support agencies, Colonel Elton adjusted his C2 method throughout the operation to match ever-evolving circumstances. Though he stated they were "uniquely prepared" for this event as a result of their recently concluded exercise, the very nature of that exercise is proof positive that a force can effectively train with agility in mind. Their success was further enabled by the authority to execute distributed operations starting from the Air Force Special Operations Command (AFSOC) Commander's simple guidance to "do good" and translated down to the lowest subordinate as "Assume you have the authority to do the right thing." The unit was able to adjust their organisation to accommodate the needs of a robust Liaison Officer (LNO) network and adapt to learning new ways of conducting missions in light of the constraints applied throughout the operation. Throughout, Colonel Elton demonstrated the importance of being proactive in approaching C2 by adjusting not only delegated authorities, but also adjusting the organisation and activities of his military network within the context of the overall international relief effort."

5.1.9 Combined Joint Task Force 7 and the Coalition Provisional Authority, Iraq

"Many of the difficulties encountered during the first year of coalition stability operations in Iraq can be traced to a flawed C2 Approach. It was flawed because little attention was given to what was required and the C2 arrangements decided upon were essentially an afterthought. Clearly, there was no design process nor was there an operational approach around which a supportive C2 Approach might have emerged. Moreover, even the flawed C2 Approach was hampered by lack of institutional support to meet the minimum staffing needs of both the Coalition Provisional Authority (CPA) and the Combined Joint Task Force 7 (CJTF-7) or to improve the C2 arrangements. It is probable that had some process like operational design been applied, a clearer operational approach would have been developed that led naturally to an appropriate C2 Approach, one that could support the operational approach. At a minimum, such a planning process could have helped CJTF-7 make a stronger case for a change in the C2 Approach, thereby accelerating the eventual adaptation to what was actually needed for successful operations. What is certain is that, necessary attention to and structured thinking about C2 obviously were missing when they were sorely needed."

Chapter 6 – IMPACT OF C2 AGILITY CONCEPTS

Several national research and development programs have built upon the work conducted by NATO C2 Agility research groups, derived key insights or knowledge from this work, or been influenced and informed by it. Some national military communities have begun to move from theory to practice, although with different levels of effort and focus. Given differences in national security and defence contexts, national priorities, the role of the military in national crisis response, culture and a wealth of other factors, the national approaches to utilizing the insights of NATO C2 Agility research are not identical nor conducted completely along the same lines. Despite this, this research holds a special place as a common base of knowledge, a provider of a common lexicon and in general a well-founded and consistent starting point for further research. This chapter describes national research and development efforts, work conducted by military communities, and international activities which have been influenced by NATO C2 Agility research.

6.1 NATIONAL RESEARCH AND DEVELOPMENT EFFORTS

The national R&D efforts of CAN, GBR, NLD, NOR, SWE, and USA are presented below.

6.1.1 Canada (CAN)

Defence Research and Development Canada (DRDC) has been contributing to the initial activities of NATO SAS C2 Agility since the beginning. The Canadian contributions leveraged the DRDC work conducted on systems of systems complexity, socio-technical C2 systems of the different military environments, as well as on human dimension of C2. Results of research activities conducted inside the NATO SAS RTG on C2 directly influenced the definition of the C2 Canadian Armed Forces of Tomorrow from the C2/CIS program by recognising, as an immediate outcome, the ability of the commander to achieve common intent, inspire, motivate, build relationships and trust at all levels, engage when and where needed, balance risks and opportunities, and make rapid, effective decisions with a comprehensive understanding of mission assurance. The C2 Agility work which provides a better understanding of the strength and weaknesses of different C2 Approaches contributed to sensitize the Canadian S&T community to the requirement of being able to identify the enablers of rapid and effective decisions and on how these enablers can be implemented from different dimensions (doctrine, processes, training, and systems).

6.1.2 United Kingdom (GBR)

GBR considers that continuing to practice traditional C2 Approaches will increase the likelihood of operational failure in the future. This narrative is generally accepted by GBR as a hypothesis, but research seeks to understand how the approach to C2 and the changing nature of conflict are related.

Some examples of ongoing activities are:

- Joint Force Command (JFC) / Dstl Warfare in the Information Age Programme (WitIA);
- GBR Future Force Concept (FFC);
- Joint Concept Note (JCN) on Future of Command and Control;
- GBR HQ Maturity Model;
- Measures Of Merit (MoM);

- Improving HQ Coordination Mechanisms (IHCM);
- Additionally, GBR fund PhDs, one of which is investigating the relationship between the environmental context and the approach to C2.

The NATO C2 Agility work has been central and fundamental to the WitIA programme, which has heavily influenced the GBR Future Force Concept (FFC) [45] and the GBR Future of C2 Joint Concept Note (JCN) [46] (see section 6.3.5.3).

WitIA analysis demands an Information Age response in proposing that the key to maintaining a competitive operational advantage in complex and uncertain operations will be deploying military capabilities as part of a coordinated approach working seamlessly with government, non-government and international partners exploiting all the levers of power (economic, diplomatic and military) in a coordinated manner as part of a coherent, multinational strategic narrative aiming to deliver a clear political outcome. The military contribution to this effort involves delivering full spectrum effect in a coordinated and agile manner across the physical, virtual and cognitive domains. A definition of agility has been adapted from the work of NATO SAS-085 by adding the words 'missions and' as follows:

Agility is the capability to successfully effect, cope with, and/or

exploit changes in missions and circumstances. [6]

Agility should be (adapted from Alberts & Hayes [47]):

- Resilient - Able to recover from or adjust to misfortune, damage, or a destabilizing perturbation in the environment;
- Responsive - Able to react to a change in the environment in a timely manner;
- Versatile - Able to maintain effectiveness across a range of tasks, situations, and conditions;
- Adaptable - Able to change the organisation and/or work processes;
- Flexible - Able to employ multiple ways to succeed and the capacity to move seamlessly between them;
- Innovative - Able to do new things or able to do old things in new ways.

The following additions were made by this activity to ensure the agility concept embraces actions prior to, during and after the change in circumstances, as well as driving/shaping changes in circumstances:

- Proactive - Able to conduct proactive and preemptive actions to drive and shape change or protect continuity;
- Learning - Able to learn and unlearn from experience.

According to WitIA, the characteristics listed above are those that Defence should seek to maximize within its Enterprise using an appropriate mix of both conventional capabilities enhanced by the information age and new kinds of capability that have been made possible by the information age. Coordinating delivery of these effects requires C2 Agility, underpinned by enhanced understanding and improved decision-making. WitIA states that realizing the benefits offered by the information age will only be achieved by understanding the interaction between technology, people and organisational ways of working as follows:

- Agile C2;
- Enhanced Understanding;

- Improved Decision-Making;
- New capabilities enabled by the information age;
- Conventional capabilities enhanced by the information age;
- Agile Communications and Information Systems.

6.1.3 The Netherlands (NLD)

Research on C2 and C2 Agility, especially the C2 Approach Space, together with future force developments within the Netherlands Defense Organization have influenced defence research in the Netherlands. The influence of C2 Agility research is most visible in two research programs: NetForce Command and Human and Organisational Adaptivity.

Research on a new paradigm of warfare is essential to be and stay successful in the Information Age. The Dutch Defense Organisation believes that operations in networked environments, NetForce operations and NetForce Command, offer a promising new form of warfare in a context of fast developing technological possibilities, globalization, hyper-connectivity, and abundance of information and data. Therefore, the Dutch Defense Organisation initiated the research program NetForce Command. The objective of the NetForce Command research program is to develop operational, net-centric concepts for command, leadership, decision-making, organisation, collaboration, manoeuvre and information management and to aggregate these concepts in an integrated NetForce Command concept that provides the Dutch Defense Organisation the opportunity to contribute and operate effectively in future operations in a networked environment. NetForce Command builds on topics like Network Centric Warfare (NCW), NEC and C2 Agility, but focuses specifically on topics in the organisational and human domain, not on technological and interoperability challenges (though it would also be relevant). The program started in 2016 and is divided into three phases as depicted in Figure 12.

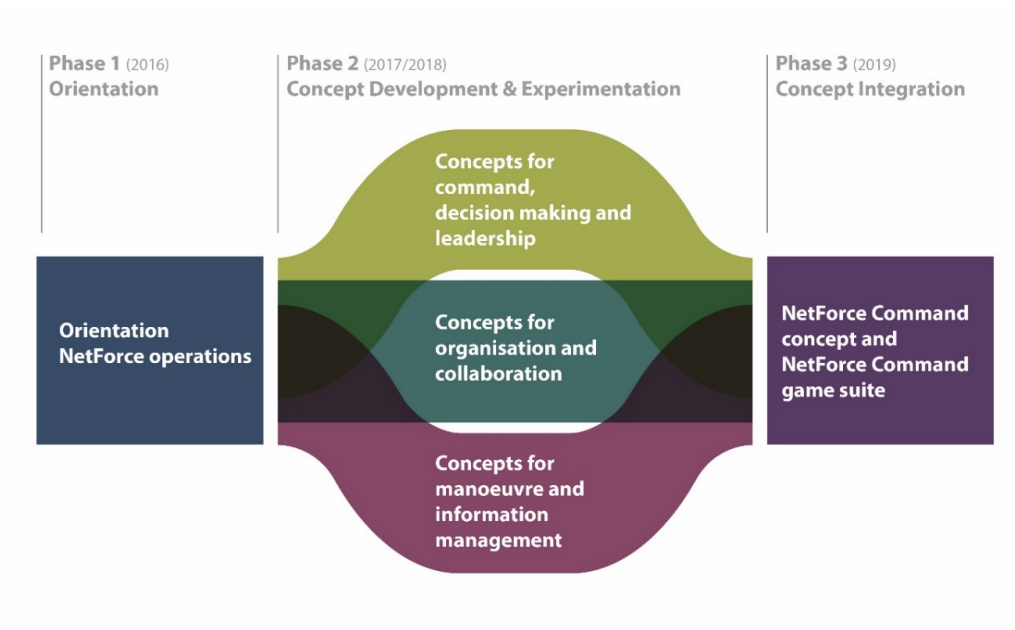

Figure 12: Phases of NetForce Command research program [48]

6.1.4 Norway (NOR)

The Norwegian Defence Research Establishment (FFI) does not have any research project which directly explores or studies C2 or C2 Agility, yet insights and conclusions from NATO SAS C2 works are used and recognised in several completed and ongoing research activities in several projects. Three such activities are:

- Practical implications of network-based defence;
- Requirements for an information infrastructure (INI) at NML3 (supporting Coordinated C2);
- Analysis of challenges and possible approaches to Cyber Defence Situational Awareness (CDSA).

It has been decided that the Norwegian Armed Forces shall be developed towards a more network enabled force (NbF[4]). Yet, how this evolution is to take place in practice has not been thoroughly described. To make the practical implications of NbF easier to understand, some thoughts on these aspects were explored based on a sensor-shooter interpretation and collaboration connections between entities like a Brigade HQ and a battalion, All Source Intelligence Centre (ASIC) or NGO with different C2 Approaches [49]. The axes of the N2C2M2 were interpreted from a practical perspective with the maturity levels concretized for planning, information flow, collaboration and delegation. A dozen aspects of the information infrastructure at different maturity levels (C2 Approaches) were described, centred on the middleware level/communication network, but also including (higher level) end user services and (lower level) transportation services.

Further work was done on determining requirements placed on the INI at NEC maturity level 3 (NML 3), i.e. for Coordinated C2 [50]. The requirements were structured by the axes of the N2C2M2, with a set of capabilities linked to each axis. This structure, together with possible operational use of the INI placed in a scenario context, enabled a gap analysis between the current INI and future INI, and resulted in suggestions for future INI developments.

In the work conducted on CDSA, a handful of trends were identified which formed an important backdrop for identifying and analysing challenges and possible approaches to CDSA [51]. One of these trends was the need for C2 Agility, as developed and conceptualized in SAS-065 and SAS-085. The work on C2 Agility points out the need for the ability to manage changing situations more dynamically, and if necessary, changing the C2 Approach to fit new circumstances. CDSA may contribute to the basis for making decisions on the C2 Approach, by reflecting the status and events in the information infrastructure. Further thinking suggests that this includes both assessing the validity of the current C2 Approach, and determining the appropriate C2 Approach.

6.1.5 Sweden (SWE)

C2 Agility theory and concepts, as described in NATO SAS-085 have influenced a number of Swedish S&T projects, primarily at the Swedish Defence Research Agency. Firstly, C2 Agility theory has been the primary influence for the research questions in the Armed Forces for three years (started in 2015) S&T project "MONiTOR" (English title "Towards C2 assessment of future naval operations"). The project aimed to develop a tool for assessing organisational adaptiveness and C2 Agility in a naval context (see 4.1 above), something that thus far has led to a mature prototype of the instrument. This is further described in section 4.1. C2 Agility theory has thus directly influenced the direction of this project.

