Research on agility and agile command and control organizations

A review of contemporary literature

BJÖRN J.E. JOHANSSON, PETER BERGGREN, AND JIRI TRNKA

FOI-R--4068--SE
ISSN 1650-1942 Mars 2015

Björn J.E. Johansson, Peter Berggren, and Jiri Trnka

Research on agility and agile command and control organizations

A review of contemporary literature

Titel	Forskning kring agilitet och agila ledningsorganisationer: Omvärldsanalys
Title	Research on agility and agile command and control organizations: A review of contemporary literature
Rapportnr/Report no	FOI-R--4068-SE
Månad/Month	Mars
Utgivningsår/Year	2015
Antal sidor/Pages	83
ISSN	1650-1942
Kund/Customer	Myndighet för samhällsskydd och beredskap
Forskningsområde	5. Krisberedskap och samhällssäkerhet
FoT-område	Ledning och MSI
Projektnr/Project no	B34107
Godkänd av/Approved by	Lars Höstbeck
Ansvarig avdelning	Informations- och aerosystem

Summary

This report presents the outcome of a literature review regarding current research related to agility and/or command and control agility. The sources identified differ in terms of both domain and theoretical heritage, but they share some basic assumptions. Either, they discuss agility, command and control agility, organizational agility, or parts of these concepts. It can be said that agility, as a common term, refers to the ability to cope with dynamics and complexity in a flexible manner. Command and control agility, or organizational agility, refers to the ability to cope with dynamics and complexity by adjusting/adapting the own organization to better fit the demands of the current situation. The ability to respond to external change, signified by complex interactions, seems to be a driving force in most research efforts found in the literature review. The identified research trends are primary:

- Theoretical Frameworks (for agility, C2 agility or both).
- Developing conceptual model(s) of the endeavour space (a way of describing the problem space).
- Assessment tools and measures (of both agility and C2 agility).
- Empirical studies (especially experiments to prove basic hypotheses and assumptions in the research domain).

Keywords: Agility, Command and Control agility, Improvisation, Complex Adaptive Systems, Work Design, Multiteam systems.

Sammanfattning

Denna rapport presenterar utfallet av en litteraturstudie rörande forskning kring agilitet och/eller ledningsagilitet. De källor som identifierats skiljer sig åt, både i termer av domänursprung och teoretisk bakgrund, men delar några grundläggande antaganden. Antingen diskuterar de agilitet, ledningsagilitet, organisatorisk agilitet eller delar av dessa koncept. Det kan sägas att agilitet som en gemensam term hänvisar till förmågan att hantera dynamik och komplexitet på ett flexibelt sätt. Ledningsagilitet, eller organisatorisk agilitet, hänvisar till förmågan att hantera dynamik och komplexitet genom att justera eller anpassa den egna organisationen för att bättre hantera de krav som ställs i den nuvarande situationen. Förmågan att hantera yttre förändringar som kännetecknas av komplexa interaktioner tycks vara en drivkraft i större delen av de forskningsansatser som identifierats i litteraturstudien. De viktigaste forskningstrenderna är:

- Teoretiska ramverk (för agilitet, ledningsagilitet eller båda).
- Utveckla modeller för uppdrags/problemrymden.
- Värderingsverktyg och mått (för både agilitet och ledningsagilitet).
- Empiriska studier (speciellt experiment för att påvisa grundläggande hypoteser och antaganden inom forskningsfältet).

Nyckelord: Agilitet, Ledningsagilitet, Improvisation, Komplexa Adaptiva System, Utformning av Arbete, Multiteamsystem.

Contents

1 Introduction

This report presents a review of contemporary research in the area of agility with focus towards agile command and control organizations. The review is based on work performed in the project "Situation-adapted command and control based on design logic with a holistic stance" (in Swedish "Situationsanpassad ledning och samverkan utifrån ett designlogiskt helhetsperspektiv"), specifically in the work package "Agile command and control organizations and information sharing".

1.1 Background

The project "Situation-adapted command and control based on design logic with a holistic stance" is a research program funded by the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap, MSB).

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

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

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

The project consists of three work packages:

- Analysis and evaluation of command and control capabilities.
- 21st century command and control challenges.
- Agile command and control organizations and information sharing.

The work package "Agile command and control organizations and information management" is based on the assumption that emergency

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

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

1.2 Objectives

The objective of the work presented in this report has been to identify important theoretical underpinnings of agility and organizational agility as well as possible methodological approaches to assess and model agility.

1.3 Method

The literature review presented in this report was primarily based on keyword search in library databases and on the Internet. Directed search efforts towards specific journals/conference proceedings were also performed. The following databases were used: *PsycARTICLES, Military and Government collection* and *SCOPUS*. Keywords used for

searches were: Agility, Agile, C2, Command and control, Adaptive, Flexible, Improvisation, Coordination, Collaboration, Emergency, Crisis, and Agile management. The keyword "disaster" was excluded, as it was bound to return a too large amount of search results that were not related to the issue of agility.

Firstly, searching was narrowed to papers published between the years 2000-2014. Secondly, publications with focus on crisis response, emergency management, and military operations were also included. Thirdly, a preliminary review, based on titles and abstracts, was performed in order to identify and exclude texts that were *not* of interest. Finally, a more thorough reading was performed where important aspects of each paper were described and stored in a database. We specifically looked for definitions of agility and C2 agility, models of agility/C2 agility, empirical evidence that could validate such constructs, methods for assessing agility/C2 agility, and trends within the research field. The final step was followed by a complementary analysis of re-occurring references (so-called "snowballing") in the texts that were not identified in the original search effort. Due to this fact, books and technical reports (in some cases printed before year 2000) were also included as they have been identified as major influences to the other texts found in the search.

The first and second step resulted in about 150 relevant papers. Of these 35 papers originated from the *International C2 journal* and the conference proceedings of the *ICCRTS* (International Command and Control Research and Technology Symposium). The third step reduced the number of papers to 75. After the final step 47 of the original 75 publications were included in the analysis.

Note: the references in the text are cited in APA-style and with one footnote on each page where a reference is cited.

1.4 Target audience

The target audience for this report is primarily researchers and subject matter experts on crisis response, emergency management, and command and control at universities, research institutes and government agencies. The purpose of the report is not to provide a detailed account of the referred literature, but to point out relevant

research within the field and identify trends and areas in need of further research. The reader is thus expected to refer to the sources in order to get a comprehensive understanding of the identified texts.

1.5 Outline of the report

The report consists of six chapters where:

Chapter 1 provides a short background to this report including its purpose, target audience, delimitations, and method for literature review and selection of literature.

Chapter 2 presents the theoretical concepts of agility and command and control agility that originates from the NATO Science and Technology Organization, the Command and Control Research Program, and the International Command and Control Research and Technology Symposium.

Chapter 3 describes other relevant theoretical concepts that relate to the identified domain and problem area from scientific literature that have been identified during the literature review, such as Complex Adaptive Systems, Multi-team systems, and improvisation.

Chapter 4 discusses methodological approaches used in agility research.

Chapter 5 summarizes and discusses main findings and trends within the field.

Chapter 6 provides abstracts and references of cited scientific texts.

2 Theoretical concepts of agility from the military domain

This chapter presents the research body originating from the Command and Control Research Program (DoD CCRP)[1], the NATO Science and Technology Organization efforts (NATO STO)[2] within the Systems Analysis and Studies (NATO STO SAS)[3] panel and the contributions to the International Command and Control Research and Technology Symposium (ICCRTS)[4]. The literature review suggested that work originating from these organizations/meetings derive from the same sources, i.e. they have emerged as consequence of the same needs, departing from the complexity that can be found in contemporary military operations. They are strongly intertwined as many of the scientists that have published agility-related publications take part in several or even all of these efforts. What all three organizations/meetings share is that they have both contributed to the development of agility-theory, as well as being a driving force for research efforts within this field.

2.1 NATO STO SAS concepts

The most reoccurring definition of agility among the studied articles is the NATO STO SAS Panel concept of *agility* and *command and control agility* (C2 agility). A number of analysed articles[5,6,7,8,9,10,11,12,13,14,15,16,17,18,19] originate directly from the work of

[1] For more information on DoD CCRP see http://www.dodccrp.org/
[2] For more information on NATO STO see http://www.cso.nato.int/
[3] For more information on NATO STO SAS see http://www.cso.nato.int/panel.asp?panel=6
[4] For more information on the ICCRTS see http://www.dodccrp.org/html4/events_past.html
[5] Alberts, D. S. (2007). Agility, Focus, and Convergence: The Future of Command and Control. *The International C2 Journal, 1*(1). 1-30.
[6] Bélanger, M. (2013). *The difficulty to document agility evidences from a C2 perspective*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.
[7] Bernier, F., Alberts, D. S., & Manso, M. (2013). *C2 in Undeveloped, Degrader and Denied Operational Environments.* Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.
[8] Dodd, L., & Markham, G. (2013). *Orders of C2 Agility and Implications for Information and Decision-Making*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

the NATO STO SAS task groups SAS-050[20], SAS-065[21], and SAS-085[22] or refer to the NATO STO SAS research findings.

The NATO STO SAS efforts in this area were performed as international collaborations, which so far has been going on for more than ten years. Originally working on novel approaches to C2 (NATO

---

[9] Dodd, L., & Markham, G. (2012). *C2 agility, different models of change and reasoning with time.* Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

[10] Farrell, P. S. E. (2011). *Organizational Agility Model and Simulation*. Proceedings of the 16th ICCRTS, Quebec, Canada, June 21-23. Washington, DC: DoD CCRP.

[11] Farrell, P. S. E., Baisini, C., Belanger, M., Henshaw, M., Mitchell, W., & Norlander, A. (2013). *SAS-085 C2 Agility Model Validation Using Case Studies*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[12] Farrell, P. S. E., & Connell, D. (2010). *Organizational Agility*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.

[13] Huber, R. K., Moffat, J., & Alberts, D. S. (2012). *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*, Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

[14] Meijer, M. (2013). *Agility in Command and Control in a Multinational Exercise*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[15] Mitchell, W. (2013). *Using Target Network Modelling to Increase Battlespace Agility*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[16] Mitchell, W. (2010). Agile sense-making in the battlefield. *The International C2-Journal, 4(1)*,1-33.

[17] Moffat, J., Scales, T., Taylor, S., & Medhurst, J. (2011). Quantifying the need for force agility. *The International C2-Journal, 5*(1), 1-25.

[18] Moffat, J., Scales, T., Taylor, S., & Medhurst, J. (2010). *Quantifying the need for force agility*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.

[19] Turcotte, I., Tremblay, S., Farrell, P., & Jobidon, M-E. (2013). *Using a Functional Simulation of Crisis Management to Test the C2 Agility Model Parameters on Key Performance Variable.* Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[20] The NATO STO SAS 050 study group aimed to develop a conceptual model of command and control that could ultimately assist decision makers in understanding command and control concepts and the implications to different approaches to command and control. The group worked during the period 2003-2006.

[21] The NATO STO SAS 065 study group had an objective to create an NATO network enabled capability command and control maturity model and use it to explore command and control concepts and issues including exploration of new network enabled command concepts such as collaborative planning and self-synchronization in an NATO network enabled capability context. The group existed during the period 2006-2009.

[22] The NATO STO SAS-085 study group had the objective to understand and validate the implications of C2 Agility for NATO missions; to match situational characteristics with appropriate Agile C2 approaches; and to support the dissemination and exploitation of C2 Agility concepts. The group existed during the period of 2009-2013.

STO SAS-050 and SAS-065), the concepts of agility and C2 agility were found to be important concepts, eventually leading to a research project focusing specifically on these two concepts (NATO STO SAS-085). The NATO STO SAS collaboration has resulted in a number of articles, primarily presented in the International C2 Journal, conference papers presented at ICCRTS, as well as books and published reports.

2.1.1 Agility and command and control agility

The NATO STO SAS-085 study group defines *agility* as the:

> *"Capability to successfully effect, cope with, and/or exploit changes in circumstances"* (NATO STO, 2013, p. 21) [23].

The purpose of this capability is primarily to keep the own organization(s) ("the self" or "the entity" when referring to individual units or organizations, or "the collective" when referring to a multitude of cooperating entities) within acceptable performance bounds, even when facing unfamiliar situations[24]. Hence, agility refers to the capacity to cope with change independently of how this is achieved. Agility, according to the NATO STO SAS-085 work, consists of six capabilities or enablers: *Responsiveness*, *Flexibility*, *Versatility*, *Resilience*, *Adaptiveness* and *Innovativeness* (NATO STO, 2013; Alberts, 2014)[25].

Alberts (2007)[26] builds upon the NATO STO SAS work and explains the need for agility based on the limitations in the dominant form of command and control as a hierarchical approach focusing on control of internal processes. Agility is motivated by the need to think about new approaches by: (1) the nature of operations and the environment in which they are undertaken; (2) the capabilities of adversaries; and (3)

[23] NATO STO (2013). *C2 Agility – Task Group SAS-085 Final Report* (STO Technical Report STO-TR-SAS-085). Brussels, Belgium: NATO Science and Technology Organization.

[24] This is in line with the cybernetic concept of "requisite variety", as formulated by Ross Ashby (1956) in his book "An introduction to Cybernetics", London: Chapman & Hall, which states that a system that wishes to control another system must present at least as much variety as the target system. Ashby presents a mathematical approach to describing how this can be achieved. However, most real-world problems will not lend themselves to such exact quantification.

[25] Alberts, D. S. (2014). *Agility Quotient (AQ).* Proceedings of the 19th ICCRTS, Alexandria, VA, June 16-19. Washington, DC: DoD CCRP.

[26] Alberts, D. S. (2007). Agility, Focus, and Convergence: The Future of Command and Control. *The International C2 Journal*, *1*(1), 1-30.

opportunities provided by advances in technology, particularly information technologies).

Agility can in part be achieved by being command and control agile, meaning that the actual C2 (systems, organization) is rearranged in order to better fit the current or foreseeable future situations. The NATO STO SAS defines *command and control agility* (C2 agility) as the ability the organization(s) must have to monitor own behaviour in relation to the ongoing situation. Also, the organization(s) must have the ability and willingness to adjust its current way of working. Command and control agility refers to the ability to do so by adapting the way the organization functions or is structured, primarily by adjusting information dissemination or the allocation of decision rights (NATO STO, 2013; Huber, Moffat & Alberts, 2012)[27,28].

2.1.2 Command and control approach space

A fundamental theoretical construct in the NATO STO SAS work is the *command and control approach space* (see Figure 1), a three axis model presenting an organization's position in terms of "information dissemination" (who gets to know what?), "allocation of decision rights" (who has the mandate to take action) and the "interactions" (who is interacting with who?) (NATO STO SAS-065, 2010) [29].This construct is closely related to the concept of command and control agility. The position an organization takes along the dimensions is called *C2 approach*, using the terminology of the NATO STO SAS work.

[27] NATO STO (2013). *C2 Agility – Task Group SAS-085 Final Report* (STO Technical Report STO-TR-SAS-085). Brussels, Belgium: NATO Science and Technology Organization.
[28] Huber, R. K., Moffat, J., & Alberts, D. S. (2012). *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.
[29] NATO STO SAS-065 (2010). *NATO NEC C2 Maturity Model* (CCRP Publication Series). Washington, DC: DoD CCRP.

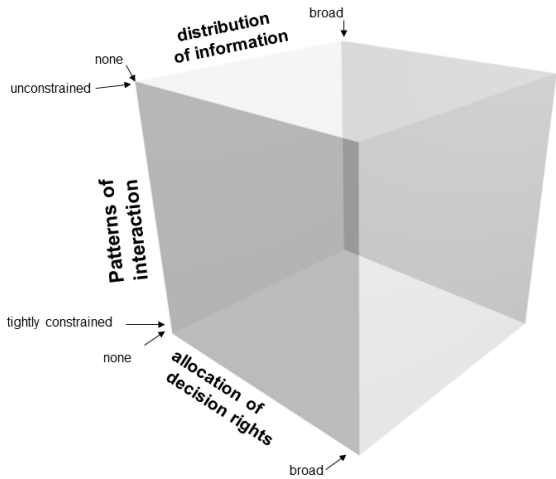

Figure 1. The C2 approach space (NATO STO SAS-065, 2010)[30].

