The Future of Command and Control – Evolution or Revolution?

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Abstract

This paper presents a hypothesis based on Cybernetic Control Theory that command and control (C2) cannot continue to develop as a directive hierarchical system to meet the challenges presented by the increasing complexity of military tasks and situations. A paradigm shift in C2 is therefore required to ensure that operations remain effective in the future operating environment. We use the cybernetic concepts of *Variety* and *The Law of Requisite Variety* to explore ideas of how the command system and the force co-evolved with the increasing sophistication of warfare. We conclude that complex circumstances create an inherent tension between the conflicting requirements of the force and the C2 system and that the capacity of directive command systems to control the force in complex circumstances may have been reached. We suggest that it may be more relevant in complex circumstances to concentrate less on *control* of the force and more on maintaining purposefulness among diverse networks of actors and actions that can be more responsive to localised needs and factors.

1 Introduction

This paper offers a theoretical explanation of the evolution of military command and control (C2). This understanding of the factors that influence how C2 has developed through the course of history provides a lens through which to view contemporary C2 challenges and to provide insights into how C2 may have to change to address the complexity of the future operating environment.

This analysis is based on concepts from the 'Variety Calculus', a body of Systems Thinking theory and associated methodology derived from Cybernetics (the science of control) and Complexity Science [1, 2]. It provides a means of characterizing situations with respect to their degree of simplicity or complexity and designing appropriate responses in terms of organizations, operations, processes and relationships.

The Variety Calculus is *universal* as it is applicable to any purposeful human endeavour, c*omprehensive* in that it provides insights to inform the effectiveness of all aspects of collective action such as organisational & process design, planning and leadership, and is *scalable* in that it is applicable from process to enterprise, or tactical to strategic levels. We previously presented a paper in this conference series that described a planning method for complex operations based on these ideas [3]. Variety Calculus has also been applied to studies of command [1], integration [4] and complexity [5]. We routinely exploit Variety Calculus in supporting stakeholders across UK Defence and Security to address complex challenges and here we consider its relevance to C2.

We will briefly outline the relevant aspects of Cybernetics theory and illustrate in this context the development of contemporary directive hierarchical C2. We will then introduce how the increasing complexity of military operations challenges the historic trajectory of C2 evolution. Finally, we will show how the theory suggests a potential paradigm shift for future C2 that embraces more diverse systems with the emphasis changing from control to maintaining the purposefulness of diverse actions and actors.

2 The Variety Calculus

Before exploring the development of C2, it is necessary to introduce a certain amount of theory and associated technical terms.

2.1 Systems

A system is a collection of interacting components that can be regarded as a coherent whole that forms a distinct entity within its environment with its own recognizable behaviors and characteristics. A computer, for example, is a system. It is composed of interconnected components but has properties that are quite different from the separate components. Indeed, the existence of the computer as a system is dependent on very specific relationships between the components - a pile of unconnected processors, drives and interfaces is not a

computer. For the purposes of this work, an operation, an operating situation, the force, and C2 are all regarded as systems.

2.2 Variety

Variety is a property of a system that is derived from the *diversity* of components, characteristics and relationships of which it is composed [6]. Variety is not easily quantified from sums or averages of the numbers and types of component and relationships. Rather, its effect is manifest in the number of different states that a system has the potential to adopt.

Systems can be envisaged as existing on a spectrum of potential states based on their variety (Figure 1). To left of arc, low-variety systems are *simple*. They have few components and relationships with low diversity and they tend towards stability or uniformity and a high degree of order. At right of arc, very high-variety systems are *chaotic*. Although they are still systems composed of specific interactions and governed by 'rules', the components and interactions are so numerous and varied as to give the appearance of randomness and disorder.

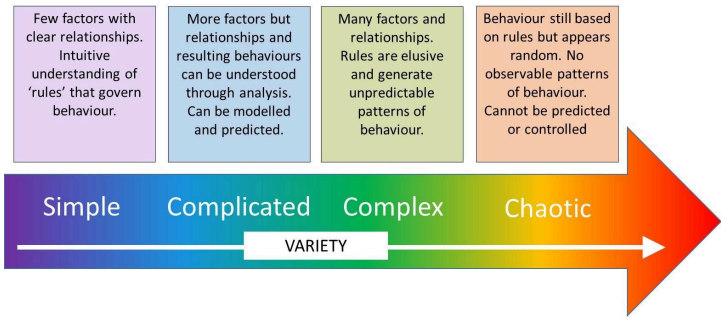

Figure 1: The 'variety spectrum' that illustrates the effects of variety on system characteristics.