Another illustration is the national framework program "Situation adapted C2 based on design logic with a holistic stance" funded by the Swedish Civil Contingencies Agency, running from 2013 until 2017. The objective of the program is to increase the societal capacity for coping with accidents, emergencies and crises by

[4] "Nettverksbasert Forsvar (NbF)": The national equivalent of Network Enabled Capability/Network Based Defence

developing indicators for command, control and collaboration, developing concepts for C2, and increasing the knowledge of the context for C2 today and in the future. The project is arranged as a consortium involving the Swedish National Defence College, the Swedish Defence Research Agency (FOI), and Lund University. The program is organized in three sub-projects, of which one concerns C2 Agility for future crisis management. The project has so far produced three reports that connect to theories developed during SAS-065 and SAS-085; a literature review of C2 Agility, organisational adaptiveness and improvisation, a case study about C2 in a large crisis, and a review of existing methods for assessing C2 Agility.

6.1.6 United States of America (USA)

The USA Army Research Laboratory (ARL) has several ongoing research threads that have used concepts from Network-centric warfare and Netcentric Operations to establish measures of performance of networks beyond objective measures. In particular, ARL has research on Quality of Information- Semantically Adaptive Networks (QoI-SAN) that considers the contextual quality of information in networks to measure information processing and delivery in tactical networks. This project is under the larger Network Science research effort. The objective is to more efficiently expend resources of the communications network in support of C2 networks. With understanding of network and environmental conditions, the network and the organisation may demonstrate resilience, robustness and greater efficiency in operations.

With such understanding, it is possible to manoeuvre through different configurations of a system to increase performance relative to mission requirements. For example, ARL has studied this in terms of manoeuvring through network configurations or C2 Approaches. This work was described in Section 3.6 where the is a complex tradeoff space of operating with the proper C2 Approach in the presence of a dynamic adversary. The investigation described the tradeoff space through various utility functions in terms of costs to switch C2 Approaches, risk of adversarial attacks and predicted benefit of switching to another C2 Approach.

6.2 INTERNATIONAL RESEARCH AND DEVELOPMENT EFFORTS

This section describes other international R&D efforts which have utilized C2 Agility concepts, including a NATO IST group, a trilateral collaboration between Canada, the Netherlands and Sweden, a bilateral collaboration between the USA and Australia, and an EU initiative.

6.2.1 NATO IST-118

The NATO IST-118 “Service Oriented Architecture (SOA) Recommendations for Disadvantaged Grids in the Tactical Domain” examined the potential of SOA at tactical environments [52], [53], [54]. The limitations of the network environment prevent the full spectrum of SOA deployments, which suggests that C2 Agility concepts may be useful to determine the best operating configuration of federated tactical network environments. C2 Agility concepts were explored in the development of experiments involving information exchange in a tactical mobile network capable of overcoming disruption and adapt to a new topology. Currently experiments to measure C2 Agility at the network level are being designed in the follow on to IST-118, IST-150 “ NATO Core Services profiling for Hybrid Tactical Networks)”.

6.2.2 DRDC-TNO-FOI - Human and Organisational Adaptiveness and Agility

Canada, Sweden, and the Netherlands have initiated a three-year joint project arrangement (PA), called Human and Organisational Adaptiveness and Agility, to address military adaptability and agility. The PA is undertaken

within a cooperative science and technology memorandum of understanding between DRDC, TNO and FOI. Each partner organisation has a research program which addresses adaptability and agility from their own perspectives.

The Canadian program focuses on institutional leadership and how it influences organisational outcomes, such as adaptability. The objective of this research is to develop imperatives for the international security environment and to validate an integrated leadership framework that addresses these requirements.

The Dutch program focuses on individual and organisational adaptability. The objective is to develop a framework of factors that underlie the capability to strengthen adaptability in individual military personnel, and in the military defence organisation.

The Swedish program focuses on the assessment of agility and adaptability in naval operations. The objective is to develop a method to evaluate the organisational adaptiveness and agility of C2 in the naval environment and identify key mechanisms, constraints, and opportunities for naval C2 assessment.

SAS-104 contributes to the project through the Swedish contribution to the trilateral PA. The Swedish effort consists of parts of the output from a three-year research project on C2 Agility and adaptability funded by the Swedish Armed Forces and led by the Swedish Defence Research Agency (FOI), as mentioned in the section 6.1.5. The aim of the project is to develop and adapt empirically based methods to evaluate future naval operational C2 capability. The primary focus is specifically on the Navy's (organisational) C2 adaptability and the human component. The theory of C2 Agility has been included in the final report of the trilateral as well as a paper submitted to the International Command and Control Research and Technology Symposium [55].

6.2.3 ARL-DST – Semantically Managed Autonomous Resilient Tactical Networks (SMARTNet)

As stated in section 6.1.6, ARL is investigating QoI as an approach to improve network performance and efficiency of tactical networks. ARL and Defence Science and Technology (DST) group (Australia) are discussing potential collaboration titled Semantically Managed Autonomous Resilient Tactical Networks (SMARTNet). The objective of this collaboration is to design and develop a middleware for tactical networks between the sensor and the tactical radio. The middleware would prioritise, transform and control data sent to the radio for transmission on the network. C2 Agility design principles were applied to these functional blocks and documented in a conference paper [56]. Given variations in C2 Approach, a middleware would enable a tactical network to adapt to mission and network configuration constraints. A bilateral collaborative agreement at the time of this report was in development.

6.2.4 Other European initiatives

Future Sky Safety (FSS) is a large European Union research program organized in several sub-projects. The Swedish Defence Research Agency participates in the sub-project "Resolving the organisational accident", managed by EuroControl[5]. The objective of this sub-project is to reduce the likelihood of organisational accidents in aviation via development and implementation of a Safe Performance System. Within this effort, there is a work package called *Agile Response Capability* (ARC), led by the Swedish Defence Research Agency [57], [58]. The ARC work package aims to develop an organisational and inter-organisational capability to

[5] EUROCONTROL is an intergovernmental organisation with 41 Member and 2 Comprehensive Agreement States. EuroControl helps member States to run safe, efficient and environmentally-friendly air traffic operations throughout the European region. For further information, please see https://www.eurocontrol.int/

respond to rapidly evolving crisis events in an effective and resilient manner. The response capability will be able to address events focusing on sudden crises and exploring aspects of the continuum towards risks that change at a slower pace with longer-term dynamics. In order to achieve this, training of crisis response personnel in the air traffic system, such as air traffic supervisors, airport security personnel, and traffic planners must include events that challenge the organisation and management of the air traffic system. A scenario-development technique called "ARC training facilitation process" (ARCTSFP) has been developed. The ARCTSFP is based on an iterative process that combines focus groups and workshops with practitioners in order to identify challenging, but realistic scenarios [59]. This method is being tested through case studies and workshops. The ARC approach is largely founded on the theoretical framework developed by SAS-085. Within the project, the utilization of new theoretical concepts have been emphasised and the "no solution fits all problems" approach is widely accepted.

6.3 MILITARY COMMUNITY EFFORTS

The military community efforts of Canada, Denmark, Norway, Sweden, United Kingdom and USA that have utilized C2 Agility concepts are presented below, followed by the efforts of NATO SACT HQ, NATO C2 CoE and MCDC.

6.3.1 Canada

In June 2017, following a major consultation amongst the Canadian population, the Canadian National Defence published the new Canada's Defence Strategy [60]. To face the current complex and unpredictable security environment, this new Defence Strategy recognised the need to have agile and combat ready armed forces. In such a context, highly capable, flexible military forces must have the ability to operate closely with allies and partners. Furthermore, the Canadian Army has also identified that, to remain operationally effective and relevant, they will require to be balanced, agile, adaptive and responsive (i.e., more capable of effectively meeting varied and unforeseen threats and challenges) [61].

6.3.2 Denmark - Informing the Royal Danish Defence College

Denmark has integrated the concept of C2 Agility into some basic C2 and Intelligence courses at the Royal Danish Defence College [62], [63].

6.3.3 Norway

The Norwegian Armed Forces are renewing their tactical C2 Information System (C2IS) for the land domain [64]. As part of the procurement and development process, the desired 'solution properties' of the C2IS are identified and described. The solution properties underpin the ability to conduct efficient and effective C2 of operations in the land domain, and may be used to compare and contrast different C2IS alternatives. Agility is identified as a desired characteristic which may shape certain properties, in order to support agile C2.

6.3.4 Sweden

Below two Swedish efforts are described, including an orientation C2 paper and a C2 course.

6.3.4.1 Informing the Swedish Armed Forces orientation C2 paper for 2025-2035

The work of SAS-065-085-104 impacted the "Huvudstudie Ledning", a major study on C2 conducted by the Swedish Armed Forces as a part of their orientation of C2 for 2025-2035, as described in the documents [65] and [66].

The "Huvudstudie Ledning" (main study on C2) initiated by the Swedish Armed Forces is an ongoing project focusing on the timeframe 2025 to 2035. The aim of the study is to define and describe a concept for operative C2 capability with a joint, integrated and interoperable view on national and international operations. The study started in 2015 and will continue until 2018. The project is a joint effort by the Swedish Armed Forces and the Swedish Defence Research Agency, supported by the Swedish Defence University. Members of the project group have been in direct contact with the Swedish member of SAS-104 in order to be informed about the work on C2 Agility. A project member has also participated in one of the SAS-104 meetings and presented the work of the main study on C2 to SAS-104, as well as having received a briefing on C2 Agility and the work of SAS-104.

The main impact of the SAS work on C2 Agility can be found in the 2016 report in a chapter describing "Trends in military C2" [66]. In this chapter, the C2 Approach space and the fundamentals of C2 Agility are described. The authors conclude that there are similarities between C2 Agility and the Swedish concept of "situationally adapted C2". The report further concludes that such an approach would create high demands on education, training, equipment, and conceptual development. The report further points to the fact that there are several initiatives working with agility-related concepts within organisations and groups like NATO ACT, TIDE and MCDC [66].

The conclusions of the study so far points out, amongst other things, that future C2 must be flexible, interoperable, and have the ability to "compress command levels" when needed. It further stated that while the foundation for C2 in Sweden is mission tactics, command tactics must be possible, especially when interacting with international partners. This is in line with C2 Agility theory which states that the constellation of members of a collective may dictate what C2 Approach, and hence allocation of decision rights, which are possible to achieve.

6.3.4.2 C2 Agility part of the Basic Course in C2 Science at the Swedish Defence University (2016)

Students of the basic course in C2 Science (Grundkurs Ledningsvetenskap) at the Swedish Defence University are given an introduction to C2 Agility and the C2 Approach space in the form of a lecture [67] (Holmberg, 2016). This is primarily done as a way to introduce how the C2 Approach space can be used to describe different types of C2. The concepts and dimensions of the C2 Approach space are translated into Swedish and adapted to the terminology used in the course, meaning that the C2 Approaches are referred to as "types of network" (nätverkstyper). It concluded that organisational structures may change over time and that different types of organisations fit different problems.

Thus, C2 Agility theory and concepts are used as a framework to classify different C2 concepts and to illustrate differences and similarities of those concepts. The students are also made aware that there is no "one size fits all" when it comes to the relation between C2 and coping with different types of problems.

6.3.5 United Kingdom

As described below, the GBR military organisations have exploited the C2 Agility concepts at the Defence

Academy, in the Future Force Concept as well as in the Joint Concept Note on Future of Command and Control.

6.3.5.1 Defence Academy

GBR military education ensures that C2 Agility is presented and discussed at the Defence Academy [68], [69], [70]. The most recent sessions were with 45 newly promoted Majors as part of their Achieving Information Superiority training. The C2 Approach cube and the implications for information were presented and discussed. Colonel Alec Bain then presented the work on the Improving HQ Coordination Mechanisms (IHCM) Work Package (including the CDME experiments) as described previously.

More generally, GBR is working at the Defence Academy on agile thinking again this year in the Defence Thinking Skills Programme and on the Support to Sense-making and Decision-making for the Defence Strategic Leadership Programme.

6.3.5.2 GBR Future Force Concept (FFC) - Enhancing Joint Action through Information, Integration and Adaptation

The GBR Future Force Concept (FFC) guides coherent force development at the strategic, joint and command levels, beyond current policy and resource horizons. As the authoritative high-level analytical concept, it supports balance of investment decision-making to shape the design and development of the Future Force out to 2035.

At the heart of the concept is the idea that the GBR can enhance Joint Action, and therefore our influence, through exploiting information, being more integrated as a force and more adaptable to changing circumstances.

FFC states that adapting to changing complex environments, rather than seeking to control them, will be fundamental so the pre-eminent quality of the future force will be the ability to adapt, combined with the agility to do so with relative ease. However, adaptation, or incremental change, is sometimes insufficient and militaries must also be able to innovate to retain their advantage over potential adversaries. Critically, it is organisational learning that underpins adaptation, innovation and agility.

FFC also states that enhancing Joint Action through exploiting information and being more integrated and adaptable will be underpinned by six foundational elements. Together, these foundational elements represent the building blocks of gaining and maintaining joint force advantage in the future operating environment:

- Agile C2;
- Partnerships;
- People;
- Technology;
- Training & experimentation (including learning);
- Future force resilience.

6.3.5.3 Joint Concept Note on Future of Command and Control

The Joint Concept Note (JCN), Future of Command and Control (FC2), provides the conceptual basis to support operations and Defence objectives out to 2035. It will influence decisions about future capability development

and stimulate further work on addressing identified future challenges for C2.

FC2 is born out of a realization that the GBR and its allies need a different and more innovative approach to C2 in order to compete effectively with state and non-state actors in an environment of ever-increasing levels of complexity and uncertainty. Much of the change in the operating environment is driven by the relentless pace of scientific and engineering advances and technological change. The FC2 JCN draws heavily on The Future Force Concept and the National Security Strategy and Strategic Defence and Security Review 2015. The concept has also been informed by the Warfare in the Information Age (WitIA) programme led by Joint Forces Command. The WitIA programme has drawn heavily from the NATO Agile C2 work.