A number of archetypical approaches can be found along an axis going from the outer lower left corner of the cube towards the upper right corner on the opposite side of the space. Two C2 approaches from the NATO Network Enabled Capability (NEC) C2 study that are often used as extreme cases to illustrate this are traditional, hierarchical organizations with stove-piped communication and centralized control (as in *de-conflicted C2*, see Figure 2) versus fully networked organizations with complete access of information for all participants and full allocation of decision rights to all members (as in *edge C2*, see Figure 2). While de-conflicted, hierarchical organization type, demands centralized coordination of all action, the edge organization is almost completely based on self-synchronization. Most real-world organizations will be somewhere between these two extremes, positioning themselves towards the middle part of the C2 approach space. For example, coordinated C2 where entities coordinate their activities and share information to a certain extent, and collaborative C2 where significant synergies are established by negotiating and establishing collective intent, making roles explicit, coupling actions and increasing shared awareness by increasing information

[30] NATO STO SAS-065 (2010). *NATO NEC C2 Maturity Model* (CCRP Publication Series). Washington, DC: DoD CCRP.

dissemination. So, while coordinate C2 demands basic efforts to coordinate in a purposeful way in order to avoid conflict, collaborative C2 actually means that the definition of purpose/goals has been negotiated among the collaborating entities.

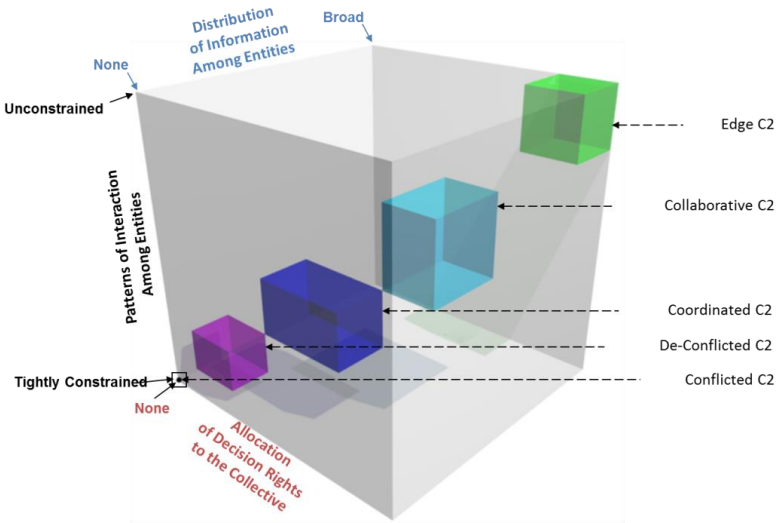

Figure 2. C2 Approach Space including prototypical organizational types (NATO STO, 2013)[31].

A fundamental hypothesis in the NATO STO SAS work has been that each type of situation/problem/mission has its own ideal point in the command and control approach space – no organization type is thus perfect for all kinds of missions/situations. The situation in which the organization operates is referred to as the *endeavour space* using the NATO STO SAS terminology.

> *"C2 Agility is an entity's capability to successfully accomplish C2 functions over the entire Endeavor space"* (NATO STO, 2013, p. 79).

[31] NATO STO (2013). *C2 Agility – Task Group SAS-085 Final Report* (STO Technical Report STO-TR-SAS-085). Brussels, Belgium: NATO Science and Technology Organization.

However, no explicit model like the C2 approach space, that describes the basic dimensions of the endeavour space has been published within the NATO STO SAS task groups.

Alberts (2007)[32] argues for the necessity of being able to adopt different C2 approaches by stating that:

> *"Nearly ten years later, no military organization has achieved full maturity although they may have units that have, at times, approached this. In fact, different levels of maturity may be appropriate for different circumstances (capabilities of the force and the characteristics of the situation) and involve different approaches to command and control."* (p. 13).

By *command and control maturity*, the author refers to the ability of the organization to function on different positions in the C2 approach space. It should be observed that there is a difference between being C2 mature and *C2 manoeuvre agile*. C2 maturity only tells what parts of the C2 approach space an entity can occupy. Having C2 manoeuvre agility means that the entity also has the ability to recognize when it should perform such a movement and do it correctly. To be C2 agile is thus a function of what parts of the C2 approach space that an entity or a collective potentially can occupy, and the ability to position itself appropriately (having C2 manoeuvre agility).

2.2 Theoretical approaches related to NATO SAS concepts

Farrell and Connell (Farrell & Connell, 2010; Farrell, 2011)[33,34] propose a *control theory* based approach to model movements within the command and control approach space (command and control maturity) using a spring-damper metaphor. Twelve organizational attributes were identified using this metaphor in simulations (Farrell & Connell, 2010) and case studies (Farrell, 2011). Most importantly, the

[32] Alberts, D. S. (2007). Agility, Focus, and Convergence: The Future of Command and Control. *The International C2 Journal, 1*(1). 1-30.
[33] Farrell, P. S. E., & Connell, D. (2010). *Organizational Agility*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.
[34] Farrell, P. S. E. (2011). *Organizational Agility Model and Simulation*. Proceedings of the 16th ICCRTS, Quebec, Canada, June 21-23. Washington, DC: DoD CCRP.

approach suggests that organizations have a degree of *stiffness* and *resistance* to change that may prevent or delay necessary movements in the command and control approach space. Also, organizations tend to have a *comfort level* in certain command and control approaches where they prefer to operate (Farrell & Connell, 2010)[35]. *Learning to learn* is also emphasized as a key enabler of organizational agility as Farrell and Connell highlight:

> *"Organizational Agility is the ability to optimize its GM approach to the situation through compensatory, anticipatory, adaptive, and learning methods or behaviours."* (p. 1)[36],

and

> *"We discover that Organizational Agility involves improving organizational attributes using compensatory, anticipatory, adaptive, and learning methods."* (p. 7).

Dodd and Markham (Dodd & Markham, 2012; 2013)[37,38] focus on *temporal aspects of agility*, suggesting that time needs to be incorporated in the concepts of agility and command and control agility. In contrast to the above mentioned studies by Farrell, they stress that purely mechanical metaphors are less suitable for describing agility and its relation to time. Instead, they suggest that:

> *"Use of different metaphors (e.g. brain, culture, organism) provides us with the stimulus to see the various forms of time being exercised in both the C2 organization and the environment in which it is operating."* (Dodd & Markham, 2012, p. 13)[39].

How organisms are born, grow, develop and decline are seen as potentially useful metaphors as human behaviour and cognition mostly

[35] Farrell, P. S. E., & Connell, D. (2010). *Organizational Agility*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.

[36] By "GM" in the citation, the authors refer to *Governance and Management*, a term that can be compared to command and control approach.

[37] Dodd, L., & Markham, G. (2012). *C2 agility, different models of change and reasoning with time.* Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

[38] Dodd, L., & Markham, G. (2013). *Orders of C2 Agility and Implications for Information and Decision-Making*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[39] Dodd, L., & Markham, G. (2012). *C2 agility, different models of change and reasoning with time.* Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

are enablers of agility. Structural components, on the other hand, such as command and control systems (as in technical systems) and other equipment rather provide the means for achieving something than the actual initiation of change.

Kallionatis, McLeod, and Kohn (2010)[40] have been working on a concept that expands the NATO STO SAS work by applying *theory from structural contingencies*, Perrow's theory of *normal accidents* (Perrow, 1984)[41], and Rittel and Webbers *wicked problems* on planning processes (Rittel & Webbers, 1973)[42]. They focus specifically on planning and claim that structure of planning should/could be varied according to mechanistic, organic or hybrid modes, according to the theories of Mintzberg (1979)[43] and Groth (1999)[44]. The point of departure in their reasoning is the tension between formalized planning processes and the need of being *agile* when facing situations that were not considered when the planning process was defined in the first place.

2.2.1 Empirical support for the NATO STO SAS concepts

The theoretical framework provided by the NATO STO SAS teams is appealing as it is comprehensive and holistic. Unfortunately, there is still a need for further empirical work to support and confirm the framework and the proposed hypotheses. Some articles describe case studies of different C2 approaches, while other articles describe case studies where transitions between C2 approaches were identified. Below follows a summary of the more important findings from the conducted work.

[40] Kalloniatis, A., MacLeod, I., & Kohn, E. (2010). *Agility in an Extended Space of Constructible Organisations*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.
[41] Perrow, C. (1984). *Normal accidents: Living with high risk technologies*. New York: Basic Books.
[42] Rittel, H. W., & Webber, M.M. (1973). Dilemmas in a general theory of planning. *Policy sciences, 4*(2), 155-169.
[43] Mintzberg, H. (1979). *The Structuring of Organizations: A Synthesis of Research*. Englewood Cliffs, NJ: Prentice Hall.
[44] Groth, L. (1999). *Future Organizational Design: The Scope for the IT-Based Enterprise*. New York: John Wiley & Sons.

In an attempt to apply the C2 approach space and validate the claims by Alberts (2007)[45] on C2 maturity, Huber et al. (2012)[46] present two case studies in support to these claims, the 2005 Hurricane Katrina and the 2004 Asian Tsunami. The Huber et al. (2007) paper state that:

> *"Both of the cases presented below have shown that 1) Collective C2 maturity and agility go hand in hand, 2) the C2 Maturity and hence, C2 Agility, is more or less limited by the C2 maturity of the participating entities, 3) entity C2 Maturity is limited by the capabilities of entity C2 systems; and 4) observed instances of agile behavior, in both cases, were restricted to situations where the respective participants had, or were able to generate, the connectivity necessary to adapt their command and management systems and processes to the dynamic changes of the operational environment."* (p. 11),

and

> *"The more complex and dynamic the mission and situation, the more network-enable the C2 Approach must be to succeed. Put another way, entities that adopt less network-enabled approaches to C2 are not able to successful cope with complex and dynamic missions and environments."* (p. 25).

Hayes (2014)[47] has analysed a number of historical cases in order to support agility. Based upon this analysis, Hayes concludes that agility has been an important contributor to successful performance also in the past. However, he also states that it is difficult, if even possible, to distinguish between potential and actual agility unless a case exists where it is possible to judge whether the outcome of a certain activity was successful or not. Similarly, he points to the difficulty of separating agility and C2 agility as they largely depend upon each other when viewing actual outcomes of real events.

[45] Alberts, D. S. (2007). Agility, Focus, and Convergence: The Future of Command and Control. *The International C2 Journal, 1*(1), 1-30.

[46] Huber, R. K., Moffat, J., & Alberts, D. S. (2012). *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

[47] Hayes, R.E. (2014). *Empirical Agility*. Proceedings of the 19th ICCRTS, Alexandria, VA, June 16-19. Washington, DC: DoD CCRP.

Bernier, Alberts and Manso (2013)[48] conducted a series of experiments intended to validate the hypothesis about C2maturity and the need to be able to move in the C2 approach space. A number of experiments were performed that aimed to investigate if more network-enabled[49] C2 approaches, exhibit more agility and if entities that are more command and control mature are potentially more agile. The results support the benefits of allocating decision rights broadly and disseminating information as widely as possible. On the other hand, the results did not show that movements in the C2 approach space increased agility compared to simply going for the most network-enabled approach. It should, however, be noted that the results were primarily based on agent-based simulations. An interesting finding from these experiments is that the relation between the C2 approach and "agility score" show strong interaction effects, which suggests that the collaborative C2 and edge C2 (see Figure 2 above) approaches are far more agile than the other C2 approaches.

2.3 Summary

The analysed articles differ in terms of theoretical heritage, but they do share basic assumptions. Although many articles discuss agility and/or organizational agility, only some (primarily the work originating from NATO STO SAS and the CCRP) make a clear distinction between agility per se and organizational/C2 agility. Either, they discuss agility, C2 agility or organizational agility or all of these concepts. For the sake of argumentation, although simplified, it can be said that agility, as a common term, refers to the ability to cope with dynamics and complexity in a flexible manner (independent of whether we discuss individuals, teams or organizations). C2 agility, or organizational agility, refers to the ability to cope with dynamics and complexity by adjusting/adapting the own organization to better fit the demands of

[48] Bernier, F., Alberts, D. S., & Manso, M. (2013). *International Multi-Experimentation Analysis on C2 Agility*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[49] Network-enabled refers to organizations with a high degree of information dissemination (everyone has access to information) and a high degree of allocation of decision rights to the members of the organization, i.e. a "flat" organization hierarchy. Such an organization would position itself in the upper, far, right corner for the C2 approach space, like an edge organization, see Figure 2.

the current situation, possibly involving structural and/or functional re-configuration. The ability to respond to external change, signified by complex interactions, seems to be a driving force in most research efforts.

3 Other relevant theoretical concepts

For apparent reasons, most C2-related research on agility was found in areas with strong ties to the military domain. However, there are several other fields that have been challenged with the same type of problems that the military have been facing the last decades. Business management, emergency management, and other areas where it is important to respond quickly in an environment characterized by constant change have all initiated a body of research on how organizations should be able to handle unforeseen or improbable events. Among such trends, we have identified approaches based on Complex Adaptive Systems (CAS), business management and work design, multiteam systems (MTS), and approaches based on improvisation. Below, we will present each of these.

3.1 Complex adaptive systems

Complex Adaptive Systems (CAS) is, in the texts found in this survey, an approach trying to link complexity theory to the development of command and control systems. Although the texts describing CAS originate from the ICCRTS, we have decided to place it in this chapter since it is not directly connected to the theories presented within the NATO STO SAS work. It has its own origin, appearance and theoretical heritage. According to CAS, most open systems that are successful are to some extent possible to see as a CAS, given that they can present context-dependent purposeful behaviour over a longer time period (Huber et al., 2012)[50].

Although CAS focuses on *adaption* rather than agility, there are some similarities between the theoretical framework of CAS and the NATO STO SAS work. An interesting conclusion made in the field of CAS is that while the complexity of modern organizations and systems makes control, in the mechanistic sense, almost impossible, it still is possible to influence a complex system, given that an understanding of that system exists. Such a system may be another organization, or a

[50] Huber, R. K., Moffat, J., & Alberts, D. S. (2012). *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

network of actors that are operating with a joint purpose. However, the "openness", the fact that there are unclear boundaries between the system under scrutiny and its surroundings together with the mere complexity within the system in terms of interactions, goals and so forth, makes it difficult to predict and control its behaviour. The way to move forward is, according to CAS, to focus on understanding the adaptive mechanisms of a system, as these are the ones that shape both the behaviour and the future "design" of the same system (Huber et al., 2012)[51].

Grisogono (2006)[52] suggests that the C2 function in a CAS can be seen as an adaptive mechanism, since it determines the measures of success and failure, as well as direct intent. The C2 function forms a recursive sensing-processing-acting chain that precedes decision and execution. A very relevant research question in the CAS field is to assess the *health* of an adaptive system. How can we make sure that a system that is labelled adaptive will be adaptive in the future? As *fitness* is a central concept in CAS, the question of variation under controlled conditions is seen as a way of assessing health. An adaptive system must be able to present a certain degree of variation, otherwise it will not be able to be adaptive, but unless this variation is compared to a certain "fit", it is likely to lose its ability to achieve fitness. Fitness, in an adaptive system, refers to the concept of "success or failure" for the system in the context of its environment. Therefore, the system must have a selection process that sorts out variations that lead to harmful errors (as such variations occur more often than useful innovations). Also, if the selection-process (of variations) is not well-aligned with the system's fitness, it may incorrectly label winners and losers in the adaptive mechanism.