As one moves from left to right from simplicity towards chaos, systems are progressively more *complicated* with greater potential for variation in the states that they can adopt. They are still amenable to analysis and can be understood and modelled in terms of how the relationships between the components result in the higher level properties of the system as a whole.

Complexity is a state that arises at a certain point further to the right of the variety spectrum where systems are balanced between order and disorder. The number and diversity of components and their entwined relationships and dependencies are such that they are inherently unpredictable and it is no longer possible to analyse or understand how the system behaviours relate to those of its components.

Variety is thus related to complexity, predictability and the ability to understand a system through analysis. It is also strongly associated with *information*. We can therefore also equate the position of a system on the variety spectrum with the amount of information that is required to understand it. The boundary between complicated and complex is blurred and subjective and relates to the capacity of the observer to assimilate and process the required information.

There is not universally agreed definition of complexity or means of quantifying it [7]. However, variety provides a heuristic measure that we can use as a practical way of characterizing systems and making inferences about their nature. We can thus distinguish between simple and complex situations based on the diversity of components and their degree of interconnection, how this relates to their degree of order or uniformity, their capacity for displaying different behaviours and states, and our ability to understand and predict their behaviours.

2.3 Requisite Variety

Ashby's *Law of Requisite Variety* [6] is a tenet of Cybernetics that states that an effective controller must have similar variety to the system that it seeks to control. 'Control' is not appropriate word to apply to our relationship with complex systems, which are largely uncontrollable. The Variety Calculus therefore talks of *agency* – the capacity to purposefully influence a system. The Law of Requisite Variety is thus stated in the Variety Calculus as:

> *To effectively observe, understand, influence or communicate, a process, organisation, operation or technology must have requisite variety with the situation or task in which it seeks to have agency.*

This provides a means of considering the requirements for the effective influence of systems on different points on the variety spectrum. If the situation is simple then our response should be biased towards uniformity and predictability and towards constraints rather than freedoms. Systems to address simple situations are therefore perhaps more process and authority driven. Conversely, the response to a complex situation with many moving parts and where understanding is elusive should exploit multiple interrelated approaches and points of influence and allow high degrees of freedom for participants to innovate and experiment. This theory therefore points towards different approaches to C2 being appropriate for different operations depending on their relative simplicity or complexity.

In general terms, it can be argued that military organisations have many characteristics that are *variety*

reducing. This implies that they are most appropriately configured for tasks and situations that are simple or complicated. For example, they are highly structured organisations that employ written doctrine, uniform training and methodologies, and with highly defined and structured relationships. Approaches to C2 are similarly configured for relatively low-variety situations. They rely on linear chains of directive command, deterministic approaches that assume clear relationships of cause and effect, and concepts such as common understanding and unity of command. In the next section we will explore the co-evolution of the force and the C2 system in variety terms to illustrate how this can be less effective under conditions of high complexity.

3 Variety in combat

3.1 The genesis of C2

Envisage the earliest form of combat: two rabbles meet on a scrap of land with the mutual aim of using violence to destroy or drive off their opponents. If the politics are stripped away and we consider only the combat itself then the situation we are dealing is inherently of low variety. It consists of two components with a single, very clear relationship between them.

The individual combatant groups on the other hand are of extremely high variety. Each person is armed as they please and will attack whom they choose and in the manner they choose in the ensuing melee. The rabbles have requisite variety with each other and so neither has an organizational advantage. But neither has requisite variety with the situation and thus they do not have the agency to resolve it in their favour. Victory will probably go to the biggest or bravest group, but this will not be a matter of art or control but of strength and determination. If evenly matched in that respect, there could be either an extremely bloody battle that will advantage neither, or a posturing stand-off without resolution.

The next time that conflict erupts, one group organizes and prepares. It has trained to fight in a phalanx with long spears. The organized force wins, even if its adversary is bigger and meaner. What the winning side did was to *attenuate their variety* to achieve requisite variety with the situation. What was previously a rabble with high levels of individual freedom and expression of diversity is now an ordered and uniform army. This presents the possibility of *control* and thus agency within its situation. It can choose to engage or to disengage, it can coordinate the activities of its participants, and it can manoeuvre and concentrate its effort.

