The lack of convergence between C^2 theory and practice[☆]

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Abstract

The purpose of this article is to discuss and make conclusions from more than 15 years research within the field of C^2 and what possible impact that has been accomplished. The point of departure is accordingly a paper presented just after the shift of the millennium where the possible impact of novel ideas and technologies for command and control (C^2), such as the network centric approach and radical views on the design of command posts were in focus. Some of the fundamental ideas of what was in vogue at the time was questioned and the "old" was put in contrast with the "new." Looking back, our thoughts as well as other contributors from that time, and the progression of theory within the field of C^2, we suggest that we are at a status quo. What actually has been achieved, may be the worst of the two straw men worlds that where suggested at the time. We suggest that it is necessary to: 1) further develop adaptive approaches to the organization and conduct of military operations, 2) develop enabling instead of controlling technologies, 3) switch focus from structure to function, 4) develop tools for assessing adaptive capacity in socio-technical systems.

Keywords: Command and control, Decision support, Information Interfaces and Presentation.

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1. Introduction

Historically, the design of military C^2 systems has been formed by the development of warfare as it looked in the beginning of the 19*th* century. At that time, changes in conditions how to exert warfare created a problem of information delays where commanders on central levels became unable to maintain an adequate appreciation of the tactical situation. Accordingly, real-time command became a practical impossibility [1]. Rigid planning was commonly used to cope with the "fog of war" and delays in communication. With the introduction of wired communication such as the telegraph and the telephone, planning and coordination of efforts could be centralised to some degree, although alterations of plans still was largely absent as communication with moving units still was impossible in practice. This was reflected in the tactics of WW I where large operations could be planned and initiated, but successful operations could rarely be exploited as the C^2 structures and systems of the time were unable to coordinate action once fighting had commenced. The introduction of radio communication allowed commanders in WW II to coordinate action in near real time and fight in a much more dynamic way. However, achieving shared situational awareness and coordinating large forces still remained a challenge to C^2. From the aftermath of the United States victory in the 1991 Gulf War against Iraq, introduction of information and communication technology (ICT) on the battlefield seemed to provide new means to overcome such problems. By appropriate utilisation of ICT, it seemed to create "information superiority" that promised a "revolution in military affairs" (RMA), which created a huge interest from military actors and industrial suppliers.

Initiatives from the US military and various industrial suppliers led to a number of experiments and extensive concept development with the aim to exploit the technological advances that operation Desert Storm foreshadowed. The ideas, emerged in the US, led to the concept of network centric warfare (NCW) [2, p. 21]:

> [The prime] objectives were to make the battlefield more transparent, to achieve "information dominance" and create situational awareness at all command levels, to disseminate target information in a timely manner to those who needed it, and to adjust command and control doctrine accordingly. The objective was to shorten the "sensor-to-shooter" time, and to improve responsiveness. In short, the US military aimed to improve military effectiveness on three different axes: lethality, visibility, and agility.

Nevertheless, the ideas behind NCW were not an isolated phenomenon for development of the US Armed Forces and its C^2 doctrines. Most Western countries had its counterparts, so also Sweden and Norway with their aim of transforming their Armed Forces to a network based defence (NBD), and the UK Defence transformation against network enabled capability (NEC). In this context, the ROLF 2010 project[2] was an effort launched in Sweden [3, 4]. The project aimed to develop a new type of mobile environment for exercising command, which should focus on collaboration, creativity, and sense-making while simultaneously dramatically reduce the size of a staffs on higher levels of command. Instead of having a fixed staff in a designated C^2 centre, a number of mobile units (containers) should be rapidly deployed wherever needed or appropriate. The size of the staff should be reduced from several hundreds of persons to around 80, including supporting personnel. This was intended to be achieved by automating large part of the information handling and presentation, from the sensor all the way to presentation of the current situation for decision makers. Furthermore, collaboration and creativity was supposed to be encouraged by design of novel decision support systems, efficient changes to work processes, and a completely new work environment [3, 5]. The output of the project, except for several publications, was a research facility, the ROLF-laboratory, located at the Swedish Defence University (SDU).

The ROLF-laboratory at SDU consisted of computer networks, multiple displays and, most importantly, an experimental setup of furniture and information technology where exercises and experiments could be conducted. The commander and his or her participating members of the staff was grouped around a table with a large horizontal display, which would serve both as a table and as an interactive work surface (figure 1).

[2]ROLF 2010 is a Swedish acronym that stands for a joint mobile command and control system intended for use after the year of 2010.

