An overview of assessment approaches for C2 agility in the crisis and emergency response domain

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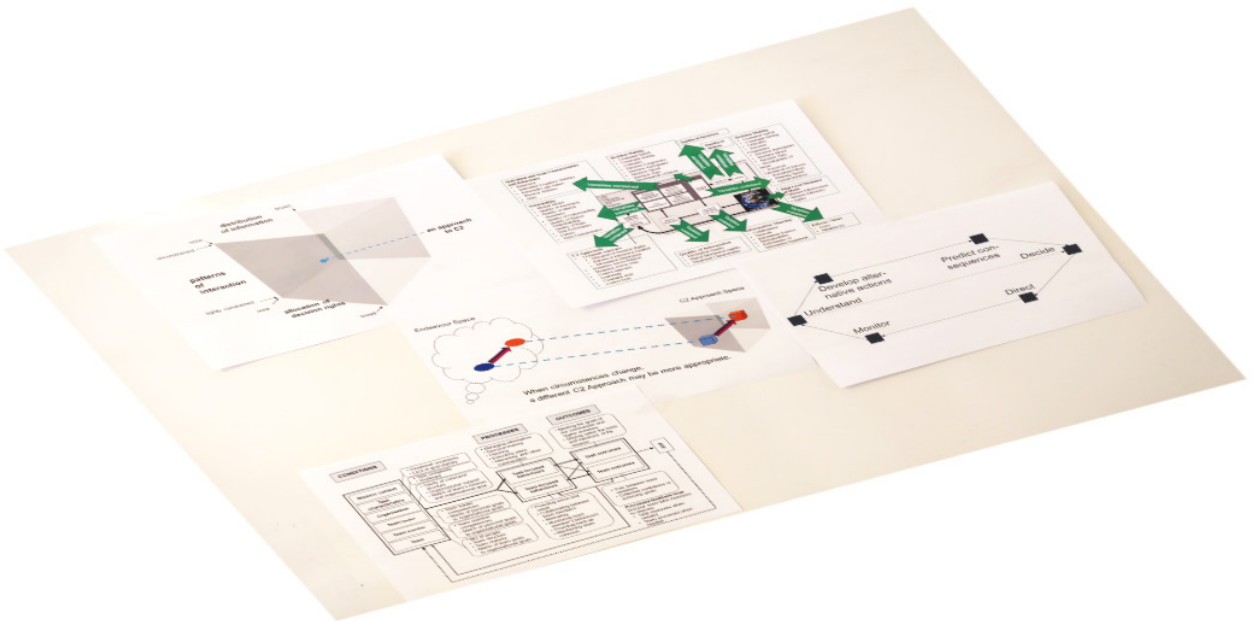

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Summary

This report focuses on assessment approaches for C2 of organisations or collectives of organisations in crisis and emergency response operations in terms of their abilities to cope with disturbances, unexpected situations and other types of changes in circumstances. The study was performed by utilizing the concept of *C2 agility* that has been devised in the military domain. A challenge in this context is to transform such a concept (C2 agility) from one domain (military operations) to another (crisis and emergency response) and as well as to define particular capabilities, factors, and properties for the domain of crisis and emergency response operations, in order to identify measurable training and evaluation objectives.

Our overview identified a number of frameworks from the military domain that capture aspects of C2 agility, but none of them were explicitly developed for assessments of C2 agility, and none of them have been used in the crisis or emergency response domain. The overview also presents some methods, like social network analysis and communication analysis that can be utilized to analyse aspects of C2 agility in the crisis and emergency response domain. Further, we describe pros and cons with a number of data collection methods that can be used for gathering data regarding C2 agility in the crisis and emergency response domain.

As no existing frameworks or methods can be applied directly for assessing C2 agility in the crisis and emergency response domain, we suggest that a new instrument is developed to support analysis of C2 agility in crisis and emergency response organisations. Such an instrument should take a functional view of C2, be able to capture the dynamics of C2 as well as the crisis or emergency events, and be applicable to development of training or exercise scenarios.

Keywords: Assessment, C2, Emergency response, Crisis response, C2 agility

Sammanfattning

Denna rapport fokuserar på metoder för att värdera förmågan att hantera oväntade situationer och andra typer av förändringar i omständigheterna i samband med ledning och samverkan. Detta görs genom att konceptet *ledningsagilitet*, som ursprungligen utvecklades inom den militära domänen, introduceras. Att överföra konceptet från en militär domän till krishanterings- och blåljusverksamhet innebär en utmaning liksom att definiera förmågor, faktorer och egenskaper som kan användas som mått för att utvärdera träning och övning samt ta fram mål för tränings- och övningsverksamhet.

I den studie som genomförts identifierades ett antal metoder och ramverk från den militära domänen som fångar olika aspekter av ledningsagilitet. Ingen av dessa var dock explicit utvecklade för att värdera ledningagilitet. Därtill har ingen av dessa metoder och ramverk använts för värdering av krishantering eller blåljusverksamhet. Studien presenterar också några metoder, som exempelvis social nätverksanalys och kommunikationsanalys, som kan användas för att värdera vissa aspekter av ledningsagilitet i kris- och olyckshanteringssammanhang. Slutligen beskrivs för- och nackdelarna med ett antal datainsamlingsmetoder som bedöms ha potential för att samla in data rörande ledningsagilitet.

Då inga existerande metoder eller ramverk kan användas direkt för att värdera ledningsagilitet i krishanterings- och blåljusdomänen finns ett behov av att utveckla ett nytt instrument för att stötta en sådan analys. Ett sådant analysstöd bör anta ett funktionellt perspektiv på ledning och samverkan, kunna fånga dynamiken i lednings- och samverkansprocesserna liksom i den händelse som ska hanteras.

Nyckelord: Värdering, Ledning, Samverkan, Blåljusdomän, Krishantering, Ledningsagilitet

Contents

1 Introduction

This report presents an overview of frameworks, methods, and measures found applicable for the evaluation of Agile Command and Control (C2) organisations in crisis and emergency response operations in terms of the organisational capability to adapt C2 to better cope with disturbances, unexpected situations and other types of changes in circumstances. An earlier report (Johansson, Trnka & Berggren, 2014) summarised theoretical approaches and concepts in the field of agility and C2 agility. This report builds upon this work and expands it by presenting an overview of methods for assessing C2 and C2 agility.

1.1 Background

This work is performed within the research project "Situation-adapted command and control based on design logic with a holistic stance". The project is part of a research program funded by the Swedish Civil Contingencies Agency (Myndigheten för Samhällsskydd och Beredskap, MSB).

The project aims to increase the societal capacity of coping with accidents, emergencies and crises by:

- Developing indicators for command, control and collaboration.
- Developing concepts for command and control based on requirements analysis.
- Increasing knowledge about the context for command, control and collaboration today and in the future.

The project involves three collaborating partners, the Swedish National Defence College (Försvarshögskolan, FHS), Lund University and The Swedish Defence Research Agency (Totalförsvarets Forskningsinstitut, FOI).

The project consists of three work packages conducted by each partner:

- Analysis and evaluation of command and control capabilities (FHS).
- 21st century command and control challenges (Lund University).
- Agile command and control organizations and information sharing (FOI).

The work package "Agile command and control organizations and information sharing" is based on the assumption that crisis and emergency management organizations in general are created and optimized towards handling certain scenarios and conditions. Such assumptions are, typically, that the organizations in question are fully manned and that the events to be handled are clearly defined and limited. Real-world experiences have often shown that this is not the case. Instead, it is common that crisis and emergency management organizations have to cope with uncertainty due to unforeseen events, that conditions are far from optimal and that information is scarce or lacking completely. The knowledge on how collectives of organizations collaborate in unusual events is also limited. "Agile" organizations have been suggested as a way of overcoming these problems. Based on this reasoning the following objectives have been set for the work package:

- Investigate how agile organizations can contribute to increased flexibility in uncertain event(s) or context(s).
- Investigate how information sharing in agile organizations can be improved.
- Investigate which factors are essential in order to assess the quality of command and control, and collaboration in relation to agile organizations.

- Contribute to the development of concepts for agile command and control and information sharing.

1.2 Objectives

This report focuses on assessment approaches for C2 of organisations or collectives of organisations in crisis and emergency response operations in terms of their abilities to cope with disturbances, unexpected situations and other types of changes in circumstances.

The objectives of the report has been:

- To present an overview of existing methods for assessing C2 and C2 agility
- To describe in what way these methods need to be complemented or adapted to be useful in the crisis and emergency response domain

This is performed by utilization of the concept of C2 agility that has been devised in military domain, defined by and in connection to the NATO STO SAS task-groups (NATO STO SAS-065, 2010; NATO STO SAS-085, 2014). A challenge in this context is to transform such a concept (C2 agility) from one domain (military operations) to another (crisis and emergency response) and as well as to define capabilities, factors, and properties for the domain of crisis and emergency response operations, in order to identify measurable training and evaluation objectives.

1.3 Target audience

The target audience for this report is primarily researchers and subject matter experts on agility, C2 agility, C2, and crisis and emergency response at universities, research institutes and government organizations.

1.4 Outline of the report

The report consists of four chapters where:

Chapter 1 provides a general background to this report as well as its purpose, target audience and method.

Chapter 2 presents an interpretation of what C2 agility is in the domain of crisis and emergency response operations

Chapter 3 presents an overview of existing frameworks, assessment, and data collection methods for assessing various aspects of C2 and C2 agility

Chapter 4 provides a discussion of the methods presented in chapter 3 and their applicability in relation to C2 agility.

2 Command and control agility in crisis and emergency response

In our earlier report (Johansson, Berggren, & Trnka, 2015), several theoretical approaches were identified that can be utilized for understanding how C2 agility, organizational adaptivity and improvisation are needed in order to cope with dynamic and uncertain events, such as crisis and emergency response. However, that work was mainly a literature review, describing the state-of-the art in relevant fields. In this chapter, we elaborate on the concept of C2 agility and its application in the crisis and emergency response domain. We also identify specific aspects of C2 in crisis and emergency response operations and discuss their implications for the use of the concept in terms of evaluations of C2 agility in crisis and emergency response operations. In order to reach this goal, we begin with a description of what C2 is and how it relates to crisis and emergency response.

2.1 Command and control – a generic view

As a basis for the argumentation and discussion in this report, a description of our view on C2 and what we believe C2 can be in the domain of crisis and emergency response, is provided below. Although there are several important differences between crisis and emergency response and military operations, which will be discussed further, it is necessary to provide some background to military C2 in order to be able to discuss and utilize some of the findings from research within the military C2 field so that it can be applied in the context of crisis and emergency response operations. Military command and control has been defined as:

”The authority, responsibilities and activities of military commanders in the direction and co-ordination of military forces and in the implementation of orders related to the execution of operations.” (NATO, EU, & UN, 2015, p. 33).

The above definition points to the human component (the commander) and the purpose of C2, *to provide direction and coordination*. In a similar fashion, the Canadian researchers McCann & Pigeau (1996) define C2 as “The establishment of common intent to achieve coordinated action” (quoted from McCann & Pigeau, 1996, p. 165). This definition of C2 emphasizes the critical role of Command (that is, the human will), while acknowledging the necessary contribution of Control (that is, technology, procedures and regulation) (McCann & Pigeau, 1996). McCann & Pigeau (2000) also add that the key to this definition of C2 is the concept of intent, which they define as “an aim or purpose along with all its associated connotations” (p. 165). They add that this definition of intent comprises two elements: (1) explicit (or public) intent, and (2) implicit (or personal) intent. The background to this definition of C2 was, according to McCann & Pigeau (2000), that they had recognized the criticality of the human component for effective operations in modern military encounters, but that the human component had been both under-emphasized and under-researched. In order to understand the conditions for executing C2, we need to understand fundamental aspects of human communication, leadership and trust. Commander competence is crucial to cope with a variety of situations, and to interact with many different persons in such a way that they grasp the intent of the commander. Technical systems provide an important foundation for this work by supporting these activities (communication systems, decision support systems, geographic information systems etc.). C2 is thus exercised as a part of a socio-technical system (Emery & Trist, 1965) where the C2 process consists of humans organised in specific ways, supported by various technologies that together form a purposeful whole. In the military context, C2 is the backbone that creates direction and coordination in an insecure and uncertain environment.