The possibility of control is actually a *demand* for control. The participants have surrendered their free will and so, for the phalanx to be effective and cohesive, it requires a single decision maker that can think on behalf of the whole group. The commander must decide when to attack or withdraw and how to manoeuvre. The constraints on individuals attenuates the variety of the group, but it enables cohesion and creates an effective force with agency. *A simple C2 system has thus been created, which is inseparable from variety attenuation of the force.*

3.2 Agency through variety attenuation

The losing side will have learned an important lesson, and the next time they go to war they too will be organized. The net result is that both armies attain a state of requisite variety with their situation. The simple C2 system also has requisite variety with the force and thus the agency to control it. Such *variety alignment* between the situation, the force and the C2 system is a requirement for effective operation according to the Law of Requisite Variety.

Warfare has had a tendency to generate more variety as time passes. This is caused partly by the 'arms race' as combatants seek competitive advantage through new technology and tactics. It is also because the increased scale of warfare introduces additional considerations into the calculus. We can move forward several millennia to the armies of the Napoleonic Era to explore the implications for C2 of this trajectory of development.

Firstly, the situation is more diverse. There are a greater number of interrelated factors to take into account in dealing with a greater scale of combat. It is fought over more varied terrain, logistics are more demanding, and there may be political or ethical considerations that have a direct impact on the battlefield. The force is also more diverse, including infantry, cavalry, and artillery, light and heavy elements, reconnaissance troops and skirmishers. *It is clear that greater variety is therefore also required by the C2 system to maintain variety alignment with the situation and the force.*

A single commander cannot hope to exert personal control over thousands of individuals. They do not have the requisite variety to do so, or the communication bandwidth, or the cognitive capacity to process the necessary information. However, variety reduction of a group of perhaps 100 people means that they can be treated as a single entity that is controllable by a single commander. Similarly, several such entities can be

combined into a larger unit that is also controllable by a higher commander. The supreme commander does not therefore need requisite variety with the entire army and only needs it with perhaps a limited number of divisions, mediated through a chain of subordinate commanders.

The C2 system generates sufficient variety because the chain of subordinate commanders and the headquarters staff amplify the supreme commander's variety and their capacity to process information. Indeed, a *military headquarters could be viewed as a mechanism for amplifying the variety of the commander*. Such a system can be evolved to generate greater variety in response to increases in the sophistication of warfare through more extensive hierarchical chains of command and larger headquarters carrying out more diverse functions. This is the traditional trajectory of C2 development up to the present day.

Variety attenuation of the force is still essential to enable control by the C2 system as it would otherwise not be possible for a large and diverse force to act in a coherent and coordinated manner. So, despite the increase in the diversity of a force, attenuation of its variety is still a key factor in its effective control by a hierarchical and directive C2 system. This is illustrated explicitly by the Napoleonic infantry where all traces of individuality were removed from the soldiers. They were drilled to move in rank and file and to fire their muskets on command by numbers. The variety within individual units remains extremely low even although that of the army has increased. The Variety Calculus is balanced by force variety attenuation and amplification of that of the control system.

3.3 The modern era

Warfare is conceptually relatively simple at the level of the fight, and it remains so even when the platforms and weapons are extremely sophisticated. It largely involves the use of destruction as a means of achieving goals. Adversarial relationships mediated through destruction do not tend to be inherently sophisticated. The principle of *C2 agency through variety attenuation of the force* thus continued in the era of industrialized warfare and to the present day.

Operations and operating environments are nevertheless considerably more complex now than they were in the 19th Century. Modern information technology and resulting globalization has increased substantially the interconnectedness of the world and the dependencies between nations, regardless of their political ideology. It is thus a much higher variety, more complex environment for any human endeavor. Furthermore, the military remit not only involves peer-to-peer kinetic warfare, but also more complex activities. These include countering asymmetric adversaries, competing for national advantage in conflicts below the threshold of war, disaster relief and supporting the civil power in a diversity of emergency situations.

Adaptations that create more variety in the force are clear – the modern soldier is far from being the automaton of their Napoleonic counterpart. There is a much greater diversity of weapon systems and platforms, partnerships with non-military actors, and the recognition of space and cyber as new domains. C2 systems have also become much more sophisticated – chains of command are longer, headquarters are larger with a greater diversity of functions and handle larger volumes of information. As the operating environment becomes more complex, there are strong pressures for further development along this trajectory.

The current C2 paradigm is one of *control*, which continues to require and demand variety attenuation of the force. Throughout the development of the military, they have thus by necessity retained and ingrained variety attenuating characteristics. They are highly structured organizations where ways of working are captured in written doctrine, with directive hierarchical relationships, and where a culture of obedience and conformity dominate. These strongly variety-reducing factors are thus inherent in the fabric of the military institution as prerequisites of control.