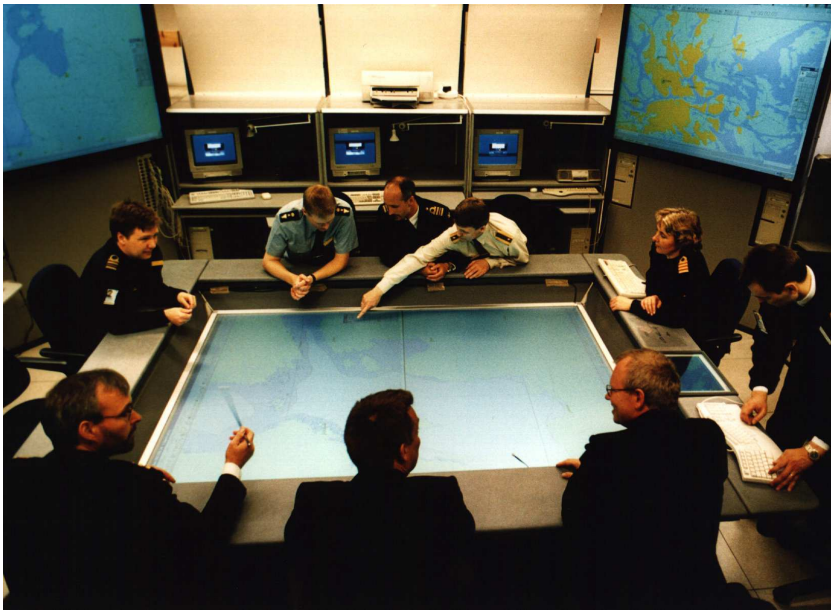

Figure 1: Exercise in the ROLF 2010 joint mobile command and control laboratory.

In theory, both the ROLF 2010 vision and its setting should harmonize well with the suggestions expressed in network centric warfare (NCW). In addition, the ROLF 2010 vision was supposed to fulfil the "prophecy" put forward by Cebrowski and Garstka in their article [6] where a decisive shift in the theory and practice of warfare was presented. The article by by Cebrowski and Garstka also became an important contribution for the development of NCW. Here, NCW was presented in contrast to "platform centric warfare (PCW)," which had dominated warfare throughout the 20*th* century.[3] PCW is characterised by its design to support industrial-age organisation and processes. This has led to rigid, top down hierarchical organisations emphasising centralised planning and coordinated execution across a coherent battlefield. Furthermore, PCW information architectures are characterised by for example, hierarchical information flows, voice communications, limited interoperability, and stove-piped C^2 systems [7, 8, 9]. Thus, systems that are engineered according to the principles of PCW often implies that communication between different platforms' C2 functions are difficult, if even possible. From this follows that it can be difficult to achieve synergy effects between different platforms and branches of the armed forces in

[3]In the military context, a platform can be any military structure or vehicle that bear weapons.

question. An example where such synergy effects could emerge is when one platform can use and combine its own sensor data with another platform "sensors" to ameliorate its assessment and awareness of a situation. Since most platforms and C^2 systems are specialised for their specific purpose, such possibility of data exchange is rare. In addition, to prevent that different platforms engage each other by accident it is often necessary to divide their areas of responsibilities—geographically and/or in time [10, p. 89, 94]. This is today referred to "deconflicted" command and control [11]. Both NCW and the ROLF-concept was suggested as a way to harmonize C^2 and avoid conflicts between entities on the battlefield. This was supposed to be achieved by allowing commanders jointly engage in problem-solving and synchronization of intent and action.

From an analogy of how multinational enterprises compete on the market, Cebrowski and Garstka [6] developed and applied a perspective whereby the NCW concept grows from society and societal changes. By comparing contemporary Information Age concepts, co-evolving business processes, economics, and organisations with the military, they stressed that battle time plays a critical role and thus is analogous to the new and time competitory economic model. A widely accepted definition of NCW was provided by Alberts, Garstka, and Stein [9, p. 2]:

> We define NCW as an information superiority-enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and a degree of self-synchronisation.

Hence, the ideas behind the NCW concept were intertwined with theories and ideas for everything between advances in ICT to the debate of societal changes due to our way of entering the so called Information Age [12, 13, 14, 15, 16, 17, 18, 19]. Furthermore, by implementing NCW Cebrowski and Garstka argued that it would allow development of increased speed of command and enable forces to organise from bottom-up by self-synchronisation to meet the commander's intent [6]. The concept of developing these capabilities was later labeled "Edge C^2" [20].

With this as background, we conclude our brief summary from earlier efforts to develop C^2 systems and try to compare what really has been accomplished from the early days of RMA. For our further discussion the authors will revisit

some of the core arguments from an earlier article published fifteen years ago [21]. Table 1 depicted below was part of that publication. It was created as an effort to understand similarities and differences between the reality of C^2 and the visions described in the NCW publications from that time. Particularly, it intended to illustrate differences in the conditions for exercising command in future military organisations.

