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”C2 FOR COMPLEX ENDEAVOURS”

Command and Control Research is a ”Science of the Artificial”

C2 CONCEPTS, THEORY AND POLICY

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This paper is concerned with the nature and development of a science of Command and Control (C2). The concept of C2 science is discussed from the point of view of Simon's (1996) concept "the sciences of the artificial", i.e., the sciences concerned with how we achieve goals by means of design of artifacts (including our own thinking). Applying Simon's conceptual framework, C2 is analyzed in terms of a goal (that of producing military effects), an outer system (the system where we seek to produce military effects) and an inner system (the model guiding the C2 process) with an interface in the form of the military system. This is then applied to C2 which is analyzed as a form of design (of military missions) but also as an activity that is itself the result of design (of the C2 system). In the latter analysis, the concept of function is used to partition the complex design task into manageable parts and to specify the design requirements. It is concluded that Simon's concept does indeed provide a useful point of departure for creating a general framework for developing C2 science.

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In a series of papers (Brehmer, 2005, 2006a,b, 2007), I have argued that command and control (C2) is best understood in terms of the logic of design. This is because it is performed within, and shaped by, C2 systems that are human artifacts, i.e., the result of more or less systematic design. In this paper, I want to take a step further and outline the consequences of this line of reasoning for a science of C2. Specifically, I want to place C2 research where I think that it belongs: among what Simon (1996) called the "sciences of the artificial", and to outline some of the implications of that perspective for understanding C2.

The "Sciences of the Artificial"

In contrast to the natural sciences, which are concerned with what *is*, the "sciences of the artificial" are concerned with what *can* and *should be* (Simon, 1996). Specifically, they are concerned with the design of artifacts that help us attain goals, both in the form of concrete artifacts, such as clocks and cars, and abstract ones in the form of formal methods, such as economic analysis and decision theory. But the sciences of the artificial are not only concerned with design, they are also concerned with the study of exiting systems that are the result of design. Thus, they include a wide range of sciences, from engineering to economics, and even those aspects of psychology that are concerned with goal oriented forms of thinking and behaviour (Simon, 1996). From Simon's point of view, both the study and design of the C4ISR systems that support C2 and its more abstract features, such as the methods and procedures used when performing C2, are artifacts that fall within the domain of the sciences of the artificial. Indeed, from this point of view, the activity of C2 as a human activity developed to attain (military) goals, is itself a matter of design, and it too falls within the domain of the sciences of the artificial. Consequently, it should be understood from a design perspective as will be explained later in this paper.

In Simon's analysis, an artifact is an interface between an *outer system* and an *inner system*. The definition of these systems and the partition between them result from the goal to be attained. The outer system consists of the environment in which a person tries to achieve his or her goals. The inner system comprises the model used as a means to achieve these goals. The inner system is embodied in the artifact, i.e., the inner system represents and processes the relevant aspects of the environment, be it in the form of a concrete artifact, an abstract procedure or a sequence of actions[1]. If this

[1] The distinction between the inner system and the artifact as an interface is not entirely clear in Simon's book. In the case of a clock, discussed by Simon (1996) as an example, the artifact and the inner system seem to be synonymous. In this paper, the interface is defined as whatever causes the effects (the attainment of the concrete goals) in the outer system. The inner system refers to the model of those aspects of the outer system that must be taken into account for achieving the goal, and embodied in the artefact. Thinking of the artifact as tool is helpful here, I think. Another problem with Simon's conception is that he was not very clear on how the inner and the outer systems are connected, nor on how one decides what the inner system must do. In this paper, I propose that this problem is solved by the concept of function, as will be discussed later in the paper.

terminology seems confusing, it helps to think of the artefact as a tool that is used to achieve goals. The outer system is the system in which these goals are to be achieved, and the inner system is the model of those aspects that are relevant to achieving the goal. This model is then embodied in the tool, either in the form of concrete parts and their relations, or abstractly in the form of procedures and processes.

