Chapter 4
Modelling Command and Control in Networks

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ABSTRACT

This chapter proposes an approach to modelling the functions of C2 performed over a network of geographically distributed entities. Any kind of command and control (C2) organisation, hierarchical, networked, or combinations thereof, can be represented with this approach. The chapter also discusses why a theory of C2 needs to be expressed in functions in order to support design and evaluation of C2 systems. The basic principle of how to model functions performed by network is borrowed from Cares' network model of warfare, which is also used to model the context in which C2 is performed. The approach requires that C2 is conceived of as fulfilling a set of necessary and sufficient functions. Brehmer proposes such a theoretical model that is at a sufficiently high level of abstraction to illustrate the suggested approach. More detailed models will be required, however, for the approach to be of practical use.

INTRODUCTION

The development in communication technology enables network centric warfare, i.e. geographically dispersed forces (consisting of entities) can share information, coordinate their actions, and act in concert to achieve specific goals (Alberts, Gartska & Stein, 1999). Not only the fighting per se, but also the commanding and controlling of it can be networked, or, in other words, performed collaboratively by a number of C2 entities connected by a network. Depending on the degree of collaboration, these C2 constellations are considered more or less mature (NATO SAS-065 Research Task Group, 2010).

When reviewing the dominating theoretical models of command and control (C2) at the time, Brehmer (2005) and Grant and Kooter (2005) independently made quite similar observations. They found no theoretical models, networked or not, that could support a systematic design and evaluation of C2 systems. In addition there was, as observed by Pigeau and McCann (2002), little agreement on the definitions of the concepts, i.e., what the terms command, control and C2 referred to.

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According to Brehmer (2010), there is a need for a general theory of C2 to organize the field, and for a suitable ontological framework. He claims that viewing C2 as a product of design provides such a framework. This places C2 science among what Simon (1996) called "the sciences of the artificial." This approach requires that the theoretical models proposed are models of *functions* (Brehmer, 2008).

In the scientific literature, there are, according to Nagel (1979), two categories of explanations that are referred to as functional explanations:

> *A functional explanation may be sought for a particular act, state, or thing occurring at a stated time…. Or, alternatively, a functional explanation may be given for a feature that is present in all systems of a certain kind, at whatever time such systems may exist. (p. 24)*

Simon (1996) refers to functional explanations of the second kind, when he discusses the science of design. This is also how the concept of function is used in engineering design (e.g., Pahl et al., 2007), and how Brehmer (2013, 2008) uses it.

Defining C2 science as a science of the artificial, or a design science, requires us to acknowledge that C2 systems are artefacts, that they are designed for a purpose. It suggests that C2 systems are probably best understood in terms of the logic that was used to construct them (Brehmer, 2008).

When analysing an artefact according to the logic of design, the system or artefact is considered from three different perspectives. These perspectives make three levels of analysis, hierarchically arranged according to the degree of abstraction. The levels are the system's purpose(s), its function(s) and its form (Brehmer, 2007).

Specifying the *purpose* of a system is to explain *why* the system exists (or needs to be constructed). Specifying the purpose of C2 is akin to defining C2. According to Alberts (2007) this purpose is to achieve focus and convergence of efforts within an organization in order to reach a common goal. Brehmer (2007) uses the terms direction and coordination instead of focus and convergence, but in a fairly similar way.

The next question is: *What* does the C2 system need to be capable of in order to fulfil its purpose? The answer is given by the system's necessary and sufficient *functions*. Functions are defined by their output, what they achieve, not how it is done (that is defined by the form). The set of functions and their relations constitute a theory of what is generally required for successful C2 (Brehmer, 2007). Brehmer suggests that the necessary and sufficient functions are data collection, orientation (or sensemaking in his earlier writings), and planning (Brehmer, 2013, 2007). Other C2 theorists may suggest another set of functions. If theories are to be compared, they need to be developed within the same ontological framework. Theories of C2 functions can only be compared with other theories of C2 functions, and not with theories based on other concepts.

A function may be thought of as an empty box. The box is labelled with what we want the content of the box to accomplish. Consider, as a simple example, an object that we want to split into two halves. The input to the function is the object to be split, and the desired output is two separate objects, i.e. the parts separated by the split. The function (the label on the box) is to split an object in two. Nothing is said about how this is supposed to be done. That is defined at the next level, the level of form.

Splitting an object in two can be done in several ways. It might be cut with scissors, torn apart, or chopped with an axe. These are possible *form* alternatives that might be chosen to fulfil the function of splitting an object in two. Which alternative is the most appropriate depends on the material of the object in question.

Defining the function splitting allows us to discuss splitting in general. It also enables us