Table 1: Characteristics of traditional C^2-systems compared with envisioned C^2-systems. Adapted from [21].

"Traditional" C^2-systems	**"Envisioned" C^2-systems**
• Organized in hierarchies. • Information distributed over a variety of systems, analogue and digital. Most common medium is text- or verbal communication. • Data is seldom retrieved directly from the sensor by the decision-maker. It is rather filtered through the chain of command by humans that interpret it and aggregates it in a fashion that they assume will fit the recipient. • Presentation of data is handled "on spot", meaning that the user of the data organises it him/her self, normally on flip-boards or paper-maps. The delay between sensor registration and presentation depends greatly on the organizational "distance" between the sensor and the receiver	• Organized in networks. • All information is distributed to all nodes in the system. Anyone can access data in the system. • Powerful sensors support the system and feed the organisation with detailed information. • Data is mostly retrieved directly from sensors. Filtering or aggregation is done by automation. • Presentation is done via computer systems. Most data is presented in dynamic digital maps. The time between data retrieval and presentation is in real or near real-time. • It is possible to communicate with anyone in the organisation, meaning that messages do not have to be mediated via different levels in the organisation.

Aside from the significant differences between the two concepts, the table also outlines the main characteristics of future technologies, which in a sense do not differ much from what is envisioned today. Whereas NCW can be regarded as a conjecture or theory of future C^2, it also has to be instantiated in a form that reflect its characteristics and claims more in detail. In [22, p. 4-26] a hierarchical arrangement of the NCW characteristics is suggested to consist of five levels. These levels depend only on those at the same level or lower in the hierarchy (table 2).

Efficient use of technology is not only the only thing that is required to respond to dynamic situations. Development of C^2 methodology and ability to change the organisation is also examples of necessary capabilities to meet such demands. So far, we have delineated how the research and theories were revealed when the authors' previous paper was published. From here, the development of C^2 theory until today will be further described and discussed.

Table 2: The characteristics of a network-centric military system arranged as a hierarchy. Adapted from [22]

Top level—force-level characteristics: • speed of command • self-synchronization • effects-based operations • information superiority • force agility and massing of effects • shared situational awareness • reachback • interoperability
Second level—characteristics of decisions: • speed • soundness
Third level—characteristics of information: • relevance • clarity • accuracy • comprehensibility • value • timeliness • consistency • secrecy • degree of interoperability • agree, currency • completeness • autheticity
Fourth level—general characteristics of networks: • availability • reliability • concurrency • survivability • coverage, homogeneity • security
Base level—physical properties: Bandwidth, network topology, server speed, etc.

2. The assumed emergence of future C^2 systems

Going back, figure 1 illustrates the envisioned use of not only new forms of interactive technologies, but also of how C^2 as an activity could be performed in the ROLF-laboratory. So, while a demo-environment depicting a command cell was created, it had far-stretching implications on how the subordinate entities should be organised and connected.

At the time of the original paper, the authors of this paper were both PhD students, working on the problem of understanding what the NCW theories in fashion at the time could provide in terms of improved C^2-processes as well as on possible effects on group- and teamwork. This work resulted in several publications that discussed various topics of collaborative C^2, decision-making, socio-technical systems and methods for studying C^2 [23, 24, 25, 26, 27, 21, 28].

Departing from the ROLF 2010 vision and the contents of table 1 that outline the differences between traditional and envisioned C^2, we would like to discuss what the current state-of-affairs in military C^2 looks like and in what way the visions and ideas that emerged around 15 years ago has been realised or not, and what that possibly means for our possibilities to exercise efficient C^2 and

"successfully effect, cope with and/or exploit changes in circumstances" as envisioned in the agility work of [29].

The definition of NCW and its objectives suggested that ICT will provide all levels of command with the same data, information, and knowledge in real or near real-time of an operation. So, while table 1, presented in the original paper mostly describes how work was done and how it was envisioned to be done, table 2 presents the assumed benefits/effects being able to reach the top-level characteristics of NCW by implementing the right-hand column in table 1. Following the concept of NCW, utilisation of future ICT gives promise to bridge the problem of information delays on central levels of command. Accordingly, it seems that the NCW application of ICT again will provide means for central levels of command to exercise or directly influence C^2 on subordinate (tactical) levels. However, NCW also aims for subordinate (tactical) units to freely act and coordinate themselves upon a situation without having to obtain approval from above as long as the purpose of the activities meet the superior commander's intent. Thus, the philosophy behind NCW seems to provide means where the exertion of C^2 can stretch all between highly centralised or decentralised C^2. This line of thought has been developed further in more recent conceptual work, which will be presented in the following chapter, and thereafter discussed in relation to concurrent military practice.