Such a socio-technical system must be able to formulate goals and present both reactive (feedback driven) as well as pro-active (feedforward driven) activities, just like any

organism or system that can present purposeful behaviour in a dynamic context (Johansson, 2014). There are several models of C2 that reflect these aspects, such as the Observe-Orient-Decide-Act (OODA) loop by Boyd, the Dynamic Observe-Orient-Decide-Act (DOODA) loop by Brehmer (2006) and the C2 Conceptual Reference Model (C2CRM) by NATO STO SAS-050 (2006). Those models are based on process, and in the case of the DOODA, core functions that must exist to produce the intended outcomes of C2, i.e. direction and coordination. In Brehmer's (2007) DOODA model of C2 systems, data collection, sensemaking, and planning are specified as core functions. In principal, these three functions would be equally central in the crisis and emergency response domain as any socio-technical system trying to control a situation needs to be able to monitor its development, understand what is happening and plan near and future actions. The DOODA-loop model further departs from *design logic*, assuming that functions have corresponding forms, that are the actual manifestations of the functions in the form of personnel (and their training), equipment, procedure, regulation etc.

However, many models of and approaches to C2 or crisis and emergency response are based on a *structural approach* where the C2 system is described as a set of structurally arranged components. The relations between the components comprise procedural arrangements that are described in terms of sequences or logical if-then steps. Structure and procedure thus maintain the system from this point of view (Alderson & Doyle, 2010[1]). Structural models are often appealing as people who recognise the concept from organizational charts and descriptions of technical artefacts, such as circuit boards. Builder, Banks, and Nordin (1999) discuss the fact that structural approaches often are interpreted as cybernetic approaches. They refer to the seducing assumption that complex socio-technical systems represented as structural models can give the impression that they are possible to describe in mathematical terms, and hence model with a high degree of prediction. This view suggests that structural models would be deterministic in the same sense a closed system, such as a circuit board, would be. Anyone with real-world experience of open systems comprising human components, or even technical components in open environments knows that this is a false assumption. It is thus important to remember, along with the propositions of Brehmer (2006), that *structure and procedure is only the manifestation of function*, although it has strong implications for in what way the same functions can be achieved.

From the above, we can conclude that C2, independent of whether it is a military or crisis and emergency response activity, has the *purpose of creating effects in time and space as to achieve specific goals*. In order to achieve this purpose, *the activity of (usually several) entities[2] must be harmonized as to coordinate their actions to create these effects*. How the goals to be achieved are formulated and the way harmonization is achieved may, and should, look differently depending on the involved organisations and the problem(s) at hand.

All these fundamental assumptions concerning what C2 is and how it should be described also influence how assessment and measurement approaches are designed, as will become evident in the following chapters. Further, the very nature of military C2 influences some of the assessment methods. For example, military C2 normally assume permanent functions for planning, intelligence, logistics, something that is far from self-evident in crisis and emergency response, which normally is a reactive activity created for coping with events of comparatively short duration, which defy (and perhaps do not need) planning to the same degree as a military endeavour. Another important distinction between military operations and crisis and emergency operations is the chain of command, or the delegation of decision rights. Military organisations are usually organised in strict hierarchies with well-defined (but rigid) C2 structures, while emergency response is

[1] In their discussion, Alderson & Doyle use the term protocol rather than procedure, but the argument is still valid.

[2] "Entity" in this case may refer to operative parts of a crisis and emergency response organisation, such as a fire engine, an ambulance or even a sub-ordinate commander.

founded on collectives of organisations, sharing certain common objectives, but without centralised command functions. Instead, crisis and emergency response, at least in Sweden, is based on collaboration, regulated by the three principles of proximity, responsibility, and similarity. This allows for a large degree of flexibility based on the assumption that the decision maker working close to the problem at hand is the one best suited to make decisions, but also demand a high level of competence and knowledge of the crisis response system to be used in an efficient manner. What C2 agility is and how it can be described in the domain of crisis and emergency response will be explained below.

2.2 Applying command and control agility on the domain of crisis and emergency response domain

While military C2 usually follows carefully defined structures and processes, crisis and emergency response operations differ in the sense that C2 structures continuously adjust to shifting demands and changing circumstances. Many of these shifting demands and changing circumstances originate in the nature of crisis and emergency response operations as they are governed by actual needs in particular emergencies, influencing which organizations will be involved, to which extent as well as how the operations will be organized. In turn, this affects the C2 structures in place. For instance, changes in the number of C2 personnel involved and allocation of tasks often change over time in a response operation. Changes of such nature will also affect C2 work as it may demand the use of diverse organizational and temporal configurations of C2 work over time. Unplanned adjustments in courses of actions or improvised deployments of procedures are other examples that can affect how C2 is conducted (see, for instance, Baber et. al., 2004; Militello, Patterson, Bowman, & Wears, 2007; Uhr, Johansson, & Fredholm, 2008).

The concept of C2 agility (NATO STO, 2013; Huber, Moffat & Alberts, 2012) has its origins in the military domain. In our previous work (Johansson, Berggren & Trnka, 2015; Johansson, Trnka & Berggren, 2016) the concept has been described and discussed in detail in relation to other similar concepts as well as to the crisis and emergency response domain. We will therefore only provide a brief description of the fundamentals of C2 agility. The most important conceptual tool developed in the NATO STO SAS work is the command and control approach space (see Figure 1), a three-axis model presenting an organization's approach to C2 (C2 approach) in terms of "information dissemination" (who gets to know what?), "allocation of decision rights" (who has the mandate to take action) and the "interactions" (who is interacting with who?) (NATO STO SAS-065, 2010). Hierarchical, formal bureaucratic organizations with limited capability to disseminate information will position themselves on the "lower" end of the dimensions while more networked, distributed organizations with a high degree of allocation of decision rights will position themselves further out on the axes. The positioning of different approaches should not be interpreted as one being "better" than another. Instead, the appropriateness of a C2 approach can only be evaluated in the light of the situation and problem in which it is applied. For some situations/problems a formal bureaucracy may be a good choice, while other situations demand other approaches to command and control/crisis management.

The SAS-065 (2010) report suggests five archetypical approaches to command and control that can be found along the diagonal going from the lower left corner of the cube towards the upper right corner on the opposite side of the space. Two C2 approaches that are often used as extreme cases to illustrate this are traditional, hierarchical organizations with stove-piped communication and centralized control, versus fully networked organizations with complete access of information for all participants and full allocation of decision rights to all members. Instead, we present our interpretation of how C2 agility can be interpreted in the domain of crisis and emergency response. There are certain domain specific aspects that characterize C2 structures managing crisis and emergency response

operations. This is something that needs to be taken into account when applying the concept of C2 agility in this domain.

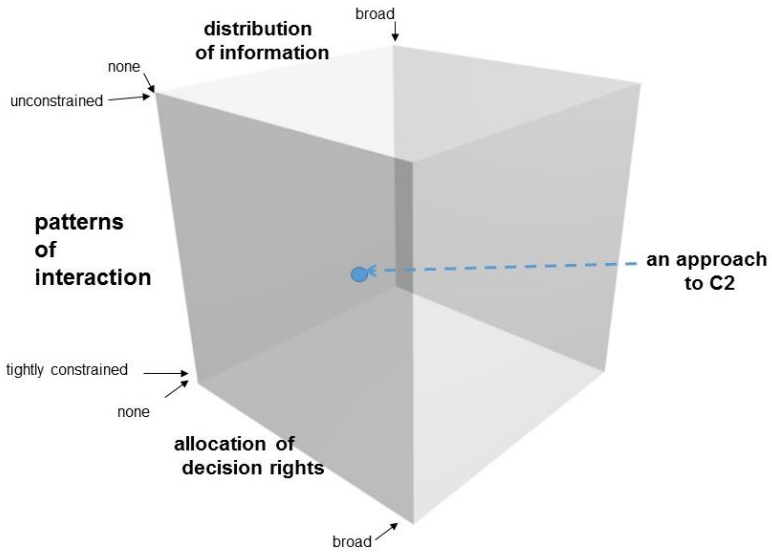

Figure 1. The C2 approach space (SAS-085, 2013).

A fundamental hypothesis presented in the work conducted by SAS-085 is that each type of situation/problem/mission has a corresponding "best choice" of C2 approach (position in the command and control approach space). No approach is thus perfect for all kinds of situations/problems/missions. The situation in which the organization operates is referred to as the endeavor space, using the NATO STO SAS terminology.

C2 Agility is an entity's capability to successfully accomplish C2 functions over the entire Endeavour space (NATO STO SAS-085, 2013, p. 79).

However, no explicit model like the C2 approach space, describing the basic dimensions of the endeavor space has been published within the NATO STO SAS research groups.

The term command and control maturity (SAS-085, 2013) refers to the ability of the organization/organizations to function at different positions in the C2 approach space. To be C2 agile is thus a function of what parts of the C2 approach space that an organization/entity or a collective of such potentially can occupy (the C2 maturity), and the ability to position itself appropriately in relation to the endeavor space (the C2 maneuver agility). Figure 2 illustrates how a change in mission circumstances suggests the need to adapt a different C2 approach.

Being C2 agile thus means to be able to recognize that the current C2 approach is inappropriate in relation to the current situation, understanding what approach would be appropriate, and, finally, to have the ability to make a transition from the current C2 approach to the desired one. Naturally, this will, in many cases, require a fundamental change in thinking about organizational design as such an approach demands that an organization or a collective of organizations not only focus on one way of organizing and performing. This stands in contrast to most current approaches where one way of working is assumed. Admittedly, crisis management/response organizations are sometimes less formalized in their processes than other types of organizations, but the most agile organizations today are probably found in business rather than military or crisis management/response organizations. A crisis will however often challenge pre-conceived views of how things should be done, promoting flexible approaches to C2/management.

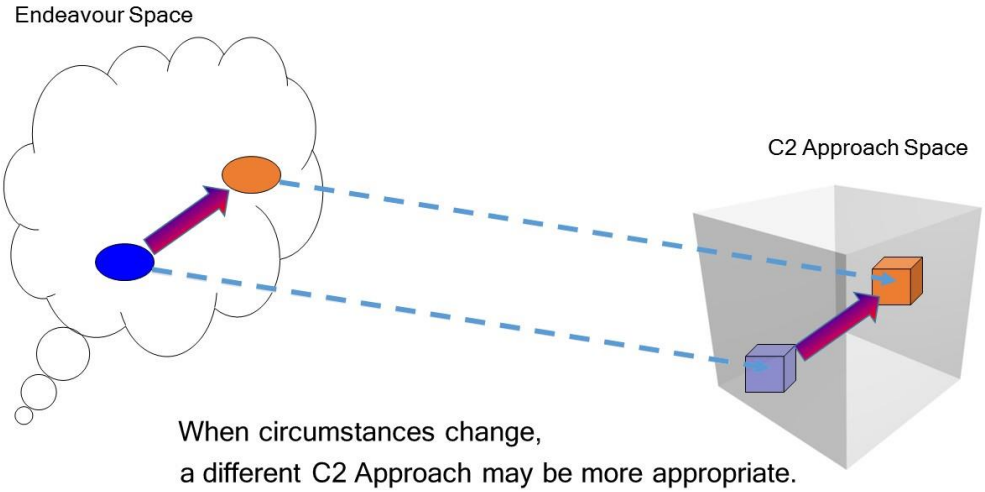

Figure 2. Adapting a different C2 approach as a function of changes in the endeavour space (SAS-085, 2013).

Unlike military C2, which normally is in place continuously, at least on the HQ level, crisis and emergency response C2 structures in charge of particular response operations are normally organized shortly after an crisis and emergency has taken place (within minutes or hours) out of the nearest available C2 resources of the involved organizations and their C2 systems. They are established "on-the-go" during the initial stages of response operations with a reactive and bottom-up approach. These C2 structures are later on disbanded as the response operations are concluded. They thus exist only for short periods of time (from hours to days, or, in extreme cases, weeks) (see, for instance, Bigley & Roberts, 2001; Svensson, Cedergårdh, Mårtensson, & Winnberg, 2009; Cedergårdh & Winnberg, 2010; Schraagen & Van de Ven, 2011). This means crisis and emergency response operations are situated and will look different (from a C2 point of view) depending on the situation, the context, involved actors and temporal constraints. However, when applying concepts such as C2 agility in the domain of crisis and emergency response, we must assume that each type of crisis and emergency, and related crisis and emergency response operation, has a corresponding "best choice" of C2 approach (position in C2 approach space[3]).

There are two issues related to this assumption. The first issue is whether the C2 approaches proposed for the military domain are equally applicable in the crisis and emergency response domain. The second issue relates to the "best choice of C2 approach", which may not be known or identified for all types of crises and emergencies[4]. These issues cannot be resolved with the current body of knowledge. This is something that has an impact on how training and evaluations can be designed as well as what can be trained and evaluated. At the same time we argue that these two issues do not disqualify the concept from being used in the crisis and emergency response domain.

