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COALITION COMMAND AND CONTROL IN THE NETWORKED AREA

One Loop to Rule Them All

C2 ANALYSIS
C2 MODELLING AND SIMULATION
COGNITIVE DOMAIN ISSUES

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Abstract

This paper argues that C2 systems, being human artefacts, must be understood in terms of the logic of design and be analyzed on three levels: the *purpose* (why), the *functions* (what) and the *form* (how). It then presents a general model of the functions in C2 called the Dynamic OODA loop (DOODA loop) which specifies three basic functions that are necessary for successful C2: *sensemaking*, *planning* and *information collection*. The model of sensemaking is based on James's pragmatic philosophy and defines sensemaking as the function that produces an understanding of the mission in terms of should be done. The action component is seen as integral to understanding. The model emphasis the conjectures produced by the commander and his/her staff as the basis for the sensemaking process, and that understanding is not produced by data. Data are instead used to test the understanding. The product of the sensemaking function is the COA which is then used by the planning function to produce orders. The information collection function produces the data used for testing the understanding of the mission. The Function DOODA (or F-DOODA) is the fundamental model ("the loop to rule them all"), but a product DOODA (or P-DOODA) describing the products that are produced by the C2 system which can then be used to evaluate the extent to which the form of the system actually accomplishes the functions (F-DOODA). Finally, research in our laboratory guided by the DOODA concept is briefly described.

ONE LOOP TO RULE THEM ALL

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The purpose of this paper is to propose a general model of command and control (C2) to serve as a basis for research on C2 in general, and for designing C2 support in particular. The model presented here builds upon and develops the model presented at last year's ICCRTS (see Brehmer, 2005a). It adds to the earlier paper by introducing a new more principled way of thinking about C2 systems in terms of the logic of design, it presents a simplified model of the functions required for successful C2, as well as a better developed view on sensemaking, which is seen as the central function of C2 in the present model.

A general point of departure

C2 it is always performed as part of a C2 system. This system, in turn, is part of what we may call the *mission system*. These systems define the demands made on the commander and his/her staff, that is, what they need to do to perform C2 successfully. Our analysis must therefore start with these systems.

C2 systems are *human artefacts*; that is, their organization. methods, processes, procedures and support systems are designed for a purpose, albeit, perhaps, not very systematically. But even if the C2 system is a patchwork, we can only understand and evaluate it in terms of the *logic of design*.

The logic of design

The logic of design requires that the C2 system be analyzed on three different levels as illustrated in Figure 1. Thus, the analysis must start with the *purpose* of the system (the "why").

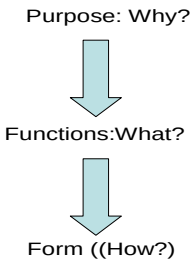

Figure 1. The logic of design requires an analysis of the C2 system on three different levels

[1] The author is indebted to Dr. Eva Jensen for her comments on earlier drafts of this paper.

Then we have to identify the *functions* required to achieve the purpose[2] (the "what" of the system) Finally, the *form* necessary to fulfil the functions must be found (the "how" of the system). The relations among these levels can be described in terms of *requirements* and *constraints*. Thus, in systematic design, the purpose requires certain functions (found by what is generally called task analysis) and at the same time, the purpose constrains the functions. The functions, in turn, require a certain form (created in the design process) and at the same time constrain the form[3]. The stringency of the constraints change as we go down the design hierarchy. Thus, while the functions are given by the purpose, making for very stringent constraints, many different forms can embody the functions depending, for example, on the level of technology that is available. Thus, the constraints become less stringent as we move down the hierarchy. This is well illustrated in the case of C2, where the form of C2 systems has varied over time as technology has offered new possibilities. The purpose and functions have remained the same, however (see van Creveld, 1985, for a historical analysis of C2).

Design logic and military C2

In the case of military C2 systems, the purpose is to accomplish military missions. To achieve this purpose, the design logic employed here demands that the C2 system must fulfil the requisite functions. These functions define *what* needs to be achieved by the commander and his/her staff, but not *how* they should achieve them. That is a matter of form. A first step towards understanding and evaluating a C2 system, as well as when designing one, is to find the functions.