3.2 Business management and work design

Agility is crucial for successful business as actors on the financial market face intense competition due to globalization and time-to-

[51] Huber, R. K., Moffat, J., & Alberts, D. S. (2012). *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

[52] Grisogono, A.M. (2006). *The Implications of Complex Adaptive Systems Theory for C2*. Proceedings of the 6th CCRTS, San Diego, CA, June 20-22. Washington, DC: DoD CCRP.

market pressures. In such competition, *collaboration*, *adaptability*, and *problem-solving* become essential. Work structures therefore continuously have to evolve in response to changes. As a way of handling these changes and how they affect work-related outcomes, the areas of work design and knowledge management have been working with definitions of agility from the business perspective, where the concept has received some attention (Holsapple & Li, 2008)[53]. Considerable research has shown that work design can influence a host of attitudinal, behavioural, cognitive, well-being, and organizational outcomes (Humphrey, Nahrgang, & Morgeson, 2007)[54].

Work design is concerned with how work routines are arranged and renewed. According to Holsapple and Li (2008) there are two major reasons to recognize a work-design perspective when looking at organizational agility. (1) Since agility is displayed through work routines it is formed by work design. (2) Work design is present in any type of organization. Therefore, to understand how to shape an agile organization the organization's system for designing and implementing work needs to be studied. By providing greater or faster awareness of changes, knowledge management practices can enable agility. Holsapple and Li (2008) propose a unifying definition of *organizational agility*:

> *"Agility is the result of integrating alertness to changes (recognizing opportunities/challenges) – both internal and environmental – with a capability to use resources in responding (proactive/reactive) to such changes, all in a timely, flexible, affordable, relevant manner."* (p. 6).

A *knowledge-intensive work-design system* is an example of an edge organization (cf. Alberts & Hayes, 2003). It involves three *work-design levels*: strategic, operational, and episodic. Also, Holsapple and Li (2008) present results of an illustrative case study.

[53] Holsapple, C. W., & Li, X. (2008). *Understanding Organizational Agility : A Work-Design Perspective*. Proceedings of the 13th ICCRTS, Seattle, WA, June 17-19. Washington, DC: DoD CCRP.

[54] Humphrey, S. E., Nahrgang, J. D., & Morgeson, F. P. (2007). Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. *Journal of Applied Psychology, 92*(5), 1332-1356.

Spaans et al. (2009)[55] argue about how a distributed learning process can influence a learning culture of an organization, which would affect the organization's adaptive ability. They propose a set of values that can direct organizational design decisions towards greater effectiveness in a dynamic and complex environment. This would rearrange work and design the efforts towards an organization that could more effectively adapt to change. Spaans et al. (2009) present the *adaptive stance* and define it as:

> *"The Adaptive Stance is an intellectual stance that creates the preconditions for being adaptive for individuals, teams, and larger groups throughout an organization such as a defense force"* (p. 4).

3.3 Multiteam systems

The multiteam systems (MTS) theory is a framework for describing and analysing situations where several teams are involved. It describes a closely coupled network of functioning teams (Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005)[56]. These teams can be inter- or intra-organizational. The common denominator is that they have a common overarching goal. The distal goals of MTS must come together and be intertwined at a higher level in a goal hierarchy for a MTS to exist (Bateman, Neill, & Ren, 2002)[57]. According to Healy, Hodgkinson, & Teo (2009)[58]:

> *"MTS: (i) are composed of two or more teams, (ii) are discrete entities larger than individual teams, but smaller than the organizations within they are embedded, (iii) comprise component teams that exhibit input, process, and outcome*

[55] Spaans, M., Spolestra, M., Douze, E., Pieneman, R., & Grisogono, A. (2009). *Learning to be Adaptive.* Proceedings of the 14th ICCRTS, Washington, DC, June 15-17. Washington, DC: DoD CCRP.

[56] Marks, M. A., DeChurch, L. A., Mathieu, J. E., Panzer, F. J., & Alonso, A. (2005). Teamwork in Multiteam Systems. *The Journal of Applied Psychology*, *90*(5), 964–71.

[57] Bateman, T. S., Neill, H. O., & Ren, A. K. (2002). A Hierarchical Taxonomy of Top Managers ' Goals. *Journal of Applied Psychology*, *87*(6), 1134–1148.

[58] Healey, M. P., Hodgkinson, G. P., & Teo, S. (2009). *Responding effectively to civil emergencies: the role of transactive memory in the performance of multi team systems*. Proceedings of the 9th Bi-annual International Conference on Naturalistic Decision Making, London, June 23-26. London: British Computer Society.

> *interdependencies with at least one other team, (iv) are open systems whose configuration stems from environmental demands, and (v) have component teams, which may not share proximal goals, but do share one or more common distal/superordinate goals."* (p. 54).

The definition suggests a strong relationship with agility theory – the concept of MTS is based on the idea that loosely formed compositions of teams can emerge when needed. The paper by Healy et al. (2009)[59] is based on the theories of Mathieu, Marks, and Zaccaro (2001)[60] whom define MTS as:

> *"Two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals. MTS boundaries are defined by virtue of the fact that all teams within the system, while pursuing different proximal goals, share at least one common distal goal; and in doing so exhibit input, process, and outcome interdependence with at least one other team in the system."* (p. 290).

DeChurch and Zaccaro (2010)[61] argue that the problems concerning the understanding of performance in complex sociotechnical systems cannot be solved using a team perspective since these types of systems display aspects such as mixed-motive goal structures and complex layered social identities. These aspects are outside the scope of many team definitions where the team members share a common goal. They argue that the focus of analysis in complex sociotechnical systems should move from team to MTS.

As stated above, MTS may include only two teams, but are usually larger than most teams, yet smaller than the organizations they belong to. Mathieu and colleagues also differentiate between MTS embedded

[59] Healey, M. P., Hodgkinson, G. P., & Teo, S. (2009). *Responding effectively to civil emergencies: the role of transactive memory in the performance of multi team systems*. Proceedings of the 9th Bi-annual International Conference on Naturalistic Decision Making, London, June 23-26. London: British Computer Society.

[60] Mathieu, J. E., Marks, M. A., & Zaccaro, S. J. (2001). Multiteam systems. In N. Anderson, D. Ones, H. K. Sinangil, & C. Viswesvaran (Eds.), *International handbook of work and organizational psychology* (pp. 289–313). London: Sage Publications.

[61] DeChurch, L. A., & Zaccaro, S. J. (2010). Perspective: Teams Won't Solve This Problem. *Human Factors*, *52*(2), 329-334.

entirely within an organization (called internal MTS) and MTS combined of teams from different embedding organizations (called cross-boundary MTS). Another important feature of MTS is the functional interdependence both within and across component teams. It is not organizational boundaries that define MTS membership; it is the type and quality of the team interdependences. Another aspect is the goal hierarchies that direct the activities of the MTS. The goal hierarchy advises both which teams constitute a MTS and how the teams' contributions must be combined to achieve higher level goals (Marks et al., 2005) [62].

Davison and colleagues (Davison et al., 2012)[63] showed that coordination across team boundaries at the component team level can be harmful to performance. Coordinated actions by component team boundary spanners (individuals in key roles) and leadership, on the other hand, may affect system performance positively if the coordination is centred around the component team that is most critical to tackling the demands of the task environment.

DeChurch, Doty, Murase, and Jiménez (2014)[64] present research where the manipulation of three *multiteam system determinants* (trust, communication, and leadership) all were found to impact relationships with relevant *multiteam system processes and performance*. These relationships were dependent on the structural characteristics of each other. The results indicate a need to consider not only the specific behaviours performed by individuals within a MTS, but also the different relational structures that occur in such a system.

Empirical support for agility from the MTS area where several experimental studies have been carried out exists (Davison et al., 2012; DeChurch & Marks, 2006; Healey et al., 2009; Marks et al.,

[62] Marks, M. A., DeChurch, L. A., Mathieu, J. E., Panzer, F. J., & Alonso, A. (2005). Teamwork in Multiteam Systems. *The Journal of Applied Psychology*, *90*(5), 964–71.

[63] Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. (2012). Coordinated action in multiteam systems. *The Journal of Applied Psychology*, *97*(4), 808-824.

[64] DeChurch, L. A., Doty, D. A., Murase, T., & Jiménez, M. (2014). *Collaboration in Multiteam Systems: The Leader and the Architect*. Proceedings of the NATO STO meetings on Collaboration in a Comprehensive Approach to Operations: Effective Collaboration in Joint, Multinational, Multiagency Teams and Staffs – Papers presented at the STO Human Factors and Medicine Panel (HFM) Workshop Held in Toronto, Canada on the 04-06 October 2010. Brussels, Belgium: NATO Science and Technology Organization.

2005)[65,66,67,68]. These experimental studies were laboratory-based due to the nature of MTS where the level of analysis deemed that a large number of participants were needed to represent all component teams and the experiments were to provide a sufficient statistical power and strength.

3.4 Improvisation

The concept of *improvisation* has been recognised in areas such as organization science and ergonomics, as well as in domains such as crisis response and emergency management. Scholars from different domains have proposed a number of definitions of improvisation in the scientific literature (see Moorman & Minner, 1998, and Cunha, Cunha, & Kamoche, 2002, for a review of definitions)[69,70]. Examples of definitions from organization science and ergonomics are improvisation as:

> *"The spontaneous and creative process of attempting to achieve an objective in a new way"* (Vera & Crossan, 2004, p. 733)[71],

and

> *"An adaptive response to unexpected or unanticipated situations that are outside the boundaries of what an organization has prepared for"* (Trotter, Salmon, & Lenné, 2013, p. 476)[72].

[65] Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. (2012). Coordinated action in multiteam systems. *The Journal of Applied Psychology*, *97*(4), 808-824.
[66] DeChurch, L. A., & Marks, M. A. (2006). Leadership in multiteam systems. *The Journal of Applied Psychology*, *91*(2), 311–29.
[67] Healey, M. P., Hodgkinson, G. P., & Teo, S. (2009). *Responding effectively to civil emergencies: the role of transactive memory in the performance of multi team systems*. In Proceedings of NDM9 the 9th international conference on naturalistic decision making (pp. 53-59).
[68] Marks, M. A., DeChurch, L. A., Mathieu, J. E., Panzer, F. J., & Alonso, A. (2005). Teamwork in Multiteam Systems. *The Journal of Applied Psychology*, *90*(5), 964–71.
[69] Moorman, C., & Minner, A.S. (1998). Organizational improvisation and organizational memory. *The Academy of Management review*, *23*(4), 698-723.
[70] Cunha, M. P., Cunha, J. V., & Kamoche, K. N. (2002). Organizational improvisation: what, when, how and why. In Kamoche, K.N., Cunha, M.P., & Cunha, J.V. (Eds.), *Organizational improvisation*, Routledge: London, pp. 93-133.
[71] Vera, D., & Crossan, M. (2004). Theatrical Improvisation: Lessons for Organizations. *Organizations Studies*, *25*(5), 727-749.
[72] Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, *14*(5), 475-498.

In the crisis response and emergency management domain improvisation is defined, for instance, as:

> *"A two-stage process. In the first stage, the responding organization recognizes either that no plan applies to the current situation or that an applicable plan cannot be executed. The second stage, given that the need to depart from planned-for procedures has been recognized, the responding organization must develop and deploy one or more new procedures."* (Mendonça & Fiedrich, 2006, p. 350)[73].

Improvisation is closely related to agility in the sense that it in many cases is the only option when facing unfamiliar situations. Improvisation research also suggests that the ability to organize in different ways when needed is a form of improvisation. For example, Mendonça and Fiedrich (2006) examined how different organizations jointly organized their work in order to restore the electric grid on Manhattan, NY, after the 9/11 attacks on World Trade Center. Improvisation is especially common under time-pressure. Limited, or lacking, planning is also a common point of departure for improvisation.

Most of the research on improvisation builds upon studies of musical and theatrical improvisation. However, Vera and Crossan (2004) highlight the difference between musical and theatrical improvisation and organizational improvisation. According to them, musical and theatrical improvisation is motivated by artistic and aesthetic purposes, while improvisation by organizations, teams, and individuals is initiated by time pressure, ambiguity, and uncertainty. Trotter et al. (2013)[74] point out differences between improvisation and creativity, innovation and adaption, and highlight the temporal element of improvisation that makes it different from creativity, innovation, and adaption.

[73] Mendonça, D., & Fiedrich, F. (2006). Training for improvisation in emergency management: opportunities and limits for information technology. *International Journal of Emergency Management*, *3*(4), 348-363.

[74] Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, *14*(5), 475-498.

Vera and Crossan (2004)[75] and Crossan et al. (2005)[76] focus their research on improvisation on defining conceptual frameworks and constructs to model improvisation taking into account the *time dimension* of improvisation. They have also proposed a model that can be illustrated by a matrix that relates improvisation to time pressure and uncertainty describing so-called *scenarios of organizational improvisation* (Crossan et al., 2005). The model describes four different scenarios: *planning, ornamented improvisation, discovery improvisation,* and *full-scale improvisation* (see Figure 3).

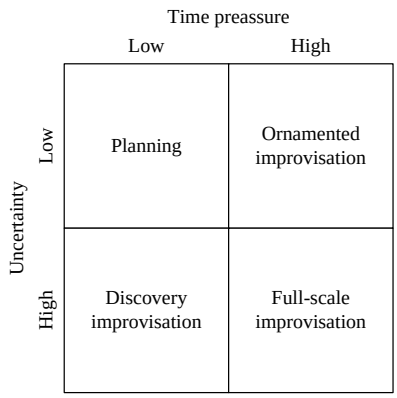

Figure 3. Scenarios of improvisation in organizations (Crossan et al., 2005).

The most relevant improvisation scenario in the context of this report is full-scale improvisation that characterizes, for example, crisis response operations. Full-scale improvisation means that improvisation is required due to the effect of time-constraints on planning or implementation of plans. It also means that, at the same time, due to the high uncertainty, implementation of plans may be inhibited or that plans to meet the changing needs and conditions may not be applicable or even non-existent. High levels of spontaneity and creativity are typical for this improvisation scenario Crossan et al. (2005).

[75] Vera, D., & Crossan, M. (2004). Theatrical Improvisation: Lessons for Organizations. *Organizations Studies*, *25*(5), 727-749.

[76] Crossan, M., Cunha, M. P., Vera, D., & Cunha, J. V. (2005). Time and organizational improvisation. *Academy of Management Review*, *30*(1), 20-35.

Trotter et al. (2013)[77] and Baker, Miner, and Essley (2003)[78] discuss the *resource dimension* of improvisation that is often handled separately from the time dimension. Performing actions with available resources to match changing needs and conditions is referred by the authors to as *bricolage*. However, as the authors point out, bricolage can occur outside improvisational situations, but improvisation will almost always involve bricolage.

Taking a socio-technical perspective, Trotter et al. (2013) review factors influencing improvisation. The factors proposed by Trotter et al. (2013) are (for full review of the factors, their theoretical underpinnings, domain and method, see p. 8-10):

- Expertise/Experience/Training
- Education/Systemic Knowledge
- Situational Awareness/Sense-making
- Teamwork quality
- Information flows/feedback/communication
- Organisational memory
- Role system
- Culture/Values/Commitment
- Organisational structure

Trotter et al. (2013) also review a number of human performance models in relation to improvisation, (Mendonça, 2007)[79], Recognition Primed Decision model (RPD) (Klein, 2008)[80] and the Skill-based, Rule-based and Knowledge-based (SRK) model (cf. Harwood & Sanderson, 1986)[81]. Of important notice in the Trotter et al. (2013) review is *flexecution*, a term coined by Klein (2008), that describes how goals in a complex situation may be dynamic and transform as

[77] Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, *14*(5), 475-498.
[78] Baker, T., Miner, A. S., & Eesley, D. T. (2003). Improvising firms: bricolage, account giving and improvisational competencies in the founding process. *Research Policy*, *32*(2), 255-276.
[79] Mendonça, D. (2007). Decision support for improvisation in response to extreme events: learning from the response to the 2001 World Trade Centre attack. *Decision Support Systems*, *43*(3), 952-967.
[80] Klein, G. A. (2008). Naturalistic Decision Making. *Human Factors*, *50*(3), 456–460.
[81] Harwood, K., & Sanderson, P. (1986,). Skills, rules and knowledge: A discussion of Rasmussen's classification. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *30*(10), 1002-1006.

events unfold due to the fact that the understanding of the situation gradually is being built up. However, note that although all the above mentioned models of human performance apply to improvisation, only the Mendonça (2007) model was explicitly developed to explain improvisation.

