Exploring C2 Capability and Effectiveness in Challenging Situations

Interorganizational Crisis Management,
Military Operations and Cyber Defence

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Exploring C2 Capability and Effectiveness in Challenging Situations: Interorganizational Crisis Management, Military Operations and Cyber Defence

by

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Abstract

Modern societies are affected by various threats and hazards, including natural disasters, cyber-attacks, extreme weather events and inter-state conflicts. Managing these challenging situations requires immediate actions, suspension of ordinary procedures, decision-making under uncertainty and coordinated action. In other words, challenging situations put high demands on the command and control (C2) capability. To strengthen the capability of C2, it is vital to identify the prerequisites for effective coordination and direction within the domain of interest. This thesis explores C2 capability and effectiveness in three domains: interorganizational crisis management, military command and control, and cyber defence operations. The thesis aims to answer three research questions: (1) What constitutes C2 capability? (2) What constitutes C2 effectiveness? and (3) How can C2 effectiveness be assessed? The work was carried out as two case studies and one systematic literature review. The main contributions of the thesis are the identification of perspectives of C2 capability in challenging situations and an overview of approaches to C2 effectiveness assessment. Based on the results of the three studies, six recurring perspectives of capability in the domains studied were identified: interaction (collaboration), direction and coordination, relationships, situation awareness, resilience and preparedness. In the domains there are differences concerning which perspectives that are most emphasized in order obtain C2 capability. C2 effectiveness is defined as the extent to which a C2 system is successful in achieving its intended result. The thesis discusses the interconnectedness of performance and effectiveness measures, and concludes that there is not a united view on the difference between measures of effectiveness and measures of performance. Different approaches to effectiveness assessment were identified, where assessment may be conducted based on one specific issue, in relation to a defined goal for a C2 function or using a more exploratory approach.

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Linköping, May 2019

Magdalena Granåsen

Included papers

The thesis is based on three publications, which are appended at the end of the thesis:

PAPER I. Granåsen, M., Olsén, M., & Oskarsson, P-A. (2019). Assessing Interorganizational Crisis Management Capability – A Systematic Literature Review. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*. Submitted for publication.

The objective was to explore how interorganizational crisis management capability is assessed in the scientific literature. A systematic literature review was performed, resulting in a dataset of 83 publications. Nine themes of crisis management capability were identified - Interaction, Relationships, Coordination/C2, System Performance, Preparedness, Situation Awareness, Resilience, Decision-making and Information Infrastructure. The analysis resulted in an overview of capability assessment methods related to the themes. The contribution of the paper is an understanding of how different themes of crisis management capability are evaluated, as well as the applicability and limitations of different methodological approaches.

PAPER II. Granåsen, M. & Marklund, J (2015). Organizational Effectiveness at the Kosovo Force Headquarters. In: Berggren, P., Nählinder, S. & Svensson, E. (eds.). *Assessing Command and Control Effectiveness: Dealing with a Changing World*. Farnham, UK: Ashgate.

The main purpose was to demonstrate how organizational effectiveness can be assessed in an operative multinational environment. The study was conducted within the NATO Research and Technology Organisation (RTO), in a research group within the Human Factors and Medicine panel (HFM): Improving the Organizational Effectiveness of Coalition Operations (NATO RTO HFM-163). A theoretical model of organizational effectiveness was validated through interviews and questionnaires at the Multinational NATO Headquarters in Kosovo. The results confirmed the developed model of organizational effectiveness with no evidence indicating needs for any larger modifications, although some factors received stronger support than others.

PAPER III. Granåsen, M., & Andersson, D. (2015). Measuring team effectiveness in cyber-defense exercises: a cross-disciplinary case study. *Cognition, Technology and Work*, 2016.

The paper aimed to increase knowledge on how to assess team effectiveness in computer defence exercises. A cross-disciplinary case study was conducted in conjunction with a multinational computer defence exercise (CDX). During the exercise, six defending (blue) teams each assumed control over a simulated power generation company and were tasked to protect their respective corporation against intrusion attempts performed by an attacking (red) team. The data set included system logs, observer reports and surveys, assessing both performance and teamwork. Performance was assessed using six different performance metrics. The cross-disciplinary approach and multiple measures created possibilities to study not only the performance-related outcome of the exercise, but also why this result was obtained in terms of team composition and teamwork.

The complete list of the author's publications is included on pages 35-36.

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1 Introduction

This thesis explores the command and control (C2), or management, of teams, organizations or clusters of organizations, that are put under pressure due to challenging situations. C2 capability and effectiveness is explored in three domains: interorganizational crisis management, military operations, and cyber defence operations.

Global threats and hazards towards societies are intensifying. The most severe threats for the near future in terms of impact as well as likelihood include natural disasters, cyber-attacks and critical information infrastructure breakdown, extreme weather events, and inter-state conflicts (World Economic Forum, 2019). The predictability and ability to influence a severe event varies, placing different demands on the ability to prevent, prepare for and manage the crisis (Gundel, 2005). When the event strikes, immediate actions, suspension of ordinary procedures, decision making under uncertainty, and coordinated actions are typically needed (Scholl and Carnes, 2017).

During crisis management, organizations manage events that are sudden, unexpected, extraordinary, unpredictable, and that affect societal functions (Al-Dahash, Thayaparan, & Kulatunga, 2016). These events can be caused by people as well as natural phenomena, or a combination of both. The complexity and magnitude of these events require interorganizational approaches where the ability to collaborate across organizations is vital.

In the military domain, the future operational environment is expected to place new and different demands on the military capability. The future operational environment is impacted by globalization, climate change, technological advancements, and ambitions and actions of various states (Ministry of Defence, 2014). The Global Risks Report (World Economic Forum, 2019) gives that increasing polarization of societies, shifting power and rising income and wealth disparity all contribute to the risk of inter-state conflicts, failure of national governance and state collapses, placing increased demands on the ability to command and control (C2) operations. The complexity increases due to, for instance, a more tangible grey zone and hybrid warfare challenges (Pogoson, 2018; Wirtz, 2017).

In the cyber domain, there is an extensive need to develop a qualified capability to defend infrastructure and other important societal functions. Cyber incidents such as the cyber-attacks on Estonia in 2007 and the attacks on British, American, German, and French resources in 2005 proved the reality of cyber threats more than ten years ago (Greenemeier, 2007). Since then, the list of attacks against telecommunication, authority databases containing sensitive information, social media accounts, financial institutions, critical infrastructure and large companies seems endless (Center for Strategic and International Studies, 2019). Cyber-related crises span across the military and civilian crisis management domains. The rising dependency on cyber and communication technology has increased the risk of cyber-attacks, data fraud or theft, critical information structure breakdown, and adverse consequences of technological advances (World Economic Forum, 2019).

The aforementioned domains share characteristics and challenges in terms of complexity, unpredictability and the risk of severe consequences. Understanding what is required for organizations or collaborative organizations to efficiently manage severe situations is essential.

1.1 Objective and research questions

The objective of this thesis is to explore different perspectives of C2 in difficult and challenging situations that affect our society. Three research questions are addressed:

Q1. What constitutes C2 capability?

Q2. What constitutes C2 effectiveness?

Q3. How can C2 effectiveness be assessed?

Military C2 is well-defined in doctrines and regulations, while civilian crisis management is more diverse. C2 in the cyber domain is to a large extent unexplored. Responding to the three research questions from the perspectives of three different domains provides an opportunity to combine and contrast existing views, that should result in insights that are useful across domains. In an increasingly interconnected society, the three domains studied are continuously approaching and overlapping each other. Insights from one domain may inspire the development within organizations in the other domains.

1.2 Contributions

The two main contributions of the present thesis are

- (1) Identification of perspectives on C2 capability in challenging situations. The capability perspectives are primarily based on the results of paper I, complemented and modified by the results in the other two papers.
- (2) An overview of approaches to C2 effectiveness assessment. All three papers contributed with different perspectives on effectiveness and performance assessment. The present thesis provides a number of different approaches to assessment of effectiveness from a team, organizational and interorganizational perspective.

Additional contributions include identification of terminological discrepancies within and between the domains studied.

1.3 Outline

Chapter 1 - Introduction, provides a scope for the thesis by introducing the three domains studied, the research questions and research contributions.

Chapter 2 - Background, is primarily centred around the three key concepts forming the title of the thesis - *C2*, *capability* and *effectiveness*. Furthermore, situation awareness and resilience are addressed, as these concepts have widely influenced C2 research.

Chapter 3 - Method, describes the three domains studied in more detail, summarizes and provides a theoretical foundation to the data collection and analysis methods used in the thesis.

Chapter 4 - Results, summarizes the results and conclusions of the three appended papers.

Chapter 5 - Discussion, is structured according to the research questions, where each research question is discussed based on the findings from the three papers.

Chapter 6 - Conclusion encompasses a brief summary of the findings and identifies main issues within each of the domains studied.

Chapter 7 - Future work identifies new areas for future research, as well as needs for increased research within existing fields of research.

2 Background

This section is centred around the three key concepts forming the title of this thesis - *C2*, *capability* and *effectiveness*. The three papers included provide diversity in terms of domain as well as unit of analysis. Thus, this section encompasses perspectives from the military, crisis response and cyber domains, as well as discussion of the meaning of concepts from a team perspective, an organizational perspective and an interorganizational perspective. Two important prerequisites for the C2 function include the ability to comprehend the situation and the ability to adjust according to the circumstances. Thus, some theoretical foundations for situation awareness and resilience are included. The terminology in the three papers differs to some extent, which is due to terminology differences between fields of research. While C2 is a well-recognized term in the military domain, it is not widely used in the civilian crisis management domain.

2.1 Command and control

Organized human activity has two fundamental requirements: the division of labour and the achievement of coordination among these tasks (Mintzberg, 1993). In the military domain, this is generally denoted as *command and control* (C2). In other domains, such as business and crisis response, *management* or *administration* are more common terms, as shown in expressions such as business management, business administration and crisis management. In management research, the terms command and control can denote management components, for instance, in Fayol's definition of management as planning, organization, *command*, coordination and *control* (Fayol, 2016). The focus of the thesis is C2 in challenging situations, characterized by pragmatic decision making under times and resources constraints, as well as increased needs for coordination and reorganization (Van Wart & Kapucu, 2011).

C2 as a composite term within the military domain is defined as “the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. C2 functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission” (Department of Defense, 2007). The latest NATO glossary of terms and abbreviations, as well as the European Union concept for military C2 generally use C2 as a composite term (C2 systems, C2 arrangements, C2 aspects, delivering C2, etc.). A *C2 system* is a sociotechnical system composed of technology, methods, organization and doctrine and personnel (Hallberg, Granåsen, Josefsson, & Ekenstierna, 2018).

