A Suggestion for Endeavour Space Dimensions☆

Björn J.E. Johansson, PhD*

Swedish Defence Research Agency, Department of C^4ISR, Linköping, Sweden

Mats Carlerby, PhD

Swedish Defence University, Science of Command and Control and Military Technology Division, Stockholm, Sweden

David Alberts, PhD

Institute for Defense Analyses
Alexandria VA, US

Abstract

The purpose of this paper is to propose a set of dimensions for the "Endeavour Space" and provide a set of examples of endeavours that can be utilized for future studies that seek to determine the appropriate of different C2 approaches for different locations (regions) of this Endeavour Space.

Keywords: Command and Control, Decision support, Endeavour Space.

1. Introduction

It is a recognised fact that missions circumstances may change over time during an operation, suggesting that C2 needs to be adapted as an operation unfolds. The core concept of C2 Agility Theory, as suggested by NATO STO SAS-065 [1] and NATO STO SAS-085 [2] is that there is "no one size fits all" C2

☆This document is a collaborative effort where the authors express their own view. Accordingly, the views set out in this article are those of the authors' and do not necessarily reflect the official opinion of the Swedish Defence. Neither the Swedish Defence institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

*Corresponding author

Email address: bjorn.j.e.johansson@foi.se (Björn J.E. Johansson, PhD)

Approach and that different C2 Approaches are appropriate for different missions and circumstances. C2 Agility Theory identifies a C2 Approach Space that contains the set of possible C2 Approaches. The C2 Approach Space, depicted in figure 1, is defined by its three dimensions that are used to specify a given C2 Approach. The following dimensions specify a C2 Approach: allocation of decision rights to the entities, the pattern of interactions among entities, and the distribution of information among entities. Different approaches to C2 are located in different regions of the C2 Approach space. This way of specifying different manifestations of C2 has gained widespread acceptance and is incorporated (or employed) in several official documents describing C2 concepts and doctrine; courses taught at various military schools and in a multitude of academic publications [3]. In reality, only a subset of the possible approaches can be adopted by a given entity depending upon its doctrine and capabilities.

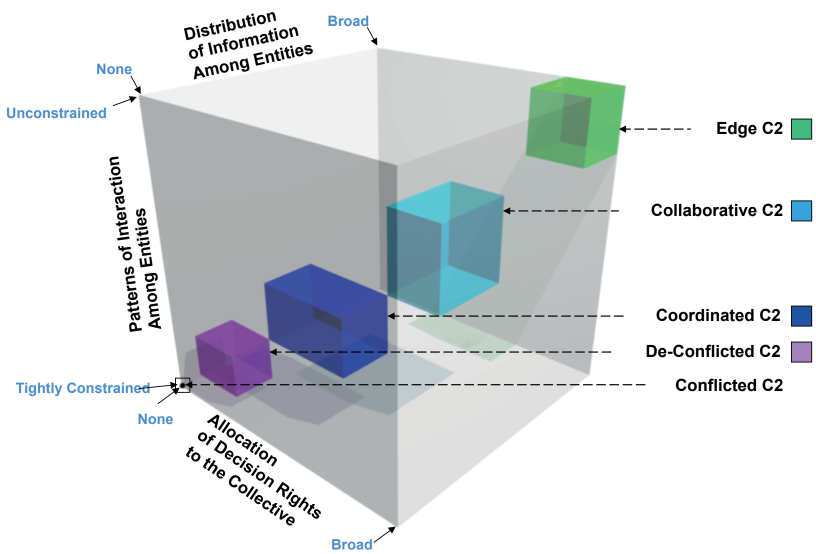

Figure 1: The C2 Approach space. Different approaches to C2 position themselves relative to the three dimensions information dissemination, allocation of decision rights, and interactions.

C2 Agility Theory suggests that an entity or collection of entities should be able to understand the location of C2 Approaches they are employing, the nature of the mission and prevailing circumstances, and whether or not their current C2 Approach is appropriate. Given that different approaches are appropriate for different missions and circumstances, it is critical for an entity, or a collective of entities, to be able to understand three things:

1. where the C2 Approach they have adopted is located in the C2 Approach Space
2. the region in the Endeavour Space that corresponds to the mission and circumstance at hand; and
3. whether the C2 Approach is appropriate or not.