4 The contemporary C2 challenge

It is already recognised that different approaches to C2 are required to address the complex operational challenges of the modern era. This is well documented in publications [8, 9] and through initiatives such as (in the UK) Multi-Domain Integration [10] and Audience-centric operations [11]. These can be seem as mechanisms that amplify C2 system variety, although they are not understood or articulated in these terms.

It is clear that headquarters cannot simply continue to grow larger and chains of command longer to increase the variety of the C2 system. Larger headquarters are highly visible and thus very vulnerable to attack. Although this may be addressed to some extent by dispersed models, there remains a practical limit to the effective size of such an organisation regardless of its physical distribution [12]. Larger systems must put proportionally more resource into their own maintenance, which results in diminishing returns.

Information takes longer to transition longer chains of command thus slowing response times, and senior commanders become progressively more remote from the point of delivery. The degree of variety reduction required between the situation on the ground and the commander means that they receive a more processed and attenuated form of understanding on which to base their decisions. There are hopes that such issues may be addressed by more sophisticated technology that can use automation and artificial intelligence to process more information, streamline decision making and reduce the manpower burden [8, 13].

However, our analysis suggests that there is a Control Theory rationale to support the hypothesis that conventional directive and hierarchical C2 may be reaching (or may have already reached) the limits of its ability to address increasing operational complexity. The co-evolution of the force and the C2 system has resulted in closely entwined systems whereby both are dependent on variety attenuation that limits their mutual ability to address complexity. For example, military units have fixed structures both individually and as a recursive organisation, and they have fixed operating relationships embodied by a rigid rank structure through which authority and communications are applied. Variety attenuation is therefore built into the fabric of military structures, processes, relationships and culture as a necessary condition for directive control. *There is thus a growing tension between the variety-amplifying pressures created by the complexity of the operating environment and the variety-attenuating pressures demanded by the command system's need for control.*

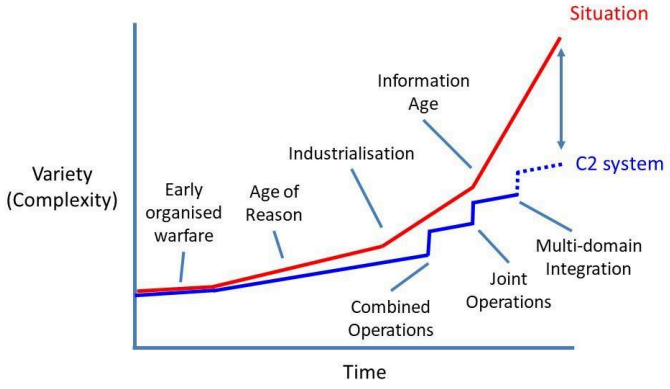

Figure 2: A representation of the variety gap between operating situations and C2 systems over time.

As illustrated in Figure 2, it could be suggested that developments in C2 have in variety terms tended to fall short of and lag behind those of the operating environment and the force. Since the start of the 21st Century, the variety deficit has grown with clear implications for the effectiveness of C2 in the future. The contemporary C2 challenge can therefore be viewed as a need to address this deficit through an alternative paradigm where agency is derived from variety amplification rather than attenuation. This has profound implications for the design of C2 systems and their purpose. *It is thus necessary to rethink the idea of 'command and control' as central to the conduct of complex operations and instead to consider how agency is most effectively achieved.*

5 Evolution or revolution?

The analysis presented here strongly suggests that military C2 cannot continue to evolve the conventional hierarchical and directive model of C2 to meet the demands of the increasing complexity of the operating environment. However, the Variety Calculus provides an indication of the nature of systems that can generate requisite variety in situations at different points of the variety spectrum.

From The Law of Requisite Variety and the idea of variety alignment, it follows that a C2 system that has agency over the design and conduct of an operation must have similar complexity characteristics to that of the situation and the force. Centralised command, directive authority and linear chains of command are inherently low-variety factors. This is entirely appropriate for situations of low complexity. A higher-variety paradigm would imply the exploitation of a greater diversity of interaction types, more networked rather than binary relationships, and distributed decision making. Complex situations require diverse actions by a range of actors and capabilities, each with the freedom to design and adapt local interventions but cohered around a common purpose. This cannot be delivered through top-down direction and so *the C2 paradigm should thus shift from one of 'command and control' to an onus on maintaining the purposefulness of a diverse enterprise.*

