Complexity Implications for Defence and C2

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Abstract

Military operations are becoming increasingly complex, with significant implications for Defence Command and Control (C2) as many current approaches and systems were designed for industrial age warfare rather than for challenges posed by complexity. To address complexity it is necessary to first understand some of its causes, including how complexity is experienced through a confluence of factors and unpredictable interactions. Multiple C2 challenges arise from complexity and from the related notions of wicked, super-wicked and messy problems; these challenges need to be considered when seeking to improve C2 capability. This paper explores these challenges in the context of Defence assumptions about future C2 capability. It also offers ways to address some of these challenges to effect change and improve future C2 capability by exploiting current sources of inspiration to create an improved approach for dealing with complexity within defence and national security contexts.

Keywords: Command and Control, complexity, complex problems, wicked problems, messy problems

1 Introduction

It is a truism that change in the world continues apace, despite commentators, such as Fukuyama [1], suggesting that certain aspects of society can reach a degree of stability. Given this continued change, there is also an unending debate about where this change has led us and how best to characterise the nature of our current situation. For example, alternatives include: post-industrial society, the information age, the post-truth era, or the post-information age. For some, as explained by Jackson [2], these characterisations suggest that we remain on the path of a continuum of change in society that first emerged in the 16th century. For others, the descriptions suggest that we have entered a new age. Regardless of which view one aligns with, we have unarguably transitioned into a world which is much more complex, and it will be difficult to avoid being entangled in the complexity within it. In using this characterisation we do not intend to imply that reality and complexity exist separately from the place and role of humans. Rather, we suggest that complexity arises mostly because of changes in human behaviour, and also because of changes in the scale and nature of human interactions, either directly with each other, but increasingly mediated in new and different ways through emerging and evolving technology.

One might ask what has led to this increase in complexity, and to respond to this, it is necessary to consider some of the macro-level trends affecting us. These include:

- An increasing pace of change in technology, especially informational, with greater digitisation and sophistication of processing, including recent accelerations in AI;
- Increasing interconnectivity with global, light-speed transmission of media, reporting, commentary and disinformation;
- Climate and biosphere degradation impacting on society, trade and supply chains;
- A more multi-polar world, with significant global hyper-competition [3];
- Increasingly hybrid conflict with competitive and conflictual actions being taken by state and non-state actors across multiple domains and environments;
- Increasing instability of politics, international norms and value-sets;
- Opinion-forming and influencing communities that lay outside the control of conventional media and authorities that are not geographically constrained.

Crucially, there is no single or primary trend that is driving change or complexity; rather, it is the confluence of multiple factors and their frequently unpredictable interactions that are of greatest concern. These will be the primary source of challenge for Command and

Control in the future in coping with the inherent complexity of conflict and crisis from now until 2040 and beyond. The fact that this is the case should not be surprising as it has been recognised for some time in other sectors. For example, as explained by Jackson [2], in 2010 an IBM survey of chief executive officers believed that rapid escalation of complexity was the biggest challenge facing them. Similarly, the OECD in 2017 noted that "Complexity is a core feature of most policy issues today; their components are interrelated in multiple, hard-to-define ways. Yet governments are ill equipped to deal with complex problems."

2 The nature of complexity in the context of Command and Control

There is a significant challenge with attempting to provide a concise explanation of complexity, as is needed for this short paper. The reason is the multitude of different perspectives and opinions on its perceived nature. Firstly, this is not helped by many misconceptions about what is complex and what is not. For example, some observers suggest that complexity is 'in the eye of the beholder'. That is, if it is perceived as complex, then it is so. This is a dangerous and deceptive path to tread as it suggests that complex problems might ultimately be easily solved, as we are blocked merely by a failure of understanding and hence, once this understanding is developed, new systematic methods could be employed. However, if one takes a more scientific perspective then there is a distinct difference in nature between complicated and complex problems, and the consequence is that no systematic solutions will ever be possible. That is, these problems will forever be difficult and challenging and we will never succeed by employing approaches, however sophisticated, that work with 'merely' complicated problems[1]. Secondly, even if one accepts that there is a difference between an informal, general public perception of complexity and a more formal scientific characterization, there are still differences of view within the latter. However, one academic [4] has critiqued repeated disclaimers about not having an agreed view, and suggests that this may be the result of mixing up a description of a field of study (in this case complexity or complexity science) with more detailed explorations of its many different parts. As an example of the latter, there are several papers which define a multitude of different types of complexity [5,6,7] including organised/disorganised complexity, chaotic dynamics, Kolmogorov complexity, Kauffman's complexity, irreducibility etc.