In the crisis and emergency response context C2 agility can be interpreted as:

> *C2 agility means that C2 structures in charge of particular crisis and emergency operations are rearranged when judged to be inappropriate in order to better fit the current or foreseeable future situations. This means adapting the ways the C2*

[3] For discussion on the C2 approach space and the different C2 approaches, see Johansson, Berggren & Trnka, (2015) or NATO STO SAS-085 (2014).

[4] This is also challenging in the military domain. What the most appropriate C2 approach is for a specific mission will always be a hypothesis based on information about operational conditions, which in most cases are limited.

structures function or are organized by adjusting information dissemination or allocation of decision rights.

This kind of action or behaviour is not a new phenomenon in crisis and emergency response as, for instance, revealed in our attempt to apply the C2 agility case study template (NATO STO SAS-085, 2014) on a large-scale forest firefighting operation (Johansson, Trnka & Berggren, 2016). Adaptation may concern the use of diverse organizational and temporal configurations of C2 work over time. Unplanned adjustments in courses of actions or improvised deployments of procedures are other examples (see, for instance, Baber et al., 2004; Militello, Patterson, Bowman, & Wears, 2007; Uhr, Johansson, & Fredholm, 2008). This means that, in order to create an operationalised assessment of C2 agility, attention should be given to behaviour, actions and conditions that support the ability to be agile, and C2 agile, rather than focusing on C2 approaches as such.

With this standpoint in mind the above presented interpretation of C2 agility can be broken down to the following definition:

To be agile in terms of C2 means that C2 structures managing crisis and emergency response operations are able to:

- *Recognize when the current C2 approach is inappropriate in relation to the current situation, [alertness to change]*
- *Understanding which C2 approach would be appropriate, and*
- *Have the ability to make a transition from the current C2 approach to the desired (in line with NATO STO SAS-085, 2013).*

These three fundamental capabilities are the essential components of C2 agility. This distinction is, however, too general for design and execution of training and evaluation. In reality it will probably be different levels, or degrees, of C2 agility that can be achieved in particular crisis and emergency response operations. A typical crisis and emergency response organisation will most likely converge towards and stabilise at a "comfort zone" in the C2 approach space (Farrell & Connell, 2010) where it will linger until a mismatch between the current C2 approach and the current mission occurs that is so large that it becomes apparent that new ways of working must be adopted. More developed organisations (in terms of agile and adaptive capabilities) may have processes and maturity in place to make more rapid adaptions.

Ideally, crisis and emergency response organisations should be as C2 agile as possible in order to cope with the variety of challenges they may face. In practice, the order of agility that C2 structures in crisis and emergency response operations can achieve depends on what attributes the specific C2 structures in place have. The NATO STO SAS-085 (2014) research suggest that for example the degree of interconnectedness within and between organizations constrains the ability to disseminate information, and hence the ability to respond to detected changes in the environment. Likewise, the allocation of decision rights tells us something about how quickly an organisation or collective of organisations will be able to respond to changes, as a broad allocation of decisions will allow front-line units to take immediate action without having to receive instructions from superiors.

To conclude, while C2 agility currently is a concept that has not been applied fully to neither military nor civilian organisations, there are some evident differences between the existing C2 structures in military organisations and crisis and emergency response organisations that were pointed out above, such as the fact that military organisations have continuously running C2 functions, while crisis and emergency response organisations normally work with a minimal of C2 involved. A shortcoming of the military arrangement is that it may be difficult to change or adapt how C2 is conducted as the structures and procedures in place may be firmly rooted. C2 in crisis and emergency response is on the other hand more flexible than military C2, but lack permanent C2 functions and usually

need some time to establish them in situations that goes beyond what is expected in everyday scenarios.

2.3 Implications for research studies

Earlier work in this project indicate that there are few, if any, established measures or methods designed to capture the potential C2 agility of an organisation or collective of organisations, independent of whether it is a military or crisis and emergency response organisation (Johansson, Berggren & Trnka, 2014). This limits the usefulness of the C2 agility concepts as it is necessary to be able to assess what C2 approach an organisation has and what ability it has to change this approach if needed. Thus, methods to assess C2 agility are needed in order to relate C2 agility to actual performance of the same organisation or organisations and thereby establishing the benefits of making transitions between different C2 approaches. Further, once validated, such methods are needed in order to assess the *potential for C2 agility* in an organisation or collective of organisations.

Chapter 3 provides an overview of existing and suggested approaches to assessing various aspects of C2 and C2 agility.

3 Assessing command and control agility

This chapter provides an overview of methodology for assessment of C2 agility, organised along three levels. First, at the highest level, is a review given of methodological frameworks that has been developed for assessment of military C2 agility. Secondly, at an intermediate level a review is given of a number of methods that can be used to assess certain aspects of C2 agility. Finally, at the lowest level, specific methods to collect data that may reflect C2 agility are described. Frameworks can thus be comprised of several methods, which in turn may include several different data collection methods.

The frameworks, methods and data collection techniques presented in this chapter have been identified in previous work conducted in this and other projects at the Swedish Defence Research agency and NATO STO research groups in which the Swedish Defence Research agency has participated.

These different assessment techniques are judged to reflect different aspects of C2 agility, such as overarching assessment frameworks that could aid in determining what C2 approach a certain entity has or holds the potential to take on, or assessments of dimensions of C2 agility, such as dissemination of information or allocation of decision rights. It is important to understand the pros and cons of different data collection methods as the frameworks and methods/assessment techniques utilize them, meaning that the practical implementation and usefulness of the same frameworks and assessment methods are heavily influenced by this.

3.1 Methodological frameworks for assessment of command and control agility

No established frameworks for assessment of C2 agility of the crisis and emergency domain or other civilian domains have been identified. On the other hand, in the military domain several approaches have been developed for aspects of C2 that can be related to C2 agility. Some of these frameworks are directly applicable to the crisis and emergency domain, while others may need to be adapted. The most promising methodological frameworks from the military domain are described below in this section. In chapter 4, we continue the discussion of their applicability in relation to C2 agility and the crisis and emergency response domain.

3.1.1 NATO C2CRM

The NATO C2 Conceptual Reference Model (CRM) was created as a framework for assessment of C2 maturity, architecture, and approaches. The model was originally developed in 2006 by the NATO SAS-050 research task group and later updated by the SAS-065 research task group (NATO SAS-050, 2006; NATO STO SAS-065, 2010). The intention by NATO SAS-050 was to create a reference model for C2 research that could be used as a detailed specification and checklist of important variables and relations. According to NATO STO SAS-085 (2014) one further purpose of SAS-050 was to create a model that could be used for exploration of new approaches to C2, and to compare them according to performance, effectiveness, and agility with traditional approaches to C2.

An updated version of C2CRM (version 2.0) is described in a separately published appendix to NATO STO SAS-065 (NATO STO SAS, 2009). The model has a hierarchical structure and consists of more than 400 variables at three levels and descriptions of their relations. At the highest level there are ten variables, which can be described as ten key dimensions of C2. These are built up by 50 underlying variables at an intermediate level, which can be described as underlying factors of C2. The variables at these two levels are latent, which means that they cannot be measured directly. Therefore, each variable at the intermediate level contains a number of manifest measurement variables. In all there are

approximately 380 measurement variables. The ten key dimensions of C2, their underlying intermediate dimensions of C2, and their relations are illustrated in Figure 3.

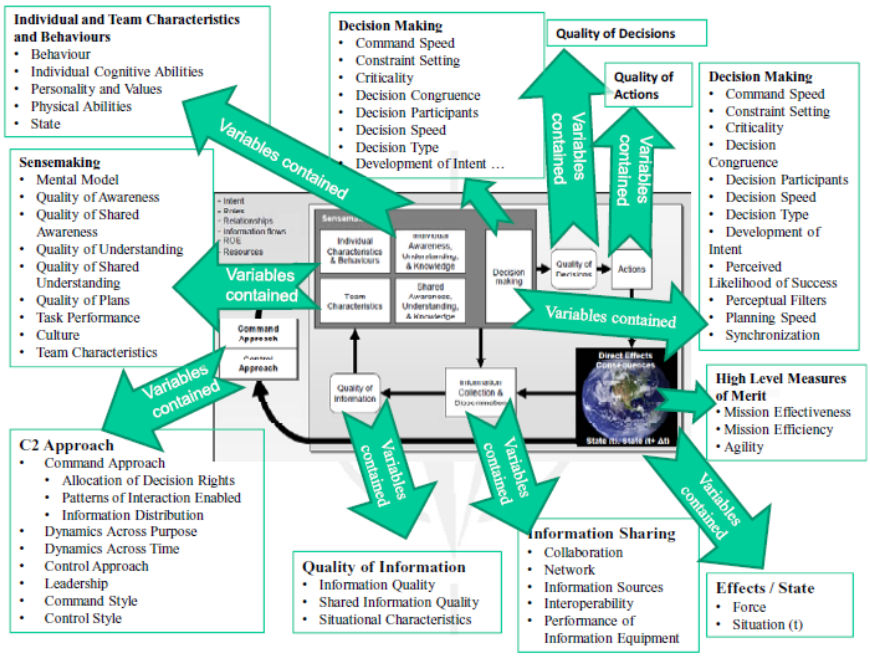

Figure 3. The NATO C2CRM model 2,0 with ten major dimensions of C2, underlying intermediate dimensions of C2, and their relations (NATO STO SAS, 2009).

C2CRM does not provide clear descriptions of measurement methods for suggested variables. However, some of the variables can be found in other frameworks (see descriptions below) from a wide range of research disciplines. The model should therefore, which also is indicated by its name, mainly be regarded as a conceptual frame of reference, that can be used as a support and checklist for C2 development and assessment.

For assessments of C2 agility in the crisis and emergency domain C2CRM can provide a valuable framework of important dimensions of C2 and a library with measurement variables for each dimension. However, work needs to be conducted in order to identify what measures are relevant and their applicability in the crisis and emergency response domain, before such a library can be operationalised.

3.1.2 HEAT

HEAT (Headquarters Effectiveness Assessment Tool) was developed in the 1980's and has been used in numerous military exercises and experiments. The purpose is to provide quantitative, objective, and reproducible effectiveness scores of C2 of units with primary responsibility of planning, supporting, and coordination of fighting forces (Hayes & Wheatley, 2001).

HEAT takes on the perspective that the headquarters or command centre is an adaptive control system that seeks to influence its environment by assigning plans or directives to its subordinates. This can be described as a cyclical process with six phases. However, because of reasons such as extreme time pressure, activation of a contingency, or the commander's knowledge and experience, in many cases there is a direct path between understanding and decision making (see Figure 4).

Measures have been developed and applied for all phases of the HEAT cycle, which means that irrespective of which decision cycle the unit chooses to follow the method can provide assessments of their C2 effectiveness.

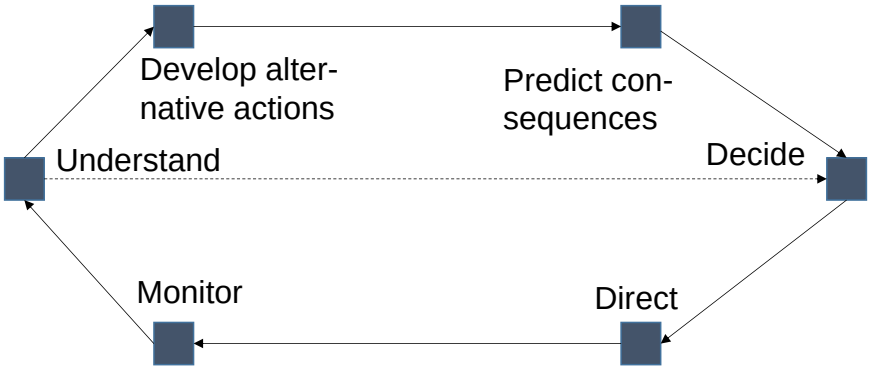

Figure 4. Illustration of the HEAT cycle (adapted from Hayes & Wheatley, 2001).

During the use of HEAT in different exercises more than over 250 different performance measures have been used to collect data. Hayes and Wheatley (2001) refers to the Military Operations Research Society (MORS) standards, also applied in the NATO Code of Best Practice for C2 Modelling.

Data is usually collected by observers and surveys and in Hayes and Wheatley (2001) an example of an observer data sheet is given.