Although C2 is used as a composite term, neither NATO nor EU *define* C2 as a whole, but separately as command and control (European Union Military Staff, 2015; NATO Standardization Office, 2018).

Command is the authority vested in an individual of the armed forces for the direction, coordination, and control of military forces.

Control is the authority exercised by a commander over part of the activities of subordinate organizations or other organizations not normally under his [sic] command, which encompasses the responsibility for implementing orders or directives. All or part of this authority may be transferred or delegated.

A somewhat more accessible explanation of the difference between command and control was described in a seminal paper by Pigeau and McCann (2002). They described *command* as “the creative expression of human will necessary to accomplish the mission”, while *control* was described as “those structures and processes devised by command to enable it and to manage risk.” Thus, command is typically connected to the commander, while control is more associated with activities among the staff or at headquarters. Although C2 as a composite term is used, one needs to take into account both the processes involved for executing and monitoring the operation, and the element of authority, including the expression of a vision of what should be accomplished (Builder, Bankes, & Nordin, 1999; Teske, Miller, & Guerin, 2018).

The most influential C2 model is the OODA-loop (observe, orient, decide, act) (Boyd, 1996), with variations and extensions including, for instance, the Dynamic OODA (Brehmer, 2005), and Cognitive OODA (Blasch, Breton, Valin, & Bosse, 2011). Within the management domain there are similar models, such as the Plan-Do-Check-Act (Sokovic, Pavletic, & Kern Pipan, 2010). Regarding the C2 Concept development for the Swedish Armed Forces, a functional model including five essential C2 functions has been suggested - data providing (sensing), assessing (understanding), estimating (deciding direction), planning (deciding coordination) and communicating (informing and directing) (Hallberg et al., 2018).

The widespread use of C2 is not undisputed even within the military domain. There have been attempts to replace C2 with terms less associated with traditional hierarchical approaches, such as *focus and convergence*, where focus would denominate the definition of purposes to accomplish an endeavour, while convergence is the guidance of actions and effects (Alberts, 2007). However, such attempts have not received sufficient impact in order to change the phrase. Instead, C2 as a term has remained, although the meaning has expanded, proving that C2 is not only about hierarchical command structures and top-down coordination, but include a wide range of approaches, where the most suitable approach varies depending on the situation (NATO Science and Technology Organization, 2014). Another way of shifting the focus from the traditional top-down approach is demonstrated in the British military C2 concept (Ministry of Defence (UK), 2017). In the concept it is stated that “the purpose of C2 is to provide focus for individuals and organizations so that they may integrate and maximize their resources and activities to achieve the desired outcomes.” Thus, the commander is an enabler and C2 is a supporting function. Paper II is focused on military C2, where the ultimate goal of the multinational headquarters was defined as *supporting* the troops on the ground.

In the Swedish Armed Forces, C2 (“ledning”) is defined as a function providing *direction* and *coordination* of an effort (Brehmer, 2007; Swedish Armed Forces, 2016a). Direction includes defining what should be accomplished (Hallberg et al., 2018) and coordination is to align the actions of actors in order to achieve a shared goal (Comfort, 2007). The Swedish Civil Contingencies Agency have adopted the use of direction and coordination. Direction and coordination may be achieved through collaboration or command (Swedish Civil Contingencies Agency, 2018).

Although more decentralized approaches are influencing C2 concepts, military C2 is still to a large extent associated with the existence of a commander and a clearly defined organizational structure. This is very different from interorganizational crisis management, which to a large extent is based on emergent networks of actors (Mendonca, Jefferson, & Harrald, 2007). Mintzberg has defined five different archetypical structural configurations

that organizations can adopt - the simple structure, the machine bureaucracy, the professional bureaucracy, the divisionalized form, and the adhocracy. Each of these structures is associated with certain coordinating mechanisms, type of centralization/decentralization, and focus on different key parts of the organization. This means that they will be suitable in different contexts (Mintzberg, 1993). The adhocracy, loosely structured and coordinated through mutual adjustment, allows for creativity and initiative, efficient use of resources and rapid adaptation to changing environments (Lunenburg, 2012). This may be favourable when innovation is key. However, in highly mechanistic production work, the machine bureaucracy may be more suitable, characterized by standardized processes to reduce the need for internal coordination and achieve internal efficiency.

The military domain, has started to appreciate that there may not be *one* effort uniting the actors that need to coordinate their activities, nor that there are always clear mandates between actors or a commander that can command the endeavour as a whole. The coordination therefore needs to aim towards a *harmonization of efforts* between participating actors (Brehmer, 2011). Furthermore, the increased unpredictability and pace of the future operational environment put increased demands on flexible and quick response, hence it is motivated to consider adhococratic approaches for certain situations (Granåsen, Barius, Hallberg, & Josefsson, 2018). It is important to stress that one approach is not appropriate in every situation (Granåsen, Barius, et al., 2018; NATO Science and Technology Organization, 2014).

2.2 Capability

Paper I is centred around interorganizational crisis management *capability*. Papers II and III are centred around *effectiveness*. These terms are interrelated and used interchangeably in the literature. Yet another related term is *performance*, assessed in paper III and identified as an capability theme in paper I. The current and next section attempt to bring some order to these terms.

In its broadest sense, *capability* is the power or ability to do something (Oxford dictionaries). Lindbom, Tehler, Eriksson, and Aven (2015) identified trends based on 15 capability definitions found in publications related to crisis management, where capability may be viewed as equivalent to, or at least strongly influenced by resources, equivalent to capacity (e.g., the ability to prepare, or the ability to carry out training), or capability as a factor affecting an outcome or goal. In paper I, certain themes constituting or affecting interorganizational crisis management capability were identified.

In team research, there are numerous frameworks describing what is required for a team to function properly. A model known as “the big five in teamwork” includes *team leadership*, *mutual performance monitoring*, *backup behaviour*, *adaptability*, and *team orientation* (Salas, Sims, & Burke, 2005). These are regarded as a focal set of teamwork components to be included in order to complete a task. In a study of cyber defence teams, *team structure*, *team communication*, and *information overload* were identified as factors affecting team performance (Champion, Rajivan, Cooke, & Jariwala, 2012). In a study on C2 ability, ten prerequisites for C2 ability were identified - *Knowledge and experience*, *operational picture*, *trust*, *information flow*, *situation awareness*, *mission intent*, *feedback*, *flexibility*, *decision-making*, and *teamwork* (Granåsen et al., 2011) (Figure 1). The model was validated empirically in a demonstrator simulating computer network operations (CNO) and electronic warfare (EW). Thus, the team solved their tasks in an information degraded environment. All ten prerequisites were found relevant and contributing to an overall C2 ability.

In analogy to the “big five in teamwork,” Rafferty, Stanton, and Walker created the “famous five model” of teamwork, including *communication*, *cooperation*, *coordination*, *schemata*,

Figure 1. Ten prerequisites for C2 ability identified during development and experimentation with a C2 warfare demonstrator (C2WD) (Granåsen et al., 2011).

and *situation awareness* (Rafferty et al., 2010). The model was used to analyze a fratricide incident, assessing a military structure including several teams. Thus, the model mainly focuses on interactions. Similarly, Comfort (2007), who is active within the field of crisis management, identified four critical functions for effective intergovernmental performance - *cognition, communication, coordination* and *control*, known as “the 4C framework.”

The definitions and scopes of the factors differ, why it is not possible to draw conclusions of differences between the models and frameworks based on the factor names only. *Adaptability* in the big five model by Salas et al. (2005), corresponds to *flexibility* in the model by Granåsen et al. (2011). In the famous five and 4C models, adaptability are not included as specific factors. However, in the famous five model, adaptability is described as an essential aspect of coordination, and in the 4C framework Comfort emphasizes that intergovernmental crisis management is a complex, adaptive system, particularly in relation to the control factor (Comfort, 2007; Rafferty et al., 2010).

The frameworks and models mentioned in this section consider primarily the *control* aspect of C2. Pigeau and McCann (2002) identified three factors of *command* capability: *competency, authority* and *responsibility*. Otherwise, the term capability in the military domain generally describes essential aspects of the system as a whole. NATO defines capability as “the ability to create an effect through employment of an integrated set of aspects categorized as doctrine, organization, training, materiel, leadership development, personnel, facilities, and interoperability”, referred to as DOTMLPFI (NATO Standardization Office, 2018). Corresponding to the DOTMLPFI model, the Swedish Armed Forces use the MOPTD model (method, organization, personnel, technology and doctrine). However, these are not denominated as capabilities, but as components of a sociotechnical C2 system. The Swedish Armed Forces have defined six essential capabilities for conducting military operations - fires, mobility, sustainability, protection, C2, and intelligence and information (Swedish Armed Forces, 2016b).

2.3 Effectiveness and performance

Is a capable system an effective system? A simple definition of *effectiveness* is the degree to which something (a system, team, organization, etc.) is successful in producing a desired result (Oxford dictionaries). Related terms to effectiveness include *efficiency* and *efficacy*. In

organizations research, efficiency is sometimes viewed as a sub-component of effectiveness (Jones, 2004, p. 14). However, there are arguments to why effectiveness, efficiency and efficacy should be treated as three distinct terms, something that is particularly emphasized in clinical research (Zidane & Olsson, 2017). A medical treatment is *effective* if it works during normal circumstances (does it work in practice?), *efficient* if it works without consuming too many resources (is it worth it?), and *efficacious* if it works under ideal conditions, that is, has the potential to lead to an effective outcome (can it work?) (Haynes, 1999; Zidane & Olsson, 2017).

The definitions of effectiveness and efficiency used for studying organizations and sociotechnical systems largely correspond to the definitions in clinical research. However, defining efficacy is not as simple. Skyttner (2006) defined the three terms as:

Effectiveness - a measure of the extent to which a system achieves its intended transformation,

Efficiency - the measure of the extent to which the system achieves its intended transformation with the minimum use of resources,

Efficacy - a measure of the extent to which the system contributes to the purposes of higher-level system of which it may be a subsystem.

Efficacy is also explained as “the extent to which an organization is perceived to be achieving outcomes that are valued by its major stakeholders” (Dickinson et al., 2010). In team research, efficacy is defined as a group's belief regarding its ability to perform effectively (Gibson, 1999). Thus, the “ideal conditions” of definitions in medical research are replaced by higher-level system expectations. McKenzie (2001) linked effectiveness, efficacy and efficiency to three predominant types, or paradigms of performance - technical performance (focus on effectiveness or task achievement), organizational performance (focus on efficiency), and cultural performance (focus on efficacy or perceived effectiveness).