To find the functions is a task for C2 theory. If C2 systems had been designed in a more systematic way, the functions would have been described in the task analysis. Since this is not always (if ever) the case, they must be found from analyses of existing C2 systems, i.e., they must be abstracted from studies of form. One possible approach is a historical analysis of C2 systems. The functions proposed in the present model of C2 have their roots in van Creveld´s (1985) history of C2. But a historical analysis is, of course, not the only alternative. However, regardless of whether the analysis is based on history or not, the functions can be found only by analyzing many examples of C2 systems. It is not possible to find them from an analysis of only a single system. Such an analysis would basically be a case study and it would not enable us to distinguish functions from form. This seems to be a common problem in analyses of C2, especially when performed by its practitioners who know the form of the system with which they work so thoroughly that it often to obscures the functions.

The *form* of the C2 system realizes the functions in concrete form, and serves to achieve these functions. In the case of a C2 system, form is not only the hardware, it also comprises the or-

[2] The term "function" are used in at least two different ways in discussions of C2. We may speak of the functions of C2 as the effects that C2 has, or we may speak of the functions that need to be achieved for successful C2. In the recent book by Alberts and Hayes (2006) the term is used in both ways, but here as we take a design perspectivem it is used only to denote what is required to achieve the purpose of C2. It is,of course, also possible to analyze C2 itself as a function of a military system at a higher level.

[3] It is not a good idea to let the form constrain the functions, for then the resulting system may not be able to meet its purpose. Yet, this may very well happen when design starts with the existing form, i.e., when we start designing decision aids to support existing C2 practice rather than thinking about which functions the new technology may help fulfil and what changes in C2 practice that is needed to use new forms of information technology in the best possible way.

ganization, methods, procedures, and processes. Thus, the form represents what the commander and his or her staff actually do in the C2 organization with the systems at their disposal to achieve the functions and thus the purpose. As noted above, however, the functions can be embodied in many different forms. Consequently, form, i.e., the organization, methods, processes, procedures and systems, may vary (and does vary) from C2 system to C2 system. Hence, there are many different ways of doing C2, even though the purpose and functions remain the same, as shown in van Creveld's (1985) analysis.

The form of a given system may be more or less adequate to fulfil the functions. If a requisite form cannot be found for one or more of the functions, the C2 system cannot achieve its purpose completely. The problems to which the C2 system is applied may then have to be limited. Conversely, not understanding the requisite functions may lead us to design systems that do things that are not really necessary to meet the purpose. Such characteristics of the system are generally discovered by the users who then dismiss with terms such as "unnecessary bureaucracy" and the like.

As will be discussed later in this paper, many factors determine the actual form of the system. Most important is the technology available and the ability to use that technology for C2. Perhaps the greatest revolution in C2 occurred when the ability to read and write became common among military commanders in the 15th century (see van Creveld, 1985). This introduced possibilities to *command at a distance*; the commander was no longer limited to commanding those who could see and hear him[4]. This, in turn, made it possible to command much larger forces than before. Indeed, much of the subsequent development of C2 can be understood as an extension of the possibility to command at a distance, i.e., as a result of more and more powerful communication systems, both for supplying the commander with information and for communicating the commander's orders to his/her subordinates. For example, Alexander, who had no communication devices except his voice and runners, could only command a small army, and the military activity that could be performed was limited to small battle fields. Two thousand years later, General Schwartzkopf could command very much larger forces in the same region of the world, relying on written orders transmitted by various forms of communication technology.

Improved communication systems have also created new problems in the form of information overload, however, a problem initially solved by the invention of a new form element: the staff. The development has continued, however, and current forms of information technology now produce amounts of information that exceed the capabilities of the staffs (even though they have become very large), and even more advanced forms of information technology are therefore being developed to make it possible to achieve the functions of the C2 system. And so it goes, and will go.

This example illustrates two principles. The first is that technology is not only a matter of hardware. Software in the form of methods and procedures is just as important, indeed sometimes even more important than hardware. The second principle illustrated by the example is that *how* things are done often also affects *what* is done, and the form of the system thus very much affects what can be achieved. This changes neither the purpose of the C2 system, nor the functions that need to be fulfilled to achieve that purpose, of course. Alexander and General Schwartzkopf were both limited to deciding what resources to apply, where to apply them

[4] Some command at a distance was possible also before commanders could read and write. For example, Alexander used runners to carry messages and observations to and from him to subordinate commanders too far a way to be seen or heard.

and when to apply them, albeit that the difference in the size of the battle field and the size of the forces that could be commanded was enormous. Changes in C2 have thus changed to scale of war, as well as how it is conducted.