Within this context, C2 is considered as a socio-technical system for directing, aligning and coordinating the intent and activities of the Joint Force with those of our military and civilian partners as part of a Full Spectrum Approach.

The GBR Command and Control Joint Concept Note is released for general distribution. Chapter 2 is entitled: “Evolution of C2 and the need for agility”. Chapter 3: Agile Command and Control contains much of the SAS-085 work and directly references and uses the C2 Approach cube at Figure 2.

6.3.6 United States of America

While the United States has not directly applied the work of SAS-085 on C2 Agility, recent documents released by the USA Army reflect the concepts and ideas documented in the report. The United States Army Training and Doctrine Command (TRADOC) is responsible for the design, development and integration of capabilities, concepts and doctrine for current and future Army forces. TRADOC has recently released a document "Multi-Domain battle" [71] that has elements inspired by the concepts developed in SAS-085. In particular, the report cites a requirement of C2 as a one of their "Required capabilities and supporting actions". In particular the report states that C2 must enable "distributed forces, including while moving, and maintain the C2 systems to manoeuvre forces and open or exploit windows of advantage".

6.3.7 NATO Supreme Allied Commander Transformation Headquarter (NATO SACT HQ)

The understanding of the challenges associated with the utilization of different types of C2 Approaches in different contexts provided support to NATO Supreme Allied Commander Transformation (SACT) HQ in the refinement of the description of the future C2 Environment [72]. NATO SAS-104 team reviewed the document “The C2 Future Operating Environment” and produced comments to NATO SACT HQ that were integrated into the final version published by NATO SACT HQ in March 2016.

6.3.8 NATO Command and Control Centre of Excellence (NATO C2COE)

As a next step in its participation in C2 Research Groups within STO, the NATO C2COE participated in SAS-104, bridging the conceptual and more practical aspects of C2. In order to disseminate knowledge on C2 Agility, the NATO C2COE held internal training to explain the topic to newcomers and members not involved in the ongoing SAS-104 work. Focusing externally, the NATO C2COE has both in its 2014/2015, 2016 and 2017 Annual Overview, aimed at its Community of Interest, and provided three articles on the work of the SAS-104 and the C2 Agility concept [73], [74] , [75].

The NATO C2COE members sense, during the major NATO exercises, that the operational level community often seems to be unaware of the previously identified C2 Approaches and the C2 Agility concept. In addition,

staff members apparently lack NATO doctrine and handbooks which mention its principles and application. The Allied Command Operation's Comprehensive Operations Planning Document (COPD), which is currently under revision, offers a first stepping stone to insert C2 Agility considerations into the formal NATO Operational Planning Process. The Comprehensive Crisis and Operations Management Centre (CCOMC) provide preliminary C2 arrangements to the Joint Task Force Commander, as a starting point. The NATO C2COE is aware of next opportunities in the Allied Joint Doctrine Campaign Plan, which is under custodianship of the Allied Command Transformation, for the insertion of C2 Agility in Capstone and Keystone publications. The GBR Joint Concept Note 2/17 on the Future of Command and Control [46] could provide useful content for NATO doctrine.

It is the NATO C2COE's opinion that the reality of operations still challenges the C2 concepts. The illustrative C2-models mention rather formal and technical arrangements. Many NATO C2COE observations during exercises at the operational level highlighted behavioural aspects. Trust as an enabler or risk averseness as a cultural blocker are not visible in the SAS-models. Finally, C2 arrangements in operations (and exercises) often reflect political considerations, not the organisational requirements to perform best in the given environment. C2 arrangements as structures, mandates (from the not well-defined and thus is understood OPCOM, OPCON to SSI), restrictions (ROEs and Red Card Holders) and C2 Support, besides the mentioned human aspects, impact the effectiveness of the formation. Therefore, the aim of the SAS-104 to "provide the basics necessary to create and develop C2 Agility so that it can become an operational capability" will need continuous attention. The NATO C2COE will continue to promote the application of the C2 Agility principles, although assessing the C2 Agility in practice at the NATO joint level, as the NATO C2COE previously experienced with NNEC C2 Maturity Model, will be a challenge.

6.3.9 NATO Modelling and Simulation Centre of Excellence

A study within the Modelling and Simulation Centre of Excellence has reported on the development of a Live, Virtual and Constructive Hybrid Cyber warfare Range called Hi-Cyber to enable the study of evolving threats of hybrid warfare in multi-domain environments [76]. The report cites the work of the SAS-085 as providing theoretical foundations for the development of a Cyber Security Simulation Environment (CSSE). The report suggests that the outcomes of SAS-085 can be used to frame scenarios involving military tactical networks and civil NGO networks subjected to cyberattacks. This represents an instance where C2 Agility concepts have been used to support a high-level conceptual scenario framing approach. It is further an example of application of C2 Agility concepts beyond the traditional C2 modelling and simulation domains.

6.3.10 Multinational Capability Development Campaign (MCDC)

The C2 Approach space describes Edge C2 as a C2 Approach in which "the entities are engaged to the collective effectiveness with self-synchronisation of the collective and self-organisation of each entity to achieve common intent." (see figure below). Required capabilities are amongst others 'self-synchronisation of the collective'.

Table 4: Edge C2

Description	C2 Tasks Required	C2 Capabilities Required
The entities are engaged to the collective effectiveness. • self-synchronisation of the collective • self-organisation of each entity to achieve common intent.	Development of shared intent, awareness, and understanding	Development of a rich, shared understanding of the common intent as well as the different entities. Self-synchronisation of the collective, self-organisation of each entity. Robust, secure, ubiquitous, interoperable, info-structure that extends to all participating entities

The MCDC Infomation Age C2 project (work strand B: Command implications of self-synchronising networks) explores the concept of self-synchronisation within the military (and with other Joint Interagency Multinational and Public (JIMP) partners on the 'outside') to increase both the speed and quality of decision-making and agility and effectiveness in future military operations. Specifically, the project seeks to explore mechanisms to maintain purpose and harmonization of efforts and effects in self-synchronizing networks as this is assessed to be the main challenge of self-synchronisation. For example, 360° self-synchronization and aggregating with other military (and other JIMP elements) creates the challenge of ever changing functional command relationships, ad hoc partnerships, shared and distributed leadership, civilian leadership, lack of unity of command, etc. Also, the tendency to align predominantly with elements within one's own network has been demonstrated to hinder self-synchronisation with elements of other networks (be they military or JIMP). In addition, the tighter the own network is aligned or led / controlled, the wider self-synchronization is hindered.

Three main requirement goals were identified to enable self-synchronisation: improved insight in other elements (e.g. insight in capabilities); a mechanism to prioritise tasks; a mechanism for harmonization of efforts.

- Improved insight in other elements. In a highly networked and connected environment, without a formal hierarchy, military forces need information on every single element in the network in order to make self-synchronization work. This includes, for example, information about capabilities, but also about recourses. This will benefit effective cooperation;
- A mechanism to prioritise tasks. A core requirement for self-synchronising networks is the ability to decide what to do and in what order, simultaneously/sequential, to be most effective. Another requirement is the ability to decide when (and how) to shift between tasks;
- A mechanism for harmonization of efforts. An armed network without a formal hierarchy relies on cooperation between its military (and other JIMP) elements. Priorities, intentions and plans need to be shared, agreed and coordinated (or disagreed and deconflicted) with multiple military (and other JIMP) elements. As each element can initiate the formation and discontinuation of military or multi-disciplinary teams to achieve effects in accordance with its own understanding of priorities, the main requirement of self-synchronisation is to have a mechanism to maintain purpose and harmonization of efforts and effects.

The MCDC project will provide conceptual approach(es) and mechanisms to maintain purpose and harmonization of efforts and effects in self-synchronising networks. This will provide insight in the requirements for a military force function as a self-synchronising network within a JIMP context. In other words: to enable Edge C2.

Chapter 7 – DISCUSSION/CONCLUSION

During the last past years, NATO SAS-104 has endeavoured to better understand and document C2 Agility concepts and their applicability to real-life situations. Through the publications of 3 books, 43 papers in conferences and journals, the conduct of 4 workshops, 6 training sessions and 6 presentations explaining C2 Agility, NATO SAS-104 has sensitised the NATO community (scientific and military) about the need to develop military organisations that will be agile by design instead of being agile only by chance. Furthermore, additional work has been conducted to develop ways to explain and assess C2 Agility and its employment in future operations.

7.1 DISCUSSION

To achieve the objective of creating more awareness and understanding of C2 Agility concepts and their implications for force structure, organisation and capabilities, NATO SAS-104 focused its efforts into three different areas:

- Adding to the evidence collected by SAS-085 that support the validity of C2 Agility Theory and its applicability to military organisations and operations;
- Contributing to the body of knowledge and literature related to C2 Agility and its applications;
- Discovering, documenting, and cataloguing the adoption or incorporation of C2 Agility Theory into the concepts, doctrine, education, training, and system capabilities of NATO and other military organisations.

SAS-104 assembled, collected, documented, and organized evidence, research findings, presentations and coursework related to C2 Agility, and applications of C2 Theory as they became known and available. The results of this search should prove extremely valuable to both the operational and R&D communities. SAS-104 members also made significant contributions to the body of knowledge and literature largely in the form of 1) research focused on Force and C2 Agility implications, and 2) case studies, experiments, C2 Agility assessment frameworks and instruments that have strengthened the empirical basis for the theory.

SAS-104 confirmed the findings of SAS-085 that agile C2 was required and found that awareness of this need for increased agility in general and more C2 Agility in particular has become more widely appreciated. In terms of cost, SAS-104 concluded that the mission costs of not being agile enough (which directly relates to mission failure) outweigh the costs associated with developing requisite C2 Agility. SAS-104 found that increasing C2 Agility requires not only adaptions during the conduct of missions but also preparation beforehand to develop and practice a variety of approaches to C2 and the transition from one approach to another (i.e. manoeuvre in the C2 Approach Space).

SAS-104 concluded that the ability to observe, measure and assess C2 Agility is critical for improvement and that several countries are investing in the development and testing of assessment frameworks, methodologies, and metrics.

While SAS-104 found that C2 Agility concepts have become more widely understood, the actual adoption of these concepts lags behind. We attribute this theory-practice gap primarily to the fact that significant improvements in C2 Agility depend upon cultural changes, the introduction of new C2 Approaches and/or a capability to transition from one approach to another either of which require the development and promulgation of doctrine, the development and introduction of education and training, and the conduct of related exercises to make the leap from theory into practice. These things take time and given the relative newness of C2 Agility

Theory there had not been sufficient time for these necessary chains of events to occur.

However, SAS-104 has seen evidence that C2 Agility concepts have made significant gains in acceptance and that organisations (e.g. in GBR, NLD, and AUS) are making efforts to translate these ideas into practice. Thus C2 Agility concepts and practices have entered the theory-practice pipeline in the forms of new concepts and doctrine and can be expected to transit through this pipeline to influence practice in the near future. SAS-104 has also noted a lack of sufficient experimentation devoted to both C2 Agility and to operating in cyber contested environments that will require more C2 Agility.

Finally, SAS-104 has noted that there remain significant gaps in our understanding that are impediments to increasing C2 Agility sufficiently to operate successfully in a world that is increasingly dynamic and complex. SAS-104 has concluded that the C2 implications of the hybrid nature of the missions NATO and member nations can expect to be called upon to undertake, the likelihood of encountering unfamiliar situations, ever more contested cyber environments, and the increased adoption of 'intelligent' agents and autonomous systems each need to be better understood.

7.2 C2 AGILITY AND THE FUTURE

During the 1990s and the first part of the 21st century, we witnessed a rapid development of information and communications technologies. These developments gave rise to the articulation of Network Centric Warfare that was seen by some as 'transformational. Later on NCW concepts gave birth to "Power to the Edge" and ultimately to C2 Agility. This led to the emergence of networked enterprises. However, one could argue that this shift, however profound, has not fundamentally affected the nature of our military organisations.

Some researchers have concluded that this is about to change. They cite, as the source of this disruptive development, the rapid adoption of advanced forms of 'machine intelligence,' in the form of robots and software agents. These 'intelligent things' will be increasingly found in military networks, in applications, and on the battlefield. These non-human entities are capable of, and will possess, some degree of autonomy. Thus, the networked force of the near future will consist not only of interconnected and interdependent humans, but also of intelligent things. The humans amongst them will find themselves to be merely a particular specie of intelligent battlefield entities.

Furthermore, our military organisations will include fewer and fewer humans in relation to robots and other intelligent agents. At least some of these robots and intelligent species need to be considered, from a C2 perspective, as entities to whom decision rights can be delegated and withdrawn, in the same ways that decision rights are allocated to humans as envisioned in C2 Agility Theory. These new entities cannot be ignored and will need to be considered in the definition of a C2 Approach and in the selection of an appropriate C2 Approach.

It is hard enough to effectively command a purely human organisation. It is even harder to do so with the agility required for the complex and dynamic environments in which we must operate. This development (one that can be expected in the near – not the distant future) raises a number of challenging issues, none more compelling and urgent than finding an answer to the question "How to command and control this new organisational form consisting of heterogeneous intelligent things (entities/agents)?"