The Command Team Effectiveness (CTEF) model is a model of *team effectiveness* mainly developed for applicability the military domain (Essens et al., 2005). It contains components of team effectiveness in terms of conditions (mission framework, task, organization, leader, team member, team), processes (task and team focused behaviours) and outcomes (task and team outcomes), relationships between these and feedback loops. Based on the CTEF model, an assessment instrument has been developed, designed to capture the status of a team at a given time (Essens et al., 2010). The instrument takes into account aspects of efficiency and effectiveness, and is thus an example of how efficiency is viewed as subordinate to effectiveness.

Scaling up from a team focus to an organization, aspects such as organizational structure and culture are added to the team models (Yanakiev & Horton, 2012). According to an internal systems approach, an effective organization needs a structure and a culture that foster adaptability and quick responses to changing conditions in the environment (Jones, 2004, p. 15). The organizational effectiveness model described in paper II was constructed based on an internal systems approach, where the effectiveness of the C2 of a NATO coalition HQ was defined by its ability to support the troops on the ground in conducting their operation.

Broadening the scope further, crisis management is often conducted in settings where organizations are consolidated in temporary networks (Mendonca et al., 2007). As shown in the effectiveness definitions described in this section, effectiveness is measured against an objective. Assessing the effectiveness of temporarily formed clusters of organizations then becomes challenging, as predefined shared objectives may not exist. A common policy program between collaborating actors creates a shared understanding and a common objective that forms the foundation for effectiveness assessment. However, the actors further need to agree on the process on how to assess collaborative effectiveness. Otherwise, the

opportunities for learning and adjustment may be replaced by power struggles and blame games between participating actors (Koppenjan, 2008).

Effectiveness and performance is used interchangeably in literature. Regarding distinctions between performance and effectiveness (where effectiveness is used as a common denominator for effectiveness, efficiency and efficacy), the literature is less than coherent. Within the military domain, NATO distinguishes measures of effectiveness from measures of performance (Office of the Assistant Secretary of Defense, 2002). NATO measures of performance describe assessments of internal system structure, characteristics and behaviour. Measures of effectiveness are divided into measures of force effectiveness, dealing with the accomplishment of the mission objectives, and measures of C2 effectiveness, dealing with the impact of C2 systems within the operational context, for instance, the ability to compile the necessary products needed for the coordination and monitoring of an operation.

Within team research, Salas, Sims and Burke (2005) have described team performance as a component of team effectiveness. Team performance is the outcome of the team's actions, while team effectiveness encompasses both the completion of the team task (performance) and the interactions and processes conducted to achieve the outcome. This approach was adopted in paper III. Various attempts have been made to identify and measure the essential aspects of teams, organizations or clusters of organizations that are assumed to affect the performance or effectiveness of a team (Barrick, Stewart, Neubert, & Mount, 1998; Hof, de Koning, & Essens, 2010; Rothrock, Cohen, Yin, Thiruvengada, & Nahum-Shani, 2009). Some of these aspects and frameworks were identified in the previous section as aspects constituting C2 Capability.

Empirical research on performance measurement has extensively been conducted in closed and simulated environments characterized by high experimental control, the ability to log and track events, and the possibility to define clear performance criteria (Macmillan, Entin, Morley, & Bennett Jr., 2013). For this reason, there are numerous examples of performance assessment studies of teams accomplishing tasks in simulated air operations (Macmillan et al., 2013; Rothrock et al., 2009). The ability to log events is further found in cyber security competitions and exercises, which are gaining an increasing interest as research platforms (Sommestad & Hallberg, 2012).

2.4 Situation awareness

Situation awareness (SA) is a theoretical concept concerning the individual's understanding of a situation or a system. It is commonly described as comprising three levels of understanding: (1) the perception of the elements in the environment within a volume of time and space, (2) the comprehension of their meaning, and (3) the projection of their status in the near future (Endsley, 1995b). *Shared SA* concerns the degree to which team members possess similar SA on shared requirements (Endsley & Jones, 1997). The concept *Distributed SA* (DSA) challenges the original and shared SA concepts, using the sociotechnical system as the unit of analysis rather than the individual mind, thus assuming that artefacts as well as humans may possess SA (Stanton, 2016). Distributed situational awareness theory explains SA as an emergent property and does not assume that different individuals have a similar SA, but acknowledges that they possess complementary views (Sorensen & Stanton, 2011). According to the distributed perspective SA is viewed as a process rather than a product. A related perspective is *Situated SA*, which further accentuates the human-agent team (Chiappe, Strybel, & Vu, 2015). According to this perspective, operators and technology form an inseparable system and offload information onto the environment. It should be noted that the foundations in terms of the three levels of understanding are not questioned in any of the different perspectives.

The different views on SA have implications on how SA is assessed. For the traditional perspectives (SA and Shared SA), query-based techniques have been developed, where operators are asked to respond to questions concerning the three levels of SA. Two of the most famous techniques include SAGAT (Situation Awareness Global Assessment Technique), based on freezes in a simulation, and SART (Situation Awareness Rating Technique), which is based on a subjective rating of SA (Endsley, 1995a; Endsley, Selcon, Hardiman, & Croft, 1998). Promoters of DSA have criticized these assessment methods on the basis that they do not take the broader sociotechnical system into account. Rather, methods focusing not only on the individuals, but on interactions between individuals are promoted, such as social network analysis (SNA) (Sorensen & Stanton, 2011). From the situated SA perspective, SART and SAGAT were criticized for not allowing the operators access to the environment onto which they offload their information during the SA testing (Chiappe et al., 2015).

Shared awareness has become significant within cyber research, often referred to as Cyber SA (CSA) (Champion et al., 2012; Franke & Brynielsson, 2014; Lif, Granåsen, & Sommestad, 2017). One interpretation of the three levels of SA for cyber is (1) Perception: identifying the type and source of an attack, awareness of the quality of information, and understanding capabilities, vulnerabilities and intents on both sides, (2) Comprehension: impact assessment and causality analysis of why and how events happened, and (3) Projection: the ability to detect how the situation evolves (Barford et al., 2010). Cyber SA fits well with the distributed and situated perspectives. Due to the complexity in the cyber domain as well as the heavy dependence on technology, no individual is believed to have a complete understanding. Cyber SA is distributed across individuals and technological agents operating in different functional domains (Tyworth, Giacobe, Mancuso, & Dancy, 2012).

2.5 Resilience and agility

Resilience is a diverse concept that has been widely studied within the crisis management domain (Bergström, 2018; Woltjer et al., 2015). *Resilience* concerns the ability to persist, adapt or transform in the face of a shock or changing environment (Béné, 2013). Four key abilities characterizing resilient systems are (1) the ability to *respond* to an event, (2) the ability to *monitor* what is happening, (3) the ability to *anticipate* what may happen next and (4) the ability to *learn* from past experiences (Hollnagel, 2011a). One influential branch of resilience research is resilience engineering, which is largely based on the cognitive systems engineering approach, dealing with how joint cognitive systems of humans and artefacts cope with complexity (Hollnagel & Woods, 2005). For this thesis, this approach is assessed to fit well with the C2 system models, and a sociotechnical perspective on C2 systems.

Woods (2015) identified four main approaches to resilience: Resilience as (1) rebounding from a trauma and returning to equilibrium, (2) robustness, (3) graceful extensibility and (4) sustained adaptability. Further, Woods (2015) promoted the last two approaches, suggesting that a resilient system to a large extent is one that is able to adapt and change rather than a system that stands firm in times of changes. In other words, the key feature of a resilient system is its ability to adjust in order to sustain required functions during expected as well as unexpected conditions (Hollnagel, 2011a). Adjustments may be reactive or proactive, conducted prior to, during or as a result of events. In order to be able to respond, it is necessary either to have prepared responses and resources at the ready, or to be flexible enough to reconfigure the existing configuration so that the necessary resources become available (Hollnagel, 2011b). Van Wart and Kapucu (2011) describe crisis management as a special type of change management, however one needs to be careful not to try to reorganize adequately operating response systems in the middle of a crisis.

Branlat and Woods (2010) identified three maladaptive patterns, impairing the ability to adapt. First, increased demands on an organization working close to its maximum capacity may cause an inability to adapt unless new resources are provided, which may take time. Second, when there is a complex network of interdependencies between functions, adaptive behaviour needs to consider all dependencies between subparts of the system. It is essential to understand how adaptation in one part of the system affects other parts of the system (Rankin, 2017). Thirdly, actors at all levels need to detect a need to adapt to ongoing challenges (Branlat & Woods, 2010).

Resilience refers to something that the system does rather than to something that the system has, why assessment of resilience focuses on what enables resilient performance. The potential of resilient performance has been assessed by addressing different aspects of each of the four identified abilities - responding, monitoring, anticipating and learning. The resilience analysis grid (RAG) developed by Hollnagel has become a baseline, which has later been applied or modified by other researchers (Hollnagel, 2011b; Patriarca, Di Gravio, Costantino, Falegnami, & Bilotta, 2018; Van Der Beek & Schraagen, 2015).

The resilience concept bears resemblance to the concept of agility, which is mainly used within the military domain. *Agility* is defined as the capability to successfully effect, cope with and/or exploit changes in circumstances (NATO Science and Technology Organization, 2014). Responsiveness, robustness, flexibility, resilience, adaptability and innovation are seen as enablers of agility. Assessment of agility may be conducted in terms of addressing potential agility in line with addressing the potential performance in resilience research, or manifest agility, in terms of what is accomplished.

C2 agility describes an organization's or actor's (entity) capability to successfully accomplish C2 functions in all circumstances in which the entity could find itself. A C2 approach space is used to illustrate how different C2 approaches vary along the three dimensions: *Allocation of decision rights*, *Patterns of interactions among entities* and *Distribution of information among entities*. C2 agility theory prescribes that more network-enabled C2 approaches are more agile than approaches relying on more formal structures. Further, C2 agility is about being able to identify the most suitable approach in a given situation, understand when changes in circumstances require another approach and be able to transfer between an insufficient approach to the more appropriate approach. The C2 agility concept has been empirically tested in simulations and case studies (NATO Science and Technology Organization, 2014).

3 Methods

This section describes the study contexts, designs, data collection and analyses employed in the included papers (Table 1). The three research all use a combination of quantitative and qualitative data and analysis. A mixed methods research perspective was applied in the knowledge that the data collection and analysis methods used were originally defined from the perspectives of various research paradigms and traditions (Creswell & Tashakkori, 2007). The methods adhere to different research traditions, and some methods are more accepted than others in certain types of research.

Table 1. Study contexts, designs, data collection and analysis methods in the three papers.