Insofar as the artifact is a physical object, such as a clock, it is, of course, subject to the laws of physics, but these laws are put to use for a purpose in the design. A clock can therefore be studied both from a physics point of view and as an artifact designed for a purpose. In the design of physical artifacts, the laws of physics provide both the opportunities for creating artifacts and the limitations on what artifacts can be designed and on how they can be designed. In the same way, mathematics provides both opportunities for designing formal methods that help us make decisions and limitations on what methods can be designed. Analogously, the characteristics of the people who perform C2 define both the opportunities and the limitations for successful C2. Thus, just like the clock, C2 can be studied both as an existing system from, say, a psychological or sociological point of view, and from the design point of view.

The exact demarcation between the outer and the inner system results from the nature of the goal to be attained. The goal determines both what aspects need to be taken into account to reach the goal and how the artifact has to function to produce what is needed to actually reach it. This means that the line of demarcation between the inner and the outer system will be positioned differently, depending on the goal. As we shall see, this is important in the study of C2, a problem to which we now turn.

What are the outer and inner systems in C2 and what is the interface?

Following van Creveld (1985), we consider C2 as a *function* of the military system. The question is what this function accomplishes, for that will determine how we partition the system of interest into an inner and an outer system.

Most definitions of C2 tend to describe it in what I have called an “inward looking” fashion, as a matter of handling the military resources (see Brehmer, 2006a). This makes the military force the outer system and the C2 system the inner system. The orders produced by the C2 system become the interface.

This conceptualization makes sense when we consider a peacetime force, where the overriding aims are to train and improve that force. But it is of little help for understanding command and control of a military mission, i.e., when the force is put to use. Here, we need a different focus. In a mission, the commander’s goal is not only controlling his troops and other resources (he or she must do that too, of course), but to achieve *military effects*. This is like switching from sharpening a knife to using it for cutting: our attention changes from the knife to the effects. It is these effects, rather than sharpening of the knife, that concern us in this paper. That is, our focus is on the command and control of missions, i.e., the effects that can be achieved *with* the force and what is required for achieving these effects, not with the effects *on* the force. As a consequence, we need a definition of C2 with an “outward focus”, a focus on effects, rather than on the force (Brehmer, 2006a). For this purpose, C2 can be defined as the function that achieves military effects by providing direction and coordination of the

military effort (see Brehmer, 2007). This leads to a different system definition and a different conception of the interface. The interface is now the military forces for it is these forces that cause the effects. The outer system becomes the environment in which the military effects are achieved (including the enemy, but also the cultural, political and geographic context), and the inner system becomes the models that govern how the military forces are used to produce the effect. C2 is now a function of the inner system, and can be conceptualized as a subsystem of that system as it is in the Dynamic OODA loop, our current conception of C2 (Brehmer, 2007). Just as in the case of cutting, the commander should not have to focus on his or her instrument. He or she should focus on the effects that can be achieved. Yet, his or her thinking must, of course, be bounded by the nature of the force that he or she commands. Just as only a person who has cutting on his mind will reach for a knife, only a person striving for military effects[2] will employ a military force, and he or she should focus on, and know, what effects can be obtained with this particular instrument. Moreover, C2 is bounded by the nature of the force. The concrete form that C2 takes and the concrete demands made upon the C2 function, will, of course, depend on the forces that are available to the commander, as will the effects that can be achieved. For example, the admiral commanding a carrier task force will have different effects in mind than a sergeant commanding a rifle squad, and the two will face very different practical problems when trying to achieve their goals. Yet, as we shall see, there are important similarities between the tasks facing the admiral and the sergeant as well. To explore these, we now turn to a discussion of the nature of goal-directed systems, of which the military system is an example. This provides the common ground for linking the science of C2 with other sciences of the artificial.

Goal-directed systems

The most general requirement that a goal-directed system must meet is that it can select the appropriate course of action for reaching its goal, and that it can do this in the range of circumstances in which it has to operate. Indeed, the latter characteristic is the very definition of a goal-directed system. We recognize such systems from the fact that they reach their goals in *different* environments, i.e., that they are adaptive. If a system will function only in one set of circumstances, we think of it as a mechanism or a device, rather than a goal-directed system.