Organization of data collection follows the elements in the HEAT cycle for organization of the command and control process, with utilization of performance indicators of C2 for the following categories (Alberts & Hayes, 2002, pp. 177-178):

- *Monitoring* – facts known to the information system, scored for completeness, correctness, currency, consistency and precision.
- *Understanding* – perceptions and understanding, scored for completeness, correctness, time horizon, and consistency.
- *Alternatives considered* – scored for variety and number of perspectives.
- *Predictions made* - scored for variety and number, completeness of alternative futures considered.
- *Decisions made* – not scored, recorded for later comparison with outcomes for mission accomplishment.
- *Directives generated* – scored for clarity and consistency with decisions made.
- *Reports* issued – scored for correctness and consistency.
- *Queries for information* – scored for response rate, response time, and correctness of response.
- *All categories* – time and speed measures of completing respective step, or tasks within the step, and quality of cooperation in the C2 processes.

The quality of cooperation measures were included in a modification process around year 2000. This resulted in five key measures of quality (Alberts & Hayes, 2002, pp. 185-186):

- *Completeness* – that information about the entities and situations of interest are available.
- *Correctness* – that there is no false information and that uncertainties of the information is known.
- *Currency* – that there are no time lags in the information and that existing time lags are known.
- *Consistency* – that there are no differences between information sets known to different parts of the information system.

- *Precision* – that the information has adequate precision for some specific application.

Since HEAT is developed for assessment of C2 of units with primary responsibility of tasks like planning, supporting, and coordination, and not for units directly involved in combat, it may have good potential for assessment of C2 in the crisis and emergency domain. However, the dynamic nature of C2 in crisis and emergency response may put limits to the applicability of the framework. Also, HEAT was not explicitly developed to assess agile C2, but rather C2 as such.

3.1.3 Army Command and Control Evaluation System (ACCES)

ACCES was developed from HEAT for application within the army with C2 from corps to division level (Keene, Michel, & Spiegel, 1990), but has mainly been used at the division level (Hayes, Layton, & Ross, 1995).

ACCES is a systematic approach to observing and assessing C2 performance of both individual participants and of the collective (Halpin, 1996). Data collection mainly builds on observation. Therefore, the assumption is that both participant and collective behaviours are doctrinally grounded and thus possible to assess in relation to doctrine (Hayes et al., 1995).

The first version of ACCES was developed 1986 and it was then further developed during the coming years, which means that descriptions of methodology and measurements differ somewhat between publications. According to the documentation from Hayes et al. (1995), ACCES includes the following six categories of process measures that parallel the behaviours that make up the C2 process:

- *Information handling* – comprises interactions with operating units to verify information. Can be obtained by monitoring of communications, monitoring status boards, reading in- and outgoing reports, and by perusing message journals.
- *Situation assessment* – comprises efforts to understand or assign meaning to information about both friendly situation and enemy situation. Can be obtained by observation of formal and informal settings where understandings are expressed.
- *Course of Action Analysis* – comprises efforts to identify and recommend a preferred option or alternative to accomplish the assigned task or mission. Can be obtained by monitoring decision briefings at initial stages, observing Planning Cells throughout the mission, and observing the presentation of recommendations to the decision maker.
- *Decision context* – comprises selection of a course of action analysis by the decision maker. Can e.g. be obtained by observing decision makers, recording activities associated with decision making, and identification of when an option is selected.
- *Preparation of directives* – comprises the development of directives. Can be obtained by recording the decision, observing the directive preparation and dissemination activities, and tracking the movements of the directives in the chain of command.
- *Information exchange* – comprises efforts to synchronize battle field events or to complete information holdings in conjunction with decision making activities. Can be obtained by monitoring request for clarification, observing staff actions to harmonize or synchronize changes on the battlefield, and tracking requests from decision makers to determine whether to follow-up on the decision or close the loop.

Typically exercises where data collection is performed are sustained 24-hours-a-day events that last for several days. Data is collected over time at different locations in the chain of command (Hayes et al., 1995).

Hayes et al. (1995) point out that even though the word "evaluation" is included in the acronym ACCES, the method does not provide recommendations for decisions of whether assessed C2 effectiveness is good enough according to a certain criteria, but rather indicators of C2 effectiveness. However, they mean that these indicators are of great value since they provide quantity and quality of the feedback that are given to commanders.

An extensive guide to assessment with ACCES can be found in Hayes et al. (1995) and Halpin (1996). This comprises, for example, preparation for data collection, guidelines for observer training, standardized observer protocols, and instructions for data analysis.

ACCES has been used in numerous division and corps command centre assessments (Alberts & Hayes, 2002) and has been further developed over the years. This indicates that the method is thoroughly tested and relatively mature. The same limitation applies to ACCES as to HEAT (see above) that it is not explicitly developed to assess the agile component of C2. Further, it holds some assumptions, for example that a planning function exists, something that does not necessarily hold for all types of crisis and emergency response work (rather, it is an exception).

3.1.4 CTEF

The Command Team Effectiveness (CTEF) model was developed by the NATO RTO HFM Task Group (HFM-87) to provide assessment of the effectiveness of operational teams or staffs (NATO RTO HFM-087, 2005). The development of the model built on an extensive literature review on team effectiveness and analysis of operational command teams. One objective was to create an assessment instrument that (a) built on data collection by participants' self-ratings instead of observation, (b) had little sophisticated data analysis, and (c) that reflected team effectiveness (Essens et al., 2005). CTEF can be used for assessment of both large and small teams, for assessment of missions with both short and long time duration, before and after a mission in the operational context, and for after action review (AAR) (NATO RTO HFM-087, 2005).

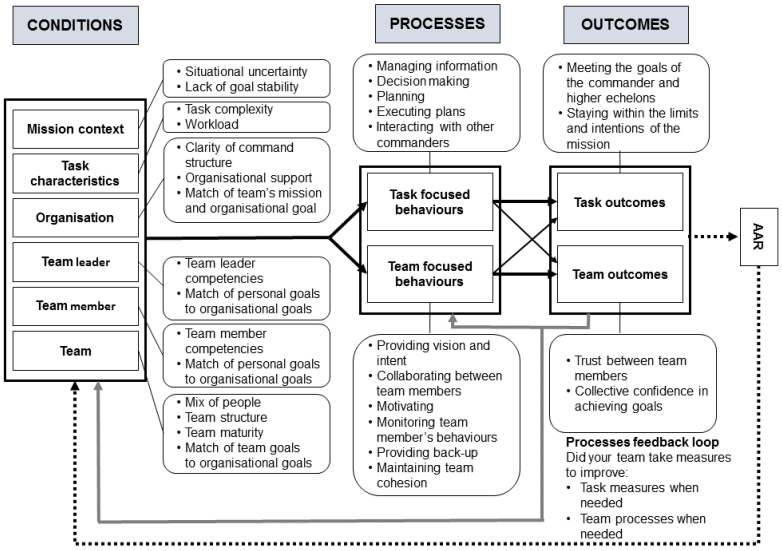

Figure 5. Illustration of the structure of the revised CTEF 2.0 model (adapted from illustration of the original CTEF model in NATO RTO HFM-087, 2005 and descriptions of revised concepts in Essens et al. 2010).

The original CTEF model from 2005 was revised during 2008-2009, which resulted in an updated model called CTEF 2.0 (Essens et al., 2010). The revision built on experiences of applications of the CTEF model in numerous operational settings and surveys in several NATO countries. Data collection with the revised model is simplified by a reduction of number of questions from 75 to 32 items, adapted formulation of remaining questions, and simplification of rating scales (Essens et al., 2010). However, the overall structure of the revised model is in principal the same as in the original model, with conditions, processes, outcomes, and feedback as critical factors for team effectiveness (Figure 5).

A survey in several NATO countries has shown high operational usability of the revised CTEF instrument (Essens et al., 2010). Also, according to Essens et al. (2010) the instrument may with some adaptions very well be used in civilian applications, as for example for assessment of crisis and emergency teams.

The CTEF questionnaire is an instrument that is organized according to the structure of the CTEF model, which is answered by the commander and/or team members. The purpose of the instrument is to support commanders' ability to systematically apply the CTEF model by helping them to: (a) asses the status of listed conditions, processes and outcomes, and (b) judge the impact which the status may potentially have on outcomes. The instrument can be used at various stages of a team mission, and the results can be used to assess, control, and improve the effectiveness of the team. The CTEF instrument comprises questions from all parts of the CTEF model and captures both task- and team focused behaviours. The questionnaire is divided into 10 categories of questions, and a score is calculated for each category. For each question the respondent rates the quality or magnitude of the aspect from low to high on the scale 1-5; and the impact of the aspect on team effectiveness from negative to positive on the scale minus 2 – plus 2. For each category there are a number of subcategories of questions, which are given in parentheses in the bullets below (Essens et al., 2005):

- *Mission framework* (situational uncertainty, operational stress, limitations, risk of damaging interests).
- *Task* (complexity, workload, goal uncertainty, goal instability).
- *Organization* (goal congruity, command structure, autonomy, organizational support).
- *Leader* (leader skills, leader knowledge, consistency between goals of leader and organization).
- *Team members* (team member skills, team member knowledge, consistency between goals of team members and organization).
- *Team* (team composition, team size, team architecture, team maturity, consistency between goals of the team and organization).
- *Task focused behaviours* (managing information, making decisions, planning, directing and controlling, interaction with other command teams).
- *Team focused behaviours* (providing and maintaining vision, maintaining common intent, interacting within the team, motivating, adapting, providing team maintenance).
- *Task outcomes* (primary stakeholder's criteria, other stakeholders' criteria, if the team stays within limits).
- *Team outcomes* (mutual trust, morale, cohesion, collective confidence in achieving the goal, shared vision, mutual respect).

A validation study of the original CTEF questionnaire (Essens et al., 2005) performed with 718 military commanders from 14 nations showed high operational usability of the instrument (Essens et al., 2010). However, this validation study also showed that the

instrument was generally perceived as too long, which resulted in a modified and abbreviated version of the instrument, which is completely reported in Essens et al. (2010).

An extensive description of the revised CTEF model, including description of its use, data analysis, interpretation of results, and forms for questionnaires can be found in Essens et al. (2010).

That the original CTEF instrument was recognized as having high operational usability, and that it has been revised into a shorter instrument even indicates potential to increased usability. CTEF is not focused on agility, or even on C2 as such, but team aspects of C2, and therefore has potential in the area of crisis and emergency response as it captures aspects of C2 agility that relate to the maturity of the organization that may be possible to translate into the order of C2 agility presented in Section 2.2 above.

3.1.5 MARTA

MARTA (Militär Analysmetod för Reliabla TAktiska Värderingar, eng. Military Method for Analysis of Reliable Tactical Validations) is a Swedish method for performance assessment of military units during exercises. The method was developed in cooperation between the Swedish Armed Forces and FOI and has been used since 2003 (Ahl, Andersson, & Lindberg, 2012).

Data is collected by observation. For this purpose, the most important part is creation of an assessment template. For this means a bank of questions is used, and in the version used for MARTA version 2012 the bank of questions was modified to increase its similarity with the NATO assessment method OCC E&F (Operational Capabilities Concept Evaluation and Feedback) (NATO SHAPE, 2011). The bank of questions consists of 15 categories of questions. Which questions from each category that are used in the assessment template is dependent on type of unit and task and does subsequently vary between assessments. Of the 15 categories, the first five in bullets below are clearly related to assessment of C2 agility and the last two somewhat more secondary related, but nevertheless relevant:

- C2/planning
- C2/accomplishment
- C2/follow-up
- C2/overall
- Intelligence and information
- Function-specific key tasks
- Solving of the task

The eight other categories in MARTA that we consider less related to assessment of C2 agility are: weapon effect, force protection, mobility, endurance of own unit, tactics and combat technique, own casualties, civilian situation, and safety and friendly fire.

Another important part of MARTA is that a weighting procedure of the categories of the assessment template is used. The purpose is to create an assessment that reflects relevant aspects of the general capability of the unit. This means that the influence of categories with high importance for the task is increased, while influence of categories with less importance is decreased.

The result is an assessment of the unit's performance and ability to accomplish its tasks in relation to external circumstances and according to tactical, operative, and economical objectives. A comprehensive guide to the use of MARTA, including descriptions of construction of assessment templates and analysis of data, can be found in Ahl et al. (2012).

It should be noted that MARTA was not developed for assessing C2 agility. Nor does it support specific evaluation of adaptive capacity. However, it is structured in such a way that it reflects aspects that are important to C2 agility, such as how information was managed, how specific tasks were performed, and how well the task at hand was solved. In addition, if only five or seven questions from MARTA are specifically selected for assessment of C2 agility the weighting procedure must also be adapted in accordance with this selection.