3. Current state of theory - adaptive capacity to cope with complexity

A more comprehensive view of the bindings between technology, organisation and command approach has been developed within the more resent concepts of "agility" and "C^2 agility." These theories have emerged as a consequence of the challenges that emerged from trying to introduce NCW during the past fifteen years. Since the NCW challenged the traditional view of command and control, several research teams performed elaborate conceptual work in order to create a model that could be used for discussing C^2 in relation to technical, organisational and command challenges [20, 30]. A widely used model is the "C^2 approach space," which is described and explained for example in [20]. The C^2 approach space describes different types of C^2 in terms of allocation of decision rights, information dissemination, and interactions between entities (see figure 2).

An archetypal hierarchical organisation, depicted as "deconflicted C^2" in figure 2, would have a limited allocation of decision rights, limited information dissemination and few interactions between entities in the organisation as decisions are made only at the top nodes of the organisation. In such an

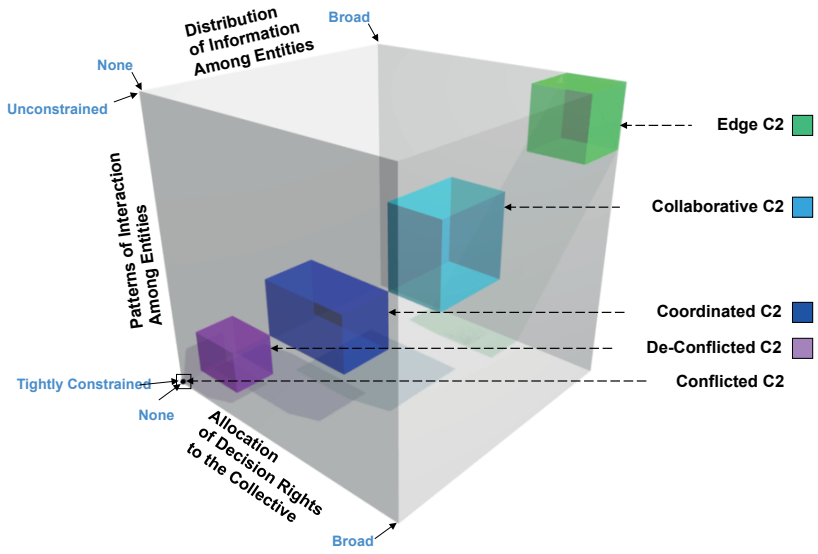

Figure 2: The C^2 Approach space. Adapted from [22]

organisation, information is only shared among high-level decision makers where the units of the organisation only need to interact with units above or below them in the organisational chart. A highly networked, "edge" organisation is envisioned to be highly networked in terms of information sharing and interactions, as well as non-hierarchical in terms of allocation of decision rights, suggesting that it would position itself in the opposite position of a traditional hierarchical organisation in the C^2 approach space. The C^2 approach space is an important tool for discussing characteristics of different organisations in the debate surrounding the hypothetical usefulness of network-centric organisations and technologies.

The NATO STO SAS-085 report defines agility as the "capability to successfully effect, cope with and/or exploit changes in circumstances" [29, p. 21]. The purpose of this capability is primarily to keep the own organisation(s) ("the self" or the "entity" or "the collective" when referring to a multitude of cooperating entities) within acceptable performance bounds. This can partly be achieved by being command and control agile, meaning that the actual command and control (e.g., viewed as a system or as an organisation) can be re-arranged in order to better fit the current or foreseeable future situations. Alberts and Hayes [31] argue for the need to be agile, the ability to move from one C^2 approach to another, as an alternative to the dominant interpretation 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) opportunities provided by advances in technology, particularly information technologies [31]. Further, the NATO STO SAS-085 report defines command and control agility as the ability the organisation(s) must have to be able to monitor own behaviour in relation to the ongoing situation and also have the ability and willingness to adjust its current way of working. Hence, agility refers to the capacity to cope with change independent of how this is achieved. Command and control agility refers to the ability to do so by adapting the way the organisation functions or is structured, most primarily by adjusting information dissemination or the allocation of decision rights [32, 29]. Such an adaptation can be described as movement within the C^2 approach space presented above (see figure 2).

However, it is important to recognise that we are discussing theoretical concepts here rather than actual C^2 systems or organisations. Accordingly, theory has developed over the last decade, and suggests that not only technology, but also organisations must be willing to adapt to different challenges. In terms of what has been realised in practice, the achievements have been very limited. Instead, the road to realisation of NCW (or edge) capabilities have been painfully slow. Technological prerequisites has only been implemented in a very limited way. Organisational change seems to be largely absent.