In Simon's conception of the sciences of the artificial, this is a question of how to design (or evolve) the inner system so that it can reach its goals in the outer system by means of a suitable artifact. The concept of artifact must, of course, be taken in the widest possible sense to include not only physical objects, but methods and procedures as well. The first problem, then, is to determine what the inner system must do, and how it must do it to reach its goals, except by happenstance. Our answer to this question, outlined in the earlier papers in this series (Brehmer, 2005, 2006a,b, 2007). It is provided by the logic of design, i.e., an analysis of artifacts in terms of *purpose* (why they exist), *function* (what they need to do) and *form* (how they do it). Specifically, the concept of function provides a bridge from the outer system to the inner system. Identifying the functions that must be achieved tells us what the system must be capable of doing to achieve its ends. Three functions seem to be necessary for any

[2] Smith (2006) describes the effects that can be obtained with a military force as *ameliorate*, *contain*, *deter/coerce* and *destruct*.

goal-directed system. First, it must be able to select an appropriate course of action, i.e., it must be able to select *what* to do. To succeed in fulfilling this function, it must then be capable of taking note of those aspects of its environment that are important for selecting the appropriate course of action. To actually reach the goal, it must then shape the action in a way that is appropriate to the circumstances in which it finds itself. That is, it needs to be capable not only of selecting *what* to do, but also *how* to do whatever it needs to do. The distinction between the "what" and the "how" is an important aspect of understanding the system as a goal-directed system, i.e., as a system that can achieve its goals despite variations in the circumstances. Such systems must, of course be able to both select what to so and how to do it.

If the reader thinks that these are trivial and obvious observations, I have to agree. To get on, and be able to understand an existing system, or design a new one, we obviously need to give some more concrete substance to the three functions outlined above. To do so, we now turn to a discussion of the functions to be achieved in C2.

The functions that must be achieved in C2

C2 is performed by people, and the description of the functions that must be fulfilled in C2 should reflect this. It should refer to functions that can, at least to some extent, be achieved by people. In the earlier papers (see, especially, Brehmer, 2007), I have suggested that the three basic functions in C2 are *data collection*, *sensemaking* and *planning*. These three functions correspond to the three functions outlined above, i.e., being able to observe the relevant features (data collection), being able to find what needs to be done (sensemaking) and being able to shape what needs to be done according to the circumstances (planning). Thus a commander and his or her staff must make sense of their mission in the light of the data they collect to come up with an idea about what do. They must then work out how to do what needs to be done and put that into orders. For example, when given the mission of destroying an enemy force, the commander may decide, based on his or her understanding of the situation and the mission, that a pincer attack will do the trick. Having decided this, it is then necessary to work out how this is to be done. For example, they must decide what unit should go where with what mission, and so on, i.e., they must plan, and express the plan in orders.

For success, all three functions must be achieved. In terms of the function of C2 in the military system, sensemaking provides direction, and planning provides coordination, while the data collection function provides the data that are required for both. There is considerable economy in separating the function that produces the "what" from the function that produces the "how", for there are many "hows" for every "what". For example, a pincer attack can be performed in many circumstances, but each set of circumstances demands its own plan for how it should be performed.

In our current conception of these functions, sensemaking is defined as the function that achieves an understanding of the mission in terms of what should be done in the situation at hand to achieve the goals stated in the mission (Brehmer, 2007). This definition reflects a commitment to a pragmatic view of understanding, based on the philosophy of William James (1907). We find that it suits our purposes better than the commitment to empiricism that seems to dominate most current work on C2. This is because a pragmatic stance emphasises that the central task in C2 is to find a course of

action. It is not sufficient to understand the situation in a cognitive sense, to merely understand what *is*. The important thing in C2 is to find what to *do*. C2 is action oriented, rather than knowledge oriented. Indeed, it is only by acting that the uncertainties inherent in military action can be resolved. Here James's (1907) well known dictum that truth is not inherent in an idea, it happens to the idea, is instructive. It is only by acting that we can determine what James called the "cash value" of our ideas. This is, of course, not specific to C2, but something that all goal-directed systems have to face.

The definition of sensemaking as a function does not imply a commitment to any particular view of the *process* that achieves the function; everybody is free to construct his or her own conception of the process, so long as it is sufficient to produce what the sensemaking function demands: an understanding of what should be done in the situation at hand.