As Trotter et al. (2013) consider improvisation as an emergent property of a socio-technical system, they suggest that Rasmussen's (1997)[82] *risk management framework* can be mapped to factors that characterize improvisation. The purpose of doing so would be to apply the diverse set of factors proposed in a systematic fashion. By doing so, factors influencing improvisation on all levels in an organization could be taken into account, not only the sharp end, where it usually is studied.

> *"The greatest impact of a systems-based model will be to guide organisations towards enhancing improvisation by managing higher level organisational factors, such as organisational structure, culture and memory."* (Trotter et al., 2013, p. 21)

Finally, Rankin, Dahlbäck, and Lundberg (2013)[83], and Lundberg and Rankin (2014)[84] have studied improvisation in crisis response teams. As Rankin, Dahlbäck, and Lundberg (2013) found a lack of studies concerning *role improvisation* (a specific kind of improvisation) "as it happens", they created a scenario with a dynamic non-routine situation and a shortage of staff, in order to get the participants to adapt and improvise their behaviour. Their focus was on how teams function when required professional competence is temporarily unavailable, that is, how they took on new necessary roles and factors contributing to performance under such conditions. They found that performance decreases as the team members act in new improvised roles for which they lack training, in new improvised organizational structures and in front of new requirements on language skills and communication. The authors recommend three strategies to compensate during role improvisation, which involve: training to take on roles outside ones

[82] Rassmusen, J. (1997). Risk Management is a dynamic Society: a modelling problem. Safety Science, 27 (2-3), 183-213.

[83] Rankin, R., Dahlbäck, N., & Lundberg, J. (2013). A case study of factor influencing role improvisation in crisis response teams. *Cognition, Technology & Work, 15*(1), 79-93.

[84] Lundberg, J., & Rankin, A. (2014). Resilience and vulnerability of small flexible crisis response teams: implications for training and preparation. *Cognition, Technology & Work, 16*(2), pp. 143-155.

professional area of specialization, routines for organizational adjustments and tools and routines for information sharing.

3.5 Summary

As can be seen in this chapter, agility-related concepts are studied within several domains, using definitions that are similar to, or touch upon, the ones used in NATO STO SAS work. In most cases the authors do not use the term agility, although they all contribute to the understanding of agility (as we interpret agility in this work) or properties thereof. Only the knowledge management and work design approaches explicitly use the term “agility”, but all of the other areas point to the need for having flexible and adaptable organizational stances to deal with dynamic situations. The MTS theory suggests that the ability to form team-of-teams within and across organizations is a driver for successful performance when facing uncertainty. CAS attempts to model and understand the adaptive mechanisms in complex socio-technical systems like command and control organizations. Research on improvisation provides a framework for understanding the ability to respond in situations where planning, preparation and resources are scarce.

4 Methodological approaches

In this section the most important findings in terms of methods that can be utilized when conducting empirical research on agility or C2 agility are presented.

4.1 Methods for studying agility

Few methods exist that have been specifically developed to study agility. One method is the *case study template* that has been utilized within the NATO STO SAS work, reported in Farrell et al. (2013)[85] and NATO STO (2013)[86]. The template is designed to provide structure to case studies and collecting evidence for agility or C2 agility. The findings from the case studies are, at least in the Farrell et al. (2013) study gathered in an *evidence table*, making it possible to compare different case studies in a convenient manner. However, as pointed out by Belanger (2013)[87], it is in many cases challenging to get access to data that can be used to analysing agility, partly because many real-world cases are poorly documented and partly because the type of documentation provided rarely have focused on collecting agility-relate data as the concept is comparatively new. Often, examples of agility must be extrapolated from available data. Belanger also points to the difficulty in defining the unit of analysis, especially in complex cases like military operations where the number and type of involved actors will vary over time and space. It may also be difficult to identifying a particular C2 approach or a transition between two different approaches.

A number of *experiments* have been carried out, mostly using agent-based simulations. Bernier, Alberts and Manso (2013)[88] report findings

[85] Farrell, P. S. E., Baisini, C., Belanger, M., Henshaw, M., Mitchell, W., & Norlander, A. (2013). *SAS-085 C2 Agility Model Validation Using Case Studies*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[86] NATO STO (2013). *C2 Agility – Task Group SAS-085 Final Report* (STO Technical Report STO-TR-SAS-085). Brussels, Belgium: NATO Science and Technology Organization.

[87] Bélanger, M. (2013). *The difficulty to document agility evidences from a C2 perspective*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[88] Bernier, F., Alberts, D.S., & Manso, M. (2013). *International Multi-Experimentation Analysis on C2 Agility*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

from six different simulations. The idea behind using the different simulations was that they all represented a different kind of endeavour space. An interesting consequence of these studies was that the researchers actually had to define the dimensions and variables that comprised the endeavour space for each simulation. However, this also pointed to the lack of a common definition since no experiment shared exactly the same dimensions and variables to explain the endeavour space and the connection to the C2 approach space.

As pointed out by Alberts (2014)[89], all attempts to measure agility in simulations or scenario-based designs suffer from the same problem, that all such assessments depend largely on the number and nature of utilized scenarios, and how well these correspond to the actual situations that the system will be confronted with. Instead, Alberts suggest that a measure called the *Agility Quotient* (AQ) should be used. The AQ measure should in principle be based on the six components of agility as described in the NATO STO (2013)[90] work: (1) robustness, (2) resilience, (3) responsiveness, (4) flexibility, (5) innovation, and (6) adaptiveness. C2-AQ, in turn, would be calculated as a function of the ability to move within the C2 approach space and the accuracy by which this can be done in relation to the endeavour space, something that can be assessed without looking at the six agility components (although a strong relation between AQ and C2-AQ can be expected).

In a similar fashion, McEver, Martin, and Hayes (2008)[91] have tried to operationalize the six agility components to make them unambiguous and measureable. In their study, they performed a literature review of works from different countries and communities. From this, they formed a definition of agility comprising of the six attributes, effectiveness, and cognitive factors. Each attribute was given a measurement approach. Although the proposals were never tested in the study, the paper is a starting point to link agility concepts to something observable and measurable.

[89] Alberts, D. S. (2014). *Agility Quotient (AQ).* Proceedings of the 19th ICCRTS. Alexandria, VA.
[90] NATO STO (2013). *C2 Agility – Task Group SAS-085 Final Report* (STO Technical Report STO-TR-SAS-085). Brussels, Belgium: NATO Science and Technology Organization.
[91] McEver, J. G., Martin, D. M., & Hayes, R. E. (2008). *Operationalizing C2 Agility: Approaches to Measuring Agility in Command and Control Contexts*. Proceedings of the 13th ICCRTS, Seattle, WA, June 17-19. Washington, DC: DoD CCRP.

Walker and colleagues have applied a *socio-technical approach to agility* (Walker et al., 2008, 2009)[92,93]. They use an adapted version of the C2 approach space that utilizes other labels than information dissemination, allocation of decision rights and patterns of interaction (see Figure 1 above). The adapted approach space show how social network analysis can be used to identify how large a portion of the approach space that a particular organization can possess, essentially a measure of command and control maturity. The "new" measurement dimensions are:

- *Diameter* refers to the largest number of (agents) which must be traversed in order to travel from one (agent) to another when paths which backtrack, detour, or loop are excluded from consideration.
- *Density* refers to number of links in the social network in relation to the number of agents.
- *Sociometric status* can be described as a way of assessing how much communication that is shared between agents in a system.

The basic hypothesis is that:

> *"an edge organization will be denser than a hierarchical one, meaning that (all things being equal) broader dissemination of information will be rendered possible because there are more direct pathways between sender and receiver (compared to a hierarchically organized counterpart)."*
> (Walker et al., 2009, p. 4).

A benefit of the suggested approach is that it relies on purely quantitative data that mostly can be collected from, for example, communication log-files without too much effort. An explicit limitation of the article is that a description is lacking of the connection between the identified command and control approach space states and actual performance. Also, the connection between the *social network*

[92] Walker, G. H., Stanton, N. A., Salmon, P. M., & Jenkins, D. P. (2008). A review of sociotechnical systems theory : a classic concept for new command and control paradigms. *Theoretical Issues in Ergonomics Science*, *9*(6), 479–499.

[93] Walker, G. H., Stanton, N. A., Salmon, P. M., Jenkins, D. P., & Rafferty, L. (2009). *Combining Social Network Analysis and the NATO Approach Space to Define Agility*. Proceedings of the 14th ICCRTS, Washington, DC, June 15-17. Washington, DC: DoD CCRP.

analysis metrics and the three axes' in the C2 approach space needs to be further refined.

Within the study of CAS a quantitative approach has been used to describe the need for agility. Moffat et al. (2011)[94] created a multi-dimensional measure of the *conflict space*, based on the UK Global Strategic Trends of the future. By applying those measures to UK, USA, French, and Israeli experiences of conflict over the past 60 years, the authors conclude that the scale and nature of conflicts have been signified by a high level of variability, as well as complex behaviour and randomness when studied from historical records. The authors use this information to argue for the need of agile forces, as such forces in theory are those best suited to cope with uncertainty.

4.2 Methods used for studying agility-related concepts

Within the research performed in the crises response and emergency management domain, a diverse set of methods have been utilized to study the agility-related concepts presented in Chapter 3. Generally, research in this domain utilizes a combination of qualitative methods, although some exceptions exist, such as in the MTS domain where quantitative measures have been applied. As the concepts presented in Chapter 3 are strongly related to the NATO STO-based concepts presented in Chapter 2, there is reason to believe that the methods applied in the related fields are relevant for studying agility as well.

From an organizational perspective, Mendonça (2007)[95] and Mendonça and Wallace (2004)[96] have studied improvisation in crisis response operations, especially in the aftermath of the 9/11 terrorist attacks on the World Trade Center. This has led to the development of a methodological approach for studying improvisation, based on three

[94] Moffat, J., Scales, T., Taylor, S., & Medhurst, J. (2011) Quantifying the need for force agility. *The International C2-Journal, 5*(1), 1-25.

[95] Mendonça, D. (2007). Decision support for improvisation in response to extreme events: learning from the response to the 2001 World Trade Centre attack. *Decision Support Systems*, *43*(3), 952-967.

[96] Mendonça, D., & Wallace, W. A. (2004). Studying organizationally-situated improvisation in response to extreme events. *International Journal of Mass Emergencies and Disasters*, *22*(2), 5-29.

questions, namely *where, when,* and *how* improvisation occur among organizations. Where refers to the physical location within the organizational structure (be it an established or ad-hoc organization), when refers to the circumstances or conditions, and how refers to the cognitive-behavioural processes that take place during improvisation (Mendonça & Wallace, 2004)[97]. They propose that there are three stages for addressing the questions: first to identify the social networks among responding organizations and individuals, second to classify cases of decision making involving these personnel, and third, to describe the cognitive and behavioural processes in these cases so that improvised decision making can be better understood and supported. What thus is proposed by Mendonça & Wallace (2004) is a combination of *analysis of recorded documentation*, such as log-files, in order to create a picture of the social networks involved, with *structured questionnaires* and *interviews* in order to identify and describe the decision-making that took place and the cognition underlying it. The method suggested by the authors is therefore primarily intended for case-studies of real-world events, but could possibly be applied to realistic exercises or simulation studies.

Trotter et al. (2013)[98], who also studied improvisation, have described a number of methods used in improvisation research, as well as three basic criteria that must be fulfilled when studying improvisation. The criteria are:

- *Identification of instances of improvisation*: Given that improvisation occurs in response to scenarios for which no procedures exist or are applicable, safety critical situations in which improvisation may be required can be relatively rare. The methodology must, therefore, allow effective extraction of data regarding rare events.
- *Sufficient detail for the identification of influencing factors*: The methodology needs to support elicitation of detailed information surroundings and influencing improvisation needs.

[97] Mendonça, D., & Wallace, W. A. (2004). Studying organizationally-situated improvisation in response to extreme events. *International Journal of Mass Emergencies and Disasters*, *22*(2), 5-29.

[98] Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, *14*(5), 475-498.

- *Identification of factors and interactions across different levels*: The methodology should be capable of identifying influencing factors across different sociotechnical system levels, along with their interactions between these factors.

Trotter et al. (2013)[99] suggest that the most plausible methods to meet the above criteria are *interviews* or *retrospective case studies*. The reason for this is that by utilizing such methods, (1) it is possible to get access to cases where improvisation actually was present, (2) it is possible to get information about details and influences around the improvisation, and (3) it is also possible to map different levels of a socio-technical organization and the interactions between different levels. Many of these assumptions also apply to agility research in general as agility often is expected to be manifested in similar situations as improvisation. The drawbacks of the mentioned methods are that they are subject to biases, time-consuming (interviews), and often hard to generalize from.

Apart from these examples, Lundberg and Rankin (2014)[100] have utilized a combination of *interviews* and *focus groups* to gather data on role improvisation and the importance of information transfer and field experience in their study of crisis response teams. Focus groups are moderated group discussions, often focused on gathering data on novel phenomena. The focus group leader presents stimuli, which may take many different forms, from individual statements about something to an actual physical artefact, which then serves as a point-of-departure for the discussion.

In work design and CAS, *case studies* have been utilized (Holsapple & Li, 2008; Huber et al., 2012)[101,102] in order to illustrate theoretical constructs and assumptions presented in the surveyed literature.

[99] Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, *14*(5), 475-498.
[100] Lundberg, J., & Rankin, A. (2014). Resilience and vulnerability of small flexible crisis response teams: implications for training and preparation. *Cognition, Technology & Work*, *16*(2), 143-155.
[101] Holsapple, C. W., & Li, X. (2008). *Understanding Organizational Agility : A Work-Design Perspective*. Proceedings of the 13th ICCRT, Seattle, WA, June 17-19. Washington, DC: DoD CCRP.
[102] Huber, R. K., Moffat, J., & Alberts, D. S. (2012) *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

Finally, the MTS perspective have mainly employed *quantitative experiments* with both system recordings/log-files as measures of performance (Davison et al., 2012)[103], as well as *questionnaires* (DeChurch & Marks, 2006)[104].

4.3 Summary

The studied literature in this report shows that the main technique for conducting research and generate empirical support for agility seems to be through case studies and different qualitative methods, such as interviews and focus groups. There seems to be two reasons for this. First, there is a lack of method for quantifying agility and its components, and, second, it is difficult to create scenarios or simulations that would require agile behaviour. Historical data, such as reports, are also an important source of data. Although such reports seldom use formulations and concepts that are related to agility, it may still be inferred from the behaviour of participating actors and the outcome of events that are described.

Several studies also use quantitative measures, primarily in the MTS and socio-technical systems literature. Within the socio-technical stance, social network analysis is presented as an important source of data. Such data can be gathered relatively easy (compared to manual data collection, such as interviews, queries etc.), but provides mostly structural information. In order to gain deeper insights into the understanding of an event, complementary data collections must be performed.

[103] Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. (2012). Coordinated action in multiteam systems. *The Journal of Applied Psychology*, *97*(4), 808-824.
[104] DeChurch, L. A., & Marks, M. A. (2006). Leadership in multiteam systems. *The Journal of Applied Psychology*, *91*(2), 311–29.

5 Discussion

This report discusses recently published research related to agility identified by the means of a literature review. The literature review has included 47 relevant journal or conference publications from several research fields.