Being able to determine which C2 Approach is appropriate for a given mission and circumstances requires that various regions of the Endeavour Space have been "mapped" to regions of the C2 Approach Space (see figure 2)

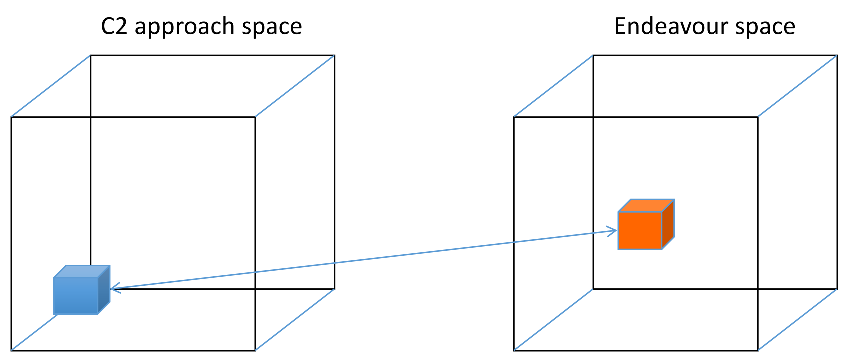

Figure 2: Each region of the Endeavour Space can be mapped to a region of the C2 Approach Space.

The Endeavour Space conceptually organizes the set of possible missions and the circumstances under which they are undertaken by its location within this space. This location is determined by where along each of its dimensions a particular mission and circumstances falls. Thus, each region of the Endeavour Space corresponds to a set of missions that pose a similar C2 challenge (requirements and stresses). While cases studies and experiments have given us some insights into this mapping, the lack of an agreed formulation for the Endeavour Space to date have prevented systematic analyses and the establishment of a definitive mapping.

This paper suggests the exploration, in case studies and experiments, of a set of specific dimensions to be used to define the Endeavour space. In proposing these dimensions we were cognizant of the fact that, from a C2 perspective, the potential for variety posed by the mission and circumstances needed to be represented in the Endeavour Space. This is because the concept of requisite variety, the relationship between the variety of behaviours that a control system can manifest compared with the states that the system that is to be controlled can take on [4].

In the case of C2, having requisite variety means that there exists a C2 approach that is fit for purpose for every unique mission challenge. Practically, speaking however, an entity will have limited C2 Approaches that can be employed and thus will not have a uniquely tailored solution at hand to account for all possible situations. The challenge is to be able to work with a limited number of C2 options to cover the most important regions of the Endeavour Space. For any given location in the Endeavor Space, there is a corresponding region in the C2 Approach Space that contains the C2 Approaches best suited for this type of mission under a specific set of circumstances (situation). This was described by NATO STO SAS-085 although the group [2] never provided any suggestions for dimensions that describe the properties of the Endeavour Space. Instead, the Endeavour Space is often described in terms like complexity, uncertainty, dynamics, etc. To our knowledge no actual suggestion exists on how to operationalise the Endeavour Space, apart maybe from a description of a "problem space" developed by Walker, Stanton, Salmon, and Jenkins [5] in their discussion on how to apply social network analysis as a means for modelling different C2 Approaches. This limits the applicability of C2 agility concepts and theory as no support exists in terms of a conceptual model describing the relation between the two sets of dimensions.

A first step to provide a foundation for extended understanding of the Endeavour Space could be to propose suggestions of Endeavour Space dimensions that can be used to investigate how the C2 Approach Space relates to the Endeavour Space. This is done in order to provide newly gained knowledge over time and providing the building of knowledge to create understanding of first perceived complicated or complex situations. This is also related to the many considerations that combined operations have to consider for fulfilling a common goal.Once the dimensions of the Endeavour Space have been specified, it will be possible to easily identify "archetypical" examples of Endeavours in a similar fashion to C2 Approaches.

1.1. Formulating the Endeavour Space

Essentially, an Endeavour Space can be viewed as a system with certain properties that affect the appropriateness of a given C2 Approach. The work conducted in SAS-085 suggest that "the self" (the organisation or collective of organisations that are to decide upon and adopt a C2 Approach) exists within, and thus is a part of, the Endeavour Space. This inter-relatedness is challenging as the way "the self" that interacts with the Endeavour Space also shapes the Endeavour Space – in a sense it is a part of it while simultaneously changing it, and thus itself.