4. An example of adaptive capacity in the military domain

There are examples of military organisations with the ability to adapt their organisation to circumstantial changes. For example, in Sweden a clear difference between command of naval forces and command of army forces is that levels of command changes depending on organisation, task, and function. In peacetime, the basic organisation of the Swedish navy is focused on training and production of units for the war time organisation. Under these circumstances, units are organised into flotillas, squadrons, battalions, and companies with a traditional hierarchical command structure. In contrast, when actual operations are carried out, the principle is to form an organisation optimised for the specific task. Viz., a Task Organisation (TaO), consisting of up to four levels of command. No new elements are normally added to the TaO (or replaced). It is just the organisational structure that is adjusted. For example, it is normally the flotilla staff that forms the basis for the staff of a task-group, which become one of the

levels. For command of functions an additional organisation is applied in parallel with either the task organisation or peace-time organisation. This organisation is labelled Warfare organisation (WaO) and concern three different functions: anti surface warfare, anti-submarine warfare, and anti air defence. The Task Group commander (TGC) is free to define the command structure for the WaO in the manner considered most suitable for solving the missions/tasks assigned. The TGC can appoint a Composite Warfare Commander (CWC) if the TGC considers it necessary. The CWC coordinate all functions, delegate anti surface warfare and anti submarine warfare to a Sea Combat commander, delegate the command to a principal warfare commander, alternatively take the role himself. Delegation of command can be with restrictions, such that the command rights only concern a specific task or area. Anyhow, the general responsibilities always remain with TGC. In addition, the TGC can also delegate command according to geographical sectors or sector warfare commanders. In the Swedish Navy, subordinate commanders to TGC have similar options to design their command structure. One implication from the WaO is that a commander responsible for a function; for example a Principal Warfare Commander (PWC) for Anti-Submarine Warfare (ASW) , also might have mandate to exert command over weapon and sensor systems on other task elements/vessels than the one actually assigned.

To conclude, the naval example shows that it is possible to implement more adaptive ways of conducting C^2 in a military organisation. Functions, as well as the right to command (decision rights) are, by necessity, moved across structures as the navy physically is bound to its structure (vessels).

The naval example also provides a scenario that applies to what can be considered as "the system approach," which is based on the same type of systems thinking that has driven the development of NEC/NCW and C^2 agility theory described earlier in this text. System thinking theories suggest that the system approach, system thinking, and the socio-technical system approach should be considered when developing desirable capabilities of C^2, as well as methodological and technological support for exerting C^2. System approaches are also viewed as means for handling uncertainties and complexities of emerging and dynamically evolving situations. Situations with emerging properties create needs for adaptiveness of both the C^2 function and its capability to utilise available resources to adapt to such situations. The system approach and system thinking are fundamentally different from the thinking that traditionally has formed the military theory and its origin. Where military theory used to be based on the mechanistic concept, it consequently focused on analytical thinking and reductionism. In contrast, the system approach has a

focus on synthetic (systemic) thinking and expansionism. Accordingly, system thinking calls for a different perspective where; for example, relations and interfaces between elements become focus to understand, think, and act upon systems viewed as wholes. Applying a system approach to the naval example, we find the system coupling diagram introduced by Lawson [33, 34] appropriate to illustrate this (figure 3).

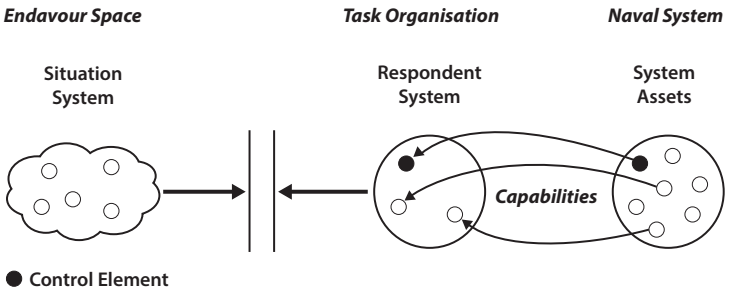

Figure 3: The system coupling diagram applied on a maritime situation. Adapted and modified from [33,34]

Situation systems (as shown i figure 3) that are dynamic and thus demand varying kinds of response, are challenging to any organisation in the sense that the organisation must decide how to put together the respondent system. The maritime system viewed as a whole can be thought of as located in an endeavour space and described in terms of contributing elements (naval units) and relationships (command rights, ITC systems etc.). Accordingly, it is also possible to think of, and view, the navy and its activities in terms of the situation system and the response system where the naval units are the system assets. For the navy to handle the maritime situation system, a respondent system can be created from available assets (people and equipment) including a control element. In the example, the respondent system is equivalent with a temporarily composited TaO that is put into action.