The academic's critique proposes that we take a different perspective, in that there appears to be more agreement on the nature of complexity than is first apparent. He notes that, for example, in 1962 Herbert Simon said "Roughly, by a complex system I mean one made up of a large number of parts that interact in a non-simple way". Then some 60 years later a more recent paper stated that "a complex system is (a) a collection of objects or agents with high cardinality, which (b) interact with one another in a nontrivial way such that (c) the collective behavior of the system is unexpected or different from, or not immediately predictable from, the aggregation of the behavior of the individual parts."

Once we transcend the debate about what complexity is, we then move into the even more challenging question of why complexity is so difficult a subject for more traditional approaches to science. Jackson [2] concisely described the challenge of complexity for science by conveying that, initially, science was able to deal with problems of organised simplicity. Here, there are a small number of elements that are related to each other in predictable ways. The mathematical tools which can be used to describe such systems are those of calculus and differential equations. Later, problems of unorganised complexity were also addressed, where there are large numbers of components exhibiting high degrees of unpredictability[2]. The appropriate mathematical tools for these problems are those of statistical mechanics and probability theory. The implied problem created by these twin considerations is that the appropriate mathematics deals only with the extremes of complexity or randomness. This leaves a huge gap, where unfortunately most real-world problems lie. That is, in the region of organised complexity. Here problems are too complex for analytical approaches and too organised for the application of statistics. This problem type predominates in the life, behavioural, social and environmental sciences and according to Weaver [8] requires ".....science to make a third great advance, an advance that must be even greater than the....conquest of problems of simplicity or the....victory over problems of disorganised complexity. Science must, over the next 50 years, learn to deal with problems of organised complexity."

However, despite all of the above, the term "complexity" is still not sufficient to fully explain the nature of the

[1] There is a distinction between complicated and complex problems. A primary difference is that with the former, cause and effect are related and thus it may be possible through analysis to predict likely outcomes if starting conditions are sufficiently known. In contrast, for complex problems, the relationship between cause and effect is frequently unknown and the same starting conditions can produce very different outcomes, being dependent on indeterminate interactions of system elements.

[2] Jackson is expressing a broader and more scientific view on complexity than is frequently envisaged in informal discussion. That is, complexity can be both organised and unorganised, but it is the former that we are usually referring to when considering the types of problems posed to defence enterprises.

challenges that defence, and hence C2, will be increasingly facing. The competitive, crisis and conflict situations of the future will increasingly produce challenges that are also known as wicked problems [9] i.e. unstable situations that 'resist being solved by classical problem-solving'[3]. Such problems can also be referred to as 'messes' [11] or 'social messes', given they concern multiple stakeholders and there is no single agreed understanding of the problem, let alone agreement on how to solve it, with no one actor having access to all the means necessary to bring about systemic change. Further, some theorists have conceived of an additional category, that of super-wicked problems, denoting those problems, such as climate change, which are considered to be near-irresolvable due to additional confounding factors being in play.

