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# Command and control as design

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# Command and control as design

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ABSTRACT

This is the final paper in a series of papers presented at previous ICCRTS conferences from 2005 on, and in the International C2 Journal, aiming at developing a science of command and control (C2). Specifically, the aim has been to search for an appropriate ontological framework for the study of C2 which will let us escape from the current fragmentation of the field. This work has led to the view of C2 as one of the "sciences of the artificial", i.e., it is a science of artifacts, or of design. In this paper I will summarize the results of these studies as they relate to the understanding of C2 systems and C2 as a function, and extend the framework to an analysis of C2 as an activity in an attempt to demonstrate that the design framework provides a coherent view of the field of C2 as a whole. This should open up the possibility for cumulative growth of C2 research.

## Introduction

Although there is no dearth of studies relating to command and control (C2), these studies, with some notable exceptions (e.g., Alberts & Hayes, 2007; Stanton, Baber & Harris, 2008), tend to be concerned with *aspects of C2* rather than with *C2 as a whole*. Thus, they are studies of selected problems in C2 as seen from the point of view of a particular science, usually one of the behavioral sciences, or one of the engineering sciences. Valuable though this work is, it leaves us with a fragmented view of C2. Nor can it be otherwise, for no science, be it one of the behavioral sciences or one of the engineering sciences, can claim to cover C2 as a whole. One of the consequences of this state of affairs is that we are left without foundations for a general theory of C2 to organize the field. To develop such a theory, we need to develop an ontological[2] framework suitable for C2 research. In earlier papers in this series (Brehmer, 2005, 2006, 2007, 2008, 2009a), I have claimed that the view of *C2 as design* provides such a framework. This places the study of C2 among what Simon (1996) called "the sciences of the artificial". In this paper, I will summarize this view and work out some of its implications for understanding not only C2 systems, which has been the main focus of earlier papers, but for understanding C2 as an activity as well. I do not suggest that this work as yet constitutes a general theory of C2, but I do claim that it offers a suitable ontological framework for the future development of such a theory.

## The point of departure

The whole enterprise starts from two simple observations. The first is that *C2 is a human activity that aims at solving (military) problems*. Put differently, C2 is concerned with *design and execution of courses of action* to achieve (military) goals. This is what positions the study

[1] I than the C2 seminar at the Swedish National defence College, Dr Russell Bryant and Dr. Keith G. Stewart for yjeir many and insightful comments on earlier versions of this paper.
[2] I use the term "ontology" in its usual philosophical sense as denoting what objects exist in a system of analysis.

of C2 among the sciences of the artificial. The second observation is that *C2 is always conducted within a C2 system*, and that it is shaped by that system. In this context, the term "C2 system" should be taken in the widest possible sense. A C2 system thus includes not only the equipment used, but also people (also the commander), how they are organized, and the methods[3] that they use. This observation has an important implication: C2 should be seen as something that is done by the C2 system, rather than something that is done by the commander alone. This is not to deny the central role of the commander, or course. It means, however, that evaluating C2 is a matter of evaluating the C2 system, rather than just the people, or the commander. It would, for example, not make any sense to compare C2 as exercised in Alexander's army with that in the forces of General Schwartzkopf, even though they conducted their campaigns in the same part of the world. To understand the differences in how C2 was exercised in these campaigns, we must compare the C2 systems used in the two cases. Both of these commanders were empowered as well as bound (and thus limited) by the organization, methods and support systems that they had at their disposal. In both cases, the commander's decisions owed a lot to their respective C2 systems[4].

The focus of analysis in C2 research, therefore, is the *C2 system*. Such systems are *artifacts*. They are the result of (more or less systematic) design, and they are created for a purpose. Understanding this purpose, what is required to achieve, and how and to what extent it is achieved in a given case, is the key to understanding C2 (Brehmer, 2007).

These observations give the ground for suggesting that a general design perspective provides the ontological framework that we need, and that the study of C2 belongs to "the sciences of the artificial".

## The elements of C2 research as a science of the artificial

A science of the artificial is a science of artifacts created to help us achieve our goals. It is concerned both with physical artifacts (such as clocks) and with methods (such as theories of economics and computer programs or human problem solving). A science of the artificial as defined by Simon (1996) aims both at providing a basis for design of such artifacts and methods and to help us understand existing artifacts as well as the functioning of systems involving persons who use physical artifacts and/or methods to achieve their goals.