Consequently, by utilising and supplying elements with proper capabilities to form the TaO, an adaptive and suitable response system can be compounded that can manage the situation at hand. In addition, by always provide a control element; for example, the Composite Warfare Commander (CWC), the respondent system is possible to be put into operation and act independently to resolve its task. Although naval C^2 never originated from NEC/NCW or C^2 agility theory, it shows how the context of naval operations have shaped C^2 to include principles and methods that

present a degree of flexibility and a preparedness to adapt C^2 to the situation at hand. This development is most likely also a consequence of the fact that the navy regularly exercise while conducting normal operations as well as operate in a highly distributed manner (geographically), suggesting that naval units must have the ability to rapidly coordinate and work with whatever units that happen to be in the vicinity. The context and historical development of the organisation thus seem to be a strong driver towards adaptiveness, far stronger than technical or theoretical development.

5. Discussion

This paper has discussed the development of military socio-technical systems during the last 25 years. The NCW/agile theory development suggests that systemic effects (e.g., emergence) can be created by increasing the "connectedness" in the military organisation while introducing a more flexible approach to coupling between nodes/entities. The envisioned enabler for doing so was and is information technology. However, it also demands a willingness to change fundamental aspects of the military organisation, something that is a much larger effort than investing in technology. There are many examples from the civilian sector where new businesses exploit the possibilities of ICT while refraining from applying traditional, Tayloristic or hierarchical approaches to organisation.

Instead, our impression is that military organisations have embraced information technology as a means for increasing internal control while preserving existing structures. This focus on preserving structure and control to achieve specific ends is in stark contrast to the adaptive functional approach that focus on how functions can manifest in different ways over a multitude of structural configurations.

In terms of theoretical development, current C^2 concepts suggests a systemic socio-technical approach with emergent capacity in terms of adaptiveness as a mean for coping with complexity and uncertainty. Military development have instead kept on investing in the idea that systems should be deterministic by reductionist approaches to technology; i.e., technology as a mean for increasing control in a futile attempt to produce predictable outcomes of military activity. However, the rapid change in the nature military operations challenges the latter approach as the concurrent problem space demands flexibility and adaptive capacity rather than highly predictable behaviours.

Why does military organisations seem to have difficulties adapting new ways of working or organising themselves? One factor that seem far more challenging than merely introducing new technologies seems to be military culture. The military profession is so deeply associated with the concept of hierarchy in command and control that more adaptive approaches to managing military forces seem to be very far away. Tradition is in many ways the fundamental structure upon which the military profession is built. Indeed, the entire career system is based on the idea that you climb the "command ladder." Adapting a networked organisational structure fundamentally challenge this basic assumption of military practice. While many military professionals embrace concepts like adaptiveness and problem solving when it comes to pragmatic issues in the field, they seem less apt to abandon the idea of rank and command.

Yet, anyone can see the difficulties that arise when military organisations clash with loosely coupled organisations like terrorist cells or insurgents that do not follow the same type of logic. Such organisations are based on, and motivated by, common intent but lack the orchestration of a professional military organisation. While military organisations can achieve high degrees of coordinate action, loosely coupled networks like terrorist organisations has a higher degree of freedom in terms of action. The emergent effect of having loosely coupled organisations with a high degree of common intent is the ability to react rapidly and seize opportunity. This ability is clearly desirable also from the viewpoint of a "traditional" military organisation. However, it comes at the sacrifice of centralised control, suggesting that trade-offs have to be made and that local adaptation of C^2 to changes in circumstances may be needed, as suggested by the NATO STO SAS-085 work [29].

6. Conclusions, remaining challenges and future research

The move towards an organisation based on system theoretical principles such as networked adaptive organisations; for example, as suggested by C^2 agility theory, is filled with challenges. This both in terms of managing changes of current C^2 systems as well as scientific challenges to support development and practical work to achieve system requirements for the future. However, the mindset and the way we think about C^2 and C^2 systems, is probably still the largest challenge. From our point of view, we observe that although C^2 theory has developed over the last twenty years, little has changed regarding organisation of or how C^2 is conducted. Naturally, specific technologies have improved over the years and some of the envisioned tools; e.g., digital maps, have been introduced, but no

way close to the connectedness contemplated or envisioned in the NEC/NCW visions. Indeed, western military powers still struggle with basic NEC concepts such as creating networks and sharing information between organisations (even within the armed forces of individual nations). C^2 is still largely a voice-based and paper map activity conducted in a hierarchical organisation, and will most likely remain so for some time. The adaptive stance towards C^2 envisioned in C^2 agility also seem far away. The lack of convergence between military C^2 theory and military C^2 practice can be explained in several ways, but our retrospective analysis suggests that the gap cannot be explained by a lack of technological innovation or a lack of working examples of networked or adaptive organisations from other domains. Instead, the lack of convergence probably originates from an inability to truly grasp the potential of systems thinking and systems practice. We propose the following points that potentially could increase this understanding and thereby support future change to C^2 practice:

- Further develop the understanding for the need of adaptive approach to organising and conducting military activities. Such work is being conducted, but further efforts are needed in terms of producing educational material, initiating training and exercises that illustrate the need for an adaptive approach to C^2 rather than optimisation/scientific management, and developing theories and understanding of organisational change needed to achieve the mindset required to embrace the possibilities of the system approach, and system thinking.

- Switch the view from controlling technologies to enabling technologies. A large part of today's ICT is designed and implemented to increase internal control within individual organisations, effectively "boxing in" our forces and hampering their ability to interact in an efficient way with other actors. New technologies must be designed and implemented so they support creativity and interaction between different actors that solve unforeseen problems on a *ad hoc* basis. Such an approach to design and procurement of new technologies recognises the fact that the complexity of today's operations prevents us from foreseeing in what situation we will work and with whom we need to cooperate.

- Switch focus from structure to function. Current C^2 thinking is often focused on, and depicted as, structure and process. This "arrow-and-box" stance to understanding C^2 may limit thinking about C^2 in the sense that an organisation, from a structural point of view, is defined by what it *is* and

not by what it *does*. A functional focus allows us to discuss what C^2 is supposed to do, which is a far better point of departure for the development of future organisations.

- Development of methods to achieve a better balance between implementation of technological innovations and proper work procedures adapted for suggested technology. Thereby, it could be easier to achieve desired objectives and better technology exploitation.

- New tools and instruments for assessing adaptive capacity in developing C^2 systems, viewed as a whole and in its own right as a socio-technical system. Current approaches to assessing C^2 typically focus on process or doctrine, based on the idea that a "best practice" exists. Current assessment approaches are generally designed to assure that existing structures and processes work as intended, something that further cement and confirm current practice - the assessment tool thus becomes part of and an enabler of military culture. Theories like C^2 agility suggest that there is no "best practice" in terms of C^2. Instead, assessment approaches should reflect the ability to adapt C^2 to changes in situation complexity and dynamics. This is needed to understand if the complex emergent capacities expected from introducing more interconnected ways of working actually are resulting in the expected capabilities, such as adaptiveness and responsiveness.

References

[1] K. G. Stewart, The evolution of command approach, in: Proc. of the 15*th* International Command and Control Research and Technology Symposium (ICCRTS), DoD Command and Control Research Program, CCRP Publications, Washington, DC, 2010.

[2] F. P. B. Osinga, The rise of military transformation, in: T. Terriff, F. P. B. Osinga, T. Farrell (Eds.), A Transformation Gap?: American innovations and European military change, Stanford Security Studies, Stanford, Calif., 2010, pp. 14–34.

[3] C. Sundin, H. Friman (Eds.), ROLF 2010: A Mobile Joint Command and Control Concept, Försvarshögskolan ACTA C3, Elanders Gotab, Stockholm, 1998.

[4] C. Sundin, H. Friman (Eds.), ROLF 2010 The Way Ahead and The First Step: A Collection of Research Papers, Försvarshögskolan ACTA C6, Elanders Gotab, Stockholm, 2000.

[5] B. Brehmer, C. Sundin, ROLF 2010: Overall Joint Command and Control in Crisies and War, Elanders Gotab, Vällingby, 2005.

[6] A. K. Cebrowski, J. J. Garstka, Network-centric warfare: Its origin and future, U.S. Naval Institute Proceedings 124 (1998) 28–35.

[7] D. S. Alberts, The Agility Advantage: A survival guide for complex enterprises and endeavors, DoD Command and Control Research Program, 2011.

[8] D. S. Alberts, J. J. Garstka, R. E. Hayes, D. A. Signori, Understanding Information Age Warfare, CCRP Publication Series, Washington, DC, 2001.

[9] D. S. Alberts, J. J. Garstka, F. P. Stein, Network-Centric Warfare: Developing and Leveraging Information Superiority, National Defense University Press, Washington, DC, 2 edition, 2000.

[10] W. A. Owens, E. Offley, Lifting the fog of war, Farrar, Straus and Giroux, New York, 1 edition, 2000.