3.1.6 Summary of frameworks for C2 assessment

A summary of the frameworks for C2 assessments presented in previous sections in this chapter is given in Table 1. For each framework, this includes: the name of the framework, a short description of the framework, suggested measurement methods, the methods applicability to C2 agility in the crisis and emergency domain, and important references to descriptions of the method.

Table 1. Summary of frameworks for C2 assessment

Framework	Description	Measurement methods	Applicability to C2 agility in the crisis and emergency domain	References
NATO C2 CRM	Framework for assessment of C2 maturity, architecture, and approaches. Consists of a hierarchical structure with more than 400 variables.	Numerous: 386 of the described variables are measurement variables.	Can provide a framework for assessment of C2 agility, e.g. by describing important dimensions of C2 agility and providing a library with measurement methods for each dimension. First the applicability of described variables and measurement methods for assessment of C2 agility in the crisis and emergency domain must be determined.	NATO SAS-050 (2006) NATO STO SAS (2009) NATO STO SAS-065 (2010)
HEAT	Description of headquarters or command centre as an adaptive control system by a cyclical five step process, which has been extended to a six step process.	Mainly observation and surveys.	HEAT is developed for assessment of C2 of units with primary responsibility of tasks as planning, support, and coordination, and may as such be translatable to assessment of C2 in the crisis and emergency domain. Limitations are that HEAT was not explicitly developed to assess agile C2 and it may not capture the dynamic nature of C2 in crisis and emergency response operations.	Hayes & Wheatley (2001) Alberts & Hayes (2002)

Framework	Description	Measurement methods	Applicability to C2 agility in the crisis and emergency domain	References
ACCES	Developed from HEAT as a systematic approach to observing and assessing C2 performance of both individual participants and the collective.	Mainly observation.	ACCES has been widely used and can thus be considered as a thoroughly tested approach to assessing C2. Limitations regarding assessment of C2 agility are, in principle, the same as for HEAT.	Keene, Michel, & Spiegel (1990) Hayes, Layton, & Ross (1995)
CTEF	Structured model for C2 assessment that can be used for assessment of both large and small teams, for assessment of missions with both short and long time duration, before and after a mission in the operational context, and for after action review	CTEF questionnaire with 10 categories of questions.	CTEF may be applicable to assessment of crisis and emergency response, as it captures certain aspects of C2 agility that relate to the maturity of the organization, which may be possible to translate into the order of C2 agility presented	NATO RTO HFM-087 (2005) Essens et al. (2005)
MARTA	Method for performance assessment of military units during exercises.	Bank of questions divided in 15 categories with 5 categories clearly related to C2.	The structure of MARTA reflects certain aspects with importance to C2 agility, as how information was managed, how specific tasks were performed, and how well the task at hand was solved. It may be thus be relevant to consider the method, or certain aspects of it, for assessment of C2 agility in the crisis and emergency domain.	Ahl, Andersson, & Lindberg (2012)

3.2 Methods for assessment of interactions and communication in command and control agility

This section provides a description of methods that were not specifically developed to study C2 or C2 agility, but may nevertheless hold potential for assessment of certain aspects relevant to C2 or C2 agility. First, two methods are described which mainly focus on analysis of communication and information exchange, as such analyses can be very useful for understanding how an entity positions itself in the C2 approach space. A similar approach is suggested by Stanton et al (2008) in their discussion about approaches to modelling C2. Further, earlier studies (Aminoff, Johansson & Trnka, 2007; Trnka & Johansson, 2011) have shown that analysis of communication and information exchange often reveal how roles and responsibilities tend to shift during the course of an event, reflecting changes in C2. In many cases, analysis of communication is the only graspable manifestation of C2, meaning that it is one of few ways of assessing how C2 develops over time. At the end of this section two methods focusing on other aspects than communication and information exchange are presented.

3.2.1 Communication analysis

Communication analysis comprises analysis of verbal or textual communication. Verbal communication may also comprise gestures and posture, but these aspects are rarely included in studies of C2 as such communication usually is mediated and restricted to sound. Communication analysis can be used in all types of studies that comprise meaningful verbal communication between participants, e.g. experiments, training, simulations, or studies of real work at work places. Sound recording is generally used to record spoken communication. Textual communication by e-mail, chat etc. is generally recorded by direct recordings/loggings from utilized software.

Before analysis, recordings of verbal communication are generally transcribed. This means that the recorded material is translated to text, with varying level of detail depending on the purpose of the study at hand. A detailed transcription includes for example notes of details of how utterances were delivered, for example, small pauses, repetitions, hesitations, stutters, hums, grunts, intonation, strength of voice, and slips of the tongue. Then, the transcribed material is analysed, for example by categorization of utterances, or by analysis of purpose and content of the conversation at certain points of time (Silverman, 1993; Linell, 1994).

Communication analysis can be used to analyse important team processes, as for example maintenance of team SA, where certain communicational aspects may be critical.

Examples of questions that can be studied through conversation analysis are:

- Contents of communication (contents analysis).
- Extent of communication and extent of different types of content.
- How much different participants or roles communicate with each other.
- Which communication channels, or systems, that are used, and how much each channel/system is used.
- Problems in the communication and what causes problems.
- Whether, or how, communication problems affect task performance.

A drawback with communication analysis is that it is time-consuming to transcribe recordings of spoken communication. However, it is possible to adapt the level of detail of the transcription according to the purpose of the study. For example, in studies where social aspects of the communication, as how the message was uttered, are not important,

but only the contents of the utterances are of interest, simplified transcription with less detail can be used to save time.

Communication analysis does not necessarily give guidance about the quality of C2 or C2 agility, even if aspects of quality in some cases can be deducted from the analysis. It can be useful for understanding how a situation unfolds and what kind of information certain actors have at specific points in time as well as what kind of information they shared and searched for. Also, it can provide an understanding of how a group of people understood and viewed problems.

At a low level communication analysis can provide immediate information for after-action reviews of, for example, how much each participant communicated with each other and when communication was performed. At a higher level analytical communication analysis of the communication can also be performed. High level communication analysis is, however, in general very time consuming and therefore less suited for direct feedback for after-action reviews.

Topical episode analysis (TEA) is a specific form of communication analysis of topics in verbal communication. In principle, communication is broken down into subunits, denoted episodes. Before TEA analysis can be initiated, verbal spoken or textual communication is transcribed in great detail by the methods described in the section of communication analysis above.

An episode can be described as a sequence of actions that is internally bound together by a topical trajectory and/or a common activity. In TEA an episode must include three or more substantial turns uttered by two or more speakers. Otherwise, episodes can vary in terms of size and structural level, but should be possible to relate to other units or organizational levels in the structure of the conversation (Korolija, 1998).

Episodes are particularly useful for studies of multiparty conversations, since they generally consists of natural units of social interaction that are bound together by a common understanding and focus of attention, are topically continuous, and represent a level where the interdependencies between discourse and context can be clearly be brought to light (Korolija & Linell, 1996). By TEA it is, for example, possible to analyse the function of interactions and how an understanding of the situation evolves through exchanges of information, directives, and feedback (Aminoff, Johansson, & Trnka, 2007).

3.2.2 Social network analysis

Social network analysis (SNA) can be used to study all types of communicational patterns in socio-technical systems, for example, organizational structures, spread of diseases, and Internet traffic. In studies of C2 agility social network analysis may be used to map structural patterns of communication between agents in the organization. The method builds on combined methodology from studies of social structures in social sciences, analytical techniques from mathematics, and graph theory (Houghton et al., 2006).

The first step is to gather relational patterns of the communication data, such as number of communication events between agents in the staff and the direction of the communications, in a matrix. In the matrix rows indicate communication “from” and columns communication “to”. The numbers in the matrix can then at the simplest level be depicted in a social network graph (Houghton et al, 2006). However, in the graph numbers indicate the sum of “from” and “to”. Figure 6 provides an example of social network analysis of number of communications between agents in a staff with one commander and three operators, to the left illustrated with a matrix and to the right with a social network graph. For example, in the matrix it can be seen that there are eight communications from Com to Op1 and four communications from Op1 to Com, which in the network graph this is presented as twelve communications between Com and Op1.

	Com	Op1	Op2	Op3
Com	-	8	3	3
Op1	4	-	2	2
Op2	2	1	-	0
Op3	2	1	2	-

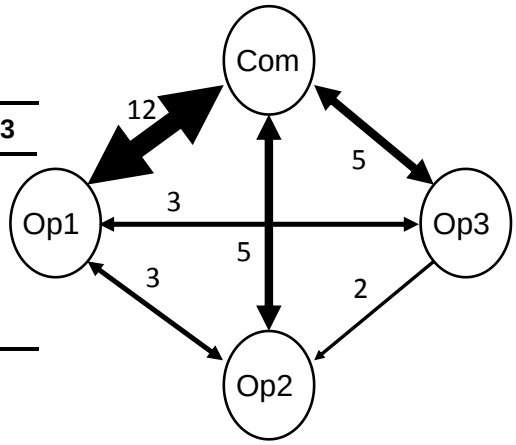

Figure 6. To the left, example of matrix of network analysis of number of communications between agents in a staff with one commander and three operators. To the right, social network graph of the contents in the matrix, showing total number of communications between each pair of agents.

Several network metrics can be calculated by further analysis. Three of the most commonly used metrics are sociometric status, centrality, and criterion.

Sociometric status is a measure of how busy a node (operator) is relative to other nodes (operators). This provides a practical indication of the relative importance, regarding communication, of individual agents in the network.

Centrality is a measure of how central a node (operator) is in a network in terms of its geodesic distance to other nodes (operators) in the network. This means that information from a node (operator) with high centrality will reach any arbitrary node (operator) in the network with few relaying hops. Thus, centrality indicates high interconnection with other nodes (operators) in the network

Although sociometric status and centrality measures different aspects of the communication in the network they may be highly correlated, since high interconnectedness (high sociometric status) may cause centrality, and the other way round, relative closeness to other nodes (centrality) may cause high interconnectedness. There are, however, exceptions when the two measures are not correlated. For example, a busy node (operator) with many connections (high sociometric status) may have low centrality if its connections are mainly to other peripheral nodes. Also, a node with high centrality, caused by its topographical position in a network, may have few connections to other operators and thus low sociometric status (Houghton et al., 2006).

For all network measures a threshold value can be calculated to decide if a node (operator) in a network has a critical role or not. It is calculated as the mean plus one standard deviation of the results on the metric achieved by the nodes in the network. Nodes (operators) with a value higher than this value are then regarded as key agents of the metric (Houghton et al., 2006).

SNA has potential for evaluating aspects of C2 agility, such as information dissemination and interactions. It is reasonable to assume that a move from one C2 approach to another should be possible to detect using this methodology.

3.2.3 C2 Agility Quotient Test

In the field of C2 research the concept of agility has become widely recognized and is nowadays regarded as an essential system capability and a requirement for successful C2 performance (see Section 2). This has raised the need of standardized methods to objectively measure and assess C2 agility. Alberts (2014) propose the C2 Agility Quotient test, an instrument for assessment of C2 agility. However, Alberts (2014) does not describe a fully developed test for assessment of C2 agility, but rather discusses the need

of an instrument and gives suggestions of measurements that could be included in a test (Alberts, 2014). Two important components of these suggestions are briefly described below.

Six agility capabilities or enablers have been identified and partially validated in experiments and case studies: responsiveness, versatility, flexibility, resilience, adaptiveness, and innovativeness (see NATO STO SAS-085, 2013). It is suggested that an initial measure of agility is calculated by measurements of these parameters (Alberts, 2014).

A process to calculate the probability that an entity manifests agility when required is described. This comprises a three step process (Alberts, 2014):

- Construct an endeavour space with missions and circumstances included (see 2.2 above). This provides the set of missions and circumstances, which must be analysed to determine they can successfully operate in different parts of this endeavour space.
- Project whether the entity can successfully operate in each part of the endeavour space.
- Sum the outcomes across the endeavour space, which provides a measure of potential agility which describes the overall probability of success.

Although Alberts (2014) envisions a scenario free assessment approach, if a need will occur, a C2 agility quotient test will most likely with minor modifications also be applicable for assessment of C2 agility in scenario based training.

3.2.4 Team situation awareness assessment

Situation awareness (SA) in teams concerns the team members' common awareness of the situation. This is an essential concept for all C2 organizations that strive to consolidate towards a common goal. There are two basic types of situation awareness measures in teams: team SA and shared SA.