However, to create a conceptual model of the Endeavour Space, we will for practical reasons view the C2 Approach space and the Endeavour Space as separate entities. The interactive relationship between them will have to be a topic for future discussions. For now, consider "the self" as an observer trying to understand the endeavour ahead of it and how it should arrange its constituent components to cope with the endeavour in the best way. Further, if we accept that it is possible to view the endeavour as a system to be "controlled"[1], then the understanding (perception and interpretation) of the endeavour will be different for different entities (as they have different pre-conditions for perceiving, for example in terms of sensors or intelligence, and different competencies when it comes to interpreting the same perceptions) and change over time. Each 'perception' of an endeavour may thus differ as the ability of the 'self' to gather information about the current situation varies and the knowledge that the 'self' has about the endeavour changes. These perceptions are but snapshots of the endeavour. We will discuss this further in the latter parts of this text.

1.2. The control dilemma

What we have to deal with here is possible to describe as a control dilemma, something that all forms of C2 must face as they attempt to cope with complex situations, or *situation systems* as described in [6]. The control dilemma is probably one of the most common models used, and often recognised by representatives in an organisation (figure 3).The model suggests that there is great potential for misunderstanding and misalignment of organisational efforts of achieving control in an endeavour, largely depending on the ability to anticipate and understand an endeavour. This problem is valid also for C2 Agility, as the ability to understand the endeavour and chose the most appropriate C2 Approach to the endeavour is crucial for success. Having a conceptual model of the endeavour space can be of great benefit as it will allow discussion and reasoning about the relation between different endeavour spaces and different C2 Approaches.

To begin to explore the relationship between a given Endeavor Space and the "C2 variety" it requires, the dimensions of the Endeavor Space need to be specified and then analyzed to see if they create 'local variety.' In other words,

[1] We recognize that applying the concept of 'control' to these sorts of missions and circumstances is problematic. They cannot be controlled – if by control one means that the outcomes can be guaranteed. Instead we seek to make it far more likely that desired outcomes will occur by avoiding problems with inappropriate C2 approaches.

are there some missions and circumstances that require dynamic adaptations to the C2 Approach?

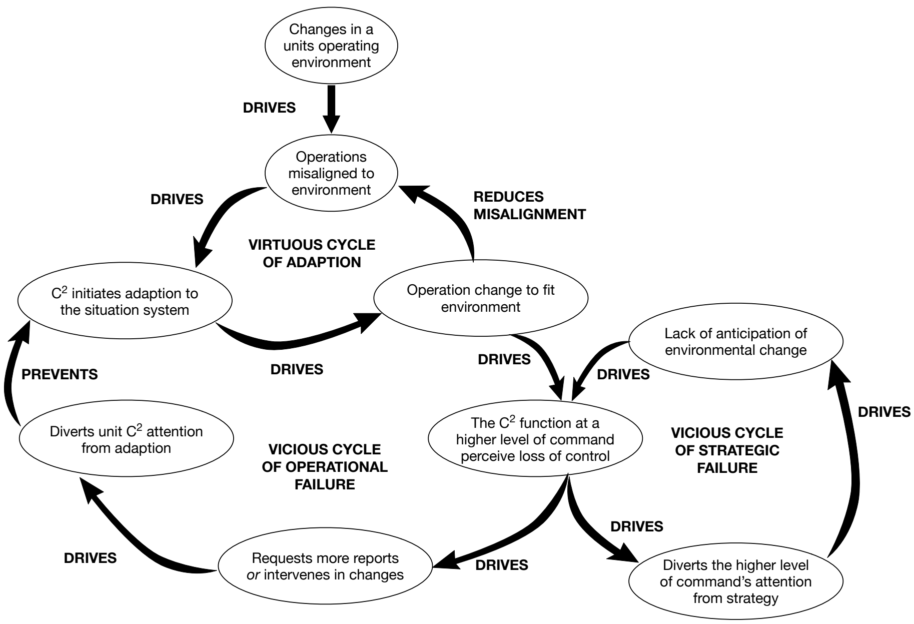

Figure 3: The Control Dilemma archetype and its dynamics. *Adapted from* [7]

2. A suggestion for Endeavour Space dimensions

Our proposal for dimensions framing the Endeavour Space is the degree of *coupling*, or causality between components, the *dynamics* that emerges from the Endeavour Space system type in question, and the perceived degree of *complexity*, or *tractability*, of the system. These can be defined as follows:

Coupling/Causality: can be described as the interdependence between the components or entities that comprise the system in question.

Dynamics: describes the potential rate of change as well as the amplitude of such change that is inherent to the system.

Degree of Complexity/Tractability: describes to what extent it is possible to describe and understand what is happening within the system. This property also describe the potential for surprising or undesired events that may occur in the system.