Simon (1996) suggests that the sciences of the artificial should be concerned with what he calls the *outer system*, the *inner system* and the *interface* between these systems. The outer system is the system where one's purpose is to be achieved, i.e., where one seeks to produce desired effects. The inner system is the system that is designed to achieve these effects, and the interface is that which is changed by the inner system so that the desired effects are achieved in the outer system.

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[3] In the case of methods, one should not uncritically assume that a staff or a commander will only use the methods that are prescribed in manuals and the like. The commander and his/her staff may well have found methods of their own that they consider better suited to the task than those prescribed. The C2 system of different commanders may therefore differ even when they belong to the same army.

[4] This is, of course, not news, and perhaps we should best view the form of talking about military campaigns that summarises all of the C2 activity in the image of the commander (what Napoleon did or what Guderian said) as convenient shortcuts and abbreviations. However, if we forget that what Napoleon or Guderian did was done within a C2 system, comprising people organized in a certain ways to accomplish the task using prescribed methods and support systems we will understand what really happened and why.

The exact system boundaries in an analysis of a C2 depend, as in a all analyses of systems, on the purpose of the analysis. If we consider the training of the troops, the inner system is the C2 system, the outer system comprises the troops and the interface consists of the orders. In combat, the outer system is the battle field with the enemy, terrain and so forth. The inner system is, again, the C2 system. The interface is the activity of own troops, since the interface is that which is changed by the inner system so that there is an effect in the outer system. The inner system (the C2 system) structures the activity of the interface (own resources) so that an effect can be obtained in the outer system (on the enemy). Designing orders is, however, still the only way for the C2 system to achieve this structuring, so for the C2 system.

These examples illustrate the complexity that has to be handled by a science of C2, as well as what the problem is: it is to construct an inner system, a C2 system that can produce what Ashby (1950) called the "requisite variety" to match the outer system. Put differently, but still using terminology borrowed from Ashby, it is to create a system that can produce, maintain and update a model of the outer system such that it becomes possible to carry out one's mission successfully (Conant & Ashby, 1970). This is, however, only one of the tasks of C2 research as a design science, or a science of the artificial. Such a science is also concerned with understanding and evaluating existing C2 systems, i.e., to understand how the C2 system actually produces its models, and the extent to which it is capable of developing and maintaining the requisite models. This is a matter of understanding C2 as an activity, a problem that will be considered later in this paper.

*A principal tool: Design logic*

Once they exist, the functioning of artifacts can be studied from a natural science perspective or a behavioral science perspective, depending on the nature of the artifact. They cannot, however, be understood *qua* artifacts from that perspective. To understand them as artifacts, we need a *design perspective*. Specifically, we need to understand their purpose (see Rubin, 1920, for a marvellous example), or the set of purposes for which they have been designed[5].

In the earlier papers, I have suggested *design logic* as a general tool for the analysis of C2 systems (e.g., Brehmer, 2007). Design logic is an adaptation of Rasmussen's well known abstraction hierarchy (e.g., Rasmussen, 1984). When applied to C2 systems, it involves an analysis in terms of three levels, each of which answers a specific question about the artifact of interest, be it an existing artifact or an artifact to be constructed, see Figure 1. The highest level is called the level of *purpose*, and it answers the question "why?", i.e., it tells us why the artifact exists, or why it should be constructed. The next level is called the level of *function*, and it answers the question "what?", i.e., it tells us what the system must do to achieve the purpose in the case of design. When analyzing an existing artifact, it tells us what the artifact does to achieve its purpose. The final level is called the level of *form*, and it answers the question "how?", i.e., it tells how the system fulfils the functions so that the purpose can be achieved.

[5] The actual form of a C2 usually does not only reflect the purpose of producing orders but also "irrelevant" factors such as command culture (see Brehmer, 2009a, for a discussion of this problem).

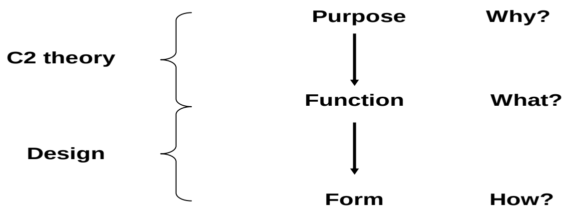


*Figure 1*. Design logic as applied to C2. The direction of the arrows depends on the problem to which the logic is applied. Design of a C2 system (the case illustrated above) is a top-down process, but understanding an existing C2 system in terms of the logic of design is a bottom-up process, where the functions are induced from the form.