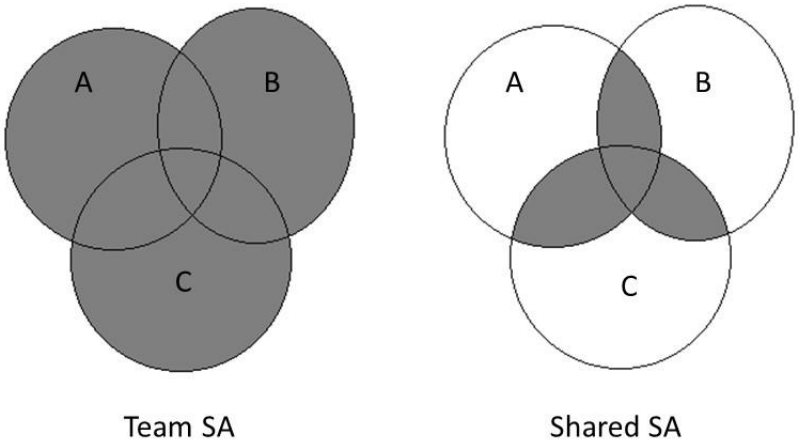

Figure 7. Illustration by Venn diagrams of team SA as the sum of the individual team members' SA on subgoals A to C (to the left) and shared SA (to the right) as the intersection between the team members' individual SA.

Team SA concerns the degree to which every team member possess the SA required for his or her responsibilities. According to this view, every team member has a subgoal related to his/her specific role in the team and for each subgoal there are a number of elements with importance for SA. Shared SA concerns the degree to which team members possess the same SA on shared requirements (Endsley & Jones, 1997). The difference

between these two views on situation awareness in teams is illustrated by the Venn diagrams in Figure 7 where team SA is the sum of the individual team members' SA on subgoals A to C, whereas shared SA is the intersection between the members' SA.

Which type of situation awareness in teams that is most relevant is dependent on the organization of the team and how its team members share tasks. Team SA is most relevant if the team members mainly perform individual tasks, with distinctly divided fields of responsibilities. Shared SA is most relevant if the team members work together and share information and tasks with each other. Shared SA does generally provide a richer and more meaningful picture of the teams' ability to work towards a common goal.

Team SA can generally be assessed by methods for assessment of individual SA (see for example, Endsley, 1995), while there are fewer established methods for assessment of shared SA.

3.2.5 Summary of C2 assessment methods

A summary of the C2 assessment methods presented in this chapter is given in Table 2. For each method the summary includes: the name of the method, a short description of the method, suggested measurement methods, the methods applicability to C2 agility in the crisis and emergency domain, and important references to descriptions of the method.

Table 2. Summary of C2 assessment methods

Method	Description	Measurement methods	Applicability to C2 agility in the crisis and emergency domain	References
Communication analysis	Structural analysis of verbal communication that can be used to study most aspects of human interaction. It can be applied in all types of activities e.g. experiments, training, simulations, or studies at work places.	Sound recording of spoken communication. Logging of textual communication. Transcription before analysis of recorded, or logged, communication.	Can be used to analyse important team processes, for example maintenance of team SA, where certain communicational aspects may be critical. Understanding how a situation unfolded and what kind of information certain actors had at specific points in time, as well as what kind of information they shared and searched for, may provide information to the overall picture of C2 agility in the crisis and emergency domain.	Linell (1994)
Social network analysis (SNA)	Method for analysis of all types of communicational patterns in socio-technical systems. In studies of C2 agility SNA can be used to map structural patterns of communication between agents in the organization.	Sound recording of spoken communication. Logging of textual communication. Recording of communication by means of C2 systems. Quantification of the number of interactions between each participant is made before analysis.	Analysis of communicational patterns and structural patterns of communication between agents in the organization may have applicability for evaluation of certain aspects of C2 agility, such as information dissemination and interactions as described in the C2 approach space, or identification of a move from one C2 approach to another.	Houghton et al. (2006)
C2 agility quotient test	Proposal of standardized methods to objectively measure and assess C2 agility. Note, since this is a proposal it is note a fully developed test.	Not completely determined, but most likely, subjective questionnaires, observer ratings, and recordings of system interaction.	A standardized and objective measure of agility may for example, provide a measure of the probability that an entity manifests agility when required.	Alberts (2014)

Method	Description	Measurement methods	Applicability to C2 agility in the crisis and emergency domain	References
Team situation awareness assessment	Assessment of the team members' common understanding of a situation.	Measures of individual team SA that by further analysis are aggregated to a measure of team SA. Ranking of predefined parameters regarding their importance for other team members.	Team SA is essential for all C2 organizations that strive to consolidate towards a common goal.	Endsley (1995) Endsley & Jones (1997) Berggren & Johansson (2010) Berggren, Johansson & Baroutsi (2016)

3.3 Methods for data collection

This chapter gives an overview of methods for data collection with applicability to assessment of C2 agility. While the frameworks and assessment methods presented above are designed to capture certain aspects of C2, these only provide frameworks for organising and interpreting data. Actual data collection will be performed by utilizing a specific method, which may be more or less applicable in the context of crisis and emergency response operations, exercises or training. Below, we discuss data collection methods and their applicability in different settings.

3.3.1 Recording of quantitative performance measures

If training is performed in a simulated environment, the possibility to implement automated recording of quantitative performance measures is usually good. Nevertheless, even if all possible performance measures are recorded, this will usually not provide enough relevant information to assess the complexity of team work in C2 operations, which is highly dependent on a large array of more subtle aspects, for example of cognitive and communicational nature, which are usually not possible to catch by quantitative performance measures. Nonetheless, situations may occur during a simulation when performance measures, or combinations of performance measures, can reveal important aspects of team performance. Provided that the effort of implementing the recording is not too high, it is therefore usually advantageous to record as many performance measures as possible. If the recording is made, the possibility to analyse the measures will always be there, whereas measures not recorded can never be analysed.

Typical quantitative performance measures that can be collected by automated recording during simulator training are:

- *Performance time* – Time needed to perform a certain task.
- *Response time* – Time from presentation of task until the participant starts to work on the task. In a team task this measure may be less applicable as a measure of actual reaction or response time, since there may be many practical reasons why a participant postpones the initiation of an action.
- *Status measures* – All measures of status, for example both regarding units in own and other organizations, as number of vehicles, equipment, and personnel.
- *Geographical location* – Coordinates of both own forces, opponent forces, and other relevant actors.
- *Distance measures* – Critical distance to own forces or units, enemy forces, and other important objects.
- *Frequency* – For example, number of times a function has been used, or number of times communication has been initiated.
- *Error frequency* – For example, number of times erroneous behaviour or responses are registered.
- *Learning effects* – Changes of performance on quantitative measures during training or exercise.
- *Learning time* – Time taken to learn certain procedures during training or exercise.

Recordings of performance measures provides a direct measure of the participant's performance, and may thus reflect learning. However, for assessment of learning of C2 agility in crisis and emergency operations, contextual factors must also be considered. For example, if an experienced operator has learned the necessity to consider more

information or parameters before making a decision, longer reaction time, or performance time, may rather reflect more elaborated rather than less efficient decision making. Also, the outcome of C2 decision making is usually difficult to capture with accurate quantitative measures.

A summary of the performance measures presented above is given in Table 3. For each performance measure this includes: the name of the measure, a short description of the measure, primary unit of collected data, type of measure, primary data collection method, and the primary type of information for assessment that the measure provides.

Table 3. Summary of performance measures.

Measure	Description	Primary Unit	Type of measure	Primary data collection method	Primary Information
Performance time	Time to perform a task	Seconds, Minutes	Quantitative performance measure	Automated recording	Task performance
Response time	Time from presentation of stimulus/information until operator initiates response	Seconds	Quantitative performance measure	Automated recording	Task performance
Frequency	Number of actions/responses etc. per time unit	Numerical value, rate	Quantitative performance measure.	Automated recording, Observer rating	Task performance System interaction
Error rate	Number of error on tasks divided by total tasks performed	Rate (0-1)	Quantitative performance measure	Automated recording, Observer rating	Task performance Accuracy
Status measures	All types measures of status e.g. regarding own forces, and opponent forces, for example number of troops, vehicles, ammunition etc.	Numerical value	Quantitative performance measure Observation	Automated recording Observer rating	Task performance Task difficulty

Measure	Description	Primary Unit	Type of measure	Primary data collection method	Primary Information
Geographical location	Geographical direction to e.g. own forces, opponent forces and certain objects	Raw value: coordinates Calculated valued: angle (0-360)	Quantitative performance measure Subjective self-rating	Automated recording Subjective self-rating	Task performance Spatial orientation Geographical situation awareness
Geographical distance	Geographical distance to e.g. own forces, opponent forces and certain objects	Raw value: coordinates Calculated valued: meters	Quantitative performance measure Subjective self-rating	Automated recording Subjective self-rating	Task performance Spatial orientation Geographical situation awareness
Learning effects	Changes of performance on performance measures during training or exercise.	Depend on measured parameter	Quantitative performance measure Subjective self-rating	Automated recording Subjective self-rating	Effects of learning by improvement over time on performance measures.
Learning time	Time taken to learn certain procedures	Seconds, minutes	Quantitative performance measure Subjective self-rating	Automated recording Subjective self-rating	Time needed for training on certain procedures. Task difficulty

3.3.2 Scenario recording

Recording of the scenario means that that the presented scenario together with the participants' interactions with the systems are recorded. This provides the possibility to record the video streams presented on the participants' displays and if it is a simulation based exercise also recordings of displays used for game control and analysis. These recordings can be used to replay the whole scenario, or specific events, which can be used both for analysis of performance and to support after-action review.

Recordings of the participants' interactions with the system can provide immediate information for after-action reviews; for example, of how much each participant interacted with each part of the system, duration of interactions, and time when each interaction occurred. Also, if status displays from the game control can visualize how important status parameters during the scenario changes and are affected by certain events, or by the participants actions towards the events, this can create good opportunities for the participants' understanding during after-action review.

Scenario recording can also comprise recordings of textual communication between participants, for example e-mail or other internal systems for text messages. At a low level this information can be analysed with more or less automatized methods, for example number of messages sent from participant A to B. However, for analysis at a higher level, for example semantic analysis of textual communication, the same types of methods used for analysis of sound recordings of spoken communication must be utilized.

3.3.3 Video and sound recording

Video and sound recording of participants' communications and interactions is mainly used to support observer assessment (see Section 3.3.4). When video and sound recording of team training is performed, it is not always possible to place the camera so it is possible to obtain one appropriate single recording of the team. Therefore, if the team is fractioned into sub teams, or if the team members are not closely gathered, it may be necessary to use several cameras and microphones.

A drawback with video and sound recording is that it is extremely time consuming to analyse the information, and if several sound and video streams are recorded, the time needed for analysis is considerably increased. It is therefore, in general, only practical that observers use video and sound recordings as a support, for example, if they are aware that they have missed some important information during a specific sequence of the training (eg. Preece, Rogers, & Sharp, 2002; Faulkner, 2000). Video and sound recording can also be used to support after-action review.

3.3.4 Observation

Observation of simulator training means that one or several persons observe the participants' behaviours, listen to their conversations, and if possible also observe information on the systems and displays that they use. A drawback is that only externally observable behaviours are readily accessible, which means less openly displayed actions are difficult to identify, as for example cognitive processes and system interactions, which usually are core components in complex activities as decision making and C2-work. Also, since observation is an inherently subjective measure, different observers may experience the same situation differently, which is a problem for inter-observer reliability (e.g. Rosen et al., 2008; van den Bosch & Riemersma, 2004). On, the other hand, by subjective observation with experienced subject-matter experts many aspects of complex behaviour can be revealed that that are, in principle, unaccusable to objective methods. However, a sufficient number of subject matter-experts are far from always accessible. On the other hand, if subject-matter experts are lacking, it is possible to perform reliable observations

with less experienced observers by use of highly structured procedures and observation protocols (Dwyer, Fowlkes, Oser, & Lane 1997).

In order to create the best opportunities for observations with high reliability and relevance it is important that observers receive proper training before observation and that structured observation protocols are used to support observation. Also, well-structured training scenarios facilitate assessment of performance by observation.