Paper	Study context	Design	Data collection	Analysis
I	Interorganizational crisis management functions during real events, exercises and experiments	Systematic literature review	Scopus literature search and snowballing	Inductive thematic analysis
II	The multinational military HQ in Kosovo. Validation of a model for organizational effectiveness.	Case study	Questionnaires, semi-structured interviews	Statistical analysis, deductive thematic analysis
III	Cyber defence teams participating in the exercise Baltic Cyber Shield. Evaluation of methods for assessing team effectiveness.	Case study	Observer ratings, system logs, questionnaires	Statistical analysis, exploratory sequential data analysis

3.1 Study context

Paper I included a broad range of interorganizational crisis management functions studied in real and simulated crises. Crisis management actors in the publications operate on municipal, regional, national and international levels. The included publications described interorganizational crisis management, why studies including, for instance, only rescue services or only health care organizations were excluded. Furthermore, crisis management

systems primarily involving voluntary organizations or with a main focus on humanitarian aid were excluded. The reason was that the result should be applicable to a Swedish context.

Paper II focused on the validation of a model for organizational effectiveness, developed by a NATO research group (Yanakiev & Horton, 2012). The developed model is described in Figure 2. Data was collected from the multinational Headquarters of the peace-support operation in Kosovo – the Kosovo Force (KFOR). The Kosovo Force was established in June 1999. It is a peace enforcement operation, thus operating under Chapter VII of the UN Charter. In the first few years, 50,000 troops were deployed in Kosovo. From 2009, these were gradually reduced as the security situation improved. At the time of the interviews, NATO had approximately 10,000 troops in Kosovo. Since then, it has been reduced to about 4,000 troops by the end of 2018 (NATO Public Diplomacy Division, 2018).

The KFOR Headquarters (HQ KFOR) has been located in Camp Film City, Pristina since it was established. When the study at the KFOR HQ was conducted, the HQ had been operational for ten years. Some locally recruited civilian staff personnel had been working at the headquarters over time, but the military personnel rotated with rotation cycles of 6-12 months.

The primary aim of the study was not to evaluate the HQ itself. Instead, the HQ was used as an empirical platform to validate the model of organizational effectiveness developed by the NATO research group (Yanakiev & Horton, 2012).

Paper III, evaluated five of the six technical cyber defence teams that participated in an international cyber defence exercise (CDX), organized by the NATO Cyber Defence Centre of Excellence in Tallinn. The teams were located in four different European countries and there were 6-12 persons in each team. The teams consisted of technical cyber security experts from government agencies, private companies and academia, where an appointed point of contact for each team was responsible for composing a team of sufficient competencies, without further regulations. The evaluation of the teams was primarily a means to understand the validity of different measures for performance and team effectiveness.

Figure 2. Model of organizational effectiveness of Non-Article 5 Crisis Response Operations' HQs.

3.2 Study designs

A *systematic literature review* was used in paper I. This is a systematic, explicit, comprehensive and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners (Okoli & Schabram, 2010, based on Fink, 2005). A systematic literature review is a useful approach when the aim is to obtain an extensive overview of an area of research, and was therefore used in Paper I. Systematic literature reviews are formalized by a structured process. Kitchenham (2004) has provided one of the most influential guidelines on procedures for performing systematic reviews, directed at the systems engineering community. A systematic literature review should include (1) Identification of research, (2) Selection of primary studies, (3) Study quality assessment, (4) Data extraction and monitoring, and (5) Data synthesis (Kitchenham, 2004). This process was adopted by the review described in Paper I. Similar structures can be found in other guidelines, which are typically targeting medicine (e.g. Pai et al., 2004). Many other review approaches exist, where the systematic review may be viewed as the type with the highest demands for formalization (Grant & Booth, 2009). However, the systematic review type can be regarded as a spectrum where rigour and structure may vary, as long as certain criteria are fulfilled (Okoli & Schabram, 2010). Other review types resembling systematic reviews, although less formalized, include systematic mapping review, state-of-the art review, scoping study and qualitative systematic review (Grant & Booth, 2009).

The study described in Paper I was designed to meet the criteria for a systematic review. Therefore, an extra effort was made to structure and systemize the work process. During a pilot study, existing systematic reviews within similar areas of research were identified, providing inspiration for the design of the work process as well as key words to be used in the search.

A *case study* may give an insight into specific situations of interest through investigating phenomena in their real context. Studying a specific case may further provide a more general understanding of a certain phenomenon (Stake, 1995). The case study approach promotes the use of multiple methods and multiple data sources for validation (Yin, 2009). The classic approach to case studies mainly includes qualitative methods for data collection, typically observations, interviews and analysis of documentation (Yin, 2009). However, combining qualitative and quantitative methods is an approach gaining increasing interest, as it enables accomplishment of both depth and breadth in the analysis (Flyvbjerg, 2011). Papers II and III describe two different case studies that both used a combination of quantitative and qualitative data.

The exercise described in Paper III can hardly be categorized as a real context and share characteristics of a controlled *experiment* conducted in a simulated environment, where the different teams participating in the exercise were exposed to similar treatment. However, due to exercise goals there was as a lack of experimental control, for instance in terms of team size, preparations and expertise. The teams were allowed a large degree of freedom in assembling the team and were responsible for manning it with sufficient expertise as well as making the necessary preparations in terms of equipment, familiarization with the infrastructure, team organization and tactics. There is a trade-off between experimental control and ecological validity, and in this case it was neither possible nor desirable to increase control.

3.1 Data collection

In Paper I, a literature search was used for data collection, which was retrieved in accordance with guidelines for systematic reviews (Kitchenham, 2004). The case studies conducted in Papers II and III employed data collection from a pluralist approach perspective, taking into account different dimensions of a situation (Mingers, 2001). For Paper II this meant combining interviews with questionnaires, where interviews allowed for depth and insight, while the questionnaires were distributed to a larger sample. In Paper III, a wide range of data was collected, including system logs, manual performance scores, observations, and questionnaires.

For the systematic literature review described in Paper I a *literature search* in the Scopus database was conducted in order to obtain a comprehensive dataset of the field of interest. Scopus is a multidisciplinary database widely used in literature reviews, proven to provide functionality for obtaining an overview of the result and a sufficient dataset (Yang & Meho, 2006). A pilot study was conducted in order to identify the sufficient keywords that would enable a comprehensive, yet manageable search result. A systematic literature review is time consuming, and it takes considerable effort to define and adjust the details of how the review process should be accomplished. In a first iteration, all titles and abstracts of the 1,197 resulting publications were evaluated by two reviewers. The first iteration resulted in a set of publications that the two reviewers agreed should be included, a set of excluded publications, and a set of publications that the two reviewers disagreed upon. A structured process was defined to manage the set of disagreements. The final dataset contained 83 publications that described assessment of crisis management capability.

In Paper II, *interviews* were used as the primary data source (Kvale & Brinkmann, 2009). Fifteen interviews were conducted with personnel at the KFOR Multinational Headquarters in Kosovo, working at ACOS (Assistant chief of staff) level in all branches within the headquarters. The interviews were semi-structured, meaning that an interview guide of topics to be covered was used, where the questions allowed for open-ended answers and follow-up questions when needed (Harrell & Bradley, 2009). The questions were based on the constructs of the theoretical model of organizational effectiveness.

Questionnaires were used in Papers II and III. In Paper II, a questionnaire was used addressing the model of operational effectiveness at the HQ. 103 questionnaire responses from military personnel at the headquarters were used in the analysis (Yanakiev & Horton, 2012). While the interviews targeted selected key personnel at a certain hierarchical level, the questionnaires had a broader scope, including personnel from different organizational structures and hierarchical levels within the headquarters. Through questionnaires, data was collected that could be used to quantitatively validate the model of organizational effectiveness. In Paper III, the questionnaires aimed to assess how the exercise participants' perceived aspects related to their skills, teamwork, strategy and performance. The questionnaires added perspectives that were not encompassed by other data collections, as other data sources focused primarily on capturing the participants' activities rather than their perceptions and experiences. The 43 exercise participants were requested to complete a background questionnaire and a questionnaire after each day of the two-day exercise. The response rate was 82% for the background survey and 84% for the survey completed after each day.

System logs were used in Paper III as a means to collect data on the team's activity in the exercise network. The most useful logged data included chat and e-mail communication, through which the researchers had access to the reports sent from the blue teams to the white (judging) team. These reports contained the teams' assessment of what they were exposed to.

Observations were used as a complement during the CDX to assess aspects that would not be visible in system logs and detect key events that would guide the system log analysis. One observer was placed in each team, recording events using a predefined coding scheme. The coding scheme narrowed down the scope of the observers to record and time-stamp certain types of events. An event can be defined as an observable occurrence at a particular point in time (Drury, 1995). Aided by the observations, the purpose was to understand the decision-making processes within the teams, as well as how the teams detected vulnerabilities, threats and attacks directed at them. Observing the CDX turned out to be challenging. Detecting team processes and decision-making was difficult as the teams to a large extent used chat functions for within-team-communication, and observing key events was difficult as it demanded interpretation of what was happening on the participants' computer screens. Still, the observations proved useful for the understanding of the exercise.

3.2 Analysis methods

All three papers that form the basis for this thesis include a combination of quantitative and qualitative analyses.

In Paper I, the publications included from the abstract review underwent a *full-text-review* using a pre-defined protocol. Some effort was made to define and refine the review process and protocol used for the full-text review, aiming to ensure that the review protocol was interpreted similarly by the reviewers and that the protocol encompassed all aspects of interest to the research questions. This reduced the risk of having to re-read papers due to questions missing. The quality of the results also increased in terms of reduced researcher bias (Kitchenham, 2004).

In order to analyze the dataset of the literature search described in Paper I as well as interview data in Paper II, *thematic analyses* were used. Thematic analysis is a method for identifying, analyzing and reporting themes within data (Braun & Clarke, 2006). Within a dataset themes are identified, capturing important aspects about the data in relation to the research question and representing some level of response pattern or meaning within the dataset. Thematic analyses can be inductive, where the themes emerge from the data, or deductive, based on a priori knowledge (Ryan & Bernard, 2003). There is a trade-off between using existing frameworks for the themes, while simultaneously trying to avoid being biased by these, thus neglecting essential aspects of the dataset that are not visible in existing frameworks (Ryan & Bernard, 2003).

In Paper I, the thematic analysis was conducted with the purpose to identify relevant themes forming crisis management capability and viable methods to assess these. The themes were identified mainly by using an inductive approach where the themes emerged during the coding process. The thematic analysis was conducted after the papers had been reviewed according to other criteria, which possibly speeded up the process as the reviewers had an overview of the dataset. During the review process, existing frameworks for essential aspects of crisis management were identified (Comfort, 2007; Sundnes, 2014; van den Heuvel, Alison, & Crego, 2012). None of them were assessed as fully sufficient for categorizing the publications in the dataset. There was a dynamic change of themes during the process. The thematic analysis process is recursive and once a new theme emerged in the data or a theme was modified, this could potentially affect the already coded papers. The papers were assigned to the themes partly based on the terminology used in the reviewed publications, but mainly based on content and meaning in the terms used. The analysis resulted in nine themes (Granåsen, Olsén & Oskarsson, 2018). The analysis further included an investigation of the methods used for assessing the different themes of crisis management capability as well as data collection methods.