A simple example will clarify this. Consider an automobile. The purpose of that artifact is to take us from A to B as quickly as possible, sparing the time and effort of doing it on foot[6]. The automobile needs to fulfil two functions to achieve this purpose: It must be possible to make it move and it must be possible to make it change its direction. These two functions are realized in the *form* of the automobile as en engine and a steering system.

In the earlier papers in this series (e.g., Brehmer, 2007) I have suggested that it is useful to analyze a C2 system in the same manner, i.e., in terms of purpose, function and form. At the level of purpose, we need to answer the question of *why*, i.e., why a C2 system exists (or should be designed). My answer to this question is: *to provide direction and coordination for the force* (Brehmer, 2007)[7]. This is similar to what is implied by Alberts (2007) when writing about C2 as providing *focus and convergence*. The level of function answers the question of *what* the C2 system needs to do to achieve the purpose. When trying to answer the question at this level, we enter the realm of C2 theory. Here, we may expect disagreement among re-searchers. I have proposed that three functions are needed (Brehmer, 2007). I call them data collection, sensemaking, and planning. In contrast, Alberts and Hayes (2007) are content with one very general function which they call sensemaking, effectively merging the functions of sensemaking and planning. The choice of functions is, of course, not arbitrary but ultimately an empirical question; a C2 theory must be testable, just as any scientific theory. In the case of sensemaking and planning, the need for a distinction between them depends of whether it is meaningful to make a distinction in C2 between *what* needs to be done (sensemaking) and a *how* it should be done (planning), as I claim. Here, it is important to remember the difference between an analysis in terms of functions and one in term of processes. An analysis at the level of form (e.g., in terms of processes or methods actually used or prescribed) in a given C2 system may well reveal interdependencies between form elements designed to achieve the functions that are not evident in an analysis in terms of functions. Such an analysis will only

[6] I realize that automobiles fulfil other purposes as well.
[7] I realize that C2 systems are complex phenomena ad that they can be studied from many different perspectives. The purpose given here defines the focus of the present analysis and it also serves as a definition of C2 for the present purposes. Readers interested in other aspects of C2 may well want a different definition of C2.

take the products of the functions into account, not how they are achieved. If such inter-dependencies among processes are found, they would stem from how the form of the C2 system has been designed in the system under consideration. This would not change the fact that for each function, it should be possible to identify a unique product, however.

Whatever the number of functions assumed and their nature, they must be realized in form at the third and final level which answers the question how the functions are to be achieved in the case of design or how they are achieved in the analysis of an existing system. That is, here we must seek an answer in terms of the organization, methods[8], and support systems[9]. As we shall see, this applies not only when we analyze C2 systems, bur also when we consider C2 as an activity.

Note that only the step from purpose to function is the realm of C2 theory proper. The step from function to form is a matter of design, and here a number of different sciences may contribute, as in most design problems. What these sciences contribute depends on the nature of the functions and the extent to which a given science can contribute to an understanding of how a function can be achieved at the level of form in a C2 system. This explains the observation above that many sciences are involved in the study of C2 and its development. At the level of design, our knowledge of C2 is necessarily fragmented. To find unity in the resulting diversity, we need to identify the functions, for it is these functions that provide the underlying unity.

The analysis of an existing C2 system should therefore start with identifying these functions. The functions are, however, abstract concepts, and they cannot be seen directly. All we can see are their *products*, and it is upon these products and the input that is necessary to produce them that we must concentrate in our study of the functions. This analysis may proceed by using the functions that have been postulated by some theory, such as ours (Brehmer, 2007). Each of the three functions in this theory produces characteristic products that can be assessed. Thus, the data collection function produces the data used for sensemaking and planning, the sensemaking function produces a notion of what should be done, and the planning function a notion of how it is to be done. It should be possible to find both of these products in the order that is the final result of the C2 function, and in various products created en route to this order.

In assessing a given C2 system, we need to keep in mind that the products of the functions of the system, will be “filtered”, so to speak, through the existing form. If the form of the C2 system is not adequate to its task, the products may not be distinct or very well articulated. It may therefore be necessary to probe for the functions by means of indicators that are specifically designed to assess a given function. Such probes may well show that the form of system produces products that are fundamentally flawed and the resulting orders inadequate to accomplish the mission at hand.