If the most likely occurring behaviours are included as check-lists in the observation protocol, the observer only has to put a mark, and perhaps perform some type of performance rating, for each performed activity. By using this procedure relatively reliable observations can be performed with much less effort than what is necessary for unstructured and exploratory observations. To create observation protocols and perform observation the following eight steps are suggested by Stanton, Salmon, Walker, Baber, and Jenkins (2005, pp. 367-372):

1. Define task(s) and team(s) under analysis. It is recommended that a hierarchical task analysis is performed to gain a complete understanding of the task(s) and the types of behaviours that are likely to occur when the task(s) is/are performed.
2. Select an existing observation protocol or develop an appropriate observation protocol.
3. Select appropriate subject matter experts as observers. The number of observers is dependent on the type of task and its complexity, but also on amount of effort or resources invested in the analysis.
4. Train the observers, for example on how to accurately detect, perceive, recall, and recognize specific behaviours.
5. Assign participants to the observers, so each observer knows which of the participants they are to observe and assess.
6. Begin the study and the observation.
7. Observers assess performance, either during training or afterwards. Observation protocols facilitate assessment during observation.
8. Calculate observer assessments, for example by summing the scores for each behavioural dimension (communication, information exchange etc.).

Regarding observation of teamwork, insights from research and empirical experience have been compiled by Salas, Reyes, and Woods (2017). Some of their insights can be used as recommendations for observation of teamwork and are summarized in the following bullets:

- Control interrater observation reliability – for example by randomly selecting sessions for more than one observer and then comparing their ratings.
- Distribute observations – by letting different observers focus on different areas based on their expertise.
    - In complex team settings one observer should not assess more than one or two team members.
    - One observer should only be trained to focus on four to five team-based constructs (observable behaviours, actions, events etc.). If more than five related constructs are observed, the dimensions starts to overlap and become difficult to distinguish. Therefore, do not try to assess more constructs than necessary.
- Multiple levels of evaluation – since teamwork is performed by individuals, team performance should also be assessed at the individual level.

- Multiple levels of team performance – assessment of both team processes and outcomes can improve assessment of team performance. Processes can provide diagnostic information for feedback and outcomes can provide a "bottom-line" for team performance.

3.3.5 Questionnaires

Questionnaires are used to gather information about participants' subjective experiences. For assessment of simulated team training, questionnaires before, during and after training, questionnaires can provide information about the development of the participants' understanding of scenarios and presented events. Also, participants' self-ratings of performance, can provide information on both individual and team performance, and effects of training. In addition, questionnaires can be used to gather subjective information from observers and also to support their observation as an integrated part of observer protocols. Questionnaires to participants after team training can also be used to gather their subjective experiences of training procedures and scenarios, which can provide important information for improvement of training scenarios and procedures. Also, questionnaires are integral instruments for data collection in many assessment methods, for example questionnaire instruments for assessment of situation awareness and mental workload.

Examples of literature reviews of questionnaire techniques and recommendations for design of questionnaires are Lyberg, Biemer, Collins, de Leeuw, Dippo, & Schwarz (1997) and Charlton (1996). Also, at the Swedish Defence Research Agency, recommendations in Swedish has been compiled (Nählinder, Nilsson, & Levin, 2015; Oskarsson, 2013).

3.3.6 Interviews

Interviews are, as questionnaires, generally used to gather information about participants' subjective experiences. For assessment of simulator based training interviews can be used to gather participants' subjective experiences of the training and thus provide important information for improvements of scenarios and training procedures. Also, interviews are often used in analytical methods such as tasks analysis, which in the context of C2 agility exercises generally must be performed to gather necessary knowledge before scenario and training procedures can be reliably implemented.

Interviews with participants can be performed with different approaches. For example, interviews are usually performed with each participant individually, but can also be performed with groups of participants, for example, by focus group discussions, as described below. Group interviews may also be more suitable to collect information on team training, and is further described below. There are three main approaches for individual interviews (Rogers, Sharp, & Preece, 2011):

- *Structured interviews* – Predetermined questions are asked in a previously determined manner and order. Questions are generally short and clearly formulated. Often closed questions are used, which means that answers are in the form of predetermined alternatives. This implies high similarity with the type of questions that are usually asked in questionnaires.
- *Semi-structured interviews* – A number of questions are formulated in advance to support interviewer if the respondent deviates from the subject or is uncommunicative. Questions need not be distinctly formulated, but the interviewer rather uses a basic manuscript to make sure that all subjects are covered. By using semi-structured interviews, the advantages with closed questions from structured interviews and open questions from unstructured interviews are often combined.

- *Unstructured (flexible) interviews* – Some content is predetermined, to ensure that all subjects are covered. Questions are open, which means that answers are not in the form of predetermined alternatives, but the respondent is free to talk and explain things. Unstructured interviews are exploratory, which means that the interviewer asks follow up questions. By this technique a large amount of unstructured information can be collected, which entails that much work is needed for analysis and reporting.

Irrespective of which type of interview technique is used, thorough preparation is necessary before the interview is performed. Structured interviews are easiest to use. Using unstructured interviews increases the possibility to obtain more complex information, which can provide a deeper understanding of the situation, but they are also more difficult to perform (e.g. Preece et al., 2011). When interviews are performed it is often difficult to take notes, and especially if unstructured interviews are used. It is, therefore, often advantageous to use sound recording. Alternatively two interviewers can participate, where one asks the questions and the other takes notes.

In principle these three approaches to interviews of single individuals can also be used for group interviews. A special type of group interview is focus group discussions.

A focus group can be described as a group interview that is led by a moderator. In the focus group a number of predetermined subjects are discussed. The moderator's task is to create the basis for the discussion, make sure that the participants keep to the subject, and that all participants are given the opportunities to express their views. An important task is therefore to make sure that also introvert or silent participants are talking and expressing their views and to prevent extrovert and talkative participants from dominating the discussion. (Rogers et al., 2011). An important difference from an ordinary group interview is that focus is rather on discussion than on extracting answers to specific questions (e.g. Bloor, Frankland, Thomas, & Robson, 2001; Wibeck, 2000). Focus group discussions are usually documented by sound recording and are usually transcribed before analysis.

4 Discussion and Conclusion

Although there are important differences between the military and crisis and emergency domains, there are also many similarities. Utilizing the already gained maturity of the theoretical framework for military C2 in the crisis and emergency domain is in many respects advantageous. Although certain adaptations in the military C2 approach must be performed to enhance its applicability to the crisis and emergency domain, this is a relatively modest endeavour compared to the efforts that would be needed to build a new methodological approach from the ground up.

As pointed out in the introduction to this report**,** there are some notable differences between C2 in the military and emergency response domains that affect transfer of C2 theories and methods from the military to the crisis and emergency domain that must be considered. One difference is that military C2, by tradition, usually follows carefully defined structures and processes, while crisis and emergency response operations, which at least in Sweden usually is conducted jointly by different actors, need to continuously adjust to shifting demands and changing circumstances. This affects how C2 is conducted in crisis and emergency response, for example by improvised deployments and procedures with effects on the number of C2 personnel involved and changes of task allocation over time. The rigid characteristic of military C2 has however been questioned during the last decade, primarily through the emergence of C2 agility theory which suggests that a variety of approaches to C2 are needed to cope with the dynamic challenges of concurrent conflict (see for example Johansson, Berggren & Trnka, 2015).
Another difference is that military C2, at least on the higher levels of command, is continuously in place, while during larger crisis and emergency response operations high level C2 is, in the best case, organized in initial stages of the operation by personnel from involved organizations. This means that crisis and emergency response C2 is situated and thus differ depending on situation, context, involved actors, and temporal constraints. Nevertheless, when applying the C2 theory and method, it must be assumed that each type of crisis and emergency, and its related crisis and emergency response operation, has a corresponding "best choice" of C2 approach. However, although the assumption of a "best choice" of C2 approach comes from in the military domain, it has been argued that is challenging to identify the most appropriate C2 approach for a specific military mission since such a decision will be based on a hypothesis of about operational conditions, which in most cases is based on limited information.

Nevertheless, irrespective of the discussion of the applicability of a "a best choice" for C2 agility in the military domain, for C2 agility in crisis and emergency response operations, an important aspect is the need for adaptability of how C2 structures work or are organized, as by adjustment of information dissemination or allocation of decision rights, for example, in order to better fit the current or foreseeable situation. Another way of putting it is to say that the *C2-system can re-configure itself in such a way that the distribution of resources between functions fit the problem at hand* – an unpredicted disturbance requires more resources to responding functions, while during calmer periods resources should be spent on planning and anticipation.

This is challenging from the point of view of assessments of C2 as the object of assessment may change over time. "Traditional" assessment procedures that are based on procedure, doctrine, utilization of resources etc. are therefore difficult to apply to adaptive or agile C2. Performance measures are only useful if it is possible to describe what successful performance is. The way forward may be to create assessment methods that aim to capture the adaptive capacity, or the agility, of an organisation. Such a measure would provide an indication of the potential to be successful in a situation signified by rapid change and complexity.

4.1 Frameworks for assessment of C2 Agility

Our review (see chapter 3) of current frameworks and methods presented above reveals that there currently is *no framework for assessing agile C2 capabilities in crisis and emergency response operations*. Examples exist where the case study template developed by SAS-085 (NATO STO SAS-085, 2014; Johansson, Trnka & Berggren, 2016) has been applied to crisis and emergency response, but that approach is purely retrospective. Other approaches may be applicable, but they will not be able to assess the potential for adaptive behaviour in an organisation or a system.

Further, most assessments of agility have been performed on an overarching system level, and are therefore lacking in detail for assessing agility of individual organisations/entities. Although no established frameworks for assessment of C2 agility of the crisis and emergency domain or other civilian domains were found, several approaches for assessment of military C2 agility have potential for use in the crisis and emergency domain. Some of these may be directly applicable to the crisis and emergency domain, while others may need to be adapted before use. In chapter 3, we presented an overview a number of frameworks and assessment techniques that can be utilized to capture different aspects of C2. These can be summarised as follows:

The *C2CRM* describes a large number of variables and measurement methods with applicability to assessment of C2 agility. This may provide a framework of important dimensions of C2 and thus serve as a library of measurement methods for each dimension. However, before it can be operationalised as a library, applicability of described variables and measurement methods for assessment of C2 agility in the crisis and emergency domain must be determined.

HEAT was developed to assess military C2 units with primary responsibility of planning, supporting, and coordination of fighting forces, but not for units directly involved in war-fighting. This suggests that HEAT is mostly useful for assessments of staff-like functions in crisis and emergency management. We are, however, not aware of any efforts to apply HEAT in the crisis and emergency domain. In relation to C2 agility, there are two major limitations that must be considered. Firstly, HEAT was not explicitly developed to assess agile C2, but rather C2 as such. Secondly, HEAT may not capture the dynamic nature of C2 in crisis and emergency response operations.

ACCES was developed from HEAT to support assessment of C2 from corps to division level, but has mainly been used on division level. Data collection mainly builds on observation, which may be a limitation in operational use regarding access to observers with adequate competence and experience of performing observations. For application as support to assessment of C2 agility in the crisis and emergency domain, the limitations of ACCES are in principle the same as for HEAT, mainly that it was not explicitly developed to assess the agile component of C2. Furthermore, it holds some assumptions that may not apply to all types of crisis and emergency work, for example that a planning function exists. An advantage is that ACCESS has been widely used and developed over the years, which indicates relative maturity.

CTEF was developed for assessment of the effectiveness of teams or staffs and captures both task- and team focused behaviours. An advantage is that original CTEF instrument was recognized as having high operational usability, and that the revised instrument is shorter even indicates potential to increased usability. Even though CTEF does not focus on agility, or even explicitly on C2, but on team aspects of C2, it may nevertheless be applicable to assessment of crisis and emergency responses as it captures certain aspects of C2 agility that relate to the maturity of the organization, which may be possible to translate into the order of C2 agility presented in Section 2.2 above.

MARTA was developed for assessment of unit performance and ability to accomplish tasks in relation to external circumstances and according to tactical, operative, and economical objectives, but not to assess C2 agility or adaptive capacity. However, since the structure of the method reflects certain aspects with importance to C2 agility, as how information

was managed, how specific tasks were performed, and how well the task at hand was solved, it may be relevant to consider the method, or certain aspects of it, for assessment of C2 agility in the crisis and emergency domain.

As can be seen from the descriptions, assessing C2 agility with existing methods may become something of a puzzle. Since the methods were developed before the development of C2 agility theory, they only capture certain aspects of C2 agility. HEAT focuses on planning and coordination, ACCES on large entities, such as corps and divisions, but none of them are based on the dimensions associated with C2 agility, such as information dissemination, allocation of decision rights, and interactions. CTEF was explicitly developed for assessing team effectiveness, which suggests that it can be applied to certain aspects of C2 agility, like how well commanders work together and maturity of organizations. MARTA is interesting as it is one of few methods that take external circumstances into account. External circumstances are drivers for adaptiveness and agility, suggesting that the method could be applied to identify when C2 agility is needed.