A deductive thematic analytical approach was used for the analysis of the interviews from the NATO HQ in Kosovo. The transcribed material of interview responses was categorized according to the model of organizational effectiveness. Each category was then analyzed, extracting the different perspectives and opinions relating to each theme.

The three papers in the thesis included basic *statistical analyses* to obtain an overview of the collected data. In paper I, analyzing how the papers were distributed in terms of publishing year, geographic location, methods used and other factors resulted in an understanding of representability and diversity of the dataset. For this purpose, there was no incitement for conducting more advanced statistical analyses than providing descriptives in terms mean values and percentages. In Paper II, the questionnaires were analyzed in order to validate the suggested model of operational effectiveness. Multiple regression analyses were calculated for every operative goal to test the extent of a significant statistical correlation between the input factors and the operative goals. In Paper III, Multivariate analysis of variance (MANOVA) was performed on questionnaire data in order to detect differences between teams regarding their perceptions of teamwork, performance and team composition (O'Brien & Kaiser, 1985).

A multitude of data from different sources was logged in the CDX. For performance analysis, six different performance measures were defined. Two of these were defined and assessed by the exercise control team, while four measures were defined by the research team, based on analysis of collected data. To structure and explore the data, exploratory sequential data analysis (ESDA) was used, which is an empirical approach for quantification of qualitative data (Sanderson & Fisher, 1994). ESDA encompasses data analysis in eight steps (8C's): *chunks, comments, codes, connections, comparisons, constraints, conversions* and *computations*. During the exercise preparations considerable efforts were made to assure that all collected data was time-stamped. Data was imported into the F-REX software, enabling synchronized visualization of several data sources (D. Andersson, 2009). The first iteration used chat logs, e-mail communication and observer reports, resulting in an overview of the course of events that was useful for the performance measures based on the reports. In a second iteration, portions of network traffic and selected video screens were selected, and further analysis included analyses of the network traffic used for two of the performance measures.

4 Results

This section summarizes the main findings of each of the three papers.

4.1 Interorganizational crisis management capability

The explorative thematic analysis of the result of the literature search resulted in the identification of nine themes addressing C2 capability. These were *interaction*, *relationships*, *coordination/C2*, *System performance*, *Situation awareness*, *resilience*, *decision-making* and *information infrastructure* (Table 2). Most papers included in the systematic review adhered to more than one theme. The thematic analysis was based on content and meaning rather than the terms used by the authors of the papers. For instance, in the resilience theme, not all

Table 2. Nine themes of interorganizational crisis management capability (Granåsen, Olsén & Oskarsson, 2018)

Capability theme	Description	Included papers (%)s
Interaction	Communication, collaboration, information sharing, or task interdependency.	54
Relationships	Knowledge of each other's roles, responsibilities, equipment and tasks, trust building, and collaborative institutions	36
Coordination/C2	Leadership and coordination structures in the management of a crisis	32
System performance	Assessments of the actual outcome of the response.	27
Preparedness	Preparedness plans and how they were related to what actually happened during an event.	17
Situation awareness	Perception of critical factors in the environment, understanding of the meaning of these factors, and understanding, or predictability, of what will happen in the near future.	16
Resilience	The ability to persist, adapt or transform in the face of a shock or changing environment	14
Decision making	Analysis of the situation, planning, and simulating the plans to assess the possible outcome of them	14
Information infrastructure	Use of technical equipment, mainly communication technology.	10

authors used the term *resilience* for the construct that they had assessed, but used related terms such as *adaptability*, *redundancy*, *adaptive capacity* and *robustness*. *Interaction* represented the largest theme, as it was found in 54% of the 83 included publications.

Collaboration was a recurring term in the publications but rarely defined. In line with the conclusions of Robinson and Gaddis (2012), it was realized that several studies used a low threshold measure, where any information sharing activity counted as collaboration. This was the reason why the capability was termed interaction rather than collaboration. When conducting a thematic analysis, it is important to consider the fact that more hits do not necessarily mean that the theme itself is more crucial (Braun & Clarke, 2006). One explanation for the dominance of collaborative studies could be that interaction is easier to assess than other themes. Furthermore, interaction is studied in conjunction with other themes, such as situation awareness. Yet another explanation may be that interaction is a broader concept than, for instance, preparedness.

The analysis of the publications within the nine themes resulted in an overview of assessment methods within each theme. The identified themes were found suitable for identifying and comparing methods that assess similar constructs, and they have further been found useful to communicate the results. As the majority of papers in the literature search represented analyses of real cases, on-scene observations were quite rare. However, most publications described case studies where data had been collected from various documentation and reports of the crisis (media, social media, incident reports), or from questioning involved actors (interviews, workshops, questionnaires). Methods for assessing how crisis management affected the actual outcome of the crisis or the effectiveness of the crisis management system were rare. As for analysis methods, social network analysis was the most dominant assessment method, which is well in line with interaction being the most studied capability theme. Paper I was preceded by a conference paper describing the review process in detail as well as the identification of the nine themes (Granåsen, Olsén, & Oskarsson, 2018).

4.2 Organizational effectiveness at a multinational HQ

The interviews revealed that the respondents believed that a flat organizational structure promotes all three operative goals of the developed model for organizational effectiveness (Figure 2). The general opinion was that the HQ had become flatter in its organizational structure than before, although the hierarchical structure was by some still perceived as impairing the ability to coordinate efforts and communicate between branches. Some perceived bottlenecks in information sharing and decision-making, while others stated that centralization is essential to ensure that political goals and strategies are met. Generally, the respondents felt that the general HQ processes were more centralized and less flexible than the processes within their own branch. While most of the respondents believed that flexibility is crucial for an efficient HQ and affects information sharing positively, some emphasized that a clear structure is essential for focusing the work.

All respondents believed that their roles in the HQ were specialized rather than overlapping, which was generally viewed as positive, thereby creating a clear division of work and allowing the staff members to focus. Some expressed a need for more overlap within the HQ to improve the understanding of the work conducted within other branches, facilitate information sharing and decision-making. Shared awareness of tasks and responsibilities was viewed as essential for efficiency. Knowing how work is distributed speeds up decision processes and facilitates synchronization within the staff. However, there were differences in opinion whether or not there actually was a high degree of such an understanding in the KFOR HQ. Training was believed to be a key factor to reach a shared awareness of tasks and responsibilities.

The leadership was described in positive terms: comfortable, inclusive, open and friendly, respectful, supportive, professional and effective. The superiors were perceived as approachable and attentive to the subordinates' opinions and suggestions before making decisions. An effective leadership was believed to be of importance for all three operative goals. The KFOR HQ was considered as improvement oriented in terms of accepting new ideas and open towards implementing change, especially on lower levels. Decision-making and shared awareness were assessed to affect the ability to implement change. The respondents believed that pre-deployment training creates a shared awareness of the roles and responsibilities within an HQ. Those who had attended the two week KFOR Key Leader training course located at the KFOR HQ appreciated it. The need for pre-deployment training was considered to depend on personal experience (number of previous deployments), and whether the position was an HQ or field position (field positions were perceived to require more training).

The rotation process is part of every multinational HQ, and this was one reason why the respondents considered a national HQ to be more efficient than a multinational HQ. Frequent rotation was believed to be extra problematic for personnel in leading positions and for positions where personal contacts with local actors are important. The rotation system with its constant change of personnel, was however assessed to hamper the organization's ability to learn and improve due to lack of institutional memory. Some respondents believed that rotations could also be positive in that 'new eyes and new solutions' are brought into the HQ. In that way, rotations may have a positive effect on decision-making.

The respondents expressed a high level of trust between the staff members in the KFOR HQ. Some described that they already from the beginning trusted the other staff members, assuming at the personnel at the HQ have the right competences and qualifications to complete the job. Others described that that trust, particularly on an individual level, has to be earned or established, based on informal relationships and daily work (products). Good information sharing and shared awareness create trust.

Information sharing at the HQ was characterized by a need to understand where to look for information and how to retrieve the relevant information (technically and procedurally). Information sharing demanded an active search for information, a willingness to share and an understanding of what information others need.

Questionnaire respondents rated a high degree of flexibility, effective leadership, trust, openness to diversity and improvement orientation at the KFOR HQ. There were significant effects between input factors and operative goals, where leadership effectiveness and trust seemed to have the utmost effect on the operative goals. Paper II was to a large extent focused on the interview results, while an extended description of the questionnaire analysis can be found in the HFM-RTG-163 report (Yanakiev & Horton, 2012).

Both the questionnaire results and the interview results supported the model and the identified themes. There was no evidence to conclude that the model needs to be modified. However, while the model was based on one-directed relationships where input factors were assumed to affect operative goals, the interview results revealed reciprocal relationships, especially regarding the input factor culture. Trust is created by shared awareness, good decision-making and well-functioning information sharing. Decision-making was perceived to influence the possibility to implement changes whereas shared awareness was believed to lead to increased openness to diversity.

4.3 Team effectiveness in a cyber defence exercise

The surveys revealed that the team members felt confident in other team members' skills. All teams but one rated the team as being composed of the essential competencies required to solve the task. The between-teams analyses of skills and organization revealed that four teams responded relatively homogeneously, whereas one team (team D) distinguished themselves from the other teams in terms of a higher ratings of team composition, individual skills and the extent to which they decided upon a team organization.

Teamwork was experienced as smooth, and the teams were highly engaged in the. In the questionnaires, team D demonstrated particularly high ratings on performance, network overview and information exchange, and further managed to maintain their initial strategy throughout the exercise. Unfortunately, teamwork aspects were only observed to a low extent by the observers. It took a lot of effort for the observers to achieve adequate situation awareness to comprehend and report on the team task achievements. As the internal team communication occurred through chat functions, it was difficult for the observers to understand how the teamwork was coordinated.

Each team could keep track of the automatic scoring of all teams during the exercise, which was based on the extent to which they were able to keep their network services up and running. Thus, as expected, the teams' questionnaire assessment of their performance largely correlated with the exercise scoring. The ESDA analysis revealed that attacks against some services were detected to a higher extent than others. Data was consistent in that the teams reporting the most discovered and removed vulnerabilities, were also the teams against which the attacking team was least successful. According to these metrics, the performance of team D was outstanding, while the results of the other teams were more mixed.