The literature review shows that several research fields study conceptually related problems and share the same basic assumptions, though in different domains. For instance, large-scale disaster response, such as the Haiti earthquake in 2010, and contemporary peace enforcing operations, such as the ISAF[105] mission in Afghanistan, share many similarities in terms of the demands put on participating organizations. They must be able to perform in most kinds of environments, cope with threats that are difficult to predict and prepare for, and adapt to rapid changes. Moreover, they need to be able to collaborate and coordinate with other organizations that may or may not share technical infrastructure, C2 processes, organizational structures, goals, as well as values.

The studied publications either discuss agility, C2 agility, organizational agility, or all of these concepts. For the sake of argumentation, although simplified, it can be said that *agility*, as a common term, refers to the ability to cope with dynamics and complexity in a flexible manner. *C2 agility*, or organizational agility, refers to the ability to cope with dynamics and complexity by adjusting/adapting the own organization to better fit the demands of the current situation. The ability to respond to external change, signified by complex interactions, seems to be a driving force in most research efforts.

A large body of research that directly uses and develops theories of agility has a military origin (19 of 47 publications). Earlier military C2 theories have in most cases not stressed the importance of adopting a flexible approach to C2, where the structures of the organization, command mandate and information dissemination are subject to change in harmony with the current demands. However, this literature review suggests that there has been a shift in focus in military C2

[105] ISAF stands for International Security Force.

research. This is caused by the fact that the military operations of today call for large scale coordination, as well as new ways of dealing with complexity and uncertainty.

Agility-related research has also been conducted within the domain of crisis response and emergency management for some time, but by use of different labels for the studied phenomena. When facing crises the responding organizations are often forced to improvise in terms of how operations are conducted and how C2 is organised. Additionally, in many crisis situations, basic C2 functions, such as communication may be disrupted for technical reasons demanding self-synchronization between units. Therefore, concepts like improvisation, role improvisation, flexecution, adaptive stance, creativity etc. have been proposed within research in this domain.

Within the research fields related to the crisis response and emergency management domain only the knowledge management and work design approaches explicitly use the term “agility”, although all of the discussed research fields somehow contribute to the understanding of agility, as defined in this work. CAS attempts to model and understand the adaptive mechanisms in complex socio-technical systems and provides a descriptive and analytical framework for understanding properties of different forms of systems and organizations. Work design concerns the development of agile organizational processes and structures. The MTS theory suggests that the ability to form team-of-teams within and across organizations is a driver for successful performance when facing uncertainty. This specifically applies to crisis response and emergency management since such activities often involve team-of-teams in order to cope with ongoing events. Research on improvisation provides a framework for understanding the ability to respond in cases where planning and preparation are missing or not applicable. At the same time, in comparison to the military domain, there are few attempts to create a holistic theoretical framework.

The publications identified in the literature review have mainly aimed at developing theory rather than applying theory, which indicate a scientific field “under development” rather than a mature field. The analysis of methodological support related to theories of agility suggests that methods for conducting experimental agility or C2 agility research still are scarce.

5.1 Theoretical development

As described above, C2 agility, or organizational agility, refers to the ability to cope with dynamics and complexity by adjusting/adapting the own organization to better fit the demands of the current situation. The NATO STO work specifically describes these adaptation(s) along the axis of the C2 approach space (see Chapter 2). An organization may thus be C2 agile without being agile and vice versa, although it is assumed that there is a coupling between the two views. This seems to be an interpretation that is shared among the body of researchers connected to the NATO STO SAS task groups.

NATO STO SAS approach is the most mature concept in terms of theory, but also CAS, work design, and the systemic approach to improvisation suggested by Trotter et al. (2013)[106] are important contributions. The main weakness of the NATO STO SAS approach is currently the lack of well-defined parameters/dimensions for assessing positions in the endeavour space (see Chapter 2). This is a critical point since one of the most interesting hypothesizes formulated in the NATO STO SAS work on agility concerns the connection between the position of an entity in the C2 approach space and the problem at hand, i.e. the position in the endeavour space.

A concern is whether the identified theories are interchangeable between military, crisis response and emergency management, or military-civilian cooperation. For example, are the concepts from business agility the same as the concepts from crisis response agility? On an overarching level they are all interested in handling unforeseen, complex, and dynamic situations. However, business agility is probably quite different from military or crisis response and emergency management agility, with the goal of surviving as a profitable business, in a competitive world, for the long run. Military operations and crisis response are usually less concerned with maintaining the organization and more concerned with achieving the purpose of their existences, namely creating safety and security in the area of operation. These differences in basic assumptions about the organizations are reflected in how expectations on agility are met, be it

[106] Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, *14*(5), 475-498.

on the organizational or C2 level. For example, improvisation and flexibility will always be a more important factor for crisis response than for military operations since the crisis response has a more difficult time to plan for what will happen before an effort is activated. Military operations, on the other hand, typically are not commenced without thorough planning.

5.2 Empirical evidence

Compared to the theoretical body concerning agility, C2 agility, and organizational agility, the body of empirical research is small, especially of experimental work. Case studies have described different C2 approaches and changes between C2 approaches, hence C2 maturity/manoeuvres in the C2 approach space. However, experimental research has so far failed to present evidence of changes (movements) in C2 approach, at least with human research participants. There are many reasons for this, partly that it is difficult to create scenarios that would trigger such behaviour and, perhaps foremost, that such studies would require extensive training of the participants. In order to change C2 approach, an organisation must be mature enough to utilize at least two distinct approaches and also be competent enough to recognise the need to change between them, something that is likely to demand extensive training.

From the crisis response and emergency management side, there exist empirical data of good quality in terms of case studies describing different types of events. Most of these are case studies with a different focus than investigating agility. However, it might be possible to extract information that may guide the pursuit of a better understanding of agility and C2 agility. One known challenge with these case studies is that they are post facto descriptions where the answers/results found reflect the assumptions of the theoretical models that the analysts use. This is known as the 'What-You-Look-For-Is-What-You-Find' or WYLFIWYF principle (cf. Lundberg, Rollenhagen, & Hollnagel, 2009)[107]. Generalizing from case studies is

[107] Lundberg, J., Rollenhagen, C., & Hollnagel, E. (2009). What-You-Look-For-Is-What-You-Find – The consequences of underlying accident models in eight accident investigation manuals. *Safety Science*, *47*(10), 1297–1311.

therefore problematic, although the focus of case studies is to provide a description and understanding of phenomena. On the other hand, with the growing body of evidence, meta-reviews of case studies can inform us about patterns that are emerging from these data. A future research suggestion is to create protocols that focus on agility or C2 agility that enable comparison of case studies over different situations and types of operations. Initial contributions have been made, for instance in the work by Farrell et al. (2013)[108], but the number of analysed cases is still limited.

Most experimental work conducted in the research area of C2 agility has been performed with agent-based simulations. This is an interesting approach in the sense that it allows large amounts of experiments to be conducted rapidly, but it is also limited in the sense that it puts high demands on the validity of the simulation. Studies with experimental participants, on the other hand are costly, complicated to set up, and time-consuming due to the fact that agility, at least on the macro-level, concerns organizations or at least teams. Currently, there are few proposals regarding how to conduct such experimentation. One of the main challenges would be to create controllable scenarios in which, for example, movements in the C2 approach space could be studied. What kind of scenario events would trigger such behaviour from people participating in the experiment? Also, few measures exist that could be used in such experiments. The measures identified in this study, such as the Agility Quotient (Alberts, 2014)[109], have yet to be tested in practice.

5.3 Methodological support

The literature discussed in this report shows that the main technique for conducting research and generate empirical support for agility seems to be through case studies and different qualitative methods, such as interviews and focus groups.

[108] Farrell, P. S. E., Baisini, C., Belanger, M., Henshaw, M., Mitchell, W., & Norlander, A. (2013). *SAS-085 C2 Agility Model Validation Using Case Studies*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

[109] Alberts, D. S. (2014). *Agility Quotient (AQ).* Proceedings of the 19th ICCRTS, Alexandria, VA, June 16-19. Washington, DC: DoD CCRP.

Currently, there is no mature assessment method for evaluating neither agility nor C2 agility. The area of agility lack scientifically and theoretically sound, reliable, and valid methods which would be accepted among researchers in related fields. An accepted, reliable, and valid method will allow for assessment of organizations both during training/exercise and operations providing a value for the organizations agile ability. It will also provide direction for commanders and decision makers on what aspects the organization is in need of focused training to reach acceptable agility levels.

Level of analysis is another methodological issue. On what level should agility and C2 agility be assessed? It is possible to assess the whole organization as one system, as well as the different component teams and subsystems. This raises two questions: (1) is it possible to assess agility the same way on the overarching organizational level as of individual subsystems or component teams (cf. Klein et al., 2003)[110]?, and (2) how can the impact of C2 agility (the C2 organization and its components) on overall agility (the whole organization or collective of organizations) be assessed and vice versa?

Studying collectives is a great challenge that calls for a major research effort. In a military head quarter on the operational level, several hundred persons can be engaged at the same time. In Haiti, after the earthquake in 2010, the relief "organization" consisted of several hundred teams and organizations connected in an ad-hoc fashion, that is, there was no overarching mandate controlling the relief operation and each actor decided whom they wanted/needed to collaborate and coordinate with (Farrell et al., 2013)[111]. Studying these types of organizations is difficult in respect of many aspects: getting the "right" informants, deciding on what types of data are important, collecting data, asking the "right" questions, providing a description that is sufficient, but not to detailed, and maintaining valid results.

Another problem studying agility is that real world operations, where agile behaviour is present, occur infrequently and it is hard to predict

[110] Klein, G. A., Ross, K. G., Moon, B. M., Klein, D. E., Hoffman, R. R., & Hollnagel, E. (2003). Macrocognition. *IEEE Intelligent Systems, 18(3),* 81–85.

[111] Farrell, P. S. E., Baisini, C., Belanger, M., Henshaw, M., Mitchell, W., & Norlander, A. (2013). *SAS-085 C2 Agility Model Validation Using Case Studies*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

when they will occur. The side effect of this is that a quantitative meta-study is dependent on a large sample of operations, and is therefore hard to accomplish. One solution to this is to study exercises or to perform large scale simulator studies, but again, generalizability can be questioned- are exercises and simulations equivalent to real world problems?

6 Conclusion

The objective of the work presented in this report has been to identify important theoretical underpinning of agility and C2 (organisational) agility as well as possible methodological approaches to assess and model agility. A literature review was conducted, by search of major databases as well as known sources, identifying 47 relevant journal or conference publications from several research fields. The identified research mainly originates from the USA, the UK, Canada, and Australia, though more nations contribute to this area through the participation in the NATO STO SAS work, the identified main driver in C2 agility research. The analysed articles differ in terms of both domain (military, crisis response, emergency management, business management) and theoretical heritage (C2, complex adaptive systems, multi-team systems, work design).

This does not mean that the theories and research questions posed are only valid in their original domain. Rather, the research performed on, for example, improvisation is clearly relevant for military operations, crisis response and emergency management. Also, collaboration between different organizations that form large collectives in order to cope with, for example, crises shows the need for a deeper understanding of C2 agility. The studied texts largely point to the need of increasing the adaptive capacity to cope with the increasing complexity of the modern world. The authors of the analysed publications seem to agree upon the view that optimisation and specialisation is the antecedent of what should be achieved, as optimisation and specialisation is ill-suited to cope with a rapid-changing context. The way forward is to create adaptive capacity which makes it possible to cope with uncertainty and dynamics.

At the same time, the analysis of the identified texts highlights that most of the publications have mainly aimed at developing theory rather than applying theory. The analysis also revealed that methodological support related to theories of agility for conducting experimental agility or C2 agility research still are scarce. Moreover, the need for a framework (or frameworks) for studying agility and C2 agility is evident. This is needed in order to formulate research programs, theoretical and empirical connections between various research efforts,

and to interpret data gathered in different studies. Further, the connection between research performed in the military and crisis response and emergency management domains can possibly be better understood using such a framework.

The literature review found a growing body of theory and concepts for agility that hopefully will be beneficial for the development of crisis management. However, the review also suggests that the following research challenges should be met:

- The need for development and validation of theoretical frameworks (for agility, C2 agility or both).
- The need for developing a conceptual model of the endeavour space/mission space (a way of describing the problem space in relation to agility or C2 agility).
- The need for validation of (the) proposed assessment tools and measures (of both agility and C2 agility) and development of further such tools and measures.
- The need for further empirical studies (especially experiments to prove basic hypotheses and assumptions).

7 Cited scientific articles with abstracts

This chapter contains references and abstracts of the scientific articles that are cited in the preceding chapters.

Alberts, D. S. (2007). Agility, Focus, and Convergence: The Future of Command and Control. ***The International C2 Journal, 1*****(1), 1–30.**

The future of command and control is not Command and Control. In fact, the term Command and Control has become a significant impediment to progress. This paper presents and discusses key terms that form the core of a new conceptual foundation; one that can provide a point of departure for the systematic exploration of future "command and control." Three concepts form this core: agility, focus, and convergence. In brief, agility is the critical capability that organizations need to meet the challenges of complexity and uncertainty; focus provides the context and defines the purposes of the endeavor; convergence is the goal-seeking process that guides actions and effects.

Alberts, D. S. (2014). ***Agility Quotient (AQ) David*****. Proceedings of the 19th ICCRTS, Alexandria, VA, June 16-19. Washington, DC: DoD CCRP.**

Agility, the capability to successfully effect, cope with, and/or exploit changes in circumstances, can be directly observed only when this capability has been manifested. Increasingly agility is seen as an essential system capability and hence a requirement. To satisfy a stated requirement for agility we need to be able to answer two questions. "How can we measure a system's Agility IQ?" and "What is the requisite amount of Agility that is required?" This paper suggests a way forward and illustrates it, in the context of C2 systems.

Baker, T., Miner, A. S., & Eesley, D. T. (2003). Improvising firms: bricolage, account giving and improvisational competencies in the founding process. *Research Policy, 32*(2), 255–276.

Improvisation occurs when the design and execution of novel activities converge. Drawing on three samples of young firms, this inductive study investigates the existence, channels and implications of strategic improvisation in knowledge-intensive new businesses. Our study suggests that not only may founding itself be improvisational in some cases, but improvisational processes and issues permeate entrepreneurial activity and have non-obvious implications for emergent firm strategies and competencies. We develop propositions in four domains: (1) the occurrence of strategic improvisation; (2) tactical improvisation rising to the level of strategy; (3) network bricolage; and (4) improvisational competencies. This study contributes to research on organizational improvisation, bricolage and entrepreneurship. Theoretically and in practice, both improvisation and bricolage represent potentially rich additions to the vocabulary of entrepreneurial action.

Bateman, T. S., Neill, H. O., & Ren, A. K. (2002). A Hierarchical Taxonomy of Top Managers ' Goals. *Journal of Applied Psychology, 87*(6), 1134–1148.

To embed goal theories more deeply in the domain of top-level leadership behavior and to provide a vehicle to facilitate future research, the authors developed a taxonomy of managerial goals. Interviews with 75 company leaders—founders and presidents—from 3 countries generated 2.182 articulated goals. Content analysis supported 2 taxonomic dimensions: goal content and hierarchical level. The goal content dimension specified 10 categories of substantive goal targets, and the second dimension captured the hierarchical structure of the top leaders' goal sets, with lower-level goals being instrumental toward achieving superordinate goals. The hierarchy comprised 5 goal levels: ultimate, enterprise, strategic, project, and process. Chi-square analyses revealed relationships between goal content and hierarchical level as well as differences between the national subsamples.

Bélanger, M. (2013). *The difficulty to document agility evidences from a C2 perspective*. Proceedings of the 18th ICCRTS. Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

Agility can be defined as the capability to successfully effect, cope with and/or exploit changes in circumstances. Based on this definition, NATO SAS-085 has proposed a conceptual model of C2 agility, making the distinction between C2 approach agility (the agility a specific C2 approach), and C2 agility (the capacity to go from one C2 approach to another C2 approach). This paper presents a C2 agility case study and proposes some explanations about the difficulty to document evidences of C2 agility in military operations.