These ideas are consistent with, and provide a supporting theoretical basis for, concepts such as the 'C2 Approach Space' [14] which advocate reconfiguring factors such as the distribution of decision rights for complex situations. However, such ideas are likely to be counter-intuitive to many. The military instrument has adapted over centuries such that its ways of working, its structures, processes and culture are thoroughly entwined with ideas of authority, command, hierarchy and control. But it should be recognised that the alternative paradigm described here is not intended for situations where end-states and relationships between cause and effect

are explicit and clearly defined, and where the manoeuvre and concentration of force are the primary concerns. Rather, it is about numerous actions by diverse agencies to address multiple points of influence, none of which can necessarily be considered a main effort and all of which must be individually adapted to dynamic local circumstances. Complex situations are inherently opaque and cannot be addressed by brigading combined actions according to a grand plan. As expressed by the Cynefin Framework, it is a matter of 'probe, sense, respond' [15] – feeling one's way iteratively.

This will require the military to be 'ambidextrous' – able to apply conventional C2 approaches where they are most effective (perhaps at more tactical levels and for less complex operations) and to embrace an alternative paradigm where complexity is experienced at strategic and operational levels or for asymmetric or sub-threshold operations. Indeed, both may have to co-exist at different levels in the same campaign or operation. This analysis thus provides additional rationale to support the idea of 'agile C2' and an understanding of the drivers that would influence the different forms that C2 could take under different circumstances. Agile C2 advocates not only the application of different C2 approaches, but also the ability to transition between them in dynamic situations, and is regarded as a critical capability for NATO member nations [16]. As such, agility is an expression of variety and thus demands high variety organisations and operating systems.

The implementation of such ways of working is not a trivial matter. The military is a highly specialized instrument where the force and the C2 system have co-evolved for a particular mode of operation. Its interlocking structures, doctrine, relationships and culture are geared specifically for this. Changes of the type indicated in this paper will have implications for many different aspects of how the military functions as they challenge the inherently variety-attenuating aspects of the institution, such as its ethos of command, rank structure and unit organisation. Paradigm shifts as a result of revolution can be extremely destructive and generally occur due to a complete breakdown of previous ideas [17]. A controlled programme of change must therefore be carefully envisaged, planned and implemented. The Variety Calculus provides a means of understanding and envisaging the necessary change.

References

[1] Niven GW, Capewell DA (2021) The Variety Calculus – Towards a new philosophy of command & design for operations. DSTL/TR129749*

[2] Niven GW, Capewell DA (2023) The Variety Calculus 2-Page Primers. DSTL/TR147302*

[3] Niven GW, Capewell DA (2022) The Variety Calculus Planning Methodology – an alternative planning concept for complex operations. 27th International Command and Control Research and Technology Symposium.

[4] Niven GW, Capewell DA (2021) The Variety Calculus and Force Integration. DSTL/TR134438*

[5] Niven GW, Capewell DA (2023) Variety Calculus – Towards a New Command and Control Paradigm for Complex Operations. DSTL/TR150770*

[6] Ashby WR (1957) An Introduction to Cybernetics. Wiley. Reprinted 2015, Martino Publishing.

[7] Mitchell M (2009) Complexity, a Guided Tour. Oxford University Press

[8] UK MOD Development, Concepts and Doctrine Centre (2017) Future of Command and Control. Joint Concept Note 2/17

[9] UK MOD Development, Concepts and Doctrine Centre (2018) Information Advantage. Joint Concept Note 2/18

[10] UK MOD Development, Concepts and Doctrine Centre (2020) Multi-Domain Integration. Joint Concept Note 1/20

[11] UK MOD Strategic Command (2022) Integrated Action: an operational level guide to the audience-centric approach for commanders and staff. Joint Tactics, Techniques and Procedures 3.81, 3rd Ed

[12] Syms PR, Catherall, J, Rawson A (2019) Historical analysis of formation and unit HQs in ground manoeuvre operations DSTL/CR110555*

[13] UK Ministry of Defence (2022) Defence Artificial Intelligence Strategy.

[14] Alberts DS, Conley KM, Freeman WD, Kurtz JH, Tillman ME (2015) C2 by Design: Putting Command and Control Agility Theory into Practice. V2. Institute for Defense Analysis.

[15] Snowden D (2002) Complex Acts of Knowing – Paradox and Descriptive Self-awareness. Journal of Knowledge Management. IBM.

[16] NATO Science and Technology Organisation (2014) Command and Control (C2) Agility. Task Group TR-SAS-085 Final Report.

[17] Kuhn TS (1962) The Structure of Scientific Revolutions. University of Chicago Press, 4th Ed

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