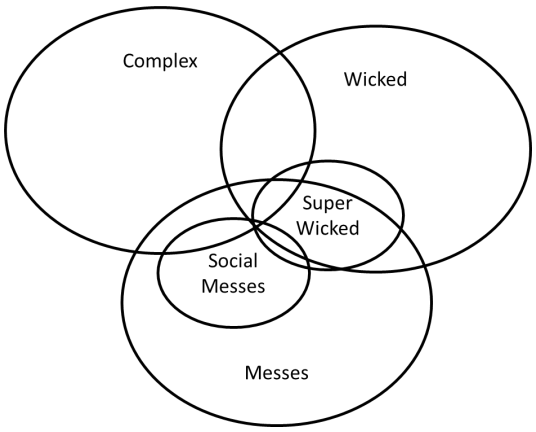

Figure 1: Overlaying of problem types

There is no easy and concise way to explain how the various problem classes relate to each other, but they are related, and they do overlap in terms of some of their properties, as Figure 1 above attempts to portray[4].

3 The implied challenge for C2

The more traditional form of Command and Control we experience today in terms of its concepts, processes and organisation, was developed in the era of industrial age warfare. Thus, it was strongly influenced the by ideas of the time, which were based on the use of machines for mass production, enforcing machine-like behaviour from humans, using principles of scientific management [13], and including an analysis of workflows to achieve economic efficiency via the use of optimised[5] and standardised processes. This perspective also imposes itself on the nature of environmental problems that organisations experience and attempt to address. It assumes that the world can be sufficiently understood, that problems can be analysed and reduced to their component parts, that causality can be determined and predicted, that solutions to the various parts can be found, and hence solutions when applied will resolve "the problem"[6]. There is thus a linearity of thinking and process that is put in place, which includes how planning of problem resolving activity is conducted. Implicit in this type of planning is a reliance on simple causal reasoning, which due to inherent complexity and 'wickedness', will in many cases will be flawed. That is, we assume from experience that if A happens, then B will necessarily follow. However, without a decent explanation as why this should be so, especially in particular settings with a multitude of different variables, such reasoning is more than likely to be in error [14]. The consequence of such errors is that we continue to, and increasingly, misjudge crisis and conflict situations, and hence the eventual outcomes are far from those desired. It is perhaps useful at this juncture to consider some further helpful words from Jackson [2], to help reinforce the previous points.

"What help can decision makers expect when tackling the messes and wicked problems that proliferate in this age of complexity? They are usually brought up on classical management theory that emphasises the need to forecast, plan, organise, lead, and control. This approach relies on there being a predictable future environment in which it is possible to set goals that remain relevant into the foreseeable future; on enough stability to ensure that tasks arranged in a fixed hierarchy continue to deliver efficiency and effectiveness; on a passive and unified workforce; and on a capacity to take control action on the basis of clear measures of success. These assumptions do not hold in the modern world, and classical management theory provides the wrong prescriptions."

"They pander to the notion that there is one best solution in all circumstances and seek to reduce complex problems to the particular issues they can deal with. They

[3] Note that complex problems are not the same as wicked problems, but they are related. For example, Conklin suggests that Rittel and Webber (the originators of the term wicked problems): 'distinguished a new domain of problem type, as opposed to, say, a new way of solving complex problems. Problem wickedness is not about a higher degree of complexity, it is about a fundamentally different kind of challenge to the design process, one that makes solution secondary and problem understanding central.'[10]

[4] This diagram is only intended to be illustrative and will not be correct, as it is far from clear how the problem types relate to each other. This is exemplified by the relevant academic literature, which contains a multitude of attempts to better characterise and explain what the relationships between the problem types are [12].

[5] Such optimization leads to organisations that find it difficult to adapt and are not resilient, which is not a desired outcome for C2 organisations.

[6] There is also an assumption of an ability to 'control' what is happening in the environment, whereas the reality for complex systems, especially those which are adaptive, is that they will either unpredictably or purposefully prevent such control having its desired effect.

concentrate on parts of the problem situation rather than on the whole, missing the crucial interactions between the parts. They fail to recognise that optimising the performance of one part may have consequences elsewhere that are damaging for the whole. They often fail to consider an organizations interactions with a rapidly changing environment. Finally, they don't acknowledge the importance of multiple viewpoints and internal politics…..Fundamentally,….they're not systemic enough."