Another significant area of research has been the conceptualization of the "C2 Problem" as a composite network. Composite networks consist of a set of interdependent multi-genre networks, that at a minimum include social networks (where the nodes are human and the links are the interactions between and amongst humans), information networks (where the nodes are information sources, information processors and visualization

capabilities, and repositories and the link represent information flows), and communication networks (where the nodes are routers, etc. and the link represent the flow of data). Given the transformation of the nature of the organisation (to include intelligent things from a socio-technical system perspective), there will be additional nodes in the social network to consider. There will also be intelligent agents living in our information and communication systems.

Another development, the increasing cyber threat, has grave implications for militaries seeking to enhance their C2 Agility. NATO SAS-065 and SAS-085 postulated and provided supporting evidence that more networked enabled C2 Approaches were more agile. Cyber attacks and the employment of cyber defences threaten to limit the connectivity and flows needed for a networked enabled approach to C2 and consequently reduce our potential C2 Agility.

It has been hypothesized that intelligent information and communications networks can provide significant enhancements to C2 Agility. SAS-104 notes that research is urgently needed to understand the implications of these developments for C2 in general and C2 Agility in particular.

7.3 FUTURE NATO SAS ACTIVITIES

Three major developments are already having a profound effect on C2 of organisations. First, NATO and its member nations face hybrid threats that require integrated responses that include military and non-military instruments of power. Kinetic, cyber, and non-kinetic capabilities need to be harmonized. SAS-085, SAS-104 and various member nations have concluded that agile multi-domain C2 is essential. Second, the automation of a variety of C2 decisions has been a fact of life for some time, albeit without a clear recognition of constraints that may be impediments to effectiveness, efficiency and agility and thus, to mission accomplishment. The emergence of autonomous systems is a more recent development. As is the case with automation, 'autonomous' systems involve delegations of decision rights whose impacts and consequences on C2 are currently not well understood. Third, the likelihood of operating in a cyber-contested environment is high increasing the need for C2 Agility and the need to understand the impacts upon C2 Approaches.

Based on the current findings, NATO SAS-104 members consider that additional work is required to explore the nature of agile multi-domain C2 (the integration of the C2's of kinetic, cyber, non-kinetic) of a socio-technical enterprise that includes humans, intelligent networks, and autonomous entities in a cyber-contested and hostile environment. The topics that could be covered in this new group would include:

- C2 Agility implications of socio-technical enterprises – collaborating teams of human, autonomous entities and intelligent networks;
- Challenges associated with agile multi-domain C2 of Hybrid Operations;
- Harmonization of C2 Approaches appropriate for Kinetic, Cyber, and Non-Kinetic operations.

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Annex A – Bibliography

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- C2 Agility Brochure
- C2 Agility Booklet
- Elevator Pitch

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5. David Alberts, keynote and lead an 'enlightenment session' , 11th NATO Operations Research and Analysis (OR&A) Conference , 2nd and 3rd of October 2017, hosted by the GBR Ministry of Defence in Kensington, London, United Kingdom
6. David Alberts, Future Headquarters workshop, NATO CD&E Conference, NATO ACT and USA J&, October 2017, London, UK

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1. C2 Concepts at C2 Science & Technology Challenges Workshop, lead by David Alberts (USA) and Paul Pearce (GBR), C2 Symposium, Tidworth, GBR, March 2015
2. Introducing C2 Agility fundamentals to navy officers of the Swedish Defense main study working group on future command and control, June 2015
3. C2 Challenges and Application of C2 Theory, Panel session, Moderator: Anthony Alston, Panelists: Calvin S. Johnson (Deputy, Mission Command Battle Lab, USA), Christopher Briggs (Dstl, GBR), Keith Stewart (DRDC, CAN), Kevin Chan (ARL, USA), Lorraine Dodd (Cranfield University, GBR) ICCRTS 2016, London, GBR, September 2016
4. Agility course/workshop for the Navy and the Swedish National Defense College at the "Marinstridsdagarna" annual navy conference, January 2018

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2. Will Mitchell , The core principals of C2 Agility, integrated in the course “Advanced Intelligence Course”, Joint Operations, Canada, 18 April 2016
3. Lorraine Dodd, C2 course, Defence Academy, Shrivenham, GBR, 19-23 September 2016
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6. Lorraine Dodd, C2 Agility to Battlefield Technology Course (Achieving Information Superiority) 19-20 July 2017

Annex B – Pakistan Earthquake 2005 and 2015

INTRODUCTION

As part of SAS-104, a number of case studies were examined to determine the validity of the NATO N2C2M2. This study compared the Oct 2005 [77] and Oct 2015 Pakistan Earthquake against the C2 Maturity Model. Both earthquakes were compared to determine if Pakistan applied lessons learned from the 2005 earthquake to the 2015 earthquake regarding the application of the N2C2M2 to a natural disaster. To verify the completeness of the considered features, this study also readdressed the list of C2variables in the NATO C2CRM.

In 2005, an earthquake measuring 7.6 on the Richter scale hit northern Pakistan on 8 Oct 05. As shown in Figure 10.1, the earthquake epicentre was located 100 km north-northeast of Islamabad, along a fault associated with the Indian subcontinent. Most of the affected people lived in mountainous regions with access impeded by landslides that blocked the roads, leaving an estimated 3.3 million homeless in Pakistan alone. The total area affected was 30,000 km^2, included a range of unprecedented damage and destruction, such as: Houses: 500,000 (56%), Medical facilities: 365 (65%), Telecommunications: Exchanges (86 - 34%); Power lines (33,225 - 13%), Schools/colleges: 6083 (50%) and over 1000 hospitals. Due to the earthquake, there was a significant loss to Pakistan's infrastructure.

In 2015, a powerful earthquake has once again hit the region in Pakistan. The earthquake occurred at 2:09 pm Pakistan time on 26 October 2015. The Pakistan Metrological department reported the magnitude of the earthquake as 8.1 (USA Geological Survey reports it at 7.5). The quake was 196 km (120 miles) deep and centred at 82 km (51 miles) south-east of Feyzabad in a remote area of Afghanistan in the Hindu Kush mountain range. Severe tremors of this earthquake were felt across the country from north to south, in Karachi, Islamabad, Lahore, Sialkot, Quetta, Peshawar, Swabi, Kohat, Abbottabad, Swat, Malakand and Gilgit etc. There were no major structural damages to health facilities and 147 schools were damaged with at least 94 people killed and over 300 people reported to be injured so far across the country.

Figure 13: 2005 Epicentre

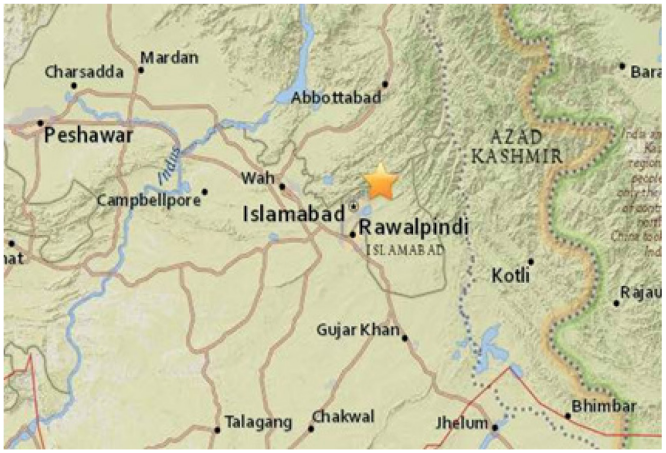

Figure 14: 2015 Epicentre

Pakistan Earthquake Phases

2005: The case study was subdivided into three distinct phases to correspond to relief activities during the aftermath of the earthquake:

a. Phase I: Search and Rescue (8 Oct - 11 Oct);

b. Phase II: Provide relief and stabilization (12 Oct – 7 Nov);

c. Phase III: Reconstruction and Rebounding (8 Nov - 31 Dec).

2015: To keep consistent with the 2005 case study, this analysis subdivided into the same three distinct phases to correspond to relief activities during the aftermath of the earthquake:

a. Phase I: Search and Rescue (26 Oct - 28 Oct);

b. Phase II: Provide relief and stabilization (29 Oct – 19 Nov);

c. Phase III: Reconstruction and Rebounding (20 Nov - 31 Dec—continues).

The same five C2 Approaches were used as follows: a) Conflicted C2; b) De-Conflicted C2; c) Coordinated C2; d) Collaborative C2; and, e) Edge C2.

SUMMARY

A key aspect of the analysis conducted comparing the 2005 and 2015 earthquake, was, again, the ease to which it was to determine the utility of the C2 Approach categories using the N2C2M2. Regarding the 2005 earthquake, a human attribute contributed to C2 Agility, namely the creation of "clusters." However, for the 2015 earthquake it was a technology attribute that contributed to C2 Agility, namely the cell phone. It's interesting to note that a large difference from the 2005 earthquake was that UN "Clusters" were not formed since the response to the 2015 earthquake was much more organized since communications were not totally disabled. Fundamentally, the use of cell phones assist in the recovery effort was a good example of C2 Agility. This ability to capture new

technologies allowed a broader C2 Approach and to rapidly implement this new capability was a good example of transitioning to a higher C2 Maturity level: In this case, transitioning from De-Conflicted C2 to Coordinated C2 in a short period of time.

The C2 Approach comparisons between 2005 and 2015 are shown below. Table 5, which is inspired by [77], illustrates the comparison of the 2005 & 2015 Collective C2 Approaches & Required Patterns of Interaction; while Table 6 illustrates the comparison of the 2005 and 2015 Measures of C2 Effectiveness and Endeavour Effectiveness.

In conclusion, analysis indicates that the difference between the 2005 and 2015 Pakistan Earthquake was the Pakistan Government was able to rapidly move from Conflicted C2 to Coordinated C2 over the period of the recovery [78].

Table 5: Comparison of the 2005 & 2015 Collective C2 Approaches & Required Patterns of Interaction

P 1 = Search and Rescue P 2 = Relief and Stabilization P 3 = Reconstruction

	Variables Defining Collective C2 Approaches						**Required Patterns of Interaction**					
	2005	2015	2005	2015	2005	2015	2005	2015	2005	2015	2005	2015
Edge C2												
Collaborative C2												
Coordinated C2		P 3 P 2		P 3 P 2		P 3 P 2	P 3 P 2	P 3 P 2	P 3 P 2	P 3 P 2	P 3 P 2	P 3 P 2
De-Conflicted C2	P 3 P 2 P 1	P 1	P 3 P 2 P 1	P 1	P 3 P 2 P 1	P 1	P 3 P 2 P 1	P 1	P 1	P 1	P 1	P 1
Conflicted C2												
C2 Approach	**Allocation of Decision Rights to the Collective**		**Inter-entity Information Sharing Behaviours**		**Distribution of Information (Entity Information Positions)**		**Cluster Attractor**	**Cell Phone Attractor**	**Degree of Inter-Cluster Connectivity**		**Frequency/Continuity of Interaction**	

Table 6: Comparison of the 2005 and 2015 Measures of C2 Effectiveness and Endeavour Effectiveness

	Variables Defining Collective C2 Approaches						Required Patterns of Interaction					
	2005	2015	2005	2015	2005	2015	2005	2015	2005	2015	2005	2015
Edge C2												
Collaborative C2												
Coordinated C2		P 3 P 2		P 3 P 2		P 3 P 2		P 3 P 2		P 3 P 2		P 3 P 2
De-Conflicted C2	P 3 P 2	P 1	P 3 P 2	P 1	P 3 P 2 P 1	P 1	P 3	P 1		P 1	P 3 P 2	P 1
Conflicted C2	P 1		P 1				P 2 P 1		P 3 P 2 P 1		P 1	
C2 Approach	**Degree of Shared Awareness**		**Degree of Shared Understanding**		**Adaptability of the Collective C2 Process**		**Relative Effectiveness**		**Efficiency, Given Effectiveness**		**Agility of the Collective C2 Process**	

P 1 = Search and Rescue P 2 = Relief and Stabilization P 3 = Reconstruction

Annex C – Initial Response of the Thai Medical System in the 2004 Indian Ocean Tsunami

The Indian Ocean Tsunami of 2004/2005 is believed to have been the deadliest natural disaster in modern History. Fanning across the Indian Ocean, the tsunami was triggered by a massive undersea earthquake that occurred in the morning of 26 September 2004 off the western coast of Northern Sumatra. It flooded coastal areas wiping away local infrastructures and killing over 227,000 and displacing 1.7 million people in 14 countries around the Indian Ocean. This analysis is focused on the initial phase of the tsunami relief operations in Thailand as described in Annex B of the SAS-065 Tsunami report [3] which is based mainly on the information provided by an Israeli medical expert group that studied the operation [2]. Involving the Thai Medical System supported by Thai military's transportation assets these initial relief operations were considered by SAS-065 as an example for having been conducted at a high level of C2 Maturity and agility.

Figure 15: Countries affected by the Indian Ocean Tsunami of 26 December 2004

The Thai Medical System

Thai Medicals System is the aggregate of Thailand's public health system and the sections/units of the Thai military that own evacuation resources and other needed support in emergency cases like terrorist attacks and natural disaster like the tsunami. Thus it may be considered an emergency coalition of two organisations.