Two other performance metrics were based on a NIDS (network intrusion detection system) analysis, although this could only be conducted on one segment of the teams' respective network. This revealed a different result from the other performance measures. Team D chose to put less effort in protecting this particular part of the network. An interview with team D further confirmed that they chose a strategy based on reconfiguration of the networks and proactive defence. This strategy made it difficult for the red team to breach and map team D networks, and harder to launch the pre-planned attacks. An important lesson from the analysis was the understanding of how different performance metrics favoured a certain strategy, and how the combination of these could be used to analyze team strategy.

The CDX is an example of how multiple data sources can be combined for a comprehensive understanding. It became clear at an early stage that different types of data were useful for analyzing different aspects of team effectiveness. Different performance measures provided an understanding not only of success as being relative, but also resulted in an increased understanding of the teams' strategies and priorities. The observer reports and the teams' action reports were the most valuable resources for evaluating team performance, while questionnaires were the most useful resources for understanding the teamwork/team cognition aspects. It follows that to assess team effectiveness observers must (1) maintain awareness of the team's activities in both dimensions, and (2) be proficient in both cyber security and team cognition. Furthermore, methods and tools to improve the observers' ability to conduct their work and obtain sufficient situation awareness are needed.

5 Discussion

This section discusses the results of thesis related to the research questions.

5.1 Q1. What constitutes C2 capability?

Capability is something that a system has in order to respond. C2 capability is here defined as the capability that the C2 system has in order to achieve its purpose. As seen in the background section, it may be material resources or abilities to conduct certain activities. For this thesis, the focus is to identify capability in terms of general prerequisites that needs to be in place for C2 effectiveness in the three domains studied. The capability concept was elaborated primarily in Paper I. However most of the nine themes of C2 capability were addressed in the other two papers as well. This section is structured into six *perspectives* as a modified version of the nine capability themes identified in Paper I. It should not be viewed as a competing model to all models and frameworks of C2 functions already in place. Instead, this section intends to summarize the factors found in the three papers in and discuss these in relation to other research. Most of the aspects found in other models will be included or mentioned.

A perspective that is discussed to a smaller extent is competence. All domains consist of people with specialized skills, however, the cyber domain is extreme in this sense (Buchler, 2018). The cyber-teams in the exercise could not have solved their tasks without sufficient technical skills, no matter how well-coordinated or agile they had been. The management of an operation further requires certain specific competencies (Van Wart & Kapucu, 2011; Pigeau & McCann, 2002). It is important to have this in mind when the other different perspectives on capability are discussed in this section. Efficient use of resources and coordinated action, may only partly compensate for lack of skills or resources.

5.1.1 Direction and coordination

The perspective Direction and coordination corresponds to the two themes Coordination/C2 and Decision-making identified in the systematic literature review. In Paper I, the theme Coordination/C2 included publications addressing hierarchical structures and coordinating activities, while the theme decision-making encompassed publications addressing planning processes. Thus, decision-making was mainly associated with staff work, related to the *control* aspect of C2, while coordination/C2 was more associated with *command* issues, although there is rarely a designated commander present in the same sense as in the military setting. During empirical studies in which the nine themes of interorganizational crisis management capability were used as a framework for categorization of observations, it was found difficult to distinguish between C2 and decision-making events, although the observers were the very same people who had conducted the literature review and thus formulated the themes (Oskarsson, Granåsen, & Olsén, 2019 (submitted)). In future work on interorganizational crisis management capability, the Coordination/C2 and decision-making themes will thus most likely merge.

Direction and coordination in the multinational headquarters that was described in Paper II took place in a hierarchical predefined organization with clear mandates. There were established procedures for how C2 was executed in the hierarchical organization. Although the multinational setting provided challenges due to personnel rotations and cultural differences regarding leadership and ways of working, there were established coordination structures as well as an established operations planning process centred around a defined intent (NATO Supreme Headquarters Allied Powers Europe, 2013). In Mintzberg's (1993) terminology the NATO headquarters would probably be categorized as partly machine bureaucracy, considering the standardization of work processes, and partly as professional bureaucracy, due to interview respondents' descriptions of the headquarters as being characterized by decentralized decision-making and openness to new ideas. It is important to consider that the military structure studied in the case study in Kosovo does not represent all military structures. There are trends towards greater agility and more flexible structures, questioning traditional norms (Granåsen, Barius, et al., 2018; NATO Science and Technology Organization, 2014). Civilian crisis management managed to pool resources on demand, whereas the cyber teams managed to coordinate their teams without any prescribed ways of working.

Publications identified in Paper I mainly focused on emerging structures, where a structured coordination approach or common strategies for coordination may not exist. Coordinating activities were based on local initiatives, and therefore the organizational structure may in many cases be categorized as adhocracies, according to Mintzberg's (1993) organizational archetypes. There are discrepancies between formal power and who turns out to be the most influential actor. A crisis creates an inflow of crisis management actors that do not need to coordinate their activities during normal circumstances. The specific crisis determines the need for coordination, why a coordination policy needs to enable organizational flexibility (Celik & Corbacioglu, 2016).

Adhocracy further describes the organizational structures of the cyber defence teams studied in Paper III, although the investigation of the teams did not render enough evidence to conclude that all teams worked in this way (Mintzberg, 1993). Coordination towards a common effort was created by the scoring. As the score was displayed in real-time, the teams received immediate feedback of whether their efforts were successful. The scoring guided the decision-making in the teams, as there was never a question of whether there would be more appropriate solutions than to keep up the availability of critical systems.

5.1.2 Collaboration

In the literature review, Paper I, a substantial amount of the publications focused on the interaction between crisis management actors. Collaboration was rarely defined and it was found that the threshold was often low, meaning that any information sharing activity would count as collaboration. Lack of definitions and undefined threshold values makes it difficult to compare studies (Robinson & Gaddis, 2012). Several of the reviewed publications in the systematic literature described social network analyses in which collaboration was assessed in terms of quantity of communicative events between different actors. However, they were not based on any analysis of what information these actors exchanged. At the other end of the collaboration scale, there were those who used collaboration and coordination as synonyms, hence, defined collaboration in terms of mutual adjustment of activities to accomplish a shared goal, joint decision-making and pool resources (Pramanik, 2015). However, it appears to be more relevant to separate the activity (collaboration) from the effect (coordination). Coordination may be the result of collaboration, whereas coordination may be achieved through other means than collaboration. In addition, collaboration may have other purposes than to achieve coordination, such as networking.

Paper III mainly addressed within-team collaboration. Participants had the possibility and were encouraged to share information with other teams. However, there was a paradox in that the exercise was designed as a competition, where sharing information could give other teams an advantage. The winning team reported that they did not have a major need to collaborate within the team during the exercise due to their preparations regarding strategy and division of labour within the team.

In Paper II, collaboration was mainly discussed in terms of information sharing between the different subsections of the headquarters. In the interview study, it was emphasized that information sharing does not happen by itself. The possessor of information needs to recognize that the information is relevant to others, be willing to share it and make it available in a way so that other people may find it. Similarly, people need to recognize what information other people may have, that may be relevant and useful for what they are doing. The same reasoning is partly applicable to coordination - without either part identifying the need for coordination, it will not occur. Curtis (2015) described that “coordination takes place when organizations work together toward a common purpose and each entity involved is aware of its own role and the role of others.”

5.1.3 Relationships

In the literature review, Paper I, the theme *relationships* was described as issues relating to trust building, collaborative institutions and knowledge of each other's roles, responsibilities, equipment and tasks. Knowledge of each other's roles was addressed in all three papers, albeit from somewhat different perspectives. These aspects of relationships are critical for collaborative activity to occur.

In the organizational effectiveness model, Paper II, shared awareness of tasks and responsibilities was an explicit operative goal. Without such an understanding, it would be difficult to know who might be interested in taking part of one's information or with whom to coordinate one's activities .

All three papers addressed *trust* in terms of professional trust, where trust was based on expectations of professional expertise, and personal trust, where trust was based more on the extent of familiarity between the people collaborating. The two-way relationship between these two types of trust was clearly demonstrated in the results and the Kosovo interview study. The publications identified in the systematic literature review also provided an understanding of the interactions between professional and personal trust (Bergström, Uhr, & Frykmer, 2016). A few of the respondents in the KFOR HQ expressed a sceptical view, claiming that trust is not there from the beginning but has to be earned. However, most of the Kosovo respondents described without hesitation that their stance was that the headquarters was manned with people that were qualified to accomplish the required tasks. This professional trust indicates a trust for the military systems of the countries participating in the mission, in terms of educating and training the personnel sent to serve in multinational headquarters. A soldier is a soldier, regardless of nationality.

It further seems that a hacker is a hacker. In the cyber exercise, the teams were temporarily formed by people who were fairly unfamiliar with each other, personally and professionally. Still, in the survey that was sent out before the exercise, team members reported that they had high confidence in other team members' skills. The most professionally experienced team, which also received the highest score, described how a high level of trust among team members reduced the need for explicit coordination. This trust was based on reputation, where the team members were aware of other team members' skills, although they had not met or worked together before.

5.1.4 Resilience

In future operational environment as well as societal developments, there are several drivers towards increased resilience, or agility, depending on one's preferred term. Technology is increasingly becoming a part of decision-making processes, rather than just being used for transmitting information, and the possibilities within the field of AI seem endless. Along with technological breakthroughs enhancing information processing and analysis capabilities, technology dependence accelerates at the same pace, making the society more vulnerable. There needs to be routines for how to cope with a situation when infrastructure is disrupted. This promotes a holistic view of the sociotechnical system as a whole needing the potential to obtain a resilient performance (Hollnagel, 2011b). Resilience may be about maintaining the ability to communicate, coordinate and share information, or it may be about finding solutions for how to function without it. In paper III, the exercise scoring was based on the ability to maintain critical functionality. Thus, this was not a dilemma for the exercise participants. In a real-life situation, actors need to prioritize and make trade-offs, deciding when to maintain a function or when the cost outweighs the benefits (Béné, 2013). In papers I and II, the ability to share information between actors within or between organizations was assessed as a critical component. Disruptions in technical infrastructure were addressed in the infrastructure theme in the systematic literature view of Paper I.

Although there has been considerable research on resilience in recent years, this was not greatly apparent in the systematic literature review. Only six of the papers assigned to the resilience theme used the term resilience, whereas others used terms such as adaptive capacity and robustness. Even fewer of the publications were actually based on an empirical study where an adaptation of procedures, strategy or organization was detected. Most studies in the cluster used questionnaires assessing the potential performance, as suggested by prominent figures of the resilience research area (Hollnagel, 2011b).