Bernier, F., Alberts, D.S., & Manso, M. (2013). *International Multi-Experimentation Analysis on C2 Agility*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

Agility is being increasingly recognized as an important capability of modern military organizations, one that will enable them to successfully cope with complexity and uncertainty. C2 Agility is a critical enabler of force agility. NATO SAS-085 has been established to better understand C2 Agility and build a conceptual model facilitating experimentation and operationalization. A core hypothesis is that more network-enabled C2 approaches exhibit more Agility than less network-enabled approaches. In this paper, we present results from experiments conducted under the aegis of the SAS-085 to sustain (or disprove) this hypothesis. Starting with a common conceptual framework (based on the Network Centric Warfare theory and the NATO Network Enabled Capability (NEC) C2 Maturity model), the experiments were conducted by different organizations and researchers (from Canada, Italy, Portugal, UK and USA) using different experimentation platforms (i.e., agent-based ELICIT, IMAGE, PANOPEA and WISE), measures of effectiveness, and endeavor spaces. Findings, analysis and results of this integrated set of experiments and the conclusions drawn from this international effort.

Crossan, M., Cunha, M. P., Vera, D., & Cunha, J. V. (2005). Time and organizational improvisation. *Academy of Management Review, 30*(1), 20–35.

We argue that effective management action is impeded by a simplistic understanding of time - one dominated by a clock-time perspective. Using the concept of improvisition, we reconcile two major time dichotomies associated with organizational phenomena: clock time versus event time and linear time versus cyclical time. We propose that improvisation offers a means for management theorists and practictioners to overcome these apparent time dichotomies.

Cunha, M. P., Cunha, J. V., & Kamoche, K. N. (2002). Organizational improvisation: what, when, how and why. In Kamoche, K.N., Cunha, M.P., & Cunha, J.V. (Eds.), *Organizational improvisation,* Routledge: London, pp. 93-133.

No abstract available.

Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. (2012). Coordinated action in multiteam systems. *The Journal of Applied Psychology, 97*(4), 808–824.

This study investigated coordinated action in multiteam systems employing 233 correspondent systems, comprising 3 highly specialized 6-person teams, that were engaged in an exercise that was simultaneously "laboratory-like" and "field-like." It enriches multiteam system theory through the combination of theoretical perspectives from the team and the large organization literatures, underscores the differential impact of large size and modular organization by specialization, and demonstrates that conventional wisdom regarding effective coordination in traditional teams and large organizations does not always transfer to multiteam systems. We empirically show that coordination enacted across team boundaries at the component team level can be detrimental to performance and that coordinated actions enacted by component team boundary spanners and system leadership positively impact system performance only when these actions are

centered around the component team most critical to addressing the demands of the task environment.

DeChurch, L. A., & Marks, M. A. (2006). Leadership in multiteam systems. *The Journal of Applied Psychology*, *91*(2), 311–29.

This study examined 2 leader functions likely to be instrumental in synchronizing large systems of teams (i.e., multiteam systems [MTSs]). Leader strategizing and coordinating were manipulated through training, and effects on functional leadership, interteam coordination, and MTS performance were examined. Three hundred eighty-four undergraduate students participated in a laboratory simulation modeling a 3-team MTS performing an F-22 battle simulation task (N = 64 MTSs). Results indicate that both leader training manipulations improved functional leadership and interteam coordination and that functional leader behavior was positively related to MTS-level performance. Functional leadership mediated the effects of both types of training on interteam coordination, and interteam coordination fully mediated the effect of MTS leadership on MTS performance.

DeChurch, L. A., & Zaccaro, S. J. (2010). Perspective: Teams Won't Solve This Problem. *Human Factors*, *52*(2), 329–334.

Objective: We link the problem of complex sociotechnical systems to a new unit-of-analysis and fruitful developing area of applied research, the multiteam system. Background: Teams are the dominant entity and theoretical lens being applied to understanding the performance of complex sociotechnical systems. We submit that such problems cannot be solved through the teams lens because complex sociotechnical systems exhibit features such as mixed- motive goal structures and complex, layered social identities that do not meet the definitional requirements of a team. Method: We present key findings from multiteam systems research and review the studies contained in the special issue on the basis of the focal constructs and unit of analysis. Results: Although progress is being made on understanding key constructs essential to understanding complex sociotechnical systems, the unit of analysis needs to be shifted upward from the team level to

the system level. Conclusion: Progress on understanding the inner workings and leverage points for the success of complex sociotechnical systems requires a fundamental shift in the unit of analysis toward understanding the macrodynamics of larger systems of teams. Application: The multiteam system perspective offers a useful theoretical lens for future research on and tool development (e.g., training, information technology) for improving the functioning of complex sociotechnical systems.

DeChurch, L. A., Doty, D. A., Murase, T., & Jiménez, M. (2014). ***Collaboration in Multiteam Systems: The Leader and the Architect.*** **Proceedings of the NATO STO meetings on Collaboration in a Comprehensive Approach to Operations: Effective Collaboration in Joint, Multinational, Multiagency Teams and Staffs – Papers presented at the STO Human Factors and Medicine Panel (HFM) Workshop Held in Toronto, Canada on the 04-06 October 2010. Brussels, Belgium: NATO Science and Technology Organization.**

As collaborative work arrangements are applied to increasingly urgent and complex problems, a consideration of the integrative processes occurring across diversely motivated teams, different organisations, and fields of expertise becomes ever more vital. A recent conceptualization of this type of collaborative approach is that of the multiteam system (MTS), which formally considers the internal and external characteristics of interdependent teams working together on a partially shared set of goals (Mathieu, Marks, & Zaccaro, 2001). The research presented in this paper extends the understanding of team process to the multiteam level and presents a more holistic perspective of the relationship between multiple processes and performance through the application of contingency theories. Within a laboratory experiment, the manipulation of three MTS determinants (trust, communication, and leadership) were all found to have relationships with relevant MTS processes and performance. These relationships, however, were found to be fully contingent on the structural characteristics of one another.

Dodd, L., & Markham, G. (2012). ***C2 agility, different models of change and reasoning with time*****. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.**

Agility is a theme which arises in relation to a range of endeavours in the military and the non-military world, appearing either in accounts of practical experience or in statements of aspirations. Concepts of agility have recently been surveyed in the course of an ongoing study of C2 agility conducted for the UK MOD. Whilst the accounts presented of agility differ widely, common to all of them is the interplay between continuity (i.e. preservation of identity and forms of order) and change. Both continuity and change imply some notion of time, but different concepts of agility adopt different uses of time, and indeed different forms of time. This paper will focus on different ways of reasoning with time in the context of agility, including both how agility is engendered and how agility is exhibited. The paper will show how using the wrong form of reasoning with time can produce inappropriate metrics for agility. The paper will further show that the pursuit of inappropriate metrics can frustrate the intention to realise particular concepts of agility in order to respond to key change drivers.

Dodd, L., & Markham, G. (2013). ***Orders of C2 agility and implications for information and decision-making*****. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.**

In a paper at 17th International Command and Control Research and Technology Symposium (ICCRTS), different forms of Command and Control (C2) agility were related to different forms of time. In this paper we broaden this idea to consider orders of agility. An immediate consequence is the clarification of the interplay between continuity and change, as seen in all manifestations of agility and, in particular, in discussions of resilience. Orders of agility also invite the re-examination of conceptions of value in informing decision- making, leading to the exposition of a hierarchical model of nested decision-making and decision-taking. Further, if we take a purposive definition of information, being that which is required to enable decision-making, then different types of information, and indeed different definitions of

information, can also be related to this hierarchical scheme. Thus, model of orders of agility provides a unifying scheme for ostensibly diverse and incompatible interpretations of decision-making and information. It also gives greater confidence that different conceptions of value and assessment measures can be organized systematically, rather than being subverted by being mapped on to inappropriate solution-driven preferences. Thus orders of agility become a useful source of rigour in the design of C2 experiments, the formulation and exercise of simulations and the assessment of C2 capability.

Farrell, P. S. E., & Connell, D. (2010). *Organizational Agility*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.

Organizational Agility has been discussed during SAS-065 NATO NEC Command and Control Maturity Model development, the Exploratory Team on C2 Agility, and other similar research efforts. In these contexts, agility is being defined as the ability to recognize changes in situation complexity and move quickly to the most appropriate C2 approach (edge, collaborative, coordinated, or de-conflicted). Proposed agility attributes are robustness, resilience, responsiveness, flexibility, innovation, and adaptation (Alberts & Hayes, 2003). However, more research is needed to determine how these attributes and their intensity relate to agility. This paper presents a conceptual model that helps us understand how certain agility attributes contribute to an organization's potential and dynamic behaviour particularly dynamic transitions from one C2 approach to the next. Conceptually, a motion system may be used as a metaphor to understand the organization's dynamic behaviour. Under this metaphor, it follows that mass is analogous to organization size attribute, damping factor is related to organization resistance to change attribute, and spring constant is equivalent to organization flexibility attribute. We find that Organizational Agility is the ability for an organization to optimize its attributes through compensatory, anticipatory, adaptive, and learning methods. Modelling and simulation is used to illustrate various C2 Approach transition profiles by varying organization size, resistance, and flexibility, while case studies are used to provide anecdotal evidence for the model.

Farrell, P. S. E. (2011). *Organizational Agility Model and Simulation*. Proceedings of the 16th ICCRTS, Quebec, Canada, June 21-23. Washington, DC: DoD CCRP.

Multiple Governance and Management (GM) approaches such as de-conflicted, coordinated, collaborative, and "edge" may all be required during complex endeavours in order to meet mission objectives effectively and efficiently. GM Approach agility is defined as an entity's (individual, team, organization, or collective) ability to transition between one GM Approach and another and to maintain that approach in the presence of disturbances, uncertainty, and self-damage. A conceptual model for GM Approach transitions is programmed into a computer simulation, demonstrating the dynamic nature of the agility concept. The model is refined using simulation, yielding a logical and internally consistent dynamic model that obeys a GM Approach Space "Law of Motion", and employs behaviours improve the transition response. The model and simulation was not developed to find numerical equivalents for socio-technical-organizational complexities. Rather this study provides a means to visualize the transition yielding key insights into GM Approach agility. For instance, entity size, resistance to transition, and stiffness (comfort level at a particular approach) determine the transition system's stability and response profile. Also, compensatory, anticipatory, adaptive, and learning behaviours (methods) are employed to modify stiffness and resistance, stabilize naturally unstable systems, improve responsiveness, provide resilience and known and unknown disturbance rejection, as well as optimize transition effectiveness and efficiency. Eventually, the model and simulation may be used to formulate recommendations for GM Approach agility strategic investments as part of comprehensive approaches to complex endeavours.

Farrell, P. S. E., Baisini, C., Bélanger, M., Henshaw, M., Mitchell, W., & Norlander, A. (2013). ***SAS-085 C2 Agility Model Validation Using Case Studies*****. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.**

Eight case studies including ISAF mission, Rwanda Genocide, Haiti Earthquakes, and Major Olympic Events were conducted to validate and improve our understanding of the the SAS-085 C2 Agility model. The C2 Agility model consists of two major concepts: 1) C2 Agility – "the ability to transition from one approach to an appropriate approach that can cope with the endeavour's level of complexity (SAS-085, draft)" and C2 Approach Agility – "the size and shape of the region of Endeavor Space where the approach in question can be successful (SAS-085, draft)" or the agility of a particular C2 approach as defined by six agility enablers: flexibility, responsiveness, versatility, adaptiveness, resilience, and innovation. Reports, interviews, and media were used to complete a case study template that provided a systematic way of capturing evidence for agility. An 'evidence' table was completed for each case study, and a meta-analysis was conducted by looking across the evidence tables, where thirteen common findings were identified (e.g., flexibility as a contributor to agility). Also fifteen new findings were discovered and subsequently used to refine the C2 Agility Model (e.g., the role of leadership in achieving and maintaining agility).

Grisogono, A.-M. (2006). ***The Implications of Complex Adaptive Systems Theory for C2*****. Proceedings of the 6th CCRTS, San Diego, CA, June 20-22. Washington, DC: DoD CCRP.**

The study of Complex Adaptive Systems (CAS) has developed within a wide range of subject domains over the last couple of decades, spanning the biological sciences, economics, organisational science, public policy, environmental sciences, computer science, cognitive and social sciences, and lately, defence sciences. We have been researching how application of a CAS perspective to the most pressing and complex problems that defence faces can provide more effective tools and techniques to enable higher levels of success in dealing with these challenging problems. This approach has proved very fruitful and has

generated insights that could lead to implementable and testable strategy options in a wide range of defence areas – from strategic policy, the capability development process, and defence enterprise management to the design and evolution of complex defence systems and the command and control of tactical to strategic levels of operations. In this paper we will focus on the implications of CAS theory for C2, drawing on the understanding we have developed of what it is possible to do in the face of complexity, how adaptive mechanisms arise spontaneously in complex systems, how we may recognise them and influence their operation to better align with our purposes, and how we may develop additional adaptive mechanisms to foster more effective outcomes. The CAS we will address include not just the complex networked systems within our own forces, but also those of our allies and adversaries, and those existing in the overall environment in which we operate. All these systems influence both what we are expected to do and what we are able to do, therefore understanding how the adaptive mechanisms already operating in them shape their behaviour and how to harness those mechanisms to our purposes is potentially a very valuable and powerful strategy.

Groth, L. (1999). ***Future Organizational Design: The Scope for the IT-Based Enterprise*****. New York: John Wiley & Sons.**

No abstract available.

Harwood, K., & Sanderson, P. (1986). Skills, rules and knowledge: a discussion of Rasmussen's classification. ***Proceedings of the Human Factors and Ergonomics Society Annual Meeting.*** ***30*****(10), 1002-1006.**

In this paper a discussion is presented of the antecedents, the emergence, and the impact of Rasmussen's skill, rule, and knowledge based behavior classification. While level-based behavioral taxonomies have been used in the past, Rasmussen's use of the concept for describing human control of complex systems has had a widespread impact. It has aided interdisciplinary communication and has provided an organizing rubric for vast areas of research.

Hayes, R. E. (2014). *Empirical Agility*. Proceedings of the 19th ICCRTS, Alexandria, VA, June 16-19. Washington, DC: DoD CCRP.

While considerable work has been done on the topic of Agility over the past decade, the major case studies related to C2 have been conducted by NATO SAS Research Task Groups (065 and 085) as efforts to validate the concepts and relationships in their analyses and models of C2 approaches. However, there is a meaningful body of relevant work carried out by historians and analysts that document empirical and observable situations where Agility has proven important, not only recently, but also over time. This paper reviews the empirical evidence captured in some these efforts, focuses attention on the long term importance of Agility in military affairs and points out significant measurement issues that remain unresolved.

Healey, M. P., Hodgkinson, G. P., & Teo, S. (2009). *Responding Effectively to Civil Emergencies : The Role of Transactive Memory in the Performance of Multiteam Systems*. Proceedings of the Proceedings of the 9th Bi-annual International Conference on Naturalistic Decision Making, London, June 23-26. London: British Computer Society.

Motivation Many of today's most significant organizational challenges require the effective collaboration of collectives of various teams. Nowhere is the performance of such multiteam systems more important than in responding to civil emergencies. Research approach This field study analyses the determinants of performance among multiteam systems responding to civil emergencies in training exercises. Findings Transactive memory – meta-knowledge of other's expertise – is critical for team and system performance, operating at both the level of individual component teams and the wider multiteam systems. Different forms of training exercise can yield differential outcomes in terms of transactive memory. Research implications We discuss the implications for research on multiteam systems and for the design of training interventions designed to develop transactive memory among emergency responders. Originality/value This is the first study to examine empirically the role of transactive memory in the performance of multiteam systems.

Holsapple, C. W., & Li, X. (2008). *Understanding Organizational Agility : A Work-Design Perspective*. Proceedings of the 13th ICCRTS, Seattle, WA, June 17-19. Washington, DC: DoD CCRP.