In research on C2, it is, perhaps, more common to work bottom-up than top-down, as suggested here. Thus, C2 research often starts with the products that can be found in the C2 system and induces the functions bottom-up. Alternatively, it starts at the level of form and

[8] In an existing system, there may, of course, be both methods that are actually part of the designer’s design of the system and documented as rules and regulations, and methods, e.g., various shortcuts, that have been invented by the users.
[9] Of course, the people in the C2 system are not part of the design, but the roles that they should fill are part of the design. These roles are subsumed under “organization”.

works upwards in search of the functions. Ideally, one should find the same functions. An example of such a bottom-up study is that of Stanton, el. al. (2008) which examined C2 in a variety of military and civilian contexts. We will compare their results with ours later in this paper. As we shall see, the results from their bottom-up analysis are remarkably similar to those from our top-down analysis.

The functions identified by a C2 theory will be normative concepts when used in design, i.e., they are then requirements that should be fulfilled by the form one designs, When trying to understand an existing C2 system, on the other hand, they are descriptive concepts, i.e., they will indicate which requirements are actually fulfilled in the system under analysis. As any science of the artificial, the study of C2 is concerned both with normative issues (normative C2 theory for design) and understanding existing C2 systems (descriptive C2 science). For a C2 system that functions well, we would expect to find the same function concepts in both. A mismatch suggests that the C2 system under analysis is dysfunctional or that our normative theory is inadequate.

In actual cases, the design of C2 systems will be influenced by factors other than the functions. Brehmer (2009a) identifies five such factors: *technology* (especially communications technology and data processing technology), *C2 requirements* (what is to be commanded), *C2 possibilities* (the extent to which the possibility to do C2 are limited, e.g., by technology, and how people try to find ways to circumvent these limitations), *command culture* (beliefs about what forms of C2 are possible) and *legal requirements* (the need to assign responsibility for the actions taken by the force being commanded) (see Brehmer, 2009a, for discussion and examples). These factors serve as secondary goals in the design, and will affect the manner and the extent to which the functions are achieved, but they do not change the requisite functions.

## Testing a theory of C2

A theory of C2 in terms of purpose and functions is an empirical theory. It specifies the conditions that must be met by a system to actually function as a C2 system. Whether the output of a C2 system can indeed be explained in terms of the functions assumed in the theory can, and must, be subjected to empirical test. Such tests will thus be concerned with identifying what functions are necessary and sufficient for the C2 system to produce the orders that it produces.

The testing of a C2 theory presents a number of problems, however. Our C2 theory defines C2 as a matter of producing orders, not outcomes of encounters with an adversary. Testing it should thus be made in terms of the extent to which the orders produced by the system give adequate direction and coordination, given the information that was available. Whether these orders then lead to a successful outcome after contact with the enemy is a matter of evaluating the resulting form of the C2 system. This outcome cannot be predicted only on basis of the quality of one's C2 function. It is also determined by the quality of the enemy's C2 function and the relations between the forces of the enemy and own forces, not to mention the frictions so eloquently described by Clausewitz (1834/1989) which make themselves felt on the modern battle field just as they did in the 19$^{th}$ century. This makes relations between the quality of C2 and final outcomes very complex and uncertain, and only partially dependent on own C2. While it may be true that God is on the side of the heaviest battalions, as Napoleon used to say, this was not always the case even for Napoleon himself, as shown, for example, in his Russian campaign. Conversely, Fredrick the Great repeatedly defeated superior forces. A C2 theory is thus not necessarily the same as a theory of how one wins a battle. C2 quality is only one of the components of winning. The outcome does not tell us anything about the extent to which an analysis of a C2 system in terms of the functions proposed here is adequate or not. It only gives us information about effectiveness of the form of these systems. However, analysis of the form should then provide information of the extent to which it was adequate to achieve the functions. It would thus provide an explanation for failure or success in battle.