4.1.1 Methods for assessment of certain aspects of C2 agility

When considering individual methods for assessing C2 agility, communication analysis and social network analysis stand out.

Communication analysis can be used to analyse important team processes where communicational aspects may be critical. This can be useful for the understanding of how a situation unfolded and what kind of information certain actors had at specific points in time, as well as what kind of information they shared and searched for. This information may provide information to the overall picture of C2 agility in the crisis and emergency domain.

Social network analysis of communicational patterns is strongly related to communication analysis (it may be seen as a subset of communication analysis). It reveals structural patterns of communication between agents within an organization or between organizations. This may have applicability for evaluation of certain aspects of C2 agility, such as information dissemination and interactions as described in the C2 approach space, or for identification of a move from one C2 approach to another. Social network analysis usually also reflects allocation of decision rights, as changes in allocation of decision rights usually also changes the communication patterns between the actors involved. The method is thus a good candidate for analysing C2 agility, but it requires access to communication and information exchange between the individuals and organisations under scrutiny. This may be challenging, especially in collectives that change over time. Real-time analysis using SNA in such situations may thus prove difficult.

C2 agility quotient test is a method that has been suggested for assessment of C2 agility. Although the development of the method is mainly in a conceptual phase, a final/future standardized method to objectively measure and assess C2 agility may, for example, provide a measure of the probability that an entity manifests agility when required. The initiative of providing a standardized measure of agility is one of the most promising approaches that we have found for assessment of C2 agility in the crisis and emergency domain. However, until an applicable method is actually is developed, it is hard to evaluate the actual usefulness and applicability of this approach.

Team situation awareness measures can be of importance for C2 agility, especially in collaborative or networked instances. That team members have a common awareness of a situation is essential for all C2 organizations that strive to consolidate towards a common goal, and should also be relevant for C2 agility in crisis and emergency operations. There are different methods available for collecting such measures, and some of these may very well be applicable to the crisis and emergency response context.

4.1.2 Methods for data collection

Independent of what framework or method is utilized, there will always be the matter of actually collecting the data that will form the basis for the assessments. Different data collection methods have different pros and cons in different situations, something that is worth considering when planning assessments as it has many practical implications, both regarding what is possible in a specific context, and in respect of what kind of analysis (and conclusions) that can be conducted based on the collected data.

Quantitative performance measures are generally too "blunt" to provide a real understanding of the complexity of team work in C2 operations, which is largely characterized by cognitive and communicational components that are difficult to capture with quantitative measures. Dynamic activities, like crisis and emergency response, are particularly challenging as it is usually difficult to determine what a good outcome is. Therefore, many measures focus on the quality of internal processes of the involved organisations rather than the actual outcome of the same processes.

Nonetheless, performance measures can in certain situations reveal important aspects of team performance. Also, quantitative performance measures may provide an important complement to qualitative or subjective measures of team performance or communication. Also, quantitative performance measures can support observer ratings of performance as well as computer generated after action reviews in simulator based training of C2 agility of crisis and emergency operations.

Scenario recording from computer simulations provides the possibility to playback events in which participants of a response operation engaged, which can provide immediate information for after-action reviews, for example of how the team performed or the scenario developed. Scenario recording may also support assessment of C2 agility after a training scenario is completed. Scenario recordings naturally depend on having access to data that actually reflects behaviour and actions by participants in a crisis and emergency response operation or exercise.

Video recording is mainly used to support observer assessment and AAR. Sound recording of spoken communication is mainly used as raw data for methods as communication analysis, and is thus completely irreplaceable, if such methods are used.

Observation by experienced subject-matter experts can reveal many aspects of complex behaviour that that are, in principle, inaccessible to quantitative or objective methods. This is probably the most common method in use today, both at exercises and during actual crisis response operations. Drawbacks are that cognitive processes and system interactions, which generally are important aspects of decision making and complex C2 work, often are difficult to capture. Another problem is that access to experienced subject-matter aspects is often limited, indicating that collected data may only be partial or that the workload imposed on the assigned observers may be high.

Q*uestionnaires* can be used to collect information for assessment of C2 work during exercises or training. For example, if participants answer the same questions before, during, and after such an event, this can provide information about their experiences or understanding as the scenario unfolds. Questionnaires are also integral instruments for data collection in many assessment methods, for example instruments for assessment of situation awareness and mental workload. Such assessments can also be used continuously. Finally, questionnaires can be valuable tools for retrospective data collection after actual crisis response operations. A positive aspect of using questionnaires is that it is usually straight forward to perform data analysis, at least regarding quantitative data. The main drawback is that the data collection is largely shaped by the design of the questionnaire – answers will only be given to questions explicitly stated.

Interviews can be used to gather more qualitative information compared to questionnaires with rating questions. Even if qualitative information, to some extent, can be gathered by open questions in questionnaires, interviews where the interviewer can urge the respondent

to provide more information, and ask follow up questions on interesting information provides a much better possibility to gather rich qualitative information. Further, interviews can be more or less structured, meaning that they can be focused on a specific topic or question, or explorative where the participant(s) are encouraged to talk freely about a phenomenon. Interviews are highly valuable as tools for understanding new events, and will most likely be a central part for understanding how C2 agility manifests itself in various situations in the crisis response domain as well as for developing new methods in the same domain.

Focus group discussions can be used to gather qualitative information from all team members. In the context of C2 agility training in the crisis and emergency domain it can be used to give the whole team the possibility to discuss their performance and the development of the scenario.

4.2 Applicability – the challenge of the adaptive system

The main challenge in creating frameworks and assessment methods for C2 agility or adaptive systems comes from the fact that both the environment in which the concerned organisations operate and the way work is organised is dynamic. Most assessment methods in use today presuppose that at least the C2 structures of the organisation(s) engaged in a crisis response operation are static in nature. Both real-world examples as well as theory concerning C2 agility suggest that this is not the case. Rather, structures are signified by continuous change - both organisations and units often join and leave collectives during the duration of an event. Further, in a multi-organisational context there may be significant differences in the organisation of C2 within and between the involved organisations, making comparisons or overall assessments difficult.

What literature does suggest is that certain functions are fundamental to C2, such as information gathering, planning, execution, and learning. To be able to establish and maintain these functions, independent of the structural configuration of the involved organisations, is therefore crucial. C2 agility theory suggests that this can be achieved by changing how information is disseminated, how interactions occur, and how decision rights are allocated in the collective. This has a number of consequences:

1. C2 must be understood, and thus assessed, from a functional rather than structural point of view.
2. The ability to establish, and maintain, fundamental C2 functions may be the only viable measure of performance that can be applied.
3. Assessments of C2 agility cannot be made at a single point. Instead such assessments must reflect the dynamics of both the events that are to be dealt with as well as the dynamics of the C2 organisation (or the lack thereof).
4. This (3) suggests that assessments must be continuous, or at least repeated, and that the assessments should reflect the ability to conduct C2 at various points in time.
5. The assessed ability to conduct agile C2 should be mapped against the actual need for C2 (if possible) at the same point in time, in order to estimate if the C2 approach utilized was appropriate for coping with the problem at hand (in line with the demands for C2 agility described in NATO SAS-085, 2014).

4.3 The road ahead

A possible road ahead is thus a method based on repeated measures that can capture the ability to establish basic C2 functions and maintain them in a collective of organisations

during a dynamic event. To our knowledge, no such method exists today, as is reflected in the frameworks and methods presented above. An attempt that moves in the direction of what is suggested above can be found in Noori, Wolbers, Boersma, and Cardon (2016) where social network analysis is utilized to describe how coordination clusters were formed and disbanded during a crisis event by creating "snapshots" of the information exchange that took place between different units and organisations. This information exchange reflects the way C2 was organised and manifested, as well as what actors and organisations were engaged in information exchange at different points in time.

For actual crisis response events, analysis is generally retrospective - meaning that the type of data that is available often decides what kind of analysis that is possible to perform. For training or exercises, there are more possibilities as it is possible to tailor scenarios in such a way that they trigger adaptive behaviour, and to plan data collection so that gathered data reflects the establishment and operation of fundamental C2 functions. Successful assessment of C2 agility during training and exercises thus depend on an approach that goes beyond mere assessment. This must also comprise the scenario design to ensure that there are both events that challenge the participants to such a degree that they have to adapt beyond normal procedure, and that there are appropriate assessment methods and assessment points that reflect adaption as well as what type of adaption that took place.

As pointed out above, we have not found methods specifically created to assess C2 agility in the crisis or emergency response context. What we have found is a number of frameworks and methods that reflect aspects of C2 agility. Our conclusion from this work is that there is a need for a new analytical support instrument for assessment of C2 agility in crisis and emergency response organisations, inspired by the frameworks and methods we have discussed above. Such an instrument would help us to:

1.) Assess the position in the C2 approach space of an entity or a collective of entities. This assessment must capture how information is disseminated, how decision rights are allocated in the collective, and, how interactions occur. C2 agility can only be evaluated if we are able to examine the movements of an organisation or a collective of organisations in the C2 approach space.

2.) Assess if basic functions of C2 are in place, such as information collection, planning, execution, and learning. In a military organisation these functions can usually be mapped directly to specific staff functions. Assessing this in a crisis or emergency response context may prove more difficult as they may not be formally established. However, this information is needed in order to determine if an organisation or collective of organisations have a functional C2 system in place.

3.) Identify triggers of adaptive behaviour in order to design scenarios that challenge organisations participating in a training session or an exercise in such a way that they must engage in agile C2, in other words, adapt the way they conduct C2. Without the ability to provoke such change, it will be impossible to assess C2 agility in the first place.

In order to reach this goal, we need to develop an instrument that reflects fundamental aspects of C2, but also the ability to adapt to changing demands and opportunities. The crisis and emergency response domain is signified by a dynamic, multi-organisational environment. The instrument must thus be applicable to a wide range of situations and be able to capture how the collective of organisations that are handling the event at hand change over time, and how the C2 functions manifest and re-manifest within the collective. It must also be able to reflect the different approaches to C2 that are taken during the event.

Although we take a functional stance, such an instrument must presuppose tangible aspects of C2, such as information exchange, organisation, processes etc. (in line with the design logic outlined by Brehmer, 2006, see above). Without such tangible assessment points it will be impossible to make an objective assessment. Exactly which data gathering

techniques and methods should be applied remains an open question, but it is reasonable to assume that it will be a mixed method. The type of situation (e.g., exercise, actual event) and unit of analysis (single unit, organisation, collective of organisations) will also affect what types of data that can be collected. Further, the purpose and context of the analysis also shape the data collection – for example, if is it an exercise, experiment, an actual event, or in retrospect?

The C2 functions and the dimensions of the C2 approach space manifest themselves in several ways. For the future instrument, we suggest three main things to consider:

1.) A process perspective (Are all C2 functions in place? When are they activated? What levels of C2 do they reflect? Where and how do the C2 functions manifest themselves?).

2.) A capability perspective (What capability do the involved organisations have to conduct C2 in terms of information gathering, planning etc.?).

3.) A competence perspective (Which type of personnel is manning the different functions? What kind of training do they have? Do they have practical experience from unusual crisis or emergency response operations?).

Our work on designing an instrument for assessment of C2 agility in crisis and emergency response organisations will continue by developing a prototype for such an instrument. This instrument will be tested and validated during different kinds of exercises. Design and applicability of the instrument will also be discussed with practitioners.

4.4 Conclusions

This report discussed the need for identifying assessment frameworks, methods, and data collection techniques for C2 agility in the crisis and emergency response domain. Our overview identified some frameworks from the military domain that capture aspects of C2 agility, but none of them were explicitly developed for assessments of C2 agility, and none of them have been used in the crisis and emergency response domain. The overview also presents some methods, like social network analysis and communication analysis that can be utilized to analyse aspects of C2 agility in the crisis and emergency response domain. Further, we describe pros and cons with a number of data collection methods that can be used for gathering data regarding C2 agility in the crisis and emergency response domain.

As no existing frameworks or methods can be applied directly for assessing C2 agility in the crisis and emergency response domain, we suggest that a new instrument is developed to support analysis of C2 agility in crisis and emergency response organisations. Such an instrument should take a functional view of C2, be able to capture the dynamics of C2 as well as the crisis or emergency events, and be applicable to development of training or exercise scenarios.

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