This paper introduces a unified theoretical model of organizational agility and investigates the attributes of knowledge-intensive work-design systems, which contribute to achieving and sustaining organizational agility. Even though there has been considerable research on the topic of agility, these studies are not unified regarding their conceptualizations of agility and/or tend to adopt fairly limited views of agility dimensionality. Here, we organize a review of existing definitions and conceptual models of organizational agility, and proceed to advance a relatively comprehensive model built from a work-design perspective. This new model offers a theoretical platform for understanding organizational agility. This paper further investigates those attributes of a work design system that contribute to organizational agility. A knowledge-intensive work-design system is an example of an edge organization. Its governance mechanism (participant engagement governance, network governance, and system dynamic governance) involves three work- design levels: strategic, operational, and episodic. We contend that an entrepreneurial governance pattern has attributes contributing to organization agility, whereby the impetus for its work-design efforts stem not from some deep hierarchical authority pattern, but rather is distributed among participants and through their networking dynamics. These attributes allow each participant positioned at the edge of the system to stay alert and respond to environing trends and forces, on behalf of the system and in concert with the system. Results of an illustrative case study are reported.

Huber, R. K., Moffat, J., & Alberts, D. S. (2012). *Achieving Agile C2 by Adopting Higher Levels of C2 Maturity*. Proceedings of the 17th ICCRTS, Fairfax, VA, June 19-21. Washington, DC: DoD CCRP.

Alberts (2007) has identified three concepts that form the core of the conceptual basis for command and control of complex endeavors in an uncertain environment: agility, focus and convergence. “In brief,

agility is the critical capability that organizations need to meet the challenges of complexity and uncertainty; focus provides the context and defines the purpose of the endeavor; convergence is the goal seeking process that guides actions and effects". These concepts are captured by the NATO Network-Enabled Command and Control (C2) Maturity Model (N2C2M2 which is discussed in this paper. The N2C2M2 is particularly apt at the present time since both the US and European nations are facing complex and uncertain futures, with the emphasis on coalition-based defense. The N2C2M2 defines a set of variables that characterize the inter-organizational structure, namely patterns of interactions and information flows between and among a disparate set of entities (which we term a 'collective') that are participating in a Complex Endeavor, and delegation of decision rights by entities to the collective. The N2C2M2 de- fines five C2 approaches that may be practiced by the Collective (conflicted, de- conflicted, coordinated, collaborative, edge) and describes the C2 Maturity and Agility of the Collective in terms of its ability to select, adapt, and employ an appropriate C2 approach to meet the challenges posed by the complexity and uncertainty of the operational environment and the nature of the response required. Complex Endeavors are typically characterized by diverse multinational coalitions of military and non-military organizations and entities. Case studies and experiments under- taken to validate the N2C2M2 have shown (inter alia) that the C2 Agility of the Collective is more or less limited by the approaches to C2 practiced by the various participants and the capabilities of the systems that support them. These studies and experiments also provide evidence that improving Collective C2 Agility requires that the participating entities have the ability to choose from and adopt a wider range of potential C2 approaches so that they may change their C2 approach as operational circumstances change. This capability is what we refer to as C2 Maturity. Two case studies on the response to complex natural disasters (hurricane Katrina and the Indian Ocean Tsunami 2004) are revisited at the end of the paper. They support the hypothesis that C2 Maturity and C2 Agility go hand in hand.

Humphrey, S. E., Nahrgang, J. D., & Morgeson, F. P. (2007). Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. *Journal of Applied Psychology, 92*(5), 1332–1356.

The authors developed and meta-analytically examined hypotheses designed to test and extend work design theory by integrating motivational, social, and work context characteristics. Results from a summary of 259 studies and 219,625 participants showed that 14 work characteristics explained, on average, 43% of the variance in the 19 worker attitudes and behaviors examined. For example, motivational characteristics explained 25% of the variance in subjective performance, 2% in turnover perceptions, 34% in job satisfaction, 24% in organizational commitment, and 26% in role perception outcomes. Beyond motivational characteristics, social characteristics explained incremental variances of 9% of the variance in subjective performance, 24% in turnover intentions, 17% in job satisfaction, 40% in organizational commitment, and 18% in role perception outcomes. Finally, beyond both motivational and social characteristics, work context characteristics explained incremental variances of 4% in job satisfaction and 16% in stress. The results of this study suggest numerous opportunities for the continued development of work design theory and practice.

Kalloniatis, A., Macleod, I., & Kohn, E. (2010). *Agility in an Extended Space of Constructible Organisations*. Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.

Traditional theorists, such as the Contingency School, classify the modes of coordinating distributed human work using a geometrical "organisational space". Such a space may be labelled by the dimensions of distribution of decision making rights and specialisation mix, or those of the C2 Cube Model. Within such spaces reside, for example, Mintzberg's five organisational types. In light of modern information technology, Groth has extended Mintzberg's list to include five new modes. By examining characteristics such as coupling and complexity, we position Groth's new modes in an extended geometric

organisational space. Contingency Theory asserts that no single organisation can be structurally optimised to match every type of environmental contingency and work structures should adapt within an available “organisational space”. How then can modern military organisations use new modes enabled by information technology? We use Perrow’s Normal Accident Theory to correspondingly analyse the space of environmental contingency or the military “problem space”. Building on our previous work, we extend a concept of military headquarters agility, seen as movement through such a space of constructible organisations according to changing contingencies, now in light of degrees of freedom offered by information technology. We compare this to the concept of the Edge Organisation.

Klein, G. A., Ross, K. G., Moon, B. M., Klein, D. E., Hoffman, R. R., & Hollnagel, E. (2003). Macrocognition. *IEEE Intelligent Systems, 18*(3), 81–85.

If we engineer complex cognitive systems on the basis of mistaken or inappropriate views of cognition, we can wind up designing systems that degrade performance rather than improve it. The results stemming from the application of any cognitive systems engineering methodology will be incomplete unless they include a description of the cognition that is needed to accomplish the work. The concept of macrocognition is a way of describing cognitive work as it naturally occurs.

Klein, G. A. (2008). Naturalistic Decision Making. *Human Factors, 50*(3), 456–460.

Objective: This article describes the origins and contributions of the naturalistic decision making (NDM) research approach. Background: NDM research emerged in the 1980s to study how people make decisions in real-world settings. Method: The findings and methods used by NDM researchers are presented along with their implications. Results: The NDM framework emphasizes the role of experience in enabling people to rapidly categorize situations to make effective decisions. Conclusion: The NDM focus on field settings and its interest in complex conditions provide insights for human factors practitioners

about ways to improve performance. Application: The NDM approach has been used to improve performance through revisions of military doctrine, training that is focused on decision requirements, and the development of information technologies to support decision making and related cognitive functions.

Lundberg, J., & Rankin, A. (2014). Resilience and vulnerability of small flexible crisis response teams: implications for training and preparation. *Cognition, Technology & Work*, *16*(2), 143–155.

Following the Asian Tsunami of 2004 and during the Israel–Lebanon Crisis of 2006, Sweden sent small crisis response teams to support civilians. The small size of the teams, combined with situations that did not always play out according to expectations and plans, presented a challenge to their resilience—their ability to adapt to circumstances outside of plans made in advance. In this paper, we analyze the experiences of 14 members of Swedish field teams involved in the crises response, based on focus group discussions. We describe a cycle of pre- paring for role improvisation, of taking improvised roles, of working in them, and of getting out of them when they are no longer a benefit. The discussions revealed that although role improvisation was seen as necessary to get the work done, they also saw a need to manage negative side effects and vulnerabilities of role improvisation in various ways. We discuss training goals based on their experiences, to address perceived strengths and vulnerabilities of role improvisation. We also discuss factors affecting role improvisation, such as a resilience climate of shared attitudes. Our results can be useful for organizations that have or that plan to adopt flexible crisis response teams. Our results can also be of interests to a more general audience with an interest in how practices necessary for resilience can bring negative side effects, for instance, resilience loss in the organization after an initial adaptive stage.

Lundberg, J., Rollenhagen, C., & Hollnagel, E. (2009). What-You-Look-For-Is-What-You-Find – The consequences of underlying accident models in eight accident investigation manuals. *Safety Science, 47*(10), 1297–1311.

Accident investigation manuals are influential documents on various levels in a safety management sys- tem, and it is therefore important to appraise them in the light of what we currently know – or assume – about the nature of accidents. Investigation manuals necessarily embody or represent an accident model, i.e., a set of assumptions about how accidents happen and what the important factors are. In this paper we examine three aspects of accident investigation as described in a number of investigation manuals. Firstly, we focus on accident models and in particular the assumptions about how different factors inter- act to cause – or prevent – accidents, i.e., the accident ‘‘mechanisms”. Secondly, we focus on the scope in the sense of the factors (or factor domains) that are considered in the models – for instance (hu)man, technology, and organization (MTO). Thirdly, we focus on the system of investigation or the activities that together constitute an accident investigation project/process. We found that the manuals all used complex linear models. The factors considered were in general (hu)man, technology, organization, and information. The causes found during an investigation reflect the assumptions of the accident model, following the ‘What-You-Look-For-Is-What-You-Find’ or WYLFIWYF principle. The identified causes typ- ically became specific problems to be fixed during an implementation of solutions. This follows what can be called ‘What-You-Find-Is-What-You-Fix’ or WYFIWYF principle.

Marks, M. A., DeChurch, L. A., Mathieu, J. E., Panzer, F. J., & Alonso, A. (2005). Teamwork in Multiteam Systems. *The Journal of Applied Psychology, 90*(5), 964–71.

The authors examined how networks of teams integrate their efforts to succeed collectively. They proposed that integration processes used to align efforts among multiple teams are important predictors of multiteam performance. The authors used a multiteam system (MTS) simulation to assess how both cross-team and within-team processes relate to MTS performance over multiple performance episodes that

differed in terms of required interdependence levels. They found that cross-team processes predicted MTS performance beyond that accounted for by within-team processes. Further, cross-team processes were more important for MTS effectiveness when there were high cross-team interdependence demands as compared with situations in which teams could work more independently. Results are discussed in terms of extending theory and applications from teams to multiteam systems.

Mathieu, J. E., Marks, M. A., & Zaccaro, S. J. (2001). Multiteam systems. In N. Anderson, D. Ones, H. K. Sinangil, & C. Viswesvaran (Eds.), ***International handbook of work and organizational psychology*** **(pp. 289–313). London: Sage.**

No abstract available.

McEver, J. C. I., Martin, M. D. M., & Hayes, R. E. (2008). ***Operationalizing C2 Agility: Approaches to Measuring Agility in Command and Control Contexts*****. Proceedings of the 13th ICCRTS, Seattle, WA, June 17-19. Washington, DC: DoD CCRP.**

Modern military operations are characterized by highly dynamic environments, complex strategic, operational, and tactical situations, a rich and evolving mix of allies and adversaries, inherent and sometimes massive uncertainty, and high risk. This combination of factors requires that military forces must continually transform and adjust to remain highly effective in extremely fluid environments. This capability, known as agility, is emerging as a key attribute of the forces and organizations that will enable them to respond to the nature of modern operations. In an everyday language sense, agility as a concept is well understood. However, operational definitions of agility, needed to enable unambiguous recognition and measurement of the different aspects of agility have been lacking. This paper lays the groundwork for a unifying approach for measuring and experimenting with agility and its enabling factors by suggesting definitions of agility and its associated attributes that are amenable to measurement, and describing potential approaches to agility measurement and description.

Meijer, M. (2013). ***Agility in Command and Control in a Multinational Exercise*****. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.**

This paper presents the results of an analysis of agility in command and control, made during a bi-annual multinational exercise to train for a joint combined military operation in a national military conflict. The analysis focuses on transformations in management and sharing of information within the NATO Comprehensive Approach. The general conclusion is that management and sharing of information need some improvements, although many activities of military command and control are performed very well. The present operational readiness appears to be sufficient for operations in a national organization of national forces. However, if the intent for future exercises is to incorporate more international participants and non-military organizations, then some preparatory measures should be taken well in advance. The NATO comprehensive approach is partly embedded in the national system, and it works fine in a well controlled training environment. Challenges will arise when civilian organizations enter an area of real life military operations. Overall observations indicate that the operational level of command made many steps forward into the future of complex international operations. Interaction with more international units and more subject matter experts on command and control might improve the effectiveness of the upcoming exercises even further to be prepared for the execution of a joint combined military operation in the NATO comprehensive approach.

Mendonça, D., & Wallace, W. A. (2004). Studying organizationally-situated improvisation in response to extreme events. ***International Journal of Mass Emergencies and Disasters, 22*****(2), 5–29.**

Extreme events such as large-scale natural disasters create the need for cooperation within and among responding organizations. Activities to mitigate the effects of these events can be expected to range from planned to improvised. This paper presents a methodology for describing both the context and substance of improvisation during the response phase. The context is described by (i) analyzing communication patterns among personnel in and among responding

organizations and (ii) determining the appropriateness of existing plans to the event. The substance of improvisation within this context is described by modeling the behavior and cognition of response personnel. Application of the methodology leads to descriptions of improvisation and its context that may be stored in machine-readable format for use either by researchers, responding organizations or designers of computer-based tools to support improvised decision making. Data collection strategies for implementing the methodology are discussed and selected steps illustrated using a data set from a large-scale natural disaster.

Mendonça, D., & Fiedrich, F. (2006). Training for improvisation in emergency management: opportunities and limits for information technology. *International Journal of Emergency Management, 3*(4), 348–363.

Skill in improvising enables emergency management personnel to make creative decisions under time constraint, even when risks are high. It therefore complements skill in plan-following, which is particularly appropriate when the current emergency is similar to a past one. This paper develops recommendations on how to use Information Technology (IT) in the design of training programmes for improvisation in emergency management. It identifies and describes key training outcomes and techniques, and provides an assessment of how training platforms can be used to support achieving the training outcomes. It therefore provides an agenda for new training methods and guidelines on how IT may best be used in executing this agenda.

Mendonça, D. (2007). Decision support for improvisation in response to extreme events: learning from the response to the 2001 World Trade Centre attack. *Decision Support Systems, 43*(3), 952–967.

Extreme events such as natural or technological disasters challenge society's capabilities for planning and response. While advanced technologies and modeling techniques continue to expand how society can limit and manage extreme events, flexibility and an ability to improvise remain crucial in responding to them. By analyzing a case

from the response to the 2001 World Trade Center attack, this paper develops a set of requirements for computer-based systems intended to support improvisation in response to extreme events. The particular goal of this analysis is to identify methods for providing cognitive-level support for organizations in determining when and how to improvise.

Mintzberg, H. (1979). *The Structuring of Organizations: A Synthesis of Research*. Englewood Cliffs, NJ: Prentice Hall.

No abstract available.

Mitchell, W. (2010) Agile sense-making in the battlefield. *The International C2-Journal, 4*(1),1–33.

It is intended that this article be a contribution to the current Command and Control (C2) focus on power to edge principles, and the search for agility through self-synchronization. It adopts a social constructivist approach, drawing a great deal of input from political science for its theoretical foundation. In this regard, the article recognizes the fundamental ontological shift from our previous understanding of strategic interaction based primarily on calculations from the physical domain, to modern war- fare that depicts two interacting domains for strategic reference, one physical and the other cognitive (or ideational). It sees the skills of battlespace intelligence analyst as the key to sense-making agility in fighting complex conflicts. Then drawing on a constructivist understanding and examples from a complex battlespace, it will suggest three mutually supporting analytical skill-sets for further experiment and research to promote analytical agility: Network philosophy; hypotheses generation and evaluation; and iterative model generation. It suggests that developing these generic skills in our military intelligence analysts will contribute greatly to building a more agile sense-making capacity within our warfighting organizations.