The data collection function should produce the data that are required by the sensemaking function. One might think that it should aim at constructing a faithful reproduction of the battle space in all its detail, as implied by the metaphor "operational *picture*". This is, however, misleading, first, because the nature of the sensors that are available limit what data can be collected, and second, because not everything of interest can be observed even with the best of sensors, be they human or electro-mechanical ones. The "fog of war" is not likely to dissolve even on the modern electronic battlefield. Moreover, even if such a detailed reproduction could be achieved, the data collection function should not supply it to the commander for he or she would probably not be able to use it, except, perhaps, for the case of C2 at the lowest levels of command. A selection is therefore necessary, and it should allow the commander to make this selection[3]. This selection should be guided by the sensemaking function, and the goals that drive that function. In short, the data collection function should be under the control of the sensemaking function. However, the data collection function needs to be separate from the sensemaking function, for the selective character of sensemaking may well lead it to overlook important developments, and there must be means of bringing such developments to its attention.

As noted above, just finding *what* should be done is not sufficient. It is also necessary to decide *how* it should be done, that is, to shape the action as the circumstances demand. This is the task for the planning function, which turns the "what" produced by the sensemaking function into a "how" and expresses this in an order[4]. The order should then express both the "what" and the "how" in a form that is appropriate to the subordinate. The order is the product of the C2 system, and it represents the means that it has for causing the military activity that is necessary for making the military system produce the effects that the commander desires.

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[3] This view is compatible with James's (1907) view of cognition as essentially selective, as a matter of selecting information required for one's purpose, rather than taking in everything as is implied by the picture metaphor.

[4] The term "order" should be taken in a very general sense and includes all manners in which the C2 function influences the action system.

The functions shape C2

The three functions described above constitute our current theory of what C2 needs to do to fulfil *its* function (Brehmer, 2007). Insofar as these three functions capture what is required for successful C2, any attempt to perform C2, can be described in terms of the extent to which these functions are achieved. In short, the extent to which the commander and his/her staff are successful in doing so determines whether the military goal is achieved, for it determines the extent to which the appropriate direction and coordination is provided for the military effort. How the C2 function goes about fulfilling the functions, or how those who perform C2 understand what they do, is, of course, another matter. Just like Monsieur Jourdain in Moliere's play who found that he had been speaking prose all his life without knowing it, the commander may find that he or she has been involved in trying to fulfil the functions of data collection, sensemaking, and planning all his or her professional life without knowing what they did under these particular headings.

What is produced by C2, the order, is the means by which the commander and his/her staff try to achieve their goal. To produce this order is, of course, an act of design, viz., design of an activity to produce the order, as well as an act of trying to design military activity by means of that order. It makes no difference if that activity is invented by those who perform it, or if they learned it from a book of rules and regulations. It is still a matter of design and it can be understood and evaluated in terms of the extent to which it achieves the goal. That the procedure has been designed by those who perform it may make it seem a "natural" way of performing C2, but that is no guarantee that it is the best possible way.

This leads to our first conclusion from considering C2 science as a "science of the artificial": *The activity of C2 is itself an artifact*. It is a human activity designed in aid of achieving military effects by producing the order, and thus the activity, that is needed and it is shaped by the functions that it tries to achieve.

C4ISR system

As noted by Simon (1996), the better an artefact functions, the less visible it is in use. A well designed artifact simply produces what is required to reach the goal and adds nothing of its own. It allows us to focus on the effects rather than the means used to produce the effects, on the cutting, rather than the knife. To borrow a term from Conant and Ashby (1970), the artifact then embodies a model of the requisite aspects of the system that it has been designed to control. In so far as we notice the characteristics of the C2 system as such, it means that the system is not functioning as well as it should.

That the artifact should become invisible in Simon's sense is an ideal that would be hard to achieve in the case of C2. This is because it is generally impossible to obtain *all* the data that would be required to mould the C2 system into the model of all those features of the outer system that need to be taken into account for perfect command and control[5]. Perhaps it is also the case that the complexity of the outer system is such

[5] We need to beware of the "cat problem" here, i.e., that the best model of a cat is another cat. However, if the second cat were a perfect model of the first cat, it would be just as intransparent and hard to control as the first cat. The important thing is to construct a model of the first cat that

that it precludes this possibility with any reasonably sized C2 system. Hence, C2 systems, and especially the commanders, will probably always be visible even if the best designed C2 systems.