The public health system is a hierarchical system based on primary clinics (regularly staffed by public health officers and a nurse authorized to prescribe medications and provide primary care, but with no hospitalization capabilities), district hospitals (30–90 beds), provincial hospitals (200–500 beds) and specialised centres in Bangkok. This system works well under normal conditions, but was not prepared for a catastrophe of the magnitude of the tsunami. Reference [2] explains the situation as follows:

Threatening scenarios were not listed, no specific preparations had been made for a tsunami, a doctrine for medical management of a disaster caused by a tsunami did not exist, and hospitals had no standards for operations. Additionally, according to a pre-¬determined scenario, the Thai hospital infrastructure was not stocked with sufficient numbers and types of beds, medications, or bandages. Annual drills were performed in

Thai hospitals, involving up to 50 casualties. However, Thai hospitals were not tested in their abilities to handle the unique aspects of a tsunami. In addition, a control system to supervise and evaluate drills was not found in Thailand.

The Tsunami Response in Thailand

Thai officials discussed the earthquake and tsunami risk an hour before the waves struck but decided against issuing warnings in order not to cause panic. However, after the tsunami had struck, Thai authorities reacted quickly. The Thai national response began with enabling the existing Civil Defence Act. This allowed senior government staff to be delegated to affected districts, redirected existing government budgets for relief efforts, and brought the response of different line ministries under the central coordination of the Ministry of the Interior. The Department of Disaster Prevention and Mitigation's Civil Defence Committee managed international and domestic call centres and a public donation centre and mobilized personnel and equipment, while the Ad Hoc Tsunami Disaster Task Force (under the Ministry of Foreign Affairs) coordinated foreign assistance.

Reference [79] describes the initial C2 actions of the Thai Ministry of Public Health (MOPH). They activated mass casualty plans and established a central command centre in Bangkok and command centres in each of the six affected provinces to coordinate activities and 6 hours after the tsunami, deployed personnel and resources started to arrive in the affected provinces. Within this structure the different entities (i.e. hospitals, etc.) seemed to have had a great deal of freedom to organize themselves according to the circumstances. An example was the method for organizing the aid different in the different provinces. Reference [2] states:

A shortage of ambulances and air-based transportation inhibited rapid evacuation of patients to hospitals. In addition, self-evacuation to hospitals was inhibited by transportation problems, damage to infrastructure, or isolation in the case of the remote islands. Approximately 70% of the casualties in Krabi province received treatment primarily in the field or were evacuated to primary care clinics. These clinics were organized rapidly with mattresses and beds in order to "hospitalize" patients until primary care was completed, and either a district or provincial hospital became available for secondary triage. In Krabi, field-based aid was given, and the evacuation of patients into hospitals (especially from Phi Phi Island) was delayed. For this reason, patient flow (1, 528 visits) was distributed over 48 hours. In Phang Nga district, most casualties were treated in the field or in the primary clinics. District and provincial hospitals sent personnel and medical supplies to reinforce primary clinics. These outreach teams provided Advanced Life Support (ALS), triaged casualties, informed the operation centers of their respective hospitals, and selectively evacuated patients to hospitals. For that reason, the Phang Nga hospitals, such as Takuapa Hospital, did not receive patients in one large mass: instead, the 990 patients arrived to hospitals in waves until midnight of 26 December 2004. Even so, Takuapa Hospital was overwhelmed, and surgeons there were forced to operate on two patients per operating room at the same time, and medical teams worked for 48 hours without rest.

In Phuket province, primary clinics and primary clinic reinforcements did not dominate the response. Instead, patients in Phuket were evacuated rapidly by ambulances, police cars, or private cars to district or provincial hospitals. Most of the patients arrived at hospitals within a few hours of the event; this created a mass- casualty incident with hundreds of casualties, a scenario that hospital teams never had exercised in a drill. Initially, there was no coordination between hospitals, and no patient allocation or secondary diversions occurred. Thalang, a district hospital in Phuket province, admitted approximately 200 casualties within the first three hours of the Tsunami. Patong Hospital, a district hospital in Phuket with a staff of 48 nurses and eight general physicians, admitted 700 casualties within two hours (but only 59 more during the next 20 hours). These hospitals reinforced primary clinics until the second or third day, after most of the casualties already had received primary treatment.

The coordination between the Thai military and the Thai health system seemed to have worked well. Although the recall of hospital teams was rapid and effective, more resources were required. Within a few hours, the Thai Ministry of Health and the Thai Air Force sent reinforcements to Phuket, including two aircraft, nurses, military and civilian physicians and surgeons.

According to [80], the international forces were primarily deployed to Indonesia, Sri Lanka and the Maldives. Thailand offered a headquarter base for the sizeable USA Combined Support Force (CSF) and accepted a limited naval search and rescue assistance. Cooperation between USA military and the Thai health authorities on health and need assessment is documented in reference [79]. During December 30, 2004 to January 6, 2005, three teams of Thai and USA health professionals from Thai MOPH–USA Centers for Disease Control and Prevention Collaboration (TUC) and Armed Forces Research Institute of Medical Sciences (AFRIMS) conducted a rapid health and needs assessment in the impacted provinces. The assessment team was using a World Health Organisation (WHO) rapid assessment tool (Rapid Health Assessment Protocols for Emergencies). Logistic and strategic support was provided by the Joint USA-Thai Military Advisory Group, Thailand. An interesting characteristic of this cooperation is that it is based on a long-standing relationship built over many years through joint exercises, attendance on joint staff courses and exchange assignments.

Overall, the hierarchically organized Thai Medical System stood out in the region affected by the tsunami because of its ability to adapt ad hoc to a situation that it had never been faced with before. Most casualties were treated locally in the field or in primary clinics. To this end, mattresses and beds were rapidly organized to "hospitalize" patients until primary care was completed and triage could be performed at a district or provincial hospital that had not been destroyed or severely damaged. District and provincial hospital sent personnel and medical supplies to reinforce primary clinics. These "outreach teams" provided advanced life support, triaged casualties, informed the surgical teams at their hospitals, and self-synchronised to selectively evacuate patients, in cooperation with Thai military ground and air transportation entities, to avoid overwhelming district and provincial hospitals and their surgeons.

C2 Maturity and Agility

C2 Maturity is a measure of the degree to which their C2 Approaches permit coalitions and organisations to cooperate in operations. C2 Approaches are categorized by how decision rights are allocated, how entities interact and how information is distributed. While the SAS-065 C2 Maturity Model emphasises complex endeavours involving coalitions [3], reference [81] points out that C2 Maturity levels are fractal and therefore can be applied to groups of individuals and organisations of any size.

C2 Agility measures the degree to which an organisation is sufficiently mature and capable of adapting its C2 Approaches to changes in the operational circumstances it is faced with. SAS-085 defines agility as "the capability to successfully effect, cope with and/ or exploit changes in circumstances" [77] and [6]. The concept of agility applies to organisations, processes, individuals, systems, equipment, and facilities [82].

The assessment made by SAS-065 considered the whole Thai initial relief operation and two selected sub operations: 1) cooperation between the Thai ministry of public health and USA military on health and need assessment; 2) and the initial relief operation by the Thai medical system.

Cooperation between the Thai ministry of public health and USA military on health and need assessment has the characteristics of coalition working at the collaboration level of C2 Maturity. In this case it is an impressive list of agencies involved in what is assessed as a coalition. These agencies had clearly a well-defined shared intention defined through the assessment tool. During the operation they worked according to a common plan as

described in [79]. There, is no mention of any need for changing the plan or the organisation. It can therefore be argued that only a capability corresponding to coordinated C2 was required for this operation, even if the coalition well may have been able to work at a collaborative C2 level.

The Thai medical system from the Thai ministry of Public Health down to the primary care clinics is an organisation rather than a coalition. It worked in close cooperation with the Thai military on evacuation but under the central coordination of the Ministry of the Interior. In this way the Thai medical system is formed as a new organisation rather than a coalition of two existing organisations. This new organisation is transformed and structured according to a plan put into effect when the Civil Defence Act is instantiated as shared intent is easily established in relief operations. In the Thai case, an integrated plan for this organisation was apparently developed and decision rights were delegated leading to the conclusion that the capability of the Thai medical system was at least at a collaborative C2 Maturity level. The discussion in reference [2] indicates that even an agile C2 Maturity level at the Edge level may apply in some cases. There, the success of relief operation in Thailand is attributed to several factors:

A combination of traditional values (i.e., faith, empathy, willingness to help and volunteer) and modern medical system (tertiary centres, medical helicopters, medical boats/or evacuation), personal leadership, ranging from the leadership displayed by the royal family and the Minister of Public Health to the leadership of individual physicians, played an important role in coping with the disaster. The changing of the hierarchical structure of the health system to a flat, non-formal, dominant leadership, and bypassing hierarchical levels by the leaders of all levels, proved to be an advantage in this disaster. Despite a low level of contingency planning, good communication eventually was established between all the healthcare components involved in the response, including primary clinics, district and provincial hospitals, the hospital in Bangkok, and Ministerial and international aid.

From these observations one may conclude that - under the umbrella of the Civil Defense Act - the Thai Medical System was agile enough to timely adapt its organisational structure and adopt C2 Approaches appropriate for coping with the dynamics of the environment. Thus, in terms of the maturity level criteria such as shared intent, sharing information, distribution of decision rights, the Thai Medical System quickly converted from the regular (de-conflicted) state into a collaborative mode. In fact, sharing the common intent of saving as many lives as possible, on the operational level components of the system seemed to self-synchronise their activities based on "Edge" principles.

Conclusions

It should be noted, however, that the complexity of the first response to the tsunami in Thailand was rather modest compared to what the response in Aceh-Sumatra had to face. In Thailand, based on the Civil Defense Act the responsibility for relief operations as well as the control of available aid resources were well defined shortly after the tsunami had struck. In Aceh, many of the local leaders had been killed and the lines of communication destroyed thus leaving it to local people to self-organize search and rescue activities. The military left was preoccupied with the Aceh-Sumatra Liberation Front mistrusting national NGOs which had no capability and means to coordinate their efforts. Aceh was virtually isolated until a UN Disaster Assessment and Coordination Team (UNDAC) arrived two days after disaster had struck to deploy and coordinate international aid that fuelled by the international media had been arriving in numbers that quickly overwhelmed the UNDAC team's capability. Thus, in terms of the C2 Maturity model, the cooperation amongst search and rescue/relief efforts of national and international governmental organisations and most NGOs in Aceh changed eventually from initially "conflicted" to "de-conflicted" and "coordinated" after the UN's OCHA had established a website

in Indonesia to facilitate information gathering and distribution of situation and needs assessment [8].

Being aware that they are unique, case studies let us know only what happened and not what could have happened. Thus, while the maturity model helped us to describe what we understood from the source materials on the events in both cases and the response to them, there was no way to go back and test what would have happened if the responders in questions took a different C2 Approach. Nevertheless, we found that by comparing the evidence provided by the case studies permitted us to draw the following conclusions with regard to the relationship between C2 Maturity and agility [8] and [83]:

- Entities/components having higher levels of C2 Maturity/agility are able to adopt a more appropriate C2 Approach than entities/components that have lower levels of C2 Maturity.
- The more complex and dynamic the mission and situation, the more is a mature the C2 Approach necessary to succeed.
- Being able to adopt Edge C2 in response to a rapidly changing environment, an organisation must be able to rapidly form task clusters of small "hardened" teams by professional competence thus capable to self-synchronise (as the Thai Medical System).
- The connectivity and performance of supporting systems (organisations/teams) can constrain the adoption of mature C2 Approaches and hence lower the effective maturity of entities.

Indirectly, these conclusions are reflected by the proposals of the Tsunami Evaluation Coalition (TEC) for a radical reform of the international disaster response that includes "de-complexing" large-scale disaster response operations essentially by having nations under risk of natural disasters to develop, to the degree possible, national structures for disaster response management and first response organisations and teams that are, in case of an emergency, reinforced by international capabilities on request to the United Nation's OCHA only [2].