Arguably, the divergence between the challenges faced in complex operating environments, and our current traditional approach to C2 is getting ever wider, such that the likelihood and severity of a future national security catastrophe in the timescales of the intended UK Future C2 concept will increase to a considerable and frightening extent. The challenge for defence is that these outdated industrial and scientific management perspectives, and many implicit assumptions derived from them, are deeply engrained in the defence institution, in its culture, in its concepts and doctrine, in its education, and even in its selection and promotion processes for personnel.

4 Where solutions might be found

The discussion above has focussed on some of the challenges created by complexity. However, in doing so it has avoided covering other problem types that Defence has to deal with. In this regard it is perhaps worth noting that not all problems are complex or wicked, and not all aspects of even complex problem situations are themselves complex. To help untangle these distinctions it is helpful to use a framework for thinking, and the one most often employed in this context is Cynefin [15], which seeks to determine during sensemaking whether a situation is clear, complicated, complex or chaotic. The framework quite reasonably suggests that we employ the appropriate approach to the relevant situation; that is, we don't apply overly sophisticated methods to clear and complicated problems or try and address complex ones with overly simplistic and standardised solutions, as discussed earlier in this paper. However, because the focus of this paper is on what we need to do differently, and not what we can safely re-use from the past, the remainder of what comes next will describe in brief terms what needs to change in C2 to better cope[7] with complexity.

Because we don't sufficiently understand the nature of complex, wicked, and messy problems[8], finding ways to resolve, or cope with them better is also extremely challenging. Therefore, there is no one single approach or method sitting on the shelf that one can employ. Neither the disciplines of science nor management have developed a definitive or commonly agreed approach. What this probably entails is that defence will need to develop its own approach for dealing with these problem types, in a way that is workable in its context, and in a way that can operate without too much friction with more routine approaches for dealing with clear and complicated problems. Unlike in the past, whatever this approach is, it cannot remain static, otherwise it will just become tomorrow's obsolescent way of working. It therefore needs to become an ever evolving, adapting and improving "thing"; more like an evolving organism [16], than a stable, scientific management machine. It almost certainly needs to be based on a learning organisation approach, with constantly reflective practice.

If one accepts the argument above, this still leaves the question of where to start, and how to start, the process of change. The good news is that there are many sources of inspiration that can be used. A necessary precondition is that, whatever approach is considered, it needs to be founded on the concepts of treating systems as wholes (borrowing appropriate ideas from systems thinking/critical systems thinking)[9], and it has to be based on an acceptance of all of the uncertainty, and unpredictability that emerges from complexity (complexity science). As an example of such potential starting point, Snowden and Rancati recently published a so-called field guide [18] to help managers cope better with complexity, a publication sponsored by the EU. A second potential source is from the 'multi-methodologists', such as Midgely, Jackson and Flood who have taken the view that we need to

[7] Note that we cannot truly "manage" complexity. In that regard Prof Michael Jackson was counselled against using the phrase "the management of complexity" in the title of his book. He agreed that we need to navigate through complexity, and that we can't manage it. However, he also believed there are some aspects of complexity that we can manage and additionally that "managing" can also carry the meaning of handling, coping, and getting by, not just "controlling".

[8] Note that a problem could simultaneously be all of these.

[9] Note prior attempts by Dstl to embed systems thinking in a military HQ, for example via the Alternative Thinking Team concept [17].

understand better what assumptions we are making when we employ a systems theory and approach, to ensure that we apply theories, concepts and approaches that are appropriate to particular problem types. Hence, they devised the so-called "System of Systems Methodologies" [2], which attempt to classify methods and approaches according to a best fit with a problem type. They did this by using two dimensions, one of which is a simplification of Cynefin (with just simple and complex types) and the other is the nature of the relationship between participants involved in problem resolution (unitary, pluralist, coercive), which refers to participants having shared views, aligned views or potentially conflicting views. Neither of the above provides a "ready to go" solution[10], but each contains a wealth of ideas and potential seeds from which to grow something usable, which could be gradually honed and adapted through practice for defence use.