Because the possibilities of ascertaining the current state of the outer system are limited, it is not possible to design a C2 machine that will win any battle. C2 is inherently fallible. Hence the outcome of any battle is uncertain as Clausewitz observed. But that does not mean that C2 cannot be improved by means of better C4ISR systems or better ways of doing C2. However, C4ISR systems can only be systems that support those who perform C2, they cannot do their job. That they are support systems means that they are designed to assist people to do something that they cannot do without their help, or at least something that they would do less well without them.

The starting point here ought to be a model of the optimal way to fulfil each of the three functions. For the reason given above, such models are nowhere in sight. Nor are we likely to find the requisite models by breaking down the three abstract functions described above until we can take the step over to a suitable form as we do in the design of physical artifacts (see Brehmer, 2007, for a discussion of this point). In this process we may reach a level of functions at a simpler and more basic level, but they will still be functions. Automatic C2 is not on the horizon. Therefore, we must concentrate on designing support for those who perform C2, and we have to limit ourselves to gradual improvement on existing systems, developing and testing new methods and support systems, and refining our models of how the functions are to be achieved in the process. The design of C2 systems is a matter of designing the form of the system, i.e., the organization, the methods and procedures and the support systems that make up the system. Some of the problems that this involves are discussed in Brehmer (2007).

As they are developed, the methods and support systems will, of course, shape what the people performing C2 will actually do. This, then, is the second way in which the conception of C2 research as a science of the artificial is relevant to our understanding of C2: *The actitives in C2 are shaped by the C4ISR systems that are the result of design*. When designing these systems, we also design C2, wittingly or unwittingly.

The output of the C2 system is design

As noted above, the design point of view can be taken one step further to include also the *product* of the C2 system. As described above, that product is a set of orders. These orders can be described as a “recipe” to be followed for a successful outcome. It is, of course, a recipe for expert users, where much is left unsaid and implicit. The output is, nevertheless, a attempt at design, design of the military activity.

In a military subscribing to mission tactics the recipe will only specify what needs to be achieved by the recipient to fulfil the commander’s intent. Nevertheless, C2 aims at designing a course of action that will achieve the goal of the military system, be it in the form of a set of goals (mission tactics) or a set of actions (directive control). In short, C2 is not only the result of design, it also produces design. To design a C2

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incorporates those features that important for controlling it (if indeed such a model of a cat is possible at all). Such a model may not even look like a cat.

system is thus to design a system that will be capable of producing design in the form of adequate ways of achieving goals.

This is not quite as trivial as it sounds for it points to the most fundamental capability that a C2 system must have. Specifically, it emphasises that the C2 system must be capable of modelling the environment in which the goals are to be achieved as was noted above in the reference to Conant and Ashby (1970). This implies that C2 is intimately connected to what is commanded, and that there is little reason to believe that just because one knows how to command one system, one is also able to command another. This lesson is well illustrated by the failures of the military style of C2 in coping with disasters (Dynes, 1994).

Conclusions

This paper is the fifth in a series of papers that started with a discussion of the nature of C2 and that has now ended up with a discussion of the nature of C2 science. Our conclusion is that its object of study is design of C2 systems and that C2 systems should be studied as designed systems. Consequently, C2 research belongs among the sciences of the artificial as defined by Simon (1996). In summary, C2 research is concerned with designing C2 systems, systems that are capable of producing design of successful action. C2 is shaped by the attempts to fulfil the requisite functions and by the C4ISR systems that are designed to support them. The design of C4ISR systems is thus also design of C2. Stressing the concept of design also makes it clear that C2 is not only a question of science. There is also room for art as in all design, for even though what needs to be designed and the evaluation of the designed artifacts may be a matter for science, the actual design solutions will require creativity and art on the part of the designer. This is true of all aspects of C2, the design of C4ISR systems as well as the design of courses of action.

Does this make a difference?

That C2 research is a science of the artificial in Simon's (1996) sense seems obvious once it has been said. The question is whether it makes a difference to consider C2 from this perspective. The main advantage, in my view, is that it provides a coherent view of C2, both for understanding C2 and for designing and evaluating C2 and C4ISR systems.