Testing a theory of C2 requires that one is able to ascertain the functions actually achieved by the C2 system. As we have noted above, the functions are abstract concepts, however[10], they cannot be observed directly. They must be defined in terms of their *products*, and these products are, of course, a result at the level of form; i.e., they are produced by how the people are organized in the C2 system and what methods and support systems they use. Hence the products cannot be seen as pure expressions of the functions. They are "filtered" through the existing form. In short, what we cam observe may well only be indicators of products that we seek. If the form elements that produce them are ill suited to the task, the result will, at best, have a weak relation to the function, and, at worst, no relation at all. They should still have strong relation to the form of the system, of course. This means that an evaluation of a C2 system does not necessarily provide a good test of a C2 theory. We must also remember that the form is flexible. Just because it was designed in one way it does not mean that the users will employ it as the designers planned that they should do. They may well create a new and different form better suited to their purposes and the circumstances (Brehmere, 2007).

The functions assumed in our current theory relate to products that can be identified. Starting with the distinction between sensemaking and planning, the main distinction here is between *what* needs to be done, and *how* it is to be done. Information about the former should be found in the commander's intent statement, whereas information about the latter should be found in the plan that is developed on the basis of that statement. An alternative, and somewhat more obtrusive, method is, of course, to develop separate measures of the "what" and the "how".

In short, our current theory says that to produce orders, a C2 system must be able to

- To collect the data that are needed (Data collection)
- Identify what needs to be done (Sensemaking)
- To translate the what into a how (Planning)

How the products will be defined and expressed will depend on the five factors listed above: level of technology, command requirements, command possibilities, command culture and legal requirements. For example, a C2 system operating under a centralised culture will elaborate the how more than a system operating under a mission command culture, However, as our knowledge of how the various functions can be achieved increases, there will be less room for other factors such as the command culture.

[10] A function is essentially a "black box" that transforms input to output. How this transformation is achieved is handled at the level of form.

### Putting it together: The Dynamic OODA-loop

A model of C2 at the level of functions requires not only that the requisite functions be listed, but also that the relations among them be clarified. As noted above, a function is “black box” defined in terms of its input and output. What we need to is thus to specify the input-output relations among the functions. The Dynamic OODA-loop (DOODA-loop[11] , Brehmer, 2007) illustrated in Fig. 2 was designed to do this. It is important to note that the relations in the loop are functional relations, not temporal relations or causal ones. They specify input-output relations among the functions and between the functions and their environment. To put matters differently, the DOODA-loop shows the communication that is needed between different functions and between functions and the environment.

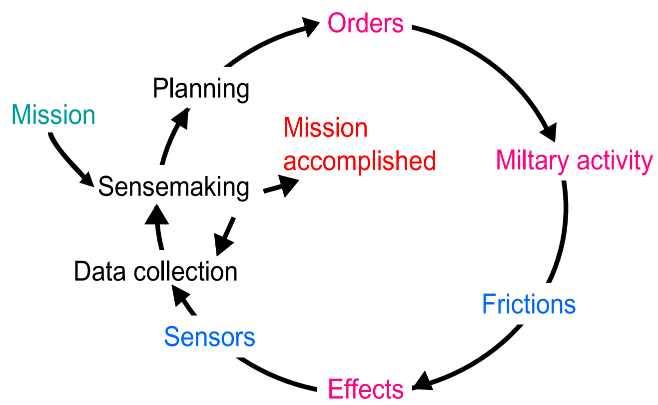


*Fig. 2.* The Dynamic OODA-loop. Red indicates products, black functions, green input and blue “filters” that affect what passes from function or product to another function or product.

The DOODA-loop is a model at the level of functions, but in the actual model, some products are also added for the sake of clarity. In the model, the C2 system, or inner system, is made up of the three functions: data collection, sensemaking and planning and their relations. Note that there is a two-way interaction between data collection and sensemaking to represent the fact that while the data collected will affect what the sensemaking function achieves, what the sensemaking function tries to achieve will determine what data are collected. The C2 system is then put into its context so that the input-output relations of the inner and outer systems are shown.

Models of this kind can, of course, be designed at different levels of detail. For example, the sensemaking function can be broken down into a number of sub-functions as required, for example, to model cooperation in sensemaking and how it relates to the quality of planning, as shown by Jensen (2009). In this case, the sensemaking function was broken down into the

[11] The term “DOODA-loop” suggests a closer relation between the current concept and Boyd’s original OODA-loop than is actually the case. The DOODA-loop is an amalgamation of the OODA loop and the dynamic decision loop (Brehmer, 2005). It was originally designed to overcome certain shortcomings of Boyd’s concept with respect to how it represents the factors that affect the temporal relations in C2 (Brehmer, 2005).

functions suggested by observations of command teams in a planning exercise to a submodel in the DOODA-model.