Before leaving this point it is worth noting that there is some disagreement between methodologists about the appropriateness of particular ways of viewing the world and their aligned methods, in the specific context of complexity. Some would argue that 'systems' thinking and methods are entirely appropriate whereas others might suggest that they are flawed and that new thinking and methods based on 'complexity science' are what is needed. Suggesting ways to resolve these different perspectives, except in an abstract and academic manner, is itself problematic, as obvious proposals are at risk of being defeated by the very nature of the problem situations discussed in this paper. That is, it may be dangerous to claim definitive success or failure, benefit or detriment of particular approaches based on experience, as this would be an inductive approach that could be invalidated by the very next experience and could also be based on flawed causal reasoning connecting any approaches taken and the eventual situational outcomes. As discussed above, the only potential viable approach may be to create some diversity, try many approaches and variants, and gradually learn our way towards something which appears to work better, noting that this also needs to be kept under continuous review, with the potential for adaptation always primed, as the operating environment continues to change around us.

To conclude this discussion, it is necessary to note that this paper has only addressed the appropriateness of concepts, theories and approaches. This is obviously just one aspect of what needs to change for Future C2, and leaves many other areas unexplored, such as how to organise C2 better to cope with these more complex, wicked and messy problems. The latter observation assumes that the types of approach referred to in this document are unlikely to be practiced well in a conventional C2 organisation. However, the detail of such a discussion is beyond the scope of this paper, and is explored in part in DCDC Concept Information Note 2 on emergent defence organizing [19].

5 Summary

This paper has attempted to convey the following chain of argument:

- That change in the future operating environment will likely continue along already observable trends, along with some surprises and unpredicted occurrences, and the result of this is increasing complexity in both the operating environment and in the nature of the problems faced by C2 within the wider national security enterprise.
- Whilst there remains significant debate about the nature of complexity, there is also considerable agreement about its primary features, and thus also in its implications.
- Future competition, crisis and conflict will most likely reside in the complex and chaotic domains[11], where cause-and-effect relationships are unclear and unpredictable.
- Relying solely on traditional C2 methods that are based on theories and concepts which no longer apply, especially in these types of situations, is likely to lead to failure.
- There is a need to include, in the context of complex environments and complex adaptive systems, a recognition that we can no longer assume an ability to effectively 'control' what is happening in the environment.
- Therefore, it is crucial to embrace the required change very soon and adopt and develop new approaches.
- By recognising the limitations of traditional C2, and adapting our approaches to better cope with the ever-changing nature of competition, crisis and conflict, national security enterprises will be better able to

[10] These are merely examples, and thus it is recommended that a careful and considered approach is taken to the selection of concepts from these sources for experimentation and potential development, and also that the pool of such sources is expanded to increase the likelihood of finding those which are most effective and practical for defence use.

[11] Note that the use of 'domain' here is in the sense that the author of Cynefin (David Snowden) intends, and not in the sense of multi-domain integration or operations.

maintain effectiveness in the face of new threats and challenges, i.e. those that will inevitably be hiding in future complexity.

It is beyond the scope of this paper to comprehensively define what defence organisations might need to do to improve their capacity to cope with complex and wicked problems. However, the following is a non-exhaustive set of proposals as to what may be needed.

- From a science and technology perspective there is a need to develop a range of approaches, with a guiding meta-approach, that collectively enable defence C2 organisations to make sense of complex situations and develop and execute a continuous adaptive and proactive response.
- From an education and training perspective there is a need to upskill leaders and wider C2 practitioners, perhaps exploiting some of the ideas embedded in extant courses such as the US Army School of Advanced Military Studies.
- From a concepts and doctrine perspective there is a need to develop new ways of thinking and acting, and this will also impact wider doctrine for various C2 activities e.g. doctrine associated with campaign planning. Consequently, these will need to be adjusted and perhaps even re-written.
- From a personnel perspective there is a need to recruit individuals with different mindsets and develop a professional cadre of staff who are educated, trained and continuously developed to cope with the ever unfolding and changing nature of complex and wicked problems.
- From an organisational perspective there is a need to be able utilise the new approaches within a partnership of diverse actors pan-government, pan-agency and pan-multi-national allies.
- From an information and technology perspective there is need to support the new approaches which will include the more diverse and adaptive ways of working required to cope. Typical C2 technology, which is designed to support standardised and optimised processes, will be inappropriate.