First, it provides a unitary conception of what C2 is about, and for understanding what is done in C2: C2 can be understood as an attempt to fulfil three functions: data collection, sensemaking and planning. The way in which these functions are fulfilled may differ, and the most important factor here is the technology that is available. It is just not possible to understand how C2 is performed in practice, nor its scope, in isolation from technology (see Keegan, 2004 and van Creveld, 1985 for historical analyses of how C2 has developed as a result of advances in technology). Yet, understanding what must be achieved by C2 is not dependent on technology, and it has not changed in the course of history. It has always involved achieving the three functions. In agreement with van Creveld (1985), I maintain that what the commanders in antiquity were trying to achieve and what commanders of today are trying to achieve can be understood in the same way: as attempts to fulfil the functions that must be fulfilled for successful C2. Technology has changed the way in which the commanders

of today perform their task compared to how their colleagues performed it in former times, however, and the scope of C2 has changed greatly. For example, Alexander being limited to commanding by voice, had to lead a relatively small force from the front, but Hitler could command troops all over Europe from the Führerbunker in Berlin by means of telephone (Keegan, 2004), and President Johnson could decide the targets for the American bombers in Vietnam from the Oval Office in Washington. This is a combined effect of developments in communication technology (writing and telecommunications) and of representation technology (maps and geographical information systems).

The way the functions are achieved as well as the scope of command and control must thus be reevaluated by each generation, but the use to which they put the technology that is available to them remains the same. It is to help the military system fulfil the functions of C2. This does not mean that we should expect unlimited growth in capabilities. As the limitations of physical law limit what clocks can be designed, so the limitations of the humans who do C2 will limit the scope of C2. But in contrast to the limitations introduced by physical law, the limitations of humans should not be regarded as fixed once and for all. They change with the technology that becomes available.

This does not mean that the commanders of antiquity were worse at their task than today's commanders, so long as they stayed within the scope of what could be achieved with the technology of their day. However, it does not seem reasonable to do C2 with the technology of today in the same way as the celebrated commanders of yesterday did it with the technology of their day[6]. With respect to C2, we may therefore have less to learn from history than from contemplating the new possibilities offered by technology in the pipeline. This is, of course, true of all designed systems.

Second, considering C2 research as a science of the artificial informs the design of C2 and C4ISR systems. The design of these systems must start from an analysis of the functions that have to be achieved in C2. This is not the same as saying that the design of such systems must use the conception of these functions outlined in this paper as the point of departure. The Dynamic OODA loop with its three functions: data collection, sensemaking and planning is just one of many possible theories of the requisite functions. Most certainly, there are many different ways of breaking down the abstract functions of the DOODA loop into lower level functions to make contact with human capabilities. Our conception of what the stopping point should be will be determined by our conception of what functions humans are able to fulfil. This is illustrated by Jensen's (2007) attempt to break down the abstract function of sensemaking into lower level functions. It is the first example of a break down to the social aspects of sensemaking in a command team. It gains credibility from that fact that the result is in close correspondence with independent examples of the breakdown of team work into components (Rosseau, Aubé & Savoie, 2006), and from the fact that it can serve as a basis for designing more effective procedures for sensemaking. Jensen's work serves as an example of how our theory can be put to use and suggest more effective forms of C2. It does so by illustrating that a breakdown of a function that is to be achieved by people must be done keeping two perspectives in mind at the same time:

[6] Leadership is, of course, a different matter. This is less affected by technology, yet changes in society and culture has probably affected what will work for a commander in this respect.

what the function requires and what people can do, and bringing these into contact. This should serve a good starting point for further analyses of the other functions in our theory.

A third perspective offered by the present conception of C2 research concerns the nature of the product of C2. It too is seen as design, design of activity in a way that makes it possible to achieve the goals given in a mission. The basic principles of a science of the artificial inform us of what is required for this: The C2 function must be capable of forming the requisite models of the outer system to find a successful course of action. This, in turn, emphasises that successful C2 requires domain knowledge, and that there is probably no such thing as a C2 system for all seasons. Yet, the functions to be achieved remain the same in all forms of C2, regardless of the domain for which it is exercised; it is only the requisite models that differ.

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