The DOODA-loop is obviously not a process model of actual C2. That would have to be a model at the level of form, which the DOODA-loop is not. It is a model at the level of functions. A model at the level of form is not likely to be as well ordered as the DOODA-loop, and there is likely to be considerably feedback among the processes that will embody the functions.

The DOODA loop can be used to model the strategic, operational or tactical level of C2. Each DOODA loop should thus be considered as part of a recursive system with DOODA loops above and below it. The DOODA above provides the mission, and DOODA loop that receives this mission delivers its orders to that below which, in relation to the model delivering the order, is part of the "military activity" in the model.

*Planning and execution*

The DOODA-loop shares the limitation of many other models inspired by cybernetics (of which here are many examples, see, for example, Mayk & Rubin, 1988, see also Brehmer, 2005 and Stanton, et al., 2008, for a general discussion of the pros and cons of cybernetic models of C2) in that it is a model only of what is generally called the execution stage of a military operation. Thus, such models do not capture the distinction between what is usually referred to as planning and execution stages of a military operation. The fundamental difference between these two stages and the importance of distinguishing between them have their classical expression in Napoleon's well known statement that "one engages and then one sees", and in Moltke's equally well known observation that no plan survives contact with the enemy.

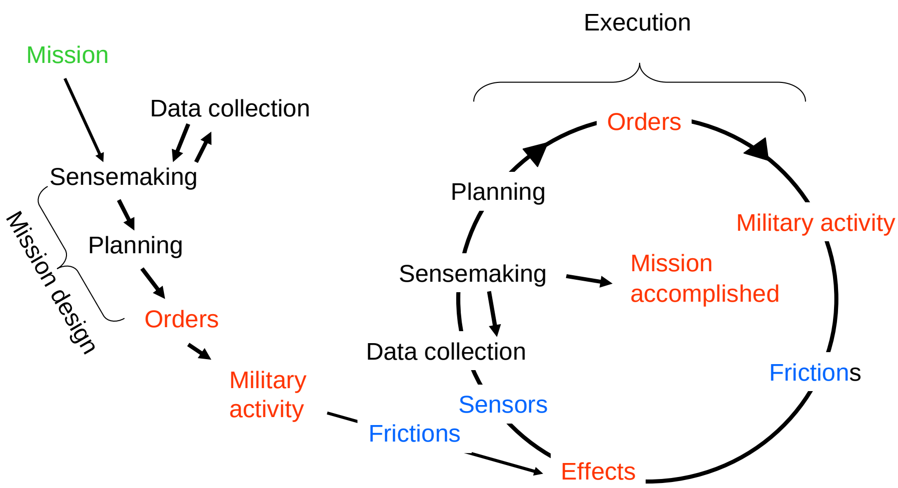


*Figure 3.* Extension of the DOODA concept to include mission design.

Figure 3 represents an attempt to handle this problem by extending the DOODA-loop by adding a segment called *mission design*. This term is preferable to planning as that term is given a more limited and specific meaning in the DOODA concept than is usual in military contexts where it often covers the whole process from mission to orders. The mission design stage represents the first attempt of the force to accomplish the mission. It starts with processing of the mission by the sensemaking function into a an understanding of what needs to be done to accomplish it, which is then input to the planning function which produces the orders that lead to military activity. The effects of this activity (or the new state of the battle space) are then picked up by the data collection function via the sensors and processed by the sensemaking function, and so the ordinary DOODA-loop starts and goes on until the mission is accomplished[12]. The functions in the mission design stage are the same as in the execution stage, only the information processed is different, Note that the model in Fig. 3 is not really a new model, it is just an ordinary DOODA loop where the first revolution has been represented separately.

Execution will involve loops of the kind illustrated in Fig. 3 at many different levels. To understand execution, therefore, it is necessary to consider all the relevant levels, that is, all levels at which execution takes place, from the operational to the tactical, if the original system modelled is at the strategic level. But the mission as seen at each of these levels will be described in terms of loops of the same kind.