From this suggestion, eight possible types of Endeavour Space types illustrating different system characteristics would emerge:

a.) Intractable, tightly coupled, non-dynamic
b.) Intractable, tightly coupled, high-dynamic
c.) Intractable, loosely coupled, non-dynamic
d.) Intractable, loosely coupled, high-dynamic
e.) Tractable, tightly coupled, non-dynamic
f.) Tractable, tightly coupled, high-dynamic
g.) Tractable, loosely coupled, non-dynamic
h.) Tractable, loosely coupled, high-dynamic

Below follows a discussion where each of the Endeavour Space types are presented and exemplified as depicted in figure 4. Finally, the connection between the Endeavour Space types and the C2 Approach Space archetypes are discussed.

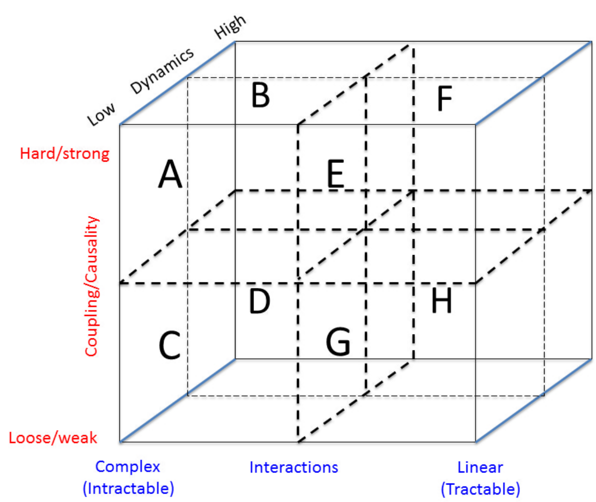

Figure 4: Endeavour Space system types.

2.1. Examples of Endeavour Space situation system types

The suggested situation system types that are possible to position in the Endeavour Space dimensions can represent most related problems, but also opportunities that can emerge, from dynamic and wicked to fairly straight forward situations with low dynamics and apparent couplings or causality.

If we consider a.) in the list above, we find systems exhibiting poor tractability while they simultaneously are tightly coupled and non-dynamic. Examples of this type of systems can be technical systems. In an engineering sense, such systems are possible to describe as blueprints and from laws of physics that can be used to explain them. Technical systems are often perceived as complex since it is hard to understand how they work resulting from the complex interactions between involved components or entities. However, processes performed by the system are not dynamic. Usually, the system either works or does not work. Mechanical watches or other non-dynamic technologies are common examples.
The type of problem in b.) ads a high degree of dynamics to the problem description. Such systems can be found in nuclear power, chemical industry, or similar systems characterised by strong and complex dependencies between the involved components that need careful tuning to resist sudden and violent change. From a military or a political point of view, this may be analogous to core societal processes that must be in place to avoid unrest. Such situations can only be mastered by a constant sensitivity to the possibility for rapid change.

The type of problem in c.) concerns situations that exhibit low dynamics while being loosely coupled and hard to track. Such systems are hard to understand because the involved components are loosely coupled to each other and hence interact in unpredictable ways. Although they are unlikely to exhibit sudden change or violent reaction to input or involvement, the outcomes of actions, such as side effects, are hard to predict. Many political situations resemble such game-like situations.

The problem space outlined in d.) is unfortunately an increasing dilemma where loosely coupled components exhibit highly dynamic behaviours. For example, terrorist cells, social media interaction, some natural disasters, and certain service-based systems, which all are examples of such systems.

Type e.) can be illustrated with many systems we use on an everyday basis like rail road traffic or other systems signified by strong dependencies between components. Although the interactions cannot cause significant non-linear dynamic change – change is proportional to the input.

The problem dilemma in f.) is in a sense an instantiation of d.) as it can be exemplified by constructed systems that are both tightly coupled and dynamic, but tractable. Many computer systems, traffic systems, and work places have these characteristics as they comprise such properties but can still be understood and managed. This type is sometimes referred to as "organised complexity" [8]. It should however be noted that this kind of systems can be devious as disturbances or errors quickly may propagate through the system and cause effects that are not predictable. Hence, while for example a computer contains both tightly coupled and dynamic processes, it may be perfectly usable until a software bug or a hacker attack puts it into a state of intractability, turning it into b.) endeavour state type.