In summary, we propose that for the future, Defence needs to take a different perspective on C2, enabling it to more effectively address challenging problems arising across all of the domains[12]. We need to be proactive in driving the changes needed to transform C2 to a new manifestation. This paper provides a few examples of actions we could take and are proposed with the intent to prompt a debate on what they should be and how we might collectively undertake them.

Note: This paper is an adaptation and expansion of DCDC Concept Information Note 1 [20] which was published by DCDC in early 2024 as a precursor to a full UK Joint Concept Note being published on the Future of C2

References

[1] Fukuyama, F. (2015). The end of history?. In Conflict after the Cold War (pp. 16-27). Routledge.
[2] Jackson, M. C. (2019). Critical systems thinking and the management of complexity. John Wiley & Sons. DCDC (2024).
[3] Freier, N. et al. (2018). Game on or game over: hypercompetition and military advantage, US Army College, War Room.
[4] Holme, P. (2021). What complexity science is. https://petterhol.me/2021/12/27/what-complexity-science-is/
[5] Lloyd, S. (2001). Measures of complexity: a non-exhaustive list, IEEE Control Systems Magazine 21:7.
[6] Couture, M. (2006). Complexity and Chaos – State-of-the-Art; Formulations and Measures of Complexity, DRDC Valcartier, TN 2006-451.
[7] Mitchell, M. (2009). Complexity: A Guided Tour. Oxford University Press, Oxford. SE Page, 2011. Diversity and Complexity. Princeton University Press, Princeton NJ.
[8] Weaver, W. (2003). Science and complexity. In: Systems Thinking (ed. F.E.Emery_, 377-385. London:Sage.
[9] Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. Policy sciences, 4(2), 155-169.
[10] Conklin, J., Basadur, M., & VanPatter, G. K. (2007). Rethinking wicked problems–Unpacking paradigms, bridging universes. NexD Journal, 10(1).

[12] i.e. referring to Cynefin domains of Clear, Complicated, Complex and Chaotic.

[11] Ackoff, R. L. (1997). Systems, messes and interactive planning. The Societal Engagement of Social Science, 3(1997), 417-438.
[12] Alford, J., & Head, B. W. (2017). Wicked and less wicked problems: a typology and a contingency framework. Policy and society, 36(3), 397-413.
[13] Taylor, F. W. (1914). Scientific management: reply from Mr. FW Taylor. The Sociological Review, 7(3), 266-269.
[14] Hume, D., Enquiries concerning Human Understanding and concerning the Principles of Morals Reprinted from 1777 edition, Third Edition, L. A. Selby-Bigge (ed.), Clarendon Press, Oxford, Sect. XII, Part III, p.165.
[15] Snowden, D. J., & Boone, M. E. (2007). A leader's framework for decision making. Harvard business review, 85(11), 68.
[16] Morgan, G., (2006), Images of Organization, 2nd ed. Sage Publications.
[17] Houghton, P., (2018). Concept Paper: Alternative Thinking Team (ATT), 23rd ICCRTS, November 2018.
[18] Snowden, D., & Rancati, A. (2021). Managing complexity (and chaos) in times of crisis. A field guide for decision makers inspired by the Cynefin framework (No. JRC123629). Publications Office of the European Union.
[19] DCDC (2024). Concept Information Note 2. Emergent Defence Organising.
https://assets.publishing.service.gov.uk/media/65d35fc2423931826ab7b8ab/20240118-Concept_information_note_2___Emergent_Defence_Organising.pdf
[20] DCDC (2024). Concept Information Note 1. Complexity Implications for Defence, and Command and Control.
https://assets.publishing.service.gov.uk/media/65d35f9ae1bdec431f322206/20240118-Concept_information_note_1___Complexity.pdf