At the time of the study at the KFOR HQ, the agility concept had not reached a broader audience, although aspects relating both to agility and resilience were addressed. One related aspect addressed in Paper II is improvement orientation. In a short-term perspective, respondents were positive to how decentralized decision-making and leadership enabled the ability to implement changes in the headquarters. However, changes need to be implemented with care, to maintain a clear structure.

Shared awareness of tasks and responsibilities was identified as a factor contributing to the ability to implement change. However, the frequent rotation of personnel had a negative impact on shared awareness and may thus be described as a maladaptive pattern, according to the terminology of Branlat and Woods (2010). In the long-term perspective, based on the description of how the decision processes of the headquarters gradually had become more decentralized, the headquarters seemed to have changed its C2 approach (NATO Science and Technology Organization, 2014). There was, however, not a deeper analysis of the magnitude of this change. According to agility research, it appears that the C2 of the headquarters had become more agile.

Paper III investigated the change of strategy among the teams. It turned out that the most successful team explicitly decided upon a strategy, which they hardly changed during the exercise. The strategy was more proactive than the other teams' strategies, which turned out to be successful. This example emphasizes the importance of preparation to obtain resilience. Furthermore, it is a good example of resilience, or agility, not only being about transformation, but also about identifying a strategy that will work when facing the unexpected. During the exercise, within-team communication was sparse. The coordination approach was based on self-synchronization, where decision-making was totally distributed between team members. Coordination was initiated only on individual initiatives, thus employing a highly agile approach (NATO Science and Technology Organization, 2014).

This gives perspective to the statement that a cyber-security defence analyst team is a group of individuals working independently with little to no communication or collaboration with team members (Champion et al., 2012). The winning CDX team had developed a clear strategy, was composed of sufficient competencies, had decided upon a team organization, and was characterized by highly skilled individuals with a high level of trust between team members. Consequently, there was not a big need for collaboration or coordination between team members during the exercise. The view that more collaboration is the solution that will automatically increase performance and effectiveness was found in the dataset of the systematic literature review as well. However, this perspective needs to be nuanced.

The resilience and agility concepts share many similarities, and the definitions are strikingly similar. However, there are differences in focus due to them being applied in different domains. Both agility and resilience theory encompass the aspect of being able to prepare for the unexpected. Preparatory activities are, however, more accentuated in the resilience concept, as was found in the literature review where a significant portion of the publications connected to the resilience theme included the aspect of preparedness. Resilience research is mainly conducted in a domain facing ad hoc-structures, informal networks and lack of common procedures. It is then natural that preparation is an essential aspect of resilience, where actors attempt to find solutions and common agreements enabling collaboration and coordination when needed. As flat structures are the norm, research may promote more centralized approaches for certain matters (Andersson & Ostrom, 2008). In the empirical C2 agility studies reviewed, preparedness is not widely studied (NATO Science and Technology Organization, 2014). Within the military domain, there is a long tradition of preparation in terms of military planning, which is conducted according to established procedures that are communicated throughout the organization (NATO Supreme Headquarters Allied Powers Europe, 2013). Agility research is rather driven by the need to become more flexible and innovative, promoting more decentralized approaches with fewer restrictions on interaction patterns.

5.1.5 Situation awareness

Cyber SA is an increasing field of research, which fits well with the distributed and situated perspectives on SA. The cyber defence teams were highly integrated with their technical infrastructure and clearly offloaded information onto their environment. It was further quite obvious that the team members did not have a shared, but rather a distributed situation awareness, as they focused their work on different parts of the network, depending on their different skills. It is clear that SA in this type of environment could not be investigated without addressing the full sociotechnical system of operators and their screens (Chiappe et al., 2015; Sorensen & Stanton, 2011). During the CDX, SA was primarily addressed through the questionnaire question regarding the extent to which the operators had an overview of their network. As for many other results, the winning team reported a significantly higher network overview than the other teams. However, at the time when they responded to the question, they knew that they were the winning team. A lesson learnt from the CDX was the challenge faced by the observers to obtain sufficient situation awareness in order to produce valid observations in this type of environment. Providing the observers with continuous information about the red team's actions and all communication channels used by the teams might have helped. However, as these exercises are characterized by a high tempo, there is a risk that the observers will still not have the time to continuously update themselves on what is happening in different information channels while simultaneously observe what is happening in the room.

The SA theme of the systematic literature review included publications specifically addressing SA as a concept as well as related topics such as sense-making, risk awareness,

situation understanding and disaster assessment (Granåsen, Olsén, et al., 2018). The importance of understanding the situation has been accentuated in various frameworks describing essential components of crisis management (Comfort, 2007; House, Power, & Alison, 2014). Still, only a small portion of the publications within this theme provided an empirical assessment of SA or similar, of which two used query-based methods to assess shared SA (Prytz et al., 2015; Van de Walle, Brugghe, & Comes, 2016). One of the studies detected differences between the study participants' SA (Prytz et al., 2015). This indicates that the distributed SA perspective may be relevant to consider for the crisis management domain.

In the model for organizational effectiveness validated for paper II, situation awareness was not specifically addressed. Achieving the operative goal information sharing will most likely contribute to an increased situation awareness. Shared awareness of tasks and responsibilities was specifically addressed. However, this operative goal is tightly connected to trust and familiarity and is thus described in the Relationships perspective.

5.1.6 Preparedness

In the systematic literature review of Paper I it was found that preparedness was mainly assessed in relation to other capability themes. What is prepared includes, for instance, plans for collaboration and coordination. As discussed in the section on resilience, preparedness is further an essential aspect of resilience. The focus on preparedness is treated differently in the three domains studied, why treating it as a theme in itself is warranted.

Within the military domain, NATO has had a great influence on planning and coordination procedures. Thus, even countries outside NATO use NATO standards and procedures for planning as well as systems development. Furthermore, military training is to some extent standardized. This creates interoperability in terms of a common terminology, common ways of working, communication, and as was reflected in the Kosovo interview study. Further, it was clear that the respondents at the Kosovo headquarters did not experience the types of problems in terms of preparedness that were addressed in the publications of the systematic literature review. Military personnel are prepared to work with military personnel.

Obtaining interoperability in a multi-national crisis management setting is completely different. There is no way to standardize training nor equipment for all crisis management actors. Although preparatory measures may result in interoperability within a specific branch or between governmental actors, there will be humanitarian organizations, spontaneous volunteers, etc. that cannot be coordinated in a similar way. There will always be upcoming issues that cannot be prepared for. It was surprising that so few studies in the systematic literature review addressed the extent to which preparedness plans were successful, or adaptations conducted in order for a system to become better prepared for the next unexpected event.

In cyber defence, preparation is critical. An understanding of the system that is to be defended is vital in order to prepare for the attacks that may come, as well as take proactive action to eliminate or at least reduce the vulnerabilities of the system. In the CDX, the cyber-teams had access to the infrastructure during a limited period of time a few days before the exercise. The observers were, however, only there during the actual exercise, as it would have been too costly for them to be present during the preparations. Studying the preparation phase would have been a key, not only for understanding the preparations that the teams made, but also to investigate how the teams formed their strategies for task accomplishment as well as within-team coordination.

5.2 Q2. What constitutes C2 effectiveness?

Capability is something that a system has, while effectiveness is something that a system achieves. A person has the ability to obtain situation awareness (capability focus), which may result in them achieving situation awareness (effectiveness focus).

C2 effectiveness may be defined as the extent to which a C2 system is successful in achieving its intended result. The question is then - what is the intended result of a C2 system? The model of organizational effectiveness in Paper II described the intended result as the ability to support the troops on the ground. This is well in line with the view of C2 as aiming to provide a focus for individuals and organizations, so that they may integrate and maximize their resources and activities to achieve the desired outcomes (Ministry of Defence (UK), 2017). This broad view is applicable not only to military forces, but also to the cyber domain and the crisis management domain. Furthermore, it is applicable irrespective of whether coordination is achieved through command or collaboration. C2 effectiveness is addressed in relation to what a C2 system should accomplish, and whether this was successful

The definitions of efficacy are diverse, as was recognized in the background section (Dickinson et al., 2010; Gibson, 1999; Skyttner, 2006). Skyttner (2006) defines efficacy as the extent to which the system contributes to the purposes of the higher-level system of which it may be a subsystem. In the KFOR headquarters case, efficacy would correspond to the extent to which the headquarters contributed to the success of the operation as a whole. In the case of the CDX, effectiveness corresponds to the accomplishment of the task, whereas efficacy corresponds to the exercise goal, namely that the blue teams would receive hands-on training in critical infrastructure defence (Geers, 2010). Furthermore, the teams may have had additional other goals than the accomplishment of the task, such as networking (Essens et al., 2005). These were not investigated during the CDX. In a real-life perspective, higher-level goals may be provided in terms of a general national strategy. The Swedish national strategy for cyber security states that central government authorities, municipalities, county councils, companies and other organizations are to have knowledge of threats and risks, assume responsibility for their cyber security and conduct systematic cyber security efforts (Ministry of Justice, 2016). The gap between a team or organizational goal and a national strategy is significant. Besides serving as an illustration of the difference between effectiveness and efficacy, it illustrates a research gap. C2 within the cyber domain is not yet widely explored. Connecting the broad strategic level with the highly specialized technical level is a challenge.

There are similar challenges in the crisis management domain. In the situations that were focused upon for the systematic literature review, assessing the effectiveness of temporarily formed clusters of organizations may face the challenge that predefined shared objectives may not exist, unless as strategic general guidelines (e.g. protection of the lives and health of the population). Within the theme *system performance* in the systematic literature review, different frameworks addressing inter-organizational crisis management in terms of operational efficiency, effectiveness, team/organizational/general performance, disaster management capacity and emergency response capability were collected. Crisis management actors may have different goals for their participation in a crisis management effort. Even the goals of a coordination or collaboration effort may be hard to determine. In the thematic analysis, 27% of the papers addressed some aspect of performance or effectiveness of the system as a whole. Of these, most described a framework or an idea for reviewing the crisis management from a holistic perspective. However, few studies contained an actual assessment, nor defined a goal that could be used for effectiveness assessment. This indicates the complexity in trying to identify relevant goals that can be used for determining measures of effectiveness. Koppenjan (2008) emphasized that actors need to agree both on the goals and on the process on how to assess effectiveness. Hence, effectiveness depends on the extent

to which actors succeed in entwining their objectives, as well as balancing the efforts with the results.

The background section elaborated on the mixed terminology used regarding performance compared to effectiveness. While Comfort (2007) described a framework of organizational *performance*, similar aspects are found in frameworks addressing *effectiveness*. Effectiveness and performance differ in the sense that effectiveness is assessed against a goal, which is not case for performance. When the winning team performed low according to the NIDS performance measure, this was rather evidence of their effective strategy as well as an efficient use of team resources, as they proactively put their effort into protecting the parts of their network that would maximize their scores in the competition.