Problem g.) represents a common type of characteristics that can be found in many systems such a naval transportation, assembly line production, and some military operations. Systems of this kind are tractable mostly because of the lack of dynamics. The behaviour of such systems may not be easy to predict, but as long as the current situation is monitored, they are understandable.

Finally, problems belonging to the category in h.) contain systems that to some extent are possible to understand, but may still be hard to predict as they are loosely coupled and highly dynamic. The components of such systems may interact according to certain rules that limit their inherent complexity, making them tractable to some degree despite their loose coupling. Team sports and disciplined/doctrinal military operations can be described in these terms. Using a game metaphor, one could say that it resembles a set of pieces that are highly independent but still only can present a certain set of behaviours.

3. Discussion

C2 agility and a set of related hypotheses have been empirically tested over the years using case studies and experiments that first employed qualitative measures but afterwards developed quantitative measures. The dimensions of the C2 Approach Space have matured to the point where they are widely accepted and employed. Case studies and experiments have provided evidence regarding the relative agility of different C2 approaches (different regions of the C2 Approach Space) and the missions and circumstances for which they are well suited. The Law of Requisite Variety would imply that the more agile a given C2 Approach is, the more variety (behaviours, states) it can create.

At this stage of developing C2 Agility Theory and its application, two major challenges and critical research paths are impending: 1) a more precise formulation of the Endeavour Space that specifies its dimensions and provides a means of quantitatively measuring them, and 2) a better understanding of what makes certain C2 Approaches more agile, viz., what enables a given C2 Approach be successful in a greater variety of missions and circumstances. An argument could be made that the concept of variety may help in both these efforts.

The archetypical C2 Approaches depicted in figure 1 can for obvious reasons not be mapped directly to the Endeavour Space types. However, some initial observations can be made. Endeavour space types that are tractable and signified by low dynamics can usually be controlled with a traditional industrial age approach to C2 as long as it is possible to describe them in sufficient detail to unravel their inner working. Scientific management is a grand example of this in the sense that specialisation and reductionist approaches could manage such problems very well.

Nevertheless, when dynamics increase in an endeavour, C2 becomes more challenging. To control such dynamic situations, the law of requisite variety applies and suggests that the controlling system must be able to counter the dynamics of the system to be controlled. Even highly complex Endeavour Space types signified by strong coupling may be controlled. Once these couplings are understood, it may be possible to take advantage of this knowledge and create the variety needed to control or destroy the variety of an opponent, thereby limiting the opponent's chances to dominate the situation.

4. The way ahead

The remaining challenges in the development of the Endeavour Space dimensions is to populate the different endeavour space types presented in figure 4 above with examples holding military relevance. A series of case studies and experiments is the most likely way forward to gain a deepened and systemic knowledge at this stage. Such an effort has been initiated within the NATO STO Research Team SAS-143. Further, the fact that the description of an Endeavour Space type will always be based on a perception of a current system and may change over time must be emphasised. This means that the assessed position of an Endeavour Space type (in the Endeavour Space) will change over time and most likely, with a continuously deepened knowledge of the problem at hand, will be able to move available and possible actions to a more conscious level.

However, all moves within the Endeavour Space seem to be different from different conditions. There seems always to be a move through the Endeavour Space that "snakes" its way as intelligence and knowledge change the controller's perception of the system. This too will need to be investigated through human-in-the-loop experimentation.

Lastly, the relationship between the C2 Approach space and the suggested Endeavour Space must be examined further. While it is proven that different approaches to C2 are more or less agile, it is yet to be demonstrated under exactly what circumstances a certain C2 approach is appropriate or not.

References

[1] NATO RTO, NATO NEC C2 Maturity Model, CCRP Publication Series, Paris, 2010.

[2] 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.

[3] NATO STO SAS-104, PRE RELEASE: C2 Agility: Next Steps, Technical Report RPD, The NATO Science and Technology Organization, 2015.

[4] W. R. Ashby, An introduction to cybernetics, Chapman & Hall, London, 1956.

[5] G. H. Walker, N. A. Stanton, P. M. Salmon, Command and Control: The Sociotechnical Perspective, Ashgate Publishing Group, Farnham, Surrey, GBR, 2009.

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

[7] P. Hoverstadt, The Fractal Organization: Creating Sustainable Organizations with the Viable System Model, John Wiley & Sons Ltd, Chichester, West Sussex; UK, 2008.

[8] W. Weaver, Science and complexity, American Scientist 36 (1948) 536–544.