Mitchell, W. (2013). ***Using Target Network Modelling to Increase Battlespace Agility*****. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.**

Battlespace agility is a warfighting concept defined as the speed at which the warfighting organisation is able to transform knowledge into actions for desired effects in a battlespace. If the Commander, the intelligence shop, and the operations people cannot draw a common picture of their battlespace – it is unlikely that the ensuing military operations will produce the desired effects. Ideally, the Commander, the intelligence silo, and the operations planning silo should have a common understanding of the battlespace in which they are fighting. The objective of this paper is to highlight one emerging communicative approach that has proven effective in facilitating shared situational awareness and understanding, called target network modelling (TNM). The paper will introduce readers to TNM as a communications methodology for making the military organization more agile in the battlespace by improving its ability to share situational awareness and understanding. It aspires to convince a unit's Commander, intelligence officers, and operational planners to strive for a structured set of common mental models defining the battlespace, before engaging in operational planning.

Moffat, J., Scales, T., Taylor, S., & Medhurst, J. (2010). ***Quantifying the Need for Force Agility*****. In Proceedings of the 15th ICCRTS, Santa Monica, CA, June 22-24. Washington, DC: DoD CCRP.**

In this paper, we address the question of the likely nature of the future conflict environment, and the need for force agility in dealing with this environment. The approach we take is to characterise this future conflict environment through five dimensions, drawn from UK work on global futures. We define metrics for each of these dimensions, and show, by looking back over the past 60 years, that it is possible to characterise these dimensions in quantitative terms. This analysis was applied across the US, UK, France and Israeli experience. It shows that in essence, random factors dominate the space, and thus agile forces are required to deal with this essentially random walk across the space of likely conflicts in the future (assuming that the future reflects this

recent history). The statistics involved also show characteristics of complexity such as power law ‘fat tails’ in the distributions. By projecting these distributions forward, we show how it is also possible to begin to quantify the likelihood of extreme shocks of certain types in the future.

Moffat, J., Scales, T., Taylor, S., & Medhurst, J. (2011). Quantifying the need for force agility. *The International C2-Journal, 5*(1), 1–25.

In this article, we address the question of the likely nature of the future conflict environment, and the need for force agility in dealing with this environment. The approach we take is to characterize this future conflict environment through five dimensions, drawn from UK work on global futures. We define metrics for each of these dimensions, and show, by looking back over the past 60 years, that it is possible to characterize these dimensions in quantitative terms. This analysis was applied across the US, UK, French, and Israeli experience. It shows that in essence, random factors dominate the space, and thus agile forces are required to deal with this essentially random walk across the space of likely conflicts in the future (assuming that the future reflects this recent history).

Moorman, C., & Minner, A.S. (1998). Organizational improvisation and organizational memory. *The Academy of Management review, 23*(4), 698–723.

We define organizational improvisation as the degree to which the composition and execution of an action converge in time, and we examine the theoretical potential of this definition. We then propose that both organizational procedural memory (skill knowledge) and declarative memory (fact knowledge) moderate improvisation's impact on organizational outcomes in distinct ways. We also suggest that improvisation influences organizational memory by (1) generating experiments and (2) permitting the development of higher-level competency in improvisation. Contemporary technological changes related to the nature of organizational memory intensify the salience of these issues.

NATO STO SAS-065 (2010). ***NATO NEC C2 Maturity Model*** **(CCRP Publication Series). Washington, DC: DoD CCRP.**

Two key realities dominate thinking about command and control (C2) in the 21st century. The first is the nature of the 21st century military mission space. This space is characterised by its extreme uncertainty. In addition to the high intensity combat operations that are traditionally associated with military operations, the 21st century mission space has expanded to include a wide spectrum of mission challenges, ranging from providing support to multi-agency disaster relief operations to complex coalition efforts within a political-military environment involving a large variety of military and non-military actors; which we describe as Complex Endeavours. The second reality is the ongoing transformation of 21st century militaries, and for that matter, other 21st century institutions and actors from the Industrial Age to the Information Age. With this transformation comes the ability to leverage new information technologies. This has had, and will continue to have, a profound effect on how institutions manage themselves and how they can work with coalition partners. These fundamental realities put the emphasis on command and control (C2), interpreted in its broadest sense to include acquiring, managing, sharing and exploiting information, and supporting individual and collective decision-making. In particular, more mature C2 includes the ability to recognise situational change, and to adopt the C2 approach required to meet that change which we term C2 Agility. The NATO NEC C2 Maturity Model (N2C2M2) we have developed builds on dearly won insights from the past, but goes beyond them in order that we can exploit Information Age approaches to address these new mission challenges. This way of thinking about C2 is thus entirely compatible with current NATO Allied Command Transformation (ACT) thinking on Future Capable Forces which puts the emphasis on Mission Command within federated complex environments and ad hoc coalitions.

NATO STO (2013). *C2 Agility – Task Group SAS-085 Final Report* (STO Technical Report STO-TR-SAS-085). Brussels, Belgium: NATO Science and Technology Organization.

Agility is the capability to successfully effect, cope with, and/or exploit changes in circumstances. While other factors will also influence outcomes, C2 Agility enables entities to effectively and efficiently employ the resources they have in a timely manner in a variety of missions and circumstances. SAS-085 was formed to improve the understanding of C2 Agility and assess its importance to NATO. SAS-085 accomplished these objectives by articulating the principles of C2 Agility, in the form of a C2 Agility Conceptual Model, substantially validating this model and establishing the importance of improving C2 Agility with empirical evidence obtained from a set of retrospective case studies and simulation-based experiments. Further, it identified next steps toward practical implementation in NATO operations and priorities for increasing the rigor and practicality of methods for measuring and improving C2 Agility.

Perrow, C. (1984). *Normal accidents: Living with high risk technologies*. New York: Basic Books.

No abstract available.

Rankin, R., Dahlbäck, N., & Lundberg, J. (2013). A case study of factor influencing role improvisation in crisis response teams. *Cognition, Technology & Work, 15*(1), 79-93.

Common characteristics of crisis situations are ambiguous and unplanned for events. The need for improvised roles can therefore be an imperative factor for the success of an operation. The aim of this study is to deepen the understanding of the processes taking place during improvised work ‘‘as it happens’’. A case study of a crisis management team at work is presented and provides an in-depth analysis of the information and communication flow of persons acting in improvised roles, including con- textual factors influencing the task at hand. The analysis suggests that three main factors lay behind

decreased per- formance by the team when some of its members were forced to take on roles for which they lacked professional training; lack of language skills, lack of domain knowledge and insufficient organizational structure of the tasks. Based on the observations from this case study, we suggest three ways of improving a team's performance and hence resilience when forced to improvise due to lack of personnel in one or more required competence areas. These are training to take on the responsibility for tasks or roles outside ones professional area of specialization, developing formal routines for changes in roles and tasks and developing and using tools and routines for information sharing.

Rassmusen, J. (1997). Risk Management is a dynamic Society: a modelling problem. ***Safety Science, 27*** **(2-3), 183-213.**

In spite of all efforts to design safer systems, we still witness severe, large-scale accidents. A basic question is: Do we actually have adequate models of accident causation in the present dynamic society? The socio-technical system involved in risk management includes several levels ranging from legislators, over managers and work planners, to system operators. This system is presently stressed by a fast pace of technological change, by an increasingly aggressive, competitive environment, and by changing regulatory practices and public pressure. Traditionally, each level of this is studied separately by a particular academic discipline, and modelling is done by generalising across systems and their particular hazard sources. It is argued that risk management must be modelled by cross-disciplinary studies, considering risk management to be a control problem and serving to represent the control structure involving all levels of society for each particular hazard category. Furthermore, it is argued that this requires a system-oriented approach based on functional abstraction rather than structural decomposition. Therefore, task analysis focused on action sequences and occasional deviation in terms of human errors should be replaced by a model of behaviour shaping mechanisms in terms of work system constraints, boundaries of acceptable performance, and subjective criteria guiding adaptation to change. It is found that at present a convergence of research paradigms of human sciences guided by cognitive science concepts supports this approach.

A review of this convergence within decision theory and management research is presented in comparison with the evolution of paradigms within safety research.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences, 4*(2), 155-169.

The search for scientific bases for confronting problems of social policy is bound to fail, because of the nature of these problems. They are "wicked" problems, whereas science has developed to deal with "tame" problems. Policy problems cannot be definitively described. Moreover, in a pluralistic society there is nothing like the undisputable public good; there is no objective definition of equity; policies that respond to social problems cannot be meaningfully correct or false; and it makes no sense to talk about "optimal solutions" to social problems unless severe qualifications are imposed first. Even worse, there are no "solutions" in the sense of definitive and objective answers.

Spaans, M., Spolestra, M., Douze, E., Pieneman, R., & Grisogono, A. (2009). *Learning to be Adaptive*. Proceedings of the 14th ICCRTS, Washington, DC, June 15-17. Washington, DC: DoD CCRP.

This paper builds on earlier work, where we investigated the adaptive use of networks to generate an Adaptive Task Force. Several of the conclusions dealt with the rich set of possibilities to use feedback and lessons learned to increase the effectiveness and adaptivity of the force generation process, an aspiration embraced by most defense organizations, including our own. We here develop more detail about the distributed learning processes that are necessary to foster a learning culture throughout the organization, and in particular, to extract lessons from deployed operations and training exercises, explore, refine and assess these lessons and implement them in an appropriate way. Drawing on the problems defense organizations face today in their complex endeavors, and inspired by theoretical understanding of adaptation and the principles and practice of learning organizations, we discuss the factors that impede or facilitate learning, and learning to

learn. A key approach which we will discuss in some detail is the Adaptive Stance. Our focus is specifically on fostering the forms of adaptivity that complex defense challenges demand, and on the particular role of C2 in enabling them. Although we recognize that top-down design alone is not sufficient to create an adaptive organization with the desired properties, we propose a set of principles which may guide organizational design decisions along a growth path towards greater effectiveness in a dynamic and complex environment.

Trotter, M. J., Salmon, P. M., & Lenné, M. G. (2013). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science, 14*(5), 475–498.

Interest in the potential of improvisation to enhance safety outcomes in safety critical situations has been increasing; however, improvisation also has the potential to make emergency situations worse rather than better. If organisations are to capitalise on improvisation's potential to produce safety benefits, a model of the factors that influence its effectiveness in safety critical situations is needed. This review draws together what is currently known about the factors influencing improvisation and the methods used to examine them. The review reveals that, unlike most contemporary ergonomics concepts, as yet no research has examined factors beyond organisational boundaries or examined the interactions of factors across different systems levels, both integral components of systems-based models. In closing, discussion is presented on the most appropriate research agenda for enhancing understanding of improvisation and its influencing factors.

Turcotte, I., Tremblay, S., Farrell, P., & Jobidon, M.-E. (2013). *Using a Functional Simulation of Crisis Management to Test the C2 Agility Model Parameters on Key Performance Variables*. Proceedings of the 18th ICCRTS, Alexandria, VA, June 19-21. Washington, DC: DoD CCRP.

Increasingly, military and security organizations face the challenge to develop organizational structures and technologies that promote the agility required to deal with today's complex operational environment.

Organizational agility (or command and control (C2) agility) has been defined as transitioning from one governance and management (GM) approach (or C2 approach) to another as required by situation complexity (SAS-065, 2010; SAS-085, draft). This paper describes a study that aimed to test key concepts of the Organizational Agility model (Farrell, 2011; Farrell & Connell, 2010; Farrell, Jobidon, & Banbury, 2012). The study focused on two approaches – de-conflicted and collaborative – and tested the model's parameters of resistance and size under varying levels of complexity. C3Fire, a forest firefighting simulation, was used as task environment. It allowed varying contextual and organizational characteristics to create conditions where a transition can arise, and the emergent behaviours displayed by participants can be observed. Teams of four and six participants were trained in the two GM approaches and completed experimental scenarios including combinations of resistance and complexity. Several metrics were used to assess teams' response, how they adjust their GM approach and how situational changes and approach transition impact team performance and teamwork. Initial findings are presented and discussed.

Vera, D., & Crossan, M. (2004). Theatrical Improvisation: Lessons for Organizations. *Organizations Studies, 25*(5), 727–749.

This article uses the improvisational theatre metaphor to examine the performance implications of improvisational processes in firms. We recognize similarities and differences between the concepts of performance and success in both theatre and organizations, and extract three main lessons from improvisational theatre that can be applied to organizational improvisation. In the first lesson, we start by recognizing the equivocal and unpredictable nature of improvisation. The second lesson emphasizes that good improvisational theatre arises because its main focus, in contrast to the focus of firms, is more on the process of improvising and less on the outcomes of improvisation. Lastly, in the third lesson, we look at the theatre techniques of 'agreement', 'awareness', 'use of ready-mades', and 'collaboration', and translate them into concepts that are relevant for organizations in developing an improvisational capability.

Walker, G. H., Stanton, N. A., Salmon, P. M., & Jenkins, D. P. (2008). A review of sociotechnical systems theory: a classic concept for new command and control paradigms. *Theoretical Issues in Ergonomics Science*, *9*(6), 479–499.

Command and control is the management infrastructure for any large, complex, dynamic resource system (Harris, C.J. and White, I., 1987. Advances in command, control and communication systems. London: Peregrinus). Traditional military command and control is increasingly challenged by a host of modern problems, namely, environmental complexity, dynamism, new technology and competition that is able to exploit the weaknesses of an organisational paradigm that has been dominant since the industrial revolution. The conceptual response to these challenges is a new type of command and control organisation called Network Enabled Capability (NEC). Although developed independently, NEC exhibits a high degree of overlap with concepts derived from sociotechnical systems theory, a fact that this paper aims to explore more fully. Uniquely, what sociotechnical theory brings to NEC research is a successful 50 year legacy in the application of open systems principles to commercial organisations. This track record is something that NEC research currently lacks. The paper reviews the twin concepts of NEC and sociotechnical systems theory, the underlying motivation behind the adoption of open systems thinking, a review of classic sociotechnical studies and the current state of the art. It is argued that 'classic' sociotechnical systems theory has much to offer 'new' command and control paradigms. The principles of sociotechnical systems theory align it exceptionally well with the challenges of modern organisational design. It is also reflective of a wider paradigm shift in ergonomics theory away from 'industrial age' modes of thought to systems-based 'information age' thinking.

Walker, G. H., Stanton, N. A., Salmon, P. M., Jenkins, D. P., & Rafferty, L. (2009). *Combining Social Network Analysis and the NATO Approach Space to Define Agility*. Proceedings of the 14th ICCRTS, Washington, DC, June 15-17. Washington, DC: DoD CCRP.

This paper takes the NATO SAS-050 Approach Space, a widely accepted model of command and control, and gives each of its primary

axes a quantitative measure using social network analysis. This means that the actual point in the approach space adopted by real-life command and control organizations can be plotted along with the way in which that point varies over time and function. Part 1 of the paper presents the rationale behind this innovation and how it was subject to verification using theoretical data. Part 2 shows how the enhanced approach space was put to use in the context of a large scale military command post exercise. Agility is represented by the number of distinct areas in the approach space that the organization was able to occupy and there was a marked disparity between where the organization thought it should be and where it actually was, furthermore, agility varied across function. The humans in this particular scenario bestowed upon the organization the levels of agility that were observed, thus the findings are properly considered from a socio-technical perspective.

FOI, Swedish Defence Research Agency, is a mainly assignment-funded agency under the Ministry of Defence. The core activities are research, method and technology development, as well as studies conducted in the interests of Swedish defence and the safety and security of society. The organisation employs approximately 1000 personnel of whom about 800 are scientists. This makes FOI Sweden's largest research institute. FOI gives its customers access to leading-edge expertise in a large number of fields such as security policy studies, defence and security related analyses, the assessment of various types of threat, systems for control and management of crises, protection against and management of hazardous substances, IT security and the potential offered by new sensors.

FOI
Swedish Defence Research Agency
SE-164 90 Stockholm

Phone: +46 8 555 030 00
Fax: +46 8 555 031 00

www.foi.se