Annex D – Case Study C2 Evidence Tables

This Annex presents the C2 evidence tables that have been completed using the template developed by SAS-085 (see Annex E) for the following case studies:

- Malaya-Singapore 1941-42 (Table 7 refers to the description provided in section 2.1.5) and
- Burma 1944 (Table 8 refers to the description provided in section 2.1.6)
- British Army and Security Forces in Northern Ireland 1969 – 2007 (Table 9 refers to the description provided in section 2.1.7)
- Operation Anaconda, Afghanistan 2002 (Table 10 refers to the description provided in section 2.1.8)

Table 7: British Commonwealth Forces Evidence Table

Concept/ Component	Malaya 1941-42 incl. Actions at Jitra and Gurun	Burma `43 1st Battle of Arakan	Burma `44 2nd Battle of Arakan, Kohima and Imphal	Burma `45 Crossing the Irrawaddy and the final British push
C2 Manoeuvre Agility				
Endeavour Space Complexity	**High** due to speed of operations, the difficult terrain and the skilled opponent.	**High** to speed of operations, the difficult terrain and the skilled opponent.	**High** to speed of operations, the difficult terrain and the skilled opponent.	**High** to speed of operations, the difficult terrain and the skilled opponent.
Appropriate (required) C2 Approach	**Collaborative** due to the need to make and implement decisions in face of a highly skilled opponent and to retain the initiative during the operation.	**Collaborative** A joint approach between the Army, Air Force, Intelligence and other special units was essential to deliver the desired effect.	**Collaborative** A joint approach between the Army, Air Force, Intelligence and other special units was essential to deliver the desired effect.	**Collaborative** A joint approach between the Army, Air Force, Intelligence and other special units was essential to deliver the desired effect.
Actual C2 Approach	**De-conflicted**	**De-conflicted**	**Coordinated to Collaborative** It was a learning process in 1944. –the new concepts had to be tried and modified before full effect was achieved.	**Collaborative and Edge** during the Irrawaddy river crossing in 1945. The assault battalions that crossed the river fragmented into smaller units. By showing an incredible high level of interaction and decision competence.
Self-Monitoring	Very limited	In a process of learning and implementing new concepts	High	High
C2 Approach Space				

Allocation of Decision Rights	Centralized at higher HQ. Unit CO's had little opportunity make important decisions when they were faced away from the action.	In training, decision rights and competence were allocated to lower level commanders but it was not yet fully implemented in the field	Broad	Broad
Distribution of Information	Limited. Much inaccurate information were shared with little opportunity to verify it.	Still limited by poor radios and organisation.	Broad	Broad
Patterns of Interaction	Tightly Constrained	Somewhat Constrained	Unconstrained	Unconstrained
C2 Agility Enablers				
Flexibility	Low	Low	High	High
Adaptiveness	Low	Medium	High the British-Indian Army successfully adapted to the new operational environment.	High
Responsive-ness	Low	Low	High the ability to respond and change the plan accordingly when the Japanese launched their offensive in Arakan 1944 showed the level of responsiveness the British had achieved.	High
Versatility	No Evidence	No Evidence	No Evidence	No Evidence
Innovative-ness	Low	Medium – the innovative concepts had been written but not yet implemented	High the way of thinking operations as a joint effort was very innovative in the British military in 1944.	High
Resilience	Low	Medium	High – Even during the Japanese offensives, the allied units stayed effective largely due the air resupply and the box concept.	High

Table 8: Imperial Japanese Army Evidence Table

Concept/Component	Malaya and Singapore 1941-42	Burma 43	Burma 44-45
C2 Manoeuvre Agility			
Endeavour Space Complexity	High	High	High

Appropriate (required) C2 Approach	Collaborative	Collaborative	Collaborative
Actual C2 Approach	Collaborative	Coordinated	Conflicted The Japanese Army could not operate at the joint level and thus their operations where not supported or coordinated.
Self-Monitoring	High	Low	Low
C2 Approach Space			
Allocation of Decision Rights	Very Broad	Broad	Low
Distribution of Information	Broad	Moderate	Low
Patterns of Interaction	Unconstrained	Unconstrained	Constrained
C2 Agility Enablers			
Flexibility	High the ability to rotate between units during the advance to Singapore allowed a greater flexibility.	High	Low suicidal charges and pointless last stands was the norm in the late war.
Adaptiveness	High	High	Low the Japanese could not counter the new British operational concepts.
Responsiveness	High the Japanese were quick to exploit any British weakness.	High	Low
Versatility	Low the Japanese had only few alternative options if their main plan had failed.	Low	Low
Innovativeness	High The Japanese plan was a departure from traditional military doctrine.	Moderate The Japanese defensive plan of the Arakan was skillfully executed.	Low The Japanese plans were weak and faulty and their ground forces were unsupported by logistics, artillery, and air support.
Resilience	High the Japanese showed an incredible level of resilience through the entire war.	High	High

Table 9: British Army and Security Forces in Northern Ireland 1969 – 2007

Concept/ Component	1969 - 1972	1973 - 1979	1980 - 1992	1993 - 2007
C2 Manoeuvre Agility				
Endeavour Space Complexity	High	High	High	High

Appropriate (required) C2 Approach	Collaborative	Edge	Edge	Coordinated
Actual C2 Approach	De-conflicted/ Coordinated	Collaborative	Edge	Coordinated – the decline of violence meant that many of the framework operations were no longer needed.
Self-Monitoring	Limited – no arrangements were in place for self-monitoring.	Very High - due to the efforts of Northern Ireland HQ and various training centers that collected lessons learned.	Very high due to the efforts of Northern Ireland HQ and various training centers that collected lessons learned.	High – the need for self-monitoring was considerable less at this stage.
C2 Approach Space				
Allocation of Decision Rights	Broad. The experience in various post-colonial conflicts highlighted the importance of decision competence with junior leaders. It was broad	Broad. Increasing allocation of decision rights due to the tactics of multi-patrolling and watchtowers.	Very broad. With the new approach, smaller units and junior leaders have broader AoDR.	Very broad – same as previously. Note although the Army may not have used this ability to its fullest potential as before, they still had the competence if the situation had demanded it.
Distribution of Information	Limited due to cooperation issues with the police (RUC and Special Branch).	Broad. Increase in ISTAR and a collaborative cooperation with the police meant a broad sharing of information.	Very broad DoI between Army units, Police and ISTAR assets as they gain experience and competence.	Very broad – same as previously. Note although the Army may not have used this ability to its fullest potential as before, they still had the competence if the situation had demanded it.
Patterns of Interaction	Tightly Constrained due to different operational boundaries with the police and a lack of understanding of the nature of the conflict.	Unconstrained. Sharing of the police operational boundaries and an increase cooperation with RUC and Ulster Defence Force resulted in broad patterns of interaction	Unconstrained within the Army and between the various security forces.	Unconstrained. Note although the Army may not have used this ability to its fullest potential as before, they still had the competence if the situation had demanded it.
C2 Agility Enablers				
Flexibility	Low – The Army either used too much force (like the very heavy-handed response on the 1972 Bloody Sunday event) or too little.	Moderate – The Army showed great skill in employing different approaches like riot-police actions, military raids, surveillance, undercover intelligence, patrolling and watchtowers.	High – same as the previous period but now the operations were conducted with greater efficiency due to increased experience.	High – Now the Army used a low-profile approach to security operations.

Adaptiveness	Moderate –.The Army had some issues in adopting a riot-police role and did not immediately use counterinsurgency or anti-terror tactics.	High - The ability to adapt from a riot-police action to a counterinsurgency and anti-terror operation shows a high degree of adaptiveness	High – as the Army learns and share their experience the adaptiveness becomes more widespread.	High – The Army changes from a counter-insurgent/anti-terror role to a peacekeeping and police support role.
Responsiveness	Low – due to a lack of situational understanding, the first stage saw a lack of appropriate responses to adversary actions.	Moderate – The new C2 Approach and the new tactics increase Army responses to adversary actions.	High – With the new C2 Approach and tactics fully implemented, the response time became so effective that the IRA could no longer operate without being caught.	High – maintained as previously.
Versatility	Low – The Army was only equipped and trained for a conventional war in Europe.	Moderate – The Army became much more versatile with the implementations of new C2 Approach, tactics and equipment.	High – versatility increases as the Army refine its C2 Approach and tactics and learn from experience.	High – same as previously.
Innovativeness	Low – despite of previously experience, no suitable C2 Approach or tactics were used.	High – Within short timeframe new initiatives to implement more appropriate C2 and tactics were adopted.	High – the new C2 Approach and tactics were maintained and further developed.	High - the new C2 Approach and tactics were maintained.
Resilience	High – Due to the high level of professionalism within the ranks of the British Army, and the political will to dedicate resources for the campaign, the Security Forces maintained throughout the entire campaign.	High – same as previously.	High - same as previously.	High – same as previously.

Table 10: C2 Agility Evidence Table: Operation Anaconda, Afghanistan 2002.

Concept/Component	Planning and D-day	From D-day + 1 till the end of the operation
Endeavour Space Complexity	High	High
Appropriate (required) C2 Approach	Coordinated	Coordinated
Actual C2 Approach	De-conflicted	Coordinated
Self-Monitoring	Limited – no arrangements were made for monitoring.	High. Evaluation after the events on D-day resulted in several C2 improvements.
C2 Approach Space		
Allocation of Decision Rights	Limited. 3rd Brigade HQ, 101st did not have sufficient authority over vital components like air and SOF units. They had to request their	Broad. Task Force Rakkasans gained greater decision competence over air support and ISTAR[6] assets.

[6] Intelligence, Surveillance, Targeting and Reconnaissance

	support through a long and cumbersome process.	
Distribution of Information	Constrained. Due to the many different component commands, intelligence services, and task forces, the information sharing was very limited. The plan was based on inaccurate intelligence and the units did not appreciate the nature of the tactical situation.	Unconstrained. The latest information from the units in contact was broadly shared and the following waves of infantry and air support could organize and plan according to the latest accurate intelligence.
Patterns of Interaction	Tightly Constrained. The interaction was insufficient for the effective planning of a joint operation. The different components did not understand the scoop and requirement of the operation.	Broad. The synergy and capabilities of each component became coordinated to deliver the required effects on the battlespace.
C2 Agility Enablers		
Flexibility	Moderate – The USA forces were able to shift from a raid with the Afghans as the main force to a sustained ground attack by the USA Infantry.	Moderate
Adaptiveness	High – The USA forces could adapt to a new C2 Approach while troops were in contact. A very difficult task.	High – The USA forces maintained the agile C2 Approach throughout the operation.
Responsiveness	High – The USA leadership was willing to evaluate, and respond, to the changing conditions on the ground.	High - The USA leadership was willing to evaluate and respond, to the changing conditions on the ground.
Versatility	High – The USA coalition forces did maintain effectiveness in both air and ground operations due to the high level of professionalism of the personnel.	High – same as previously.
Innovativeness	Low – the operation was properly too short to allow for innovative solutions.	Low – same as previously.
Resilience	High – The USA forces had a very high resilience due to the superior firepower, logistics and technology.	High – The USA forces had a very high resilience due to the superior firepower, logistics and technology.

Annex E – NATO SAS-085 C2 Agility Template

This Annex presents the C2 Agility template that has been developed by SAS-085 [6].

I. Executive Summary

a. **Focus and Boundaries**

b. **Challenge or Opportunity for *C2 Approach Agility and* C2 Agility**

c. **Was Agility Manifested? If so, How?**

d. **Enablers and Inhibitors of C2 *Approach* Agility**

e. **Summary of Observations/Conclusions about C2 Agility**

f. **Important stories or vignettes in the case study.**

II: Identify the Focus of and the Boundaries for the Case Study

a. **What is the level of analysis? (e.g. Individual, Team, Organisation, or Collective)**

b. **Who or What Organisations are included in the case study? (e.g. the Collective responding to the Haiti Earthquake Crisis, Air-Ground Control Strike Teams in Iraq and Afghanistan)**

c. **What temporal boundaries are included?**

   a. **When does the case begin and end?**

   b. **Are there phases involved? If so, what are their boundaries?**

d. **Other boundaries (e.g. separate analyses of the collective and of specific organisations within the collective).**

III. Describe the Challenge or Opportunity that gave rise to the need for *C2 Approach and* C2 Agilities.

IV: What would have been the consequences of a failure to act in a way that demonstrates *C2 Approach Agility and* C2 Agility?

V: Was *C2 Approach Agility and* C2 Agility Manifested? If so, How? (Be as clear and precise as possible, but keep this simple so that it does not require repetition in the next steps.)

VI: Which Enablers and Inhibitors of C2 *Approach* Agility were observable? (Remember that the basic six may not be independent. Include discussions of the relevant Agile Behaviours, but try to tie them to one or more Enablers. Specify inhibitors that impacted C2 Agility)

VII: What C2 Approaches were relevant *(i.e., did different situation complexity levels require a corresponding different C2 Approach)*? (How can C2 Agility be inferred from what was reported or observed?) Did C2 Approach change *to the appropriate C2 Approach*, either for a collective, organisation, team or one or more individuals?
VIII: What interesting and important vignettes are included or can be derived from the case study to help create illustrative stories?
IX: Case Study Assumptions and Limitations: **a. What constraints did you encounter that might limit the case study or the evidence supporting it?** **b. What assumptions did you make when carrying out or documenting the case study?**
X: Conclusions **a. This is not a summary – that is in the Executive Summary** **b. Conclusions relate to the purposes of the case study** **a. Enablers, Constraints, and Behaviours identified** **b. Language – Clarity and Definitions** **c. Applicability of the SAS-085 Concepts and Model** **d. Statements about Validity**
XI: Bibliography

Annex F – NATO SAS-104 C2 Agility Template

This Annex presents the new C2 Agility template that is being proposed by SAS-104.

Section I: Characterisation of the situation

- Case study description
  - Who or What Organisations are included in the case study? (e.g. the Collective responding to the crisis)
  - What processes are being included?
  - What technology is being included?
  - What temporal boundaries are included?
    - When does the case begin and end?
    - Are there phases involved? If so, what are their boundaries?
  - Other boundaries (e.g. separate analyses of the collective and of specific organisations within the collective)
  - What is the level of analysis? (e.g. Individual, Team, Organisation, or Collective)

- Case Study Assumptions and Limitations:
  a. What constraints did you encounter that might limit the case study or the evidence supporting it?
  b. What assumptions did you make when carrying out or documenting the case study?

- Assessment of the mission success
  - At the time the operation was conducted, what was their assessment not only globally but areas of improvement identified by lessons learned or after action reports.

Section II. Challenge or Opportunity

- Describe the Challenge(s) or Opportunity(ies) that gave rise to the need for C2 Agility. This usually relates to one or many changes of circumstances.