The coupling of the loops at different levels will be of central importance for the functioning of the system as a whole. If the loops are tightly coupled, as they will be if the orders are very detailed (they specify the "how" for the next level in very precise terms) as they will be in a centralized C2 system, the C2 process of the forces as a whole necessarily becomes rigid. Hence the assumed superiority of a C2 system embracing mission command as a C2 philosophy with a much looser coupling (a system where orders to the next level are mainly in terms of what should be achieved, rather than in terms of how to carry out its mission).

*Convergence of top-down and bottom-up analyses*

It is interesting to compare our concept with the model proposed by Stanton, et al. (2008) as a general model of C2. Their model is based on the results from a series of studies of command teams in a variety of civilian and military contexts. Like our model, it is a model in terms of functions (although Stanton, et al. do not describe it as such). The model was developed bottom-up from observations of communication and products in command teams This is how they describe the model in their abstract:

> *It is proposed that the command and control activities are triggered by events such as the receipt of orders or information, which provide a mission and a description of the current situation of events in the field. The gap between the mission and the current situation lead the command system to determine the effects that narrow that gap. This in turn requires the analysis of the resources and constraints in the given situation. From these activities, plans are developed, evaluated and selected. The chosen plans are then rehearsed before being communicated to agents in the field. As the plan is enacted, feedback from the field is sought to check that events are unfolding as expected. Changes in the mission or the events in the field may require the plan to be updated or re-*

[12] There is, of course, an alternative: the process is interrupted because of failure, for example, defeat.

*vised. When the mission has achieved the required effects the current set of command and control activities come to an end.*

*The model distinguishes between 'command' activities and 'control' activities. Command comprises proactive, mission-driven, planning and co-ordination activities. Control comprises reactive, event-driven monitoring and communication activities. The former implies the transmission of mission intent whereas the latter implies reactions to specific situations.* (Stanton, et al., 2008, p. 6)

The model is derived from C2 activity at the tactical level, but, the resulting description fits any level in a C2 hierarchy.

In Fig. 4, the Stanton, Baber and Harrris model has been redrawn in DOODA format. Specifically, their various functions have been repackaged in the more general functions of the DOODA loop, and represented as subfunctions of these more general functions. As can be seen from this figure, the result is a model that is remarkably similar to the original DOODA-

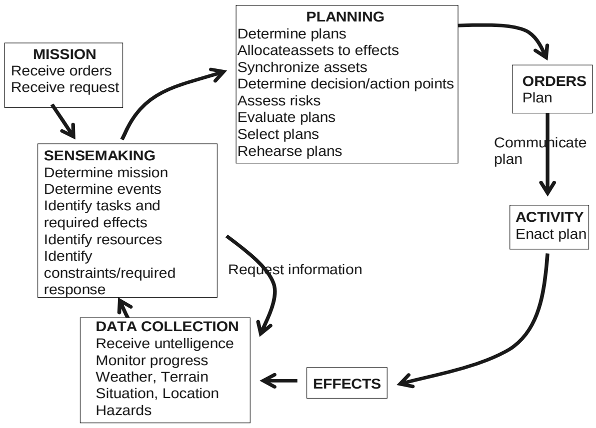


Fig. 4. The Stanton, Baber and Harris C2 model redrawn in DOODA format (After Fig. 7.1, p. 232, in Stanton, et al., 2008). The "Effects" box is not in their model and has been added.

loop, despite that it is derived bottom-up from observations of C2 activity, i.e., from observations of form, while the DOODA-loop is developed top-down from a design perspective. As in the DOODA-loop, the C2 process in the Stanton, et al. model starts with the mission, and the C2 system then determines what needs to be done (sensemaking) by combining the mission information and information about the current situation (sensemaking, in DOODA terminology), it goes on to planning which results in orders that are communicated and the results observed to determine the effects.

The model proposed by Stanton, et al. is at a higher level of detail than the DOODA loop. For example, the sensemaking function in the DOODA loop is represented by a number of subfunctions in the Stanton, et al. model: Receive order, Recive request, Receive information, Receive report (when information is fed back during execution), Determine mission, Determine events, Identify risks and required effects, Identify resources, and Identify constraints. The planning function has three subfunctions: Determine plan, Rehearse Plan and Communicate plan. Such breakdown into subfunctions would be a natural step also in a top down analysis (see Jensen, 2009)

These results suggest that our top-down approach and the bottom-up approach of Stanton, et al. converge on a general conception of C2 at the level of functions. This is encouraging, as it suggests that the functions proposed here do indeed provide a basis for finding unity in the diversity of C2 models.