[11] D. S. Alberts, R. K. Huber, J. Moffat, NATO NEC C2 maturity model, Technical Report, DTIC Document, 2010.

[12] M. Castells, The power of identity, volume 2 of *The information age: economy, society and culture*, Blackwell Publishers, Malden, MA, 1997.

[13] M. Castells, End of millennium, volume 3 of *The information age: economy, society and culture*, Blackwell Publishers, Malden, MA, 1998.

[14] M. Castells, The rise of the network society, volume 1 of *The information age: economy, society and culture*, Blackwell Publishers, Malden, MA, 2 edition, 2000.

[15] P. Evans, T. S. Wurster, Blown to bits: How the new economics of information transforms strategy, Harvard Business School Press, Boston, MA, 2000.

[16] L. Groth, Future organizational design: The scope for the IT-based enterprise, Wiley Series in Information Systems, Wiley, Chichester, 1999.

[17] M. Schrage, No more teams!: Mastering the dynamics of creative collaboration, Currency Doubleday, New York, 1 edition, 1995.

[18] M. van Alstyne, The state of network organization: A survey in three frameworks, J Organ Comput Electronic Commer 7 (1997) 83–151.

[19] F. Webster, Theories of the information society, International library of sociology, Routledge, London; New York, 3 edition, 2006.

[20] Nato, RTO, NATO NEC C2 Maturity Model, Technical Report, DTIC Document, 2010.

[21] M. Persson, B. Johansson, Creativity or diversity in command and control environments, in: M. J. Smith, G. Salvendy, D. Harris, R. Koubek (Eds.), Proc. of the 9*th* International Conference on Human-Computer Interaction, HCI International 2001, volume 1, Lawrence Erlbaum and Associates, New Orleans, 2001, pp. 1508–1512.

[22] M. P. Fewell, M. G. Hazen, Network-Centric Warfare: Its Nature and Modelling, Technical Report DSTO-RR-0262, Defence Science and Technology Organisation (DSTO), 2003.

[23] H. Artman, M. Persson, Old practices – new technology: Observation of how established practices meet new technology, in: R. Dieng, A. Giboin,

L. Karsenty, G. De Michelis (Eds.), Designing Cooperative systems: The Use of Theories and Models - Proc. of the 5*th* Int. Conf. on the Design of Cooperative Systems (COOP'2000), volume 58 of *Frontiers in Artificial Intelligence and Applications*, IOS Press, Amsterdam, 2000, pp. 35–49.

[24] H. Artman, Y. Wærn, C. Garbis, B. Johansson, Discourse about technology and use of technology in future crisis management systems, in: Proceedings of the 7*th* International Pragmatics Conference, Budapest, Hungary.

[25] B. Johansson, H. Artman, Y. Waern, Technology in crisis managment systems-ideas and effects, Document Design Journal of Research and Problem Solving in Organizational Communication 2 (2001) 247–258.

[26] B. Johansson, R. Granlund, Y. Wærn, Yvonnern, Research on decision making and new technology–methodological issues, in: B. Brehmer, R. Lipshitz, H. Montgomery (Eds.), How Professionals Make Expert Decisions, Lawrence Erlbaum Associates, Mahaw, New Jersey, 2005.

[27] B. Johansson, M. Persson, R. Granlund, P. Mattsson, C3Fire in command and control research, Cognition, Technology & Work 5 (2003) 191–196.

[28] M. Persson, G. Rigas, Complexity: the dark side of network-centric warfare, Cognition, Technology & Work 16 (2014) 103–115.

[29] NATO-STO-SAS-085, C2 Agility – Task Group SAS-085 Final Report (STO Technical Report STO-TR-SAS-085), Technical Report, The NATO Science and Technology Organization (STO), 2013.

[30] D. Maxwell, SAS-050 conceptual model version 1.0, Technical Report, DTIC Document, 2004.

[31] D. S. Alberts, R. E. Hayes, Planning: Complex Endeavors, CCRP Publications, Washington D.C., 2007.

[32] R. K. Huber, J. Moffat, D. S. Alberts, Achieving agile C2 by adopting higher levels of C2 maturity, in: Proc. of the 17*th* International Command and Control Research and Technology Symposium (ICCRTS), DoD Command and Control Research Program, CCRP Publications, Washington, DC, 2012.

[33] H. W. Lawson, A journey through the systems landscape, College Publications, 2010.

[34] H. W. Lawson, Attaining a systems perspective, in: I. Jacobson, H. B. Lawson (Eds.), Software Engineering in the Systems Context: Adressing Frontiers, Practice and Education, volume 7 of *Systems*, College Publications, 2015, pp. 41–66.