Section III: C2 Agility conditions

- What are the conditions (favourable and unfavourable) that impacted C2 Agility (e.g. situation awareness, risk assessment)
- Do the organisation have potential C2 Agility

Section V: C2 Agility Manifested

- Was C2 Agility Manifested? See appendix A for more details

Section VI: Analyst's Recommendation

- Potential C2 Agility vignettes
  - What interesting and important events/incidents included in the case study could help

create illustrative stories (events – examples – incidents)?

- Anticipated Required C2 Approaches
  - Based on your own assessment, identify the C2 Approaches that were relevant and say why (i.e., did different situation complexity levels require a corresponding different C2 Approach)? (How C2 Agility be inferred from what was reported or observed?) Did C2 Approach change to the appropriate C2 Approach, either for a collective, organisation, team or one or more individuals?
- Consequence of lack of C2 Agility
  - What would have been the consequences of a failure to act in a way that demonstrates C2 Agility?
- Global assessment of the analyst

Section VII: Conclusions

a. Conclusions relate to the purposes of the case study
b. Enablers, Constraints, and Behaviours identified
c. Language – Clarity and Definitions
d. Applicability of the SAS-085 Concepts and Model
e. Statements about Validity

Appendix A – C2 Agility

- C2 Agility is composed of :
  - C2 Approach Agility: a change of circumstances that the entity was able to cope with a specific C2 Approach
  - C2 Manoeuvre Agility: a change of C2 Approaches that allow the entity to cope with a change of circumstances. This also covers the case where more than one C2 Approach has to be executed in parallel while working with different organisations that have different levels of C2 Maturity. Capacity to conduct multiple approaches at the same time.
- Specific C2 Approaches can be identified using:
  - C2 Approaches variables of allocation of decision rights, patterns of interaction, distribution of information:

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

- The C2 tasks conducted and capabilities available:

C2 Approach	Description	C2 Tasks Required	C2 Capabilities Required
Edge C2	The entities are engaged to the collective effectiveness. • self-synchronisation of the collective • self-organisation of each entity to achieve common intent.	Development of shared intent, awareness, and understanding	Development of a rich, shared understanding of the common intent as well as the different entities. Self-synchronisation of the collective, self-organisation of each entity. Robust, secure, ubiquitous, interoperable, info-structure that extends to all participating entities
Collaborative C2	The entities are looking to maximize overall collective effectiveness. • collaborative development of a shared single plan that will achieve common intent	Development of common intent, shared understanding and trust Development of a single integrated plan, and parallel development of entities' plans that are synchronized with the overall plan. The different entities' resources are being used for the benefit of the mission	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)
Coordinated C2	The entities consider the increase of the overall collective effectiveness. • development of some common intent leading to an agreement about linking actions in the various plans developed by the different entities;	Development of a limited degree of common intent and development of links between and among individual plans and actions	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)
De-Conflicted C2	The entities of the collective C2 are trying to de-conflict their intents, plans or actions. The aim is to avoid negative impacts between and among the entities. Accordingly, they first need to recognize potential conflicts. Partitioning of activities, space, time and/or resources may be one approach to resolve the conflicts	Identification of potential conflicts and resolution of conflicts by establishing constraints and/or boundaries	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)
Conflicted C2	There is no collective C2. Each entity is working independently of the collective	No specific C2 tasks	No specific capabilities

Annex G – NetForce Command

The research program NetForce Command may offer new concepts to imply nonhierarchical C2 Approaches, e.g. the Edge C2 Approach. NetForce is a new concept that can complement traditional hierarchical C2. NetForce is characterized by (near) autonomous functional civilian and military nodes that are self-synchronising, aggregating and disaggregating in accordance with the demands of operational reality.

The term NetForce was first introduced in an article on 'Netforce principles' [84]. From a system of systems point of view Keus describes a NetForce as "the total collection of connected nodes that work together to perform a specific networked enabled capability." [84] and [85] describe NetForce as the total power that an adaptive civilian-military network can develop. We define NetForce as the total collection of civilian and military capacities, nodes, interacting and collaborating with each other in a technical, social and organisational connected network of capacities and working towards achieving a common objective in an ecosystem. In the most extreme form the nodes in a NetForce synchronise their activities without being ordered to do so, aggregating and disaggregating in accordance with the demands of operational reality.

Hence, a NetForce is not a formal organisation with clear tasks, roles, functions, processes, procedures and structures, but a loose, fluid, temporary, and often, spontaneous coalition of military and civilian nodes. A NetForce receives its power and influence from the connections and collaborations of the different nodes. Examples of nodes are an infantry platoon, an EOD unit, a political advisor, an UN OCHA employee or a team of engineers working on bridges. Each node is a representative of a military or civilian actor (parent organisation), whom may contribute to the coalition with one or more nodes. In practice, military forces will often contribute with more than one node. The parent organisations of these nodes often also have representatives in a more overarching organisation or entity like NATO or the UN. This overarching organisation provides mandate, rules/boundaries and support.

In principle, the network has a fluid structure, which means that nodes can decide at all times to leave the networked coalition or to become part of it. Parent organisations decide which capacities to deploy and provide information, organisational intent, preconditions and boundaries to the extent that these differ from or complement those in the mandate of the coalition. The parent organisations control and evaluate the performance of its own capacities in the network. For instance, to see if additional nodes need to be activated, nodes can be deactivated, or boundaries should be (re-)set. It does not manage or command the conduct of operations by the nodes it deploys.

A NetForce may have different appearances, varying from maximum self-synchronisation to maximum orchestration of the networked coalition. Maximum orchestration resembles the traditional hierarchical organisation. The scale is depicted in Figure 7.

The appearance of a NetForce depends on the context of the ecosystem, the actors that are contributing and the characteristics of the various capacities in the networked coalition. When these variables change, the appearance of a NetForce may change and as a consequence the approach to C2 may change as well. As part of the research program NetForce Command, we develop three typical variants of NetForce (archetype A, B and C), varying on the scale from maximum self-synchronisation to maximum orchestration.

The emergent NetForce (archetype A)

Archetype A, as depicted in Figure 16, is a NetForce variant in which a 'spontaneous and fluid' networked coalition emerges by different kinds of actors who are all committed (by a more or less formalized proclaimed

intention or objective) to improve/ change the situation in a certain ecosystem.

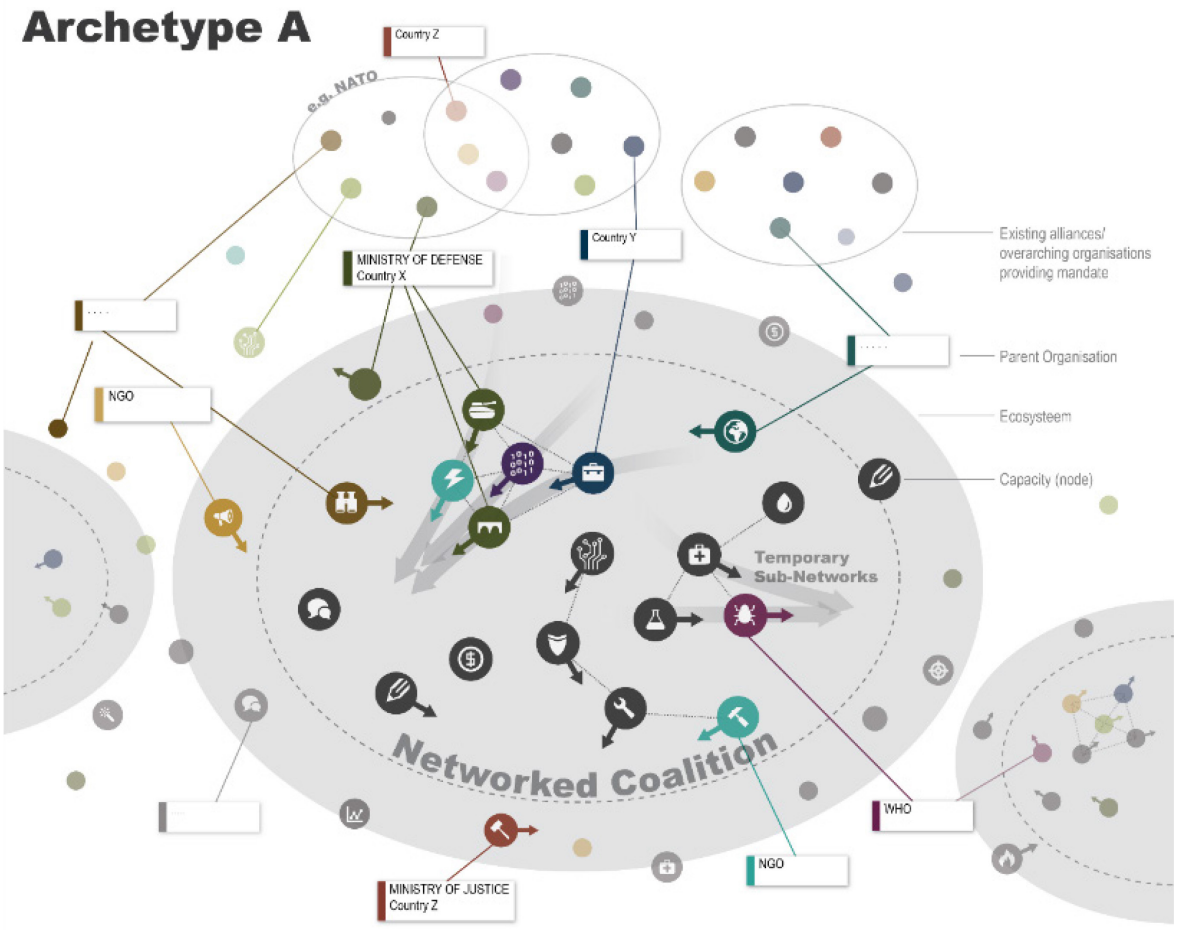

Figure 16: illustration of NetForce archetype A [21]

The nodes in the networked coalition operate by synchronising their activities. There is no commanding or steering node for the entire networked coalition. Besides the overarching organisation that issues the mandate for military nodes, there are no nodes that function as military staff levels and there are no commanders on higher levels than the commanders of the specific military nodes. The military nodes in the networked coalition are commanded by the commanders that belong to those military capacities. For example: when the military node is an infantry platoon with enablers, this platoon will be commanded by its platoon commander; when the military node is a role 2 facility, this facility will be commanded by its military commander. The same applies for civilian nodes: a team of a NGO will be managed by a manager of the NGO and a team of engineers of a certain company will be managed by their own head/ chief of engineers.

Coordination between the nodes results from self-synchronisation efforts of the nodes. In general, the nodes may be influenced or consulted, but are not commanded or controlled by one of the other nodes. Synchronisation between the nodes will or may occur when developments in the ecosystem seem to require this. The wish to synchronise will probably give rise to the development of temporary sub-networks. These sub-networks have their own objective, often related to the overall objective of the networked coalition. Examples are providing

security in a certain village to enable humanitarian or development actors, the development of a road through a specific area, or neutralizing an opponent's influence on a part of the ecosystem. A sub-network resolves when its objective is realized or when the situation or context changes and the sub-network is no longer relevant. A form of command or management may emerge in the sub-networks and will then have a temporary character. It will exist for as long as the sub-network is needed. Depending on the objective, the task and the type of nodes in the temporary sub-network, command or management may be distributed amongst the nodes in the sub-network, or be allocated to a single node. It may have an enabling or a more traditional, military character. Management can be fulfilled by any kind of node, military or civilian, and will usually follow from the expertise and the role of the node in relation to the objective. When military-style command is required in the sub-network, a military commander is likely to fulfill this role. In a sub-network that consists of multiple military nodes, the situation and the objective of the sub-network determines which commander of the military nodes will command the sub-network. This does not necessarily need to be the highest in rank. The hierarchy within such a sub-network is functional not formal. To be able to operate in a NetForce, military commanders need to become accustomed to being 'commanded' or managed by the sub-network and they need to be able to switch between different roles: from the commander of military nodes to strategist, influencer and/or diplomat.