## C2 as a function and C2 as an activity

As noted by Alberts (2007), the term "command" is both a verb and a substantive. This goes for its companion "control" also, as well as for the pair of concepts. It is important to keep these two aspects apart, for their implications for understanding C2 are different. As a verb, command implies a subject, somebody who does the commanding. As a substantive, it does not necessarily do so. Alberts's observation parallels the distinction between C2 as a function and C2 as an activity in the present paper. As an activity, it implies a commander, a subject who does the commanding, or at least a C2 system that can produce the orders needed. When seen as a function, on the other hand, the question of *how* the C2 function achieves direction and coordination (or focus and convergence in Alberts's terminology) is open. "By a commander" is only one of the possible answers (Brehmer, 2009b). This becomes important when discussing the prospects of self synchronization, one raison d'etre of the new network centric C2 systems. Many of the obstacles to implementing a network centric approach to C2 seem to have their origin in our exclusive focus on command as a verb and its emphasis on the role of the commander and, of course, from prior training and experience of officers.

Activity and function are related, of course: C2 as an activity is just a matter of fulfilling the C2 function. This suggests that it should be possible to think of the activity of C2 in design terms also, a problem to which we now turn.

## C2 as an activity from a design point of view

As an activity, C2 takes place at the level of form. What goes on here is best described as action using tools. Thus, C2 as an activity aims at achieving military effects using a system consisting of military units and equipment that offer a set of capabilities for action. C2 chooses among these possibilities, and structures the activity of the military system by means of orders, thus transforming it into the tool that is needed to achieve the current goal. Thus, C2 is a matter of designing military activity, and it does so by means of designing orders that structure the activity of the military system. From a design point of view, this can only be a question of doing whatever is required to achieve the functions that are necessary to produce orders[13]. The requisite functions are the functions that we have already described above: data collection, sensemaking, and planning. C2 at the level of form is simply the set of activities that produce and communicate the products of these functions. Understanding C2 as an activity therefore becomes a matter of understanding (1) how the system collects the data that it needs, (2) how it does sensemaking to produces the understanding of what needs to be done to accomplish the mission in the situation at hand, (3) how it does the planning required to transform the understanding of *what* needs to be done into an understanding of *how* the mission should be accomplished and expresses this in an order and (4) how it manages to communicate the results and what is required to produce these results, both in the inner C2 system and between the C2 system and the outer system.

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[13] A more detailed analysis of C2 activity as design is given by the paper by Jensen (2010) in this track.

How the functions are fulfilled, i.e., how the processes designed to achieve this (the actual form of he system) will express the current understanding of how the functions are best achieved for the task at hand. That is, these processes will differ from C2 system to C2 system, depending on the level of technology, command requirements, command possibilities, command culture and legal requirements as described by Brehmer (2009a).

As a consequence, a general theory of C2 at the level of form is likely to consist of a number of subtheories: one about how data can and should be collected, one about sensemaking, one about planning, and one about communication. It will, of course, be possible to achieve the functions in many different ways (otherwise C2 would have been impossible at more primitive stages of technology development, for example). Yet, some ways of fulfilling a function may be more effective than others, as the example of Jensen's (2009) study of effects of how sensemaking is organized demonstrates. Specifically, Jensen showed that how the commander organized the sensemaking process had a stronger relation to the quality of the plans produced by the command group than the amount of information that was available to the command teams.

To summarize: just as in the case of the design of a C2 system, we need to uphold the distinction between C2 theory and design when discussing C2 as an activity. Doing C2 is fulfilling the functions, but how they are fulfilled will be affected by many considerations in addition to understanding what products are needed, such as, for example technology, command culture and legal requirements, to give just a few examples.

## Conclusions

In this paper I have tried to demonstrate that a conceptual framework of C2 as design provides the ontology we need as a foundation for a science of C2. The framework seems to cover all problems that should concern  a science of C2, the design and understanding of C2 systems, as well as understanding and designing the activity of C2. It provides a basis for understanding both the diversity of C2 systems as expressions of factors influencing the design stage, and the unity of all C2 systems and C2 activities in terms of the functions that need to be achieved. However, although the design framework seems general, the particular three-function model suggested here is only one of many possibilities. Whether that particular set of functions is sufficient, or even the best set, remains an open question, however.

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