5.3 Q3. How can C2 effectiveness be assessed?

Assessment of C2 effectiveness may be based on a *predefined model* containing components constituting effectiveness (Matthews, 2011), or based on *one specific issue*, such as collaboration or situation awareness. There could also be a more *explorative approach*. A phenomenon may be assessed through the approach of addressing the *manifest* phenomenon or the *potential* (Hollnagel, 2011b; NATO Science and Technology Organization, 2014). Paper I described the assessment of manifest effectiveness, based on performance measures, observations and self-ratings in relation to task accomplishment in the particular exercise. The evaluation of the organizational model for organizational effectiveness in the KFOR HQ is an example of assessment of potential effectiveness, as there was no particular situation that was assessed using the model. The interview participants described in general terms how they perceived the work at the headquarters. The publications identified in the systematic literature review included assessment from both these perspectives.

The CDX is favourable for analysis as the technical system is closed. What happens in the system is fully dependent on the activities of the defending and the attacking teams. All actions taken in the technical infrastructure can potentially be logged, as long as the participants agree to it. The observers were tasked to primarily focus on activities that were not logged or would be hard to retrieve in logs without knowing what to look for. During the exercise, it was found that team members to a great extent used chat functions for within-team communication, which means that parts of the coordination were logged as well. However, this made it difficult for the observers to understand the processes within the teams in real time, as it occurred in parallel media - partly spoken and partly through the technical systems. During the CDX, a comprehensive data collection was conducted. The main problem is then how to analyse this massive dataset. An important lesson from the exercise was that the data collection and analysis of CDX demand an extensive effort during the planning phase to ensure that data is collected. There also needs to be a plan for data analysis. It was found useful to combine different data collection methods. Observations guided the identification of key events, which were interesting for analyses of system logs. Questionnaires were useful for understanding how the teams perceived the teamwork, as the observers found it difficult to observe this although the team members were located in one room. One further lesson learnt during the CDX was that an interdisciplinary approach placed extensive demands on the observers. Not only did they need the technical understanding to obtain the situation awareness required in order to understand *what* the teams were working on, but they also needed to understand *how* the teams were working. When having observed the work in a cyber defence team, it is easy to draw conclusions in line with Champion et al. (2012), namely that cyber security teams are characterized by little to no communication or collaborative effort with team members. However, an alternative explanation is that there is collaboration and communication. However, it is embedded in the accomplishment of the task and conducted in ways that are difficult to detect by the observer.

Most of the publications in the systematic literature review for Paper I described case studies, where analyses were based on documentation and reports from an incident, communication logs, and interviews conducted post-incident. A substantial number of papers assessed collaboration and coordination through social network analysis. However, these analyses were mainly based on the *quantity* of communication rather than the *content* of the information or coordination that was transmitted through different communication channels to a small extent. It can be concluded that these studies to some extent were conducted based on an underlying assumption that the amount of communication between actors determines the effectiveness. Examples of the contrary was found in case studies based on analysis of the content in communication (Dowell, 2016). In this case study, situations where information would have been communicated but was not were identified, as well as situations where communication occurred but was misinterpreted by the receiver, resulting in faulty decisions. It can be concluded that although collaboration is critical in interorganizational crisis management, it needs to be assessed in relation to what is accomplished, either in terms of the purpose of the collaborative activity (effectiveness), or in terms of the crisis management effort (efficacy). One conclusion of the systematic literature review was that analysis of outcome is rarely explored in research about crises and disasters.

Interviews and questionnaires were found to serve their purpose for validating the defined model of organizational effectiveness at the KFOR HQ. Besides validating the model, the findings provided an understanding of how the personnel working at the headquarters perceived the effectiveness of the KFOR HQ. Assessing effectiveness through a model creates transparency in visualizing how different components of the model contribute to effectiveness. However, it placed high demands on the creation of the model. There is a risk that components that are not encompassed in the model remain undetected, resulting in results failing to reflect all important issues that determine effectiveness in the area of interest. Furthermore, dependencies and conceptual overlaps between the components constituting the model need to be considered during evaluations. In the validation of the model of organizational effectiveness developed within the NATO research group, several dependencies between the different components of the model were detected.

Effectiveness assessment based on models is to a large extent based on self-reporting through a defined set of questions addressing the different components form the model of effectiveness (Essens et al., 2005, 2010; Hollnagel, 2011b; Van Der Beek & Schraagen, 2015). Evaluation of perceived effectiveness may be relevant for some topics. For understanding the level of trust between actors, the most reliable measure is probably to ask them. However, for other topics, such as situation awareness, actors may perceive that they have full understanding of the situation that they are experiencing, while another type of assessment might conclude that their understanding is actually incomplete. In the author's experience, the most useful approach is to employ a pragmatic pluralist perspective, trying to identify what types of data are the most suitable for understanding a particular phenomenon, and further to try to study a phenomenon using different measures. The different performance measures employed during the CDX provide a good example of this.

6 Future work

The work with this thesis has revealed that there are areas that need further exploration and research. Human factors research, including C2, within the cyber domain is such an area. Trying to enforce a military C2 perspective on the cyber domain is probably not the right way to go, due to the specific characteristics of the domain as well as the people populating it. A first step is to explore when and how coordination is needed, imposing only the degree of coordination needed without transforming an environment characterized by innovation, creativity and initiative into a bureaucratic and slow structure. Interdisciplinary research is required, where there is an understanding of the specific challenges and requirements faced by different domains.

The nine themes of interorganizational crisis management capability identified through a systematic literature review provided a good overview of what is considered as critical components of C2 capability. However, one conclusion in Paper I was that the aspects that are most commonly explored in research might not necessarily be the aspects that are the most critical in a real situation. Instead, it could be that they are those most accessible to assess. Hence, a topic for future research is thus a continued investigation, theoretically as well as empirically, of what constitutes C2 capability for interorganizational crisis management, cyber defence and military operations.

Studying different domains has the great advantage of the researcher coming into contact with different frames of reference. Each domain has its most influential role models and pioneers, who adhere to different research traditions. Within domains, new concepts arise, either as something completely new or as an influence from a different domain. This results in a parallel existence of concepts, which are used in different domains. However, they might appear to be fairly similar when they are compared. One example is resilience within the crisis management domain that corresponds to agility within the military (C2) domain. The disadvantage of being involved in different research domains is the extensive time and resources required to understand the perspectives in depth. Future research may thus include explorations of the relationships between concepts and paradigms that influence research in the various domains. This will provide an understanding of what concepts and frames of references that are applicable to another domain, and when.

A similar topic is terms that are used broadly across domains, albeit with different meanings. In order to thoroughly compare different frameworks it is not sufficient to acknowledge that they include similar terms, but the investigation needs to include what the founders of these frameworks meant by these terms. Does *coordination* in one model have the similar meaning as coordination in another model? Hence, a topic for future work would be to make a detailed comparison of existing frameworks and models on C2 capability and C2 effectiveness across research domains, including analyses of how terms are used.

7 Conclusion

This thesis aimed to explore C2 capability and effectiveness in challenging situations that affect the society. C2 capability is the capability that a *C2 system has* in order to achieve its intended purpose, while C2 effectiveness is the extent to which a C2 system is *successful* in achieving its intended purpose. The intended result may for instance be to provide focus for individuals and organizations so that they may integrate and maximize their resources and activities. Assessment of C2 effectiveness may include assessment of the *potential* of a system to obtain C2 effectiveness, as well as assessment of whether C2 effectiveness was obtained in a specific case (*manifested*). The studies contributing to this thesis provided examples of assessment addressing the potential as well as the manifest effectiveness. The CDX proved useful for addressing manifest effectiveness due to the opportunities of logging and observing activity. The case study of organizational effectiveness conducted at the Kosovo Force Headquarters was an example of how potential effectiveness may be assessed with the aid of a predefined model including different components of organizational effectiveness. A systematic literature review of interorganizational effectiveness identified examples of both manifest and potential effectiveness assessment.

Comparing and contrasting findings from research within the three domains interorganizational crisis management, military operations, and cyber defence operations was useful for understanding the similarities as well as the differences between the domains. Findings or theoretical perspectives from one domain may potentially be applied to increase the effect in another domain. Acknowledging that each domain faces unique challenges that are not transferrable between domains is equally important, in order to avoid trying to impose a way of thinking or acting that will be counter-productive. It is important to state that within each *domain* there are large variations depending on several aspects, such as national regulations, cultural traditions, branches, tasks and situations. The *cyber defence domain* encompasses military operations as well as the civilian crisis management.

In interorganizational crisis management research is to a large extent centred around collaboration, mainly conducted in emergent networks of actors that do not have the mandate to command each other. Coordination is achieved through collaboration. Hence, collaboration is a key to achieve effectiveness. However, there is a lack of studies addressing the outcome of the collaborative activities, in terms of whether the collaboration actually increased the effectiveness of the crisis management. Studying the effects of collaborative activities, coordination efforts and other C2-related issues is difficult due to the complexity in the domain. However, this is still important. Drawing the conclusion that increased collaboration automatically implies increased effectiveness is not enough.

In CDXs on the other hand, task achievement is a major focus, while the question of *why* a certain result has been obtained has received much less attention. In a CDX, the result of actions can be followed through system logs, although understanding how coordination is achieved and information is shared and situation awareness is obtained requires an approach combining data from different sources, such as observations, communication analysis, questionnaires and analysis of reports, where each source may add new information. For observers used to being able to explicitly observe coordination through regular coordination

meetings, the cyber defence team provides a completely different environment. In terms of human factors- related research in the cyber domain, research concerning cyber situation awareness has gained a significant interest, while issues related to other perspectives on C2 capability are mainly in their infancy.

C2 research is well-explored in the military domain. The study at the Kosovo force headquarters identified a trend towards more decentralized decision-making. The results from the headquarters emphasized the importance of shared awareness of tasks and responsibilities, a perspective not always considered in military C2 research. However, it is accentuated in interorganizational crisis management. The headquarters was based on a hierarchical structure with defined mandates and common established procedures for planning and execution of operations. However, the military domain has recognized the need for increased pace and flexibility in operations, as well as a harmonization between the military component and other parts of the society. Crisis management research shows that direction and coordination can be achieved with minimal resources in a degraded environment without a predefined structure or established common procedures, why military research on how direction and coordination need to adjust in order to meet future demands may find inspiration there. Similarly, e crisis management research draws inspiration from the military domain regarding how to structure and define procedures and mechanisms to enhance C2 effectiveness.

List of author's publications

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