The emergent, orchestrated NetForce (Archetype B)

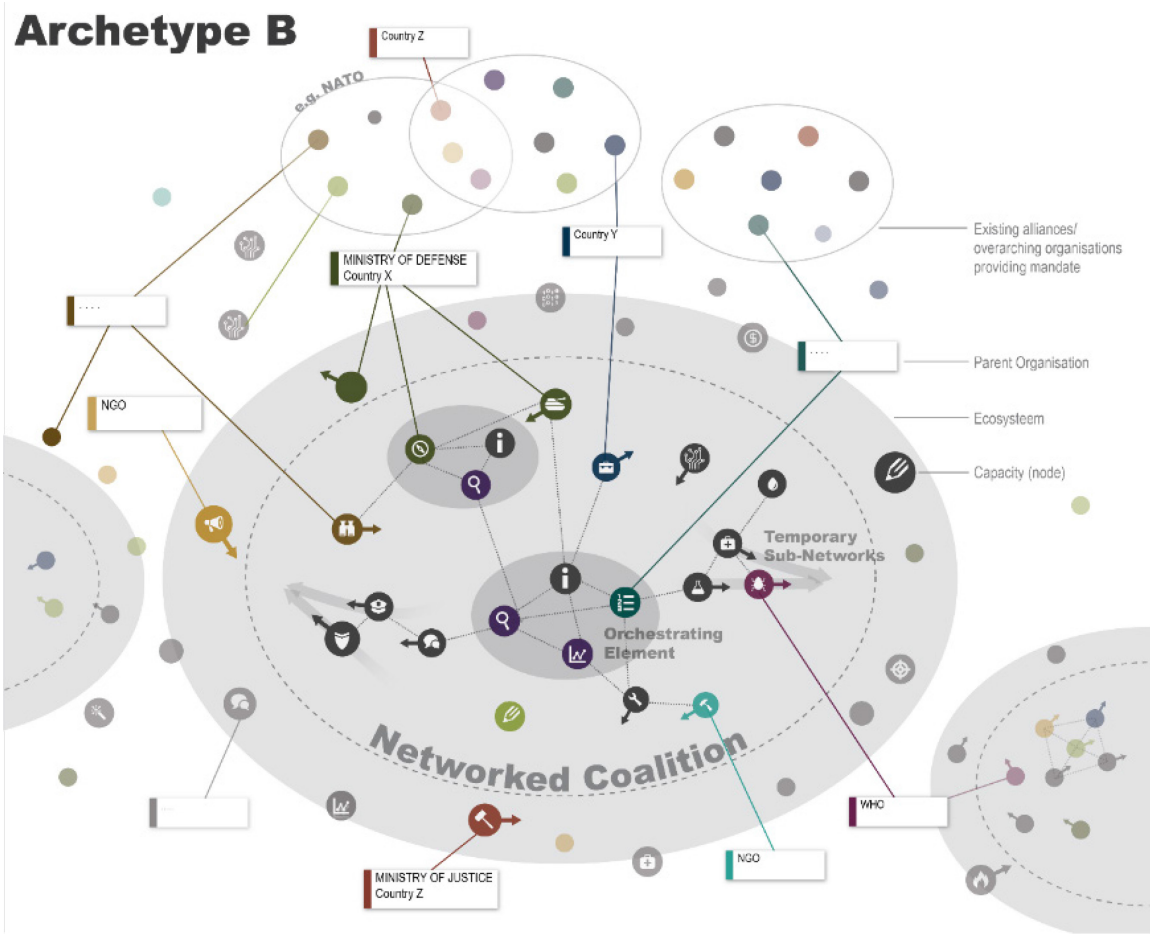

Figure 17: illustration of NetForce archetype B [21]

Archetype B, as depicted in Figure 17, is a NetForce variant that distinguishes itself from Archetype A by orchestrating elements. The orchestrating elements, consisting of one or more nodes, provide services to the networked coalition and may support the other nodes within the networked coalition on specific processes, for example information exchange, communication, data collection, coordination and overview. There are different views on where the decision to 'add' orchestrating elements is made. On the one hand, the orchestrating elements emerge and provide their service when there occurs a need for the service within the networked coalition. On the other hand, the orchestrating elements are assigned by the parent organisations or the overarching organisations and provide their service and guidance from the start of the existence of the networked coalition. One might argue that these two variants represent two different NetForce archetypes. At this stage we chose to incorporate both in archetype B, but both variants represent a different point on the scale from maximum self-synchronisation to maximum orchestration, represented in figure 1. It is expected that in the latter the orchestrating elements will have more guiding influence and some decision rights can be allocated to the orchestrating elements.

Depending on the needs of the networked coalition it is possible that there are more orchestrating elements for the same service. With these services the orchestrating elements can fulfill a form of management or parts of the function of command (e.g. leadership, support decision-making, provide control and attune), however it will not have direct control over the nodes in the networked coalition. The orchestrating element will only function properly when it is accepted and used by the nodes in the networked coalition. The orchestrating elements can dismantle itself and/or change its composition when the needs of the networked coalition change. However, it is expected that the services of the orchestrating elements will be required for a longer period of time. Contrary, the temporary sub-networks exist for a shorter period of time. The orchestrating element may stimulate the forming of temporary sub-networks to influence the ecosystem. The orchestrating elements may also support and facilitate collaboration, for example by connecting nodes, by providing knowledge about activities of nodes in the networked coalition.

The strategic, orchestrated NetForce (archetype C)

Archetype C, as depicted in Figure 18, is a NetForce variant that differs from archetype A and B in the sense that the networked coalition is guided and supported by a coalition on political strategic level, a strategic coalition. A strategic coalition is not part of a networked coalition that operates in the ecosystem and is often not physically present in the ecosystem where the crisis or mission takes place. A strategic coalition consists of different actors, political strategic representatives of JIMP organisations, that also have capacities, nodes, in a networked coalition. The main difference with archetype A and B is that the representatives of the parent organisations in a more overarching organisation or entity like NATO or the UN (also present in archetype A and B) form a strategic coalition. The objective of a strategic coalition is to develop a design and a strategy that provides guidance and support for the nodes in the networked coalition, specifically for the orchestrating elements. By developing a design and a strategy on political strategic level the potential efforts of the nodes are attuned in advance, which could increase the effectiveness and efficiency of the nodes. However, it takes time to form a strategic coalition and to develop a design and a strategy.

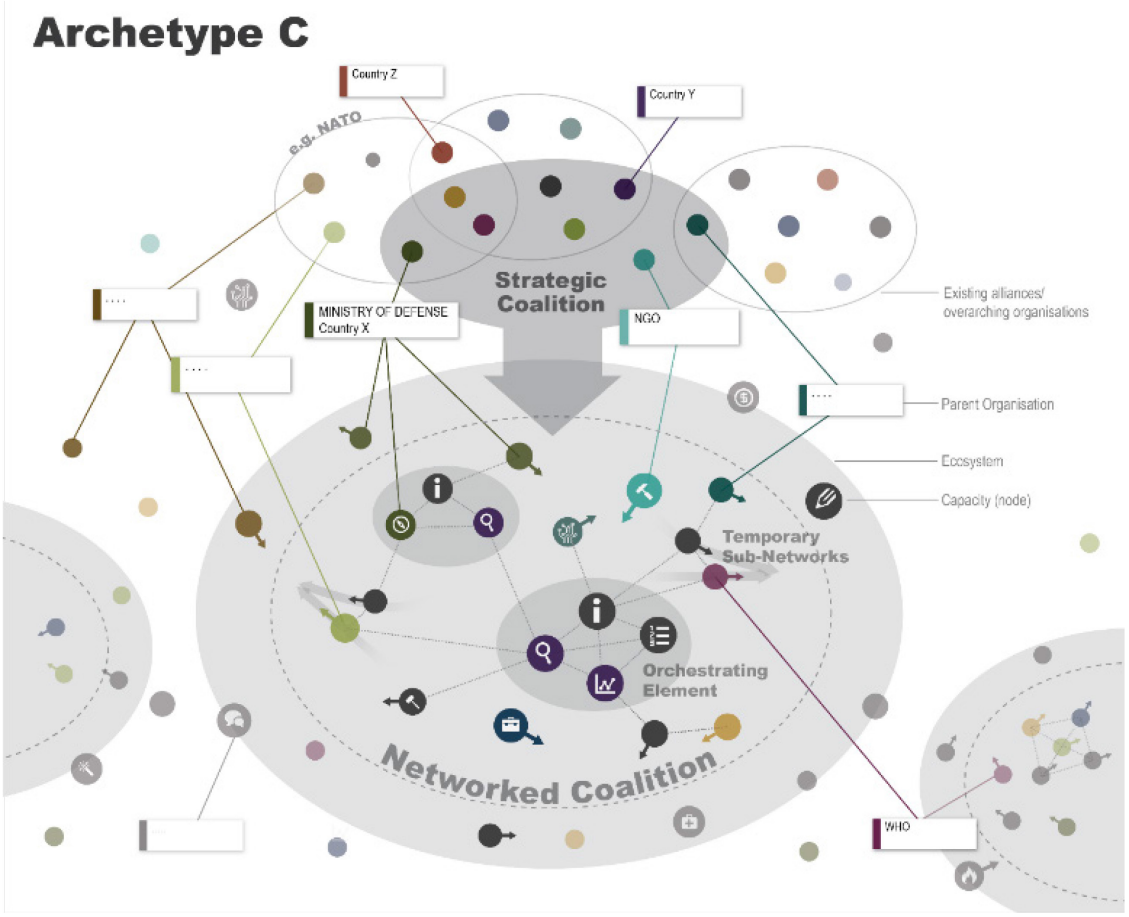

Figure 18: illustration of NetForce archetype C [21]

The strategic coalition and the orchestrating elements fulfill a form of management or parts of the function of command. Although a strategic coalition will not have nor provide direct control over the orchestrating elements and the nodes, it is possible that political strategic developments overrule local initiatives and activities. The strategic coalition will guide and influence the nodes to function in line with the design and strategy. Because of the guidance and support from political strategic level, it is expected that the orchestrating elements in the networked coalition will have more guiding influence in this archetype than in archetype B. Also, the leadership role of the orchestrating elements may become more formalized. The strategic commission will also monitor progress in order to update the design and strategy when necessary.

Annex H – GBR Approach to Agility

The GBR conducts interdisciplinary research that generates and assesses novel socio-technical options in order to result in transformational gains in the cost effectiveness of C2 capability in a Full Spectrum Approach (FSA) context. This includes interventions aimed at the personnel, team, intra-organisational and inter-organisational levels of analysis. The GBR uses an incrementalist approach based on the principles of systems thinking to rapidly gain insights from our attempts to create and innovate as part of an iterative research process, and seek to exploit research opportunities in both naturalistic (e.g. exercise and operations) and controlled settings (e.g. war games, laboratory experiments, trials, etc.). The GBR works with their stakeholders to strike an appropriate balance between short-term and longer-term focused research, whilst collaborating with international partners and also investing in the longer-term development research capabilities.

Whilst there are many perspectives on what C2 'is', we tend to use systems theory to think of C2 as a means: of cohering, of 'forming a unified whole or collective', of bringing separate agents into purposeful collective action. Without C2, the consequences from individual agents acting in isolation upon the collective would not be considered within the process of regulating those individual actions (through control, negotiation or influence actions). This positions C2 within cycles, where the consequences of prior action upon the collective stimulate future actions. It operates simultaneously in both an anticipatory mode (feed forward) before change, and a responsive mode (feedback) during ongoing change or afterwards, in order to simultaneously and selectively drive change and provide continuity in collective circumstances.

A common mistake made is to consider C2 as only considering those agents under direct command, i.e. limited to the subordinate military force elements. To paraphrase Von Clausewitz, the military are one instrument of politics and act in support of political processes, particularly when a process of peaceful conflict resolution by political discourse is absent. In thinking about C2 from a system's perspective, it follows that C2 is about regulating the consequences of action upon the relationships between all agents, be it their own forces, friends, neutrals, spoilers or enemies. It is about building a collective of cooperating agents capable of engaging in purposeful collective action that provides security and resolves the underlying drivers of conflict and crises as part of a political process. It should result in the establishment of an ongoing political process of peaceful conflict resolution agreed to by all parties (Figure 19). It achieves and maintains this collective state of cooperation through influence of negotiation/dialogue, de-confliction, coordination or collaboration with others. This is the meaning of what the GBR MOD calls a Full Spectrum Approach (FSA). When C2 is within a FSA context, C2 and FSA become synonymous.

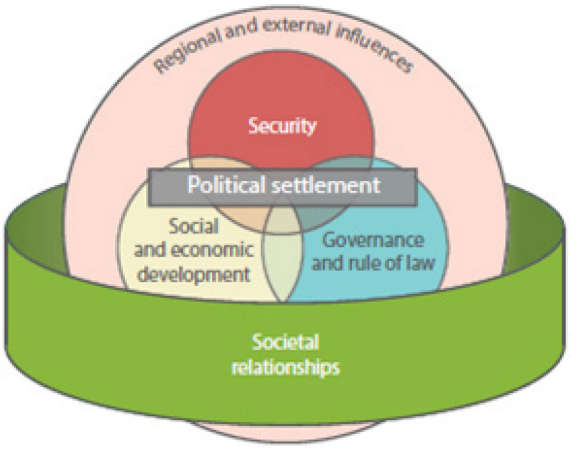

Figure 19: The stable state model (JDP05)

When is C2 cost-effective? C2 is not the same concept as agility. Whilst C2 is a means of cohering purposeful collective action that will drive change and continuity in collective circumstances (i.e. to cause, shape or stop change), agility is the ability "to successfully effect, cope with and/or exploit changes in circumstances". Specifically, agility is a concept about the effectiveness of C2 on operations, where the emphasis on what constitutes successful C2 is placed on driving, shaping and exploiting change in a manner appropriate to the context of operations, rather than just surviving and reacting to it afterwards. However, there are omissions in the literature about the agility concept. The literature does not generally include:

- Whole-life Cost (£) or real constraints (e.g. art of the possible);
- The idea of action that seeks to preserve or provide continuity, or of action that stops change from occurring, which still requires agility;
- A broad-enough concept of the Resilience of C2. A sufficient concept of C2 effectiveness would cover both agility and resilience. For example, agility as an abstract concept does not include the broader range of additional Resilience factors necessary for the physical operation and survival of the people, technology and organisations engaged in C2 of operations; and
- A consideration of all the end-to-end activities conducted prior to and after operations that are necessary to ensure the cost effectiveness of C2 on operations. Interventions here may produce transformational gains.