Two varieties of C2 science

Viewing the problem of C2 from the vantage point of the logic of design suggests two different directions that research on C2 can take.

The first can be called *normative C2 science*. It is concerned with C2 as it *should* be performed, that is, it involves finding the requisite functions, and designing ways in which these functions can be fulfilled. The second direction can be called *descriptive C2 science*, and it involves empirical study of the form of existing C2 systems, i.e., the study of C2 as it *is* performed in a given historical context, their organization, as well as the methods, procedures, processes and systems are used, and how they are used. In view of our initial point of departure that C2 systems are designed systems, it might seem unnecessary to study existing C2 systems, but descriptive studies are, in fact, necessary. First, as already noted, although C2 systems are artefacts, they are not necessarily constructed according to any coherent set of design specifications. Many existing C2 systems seem to be patchworks, where new methods and systems have been added as they have become available, rather than according to some overall plan. As a consequence, the relation between function and form has become blurred. Second, the functions do not sufficiently constrain the form; there is no guarantee that the current form actually achieves the functions. Moreover, the technology available may not have made it possible to design a form that actually achieves the functions. In addition, what is required to achieve a given function may not be well understood at the time when the C2 system was designed. This is true even today. As we shall see below, especially those functions that have to be achieved by human activities are poorly understood, Empirical studies are therefore needed to show the extent to which the existing form actually achieves what it was designed to achieve. Third, even if there were a perfect specification of what should be done, there is no guarantee that the practitioners in the system, being human, would follow the specification. They may well have found ways of working around the limitations of given methods or systems. It is therefore possible that they are able to achieve more than what would be expected from the specification of the system in terms of the support that they have and the rules and regulations that guide their activity. Descriptive work is therefore necessary to provide a basis for an evaluation of any existing system.

Descriptive C2 science provides information, both about the *form*, i.e., about the organization as well as the processes, methods, procedures and systems employed to fulfil the functions on the one hand, and the *products* of the system on the other. These products provide a basis for ascertaining the extent to which the various functions are fulfilled in a given C2 system, as well as about the extent to which these functions are indeed sufficient to achieve the purpose of the system[5].

As a basis for design, assessing the functions of the C2 system must take precedence over the study of the form of the system. If we have no understanding of the functions, we can neither evaluate nor improve its form. The latter point is important. According to a design logic, the design of concrete C2 systems must be based on an understanding of the functions that must

[5] When evaluated in terms of some metric, these products provide the basis for what Alberts and Hayes (2006) call a value view of the C2 system. We insist that the metrics chosen enable us to ascertain the extent to which the functions have been achieved.

be fulfilled for successful C2, and proceed from an understanding of the functions to the design of form that achieves the functions. It cannot start with at the level of form. This would limit the scope of the new systems to supporting existing ways of doing C2. As a consequence, the potential of new technology would probably not be realised. For new technology requires new ways of doing C2, if its potential is to be realized. This is illustrated, historically, by the introduction of writing, and today by the current debate about utility of the new network concepts of C2.

The requisite functions: The Dynamic OODA-loop

The dominant model of military C2 is Boyd's Observe-Orient-Decide-Act-loop (OODA loop). It is part of the doctrine of all four branches of the US Armed Forces, as well as of that of many other armed forces, including that of Sweden (Swedish Armed Foces Headquarters, 2003). As I have argued elsewhere (Brehmer, 2005a,b), it is fundamentally inadequate as a model of C2 and it was not designed as a such a model of C2 by Boyd. It has very limited use as a basis for the design of new systems. There are two reasons for this. First, it does not include a representation of the *effects* of the ACT-stage. This may not have been a serious limitation in the original use of the OODA loop which was to explain why the American F-86 pilots were more successful than the North Korean Mig-15 pilots in Korea. It limits the extent to which the OODA loop can be used as a general model of the C2 process, however. Because it does not include a representation of the effects of the ACT stage it is not possible to represent the various delays that are important in C2. This limits the scope of the model, and, in fact, the only conclusion that has been drawn from the OODA loop with respect to C2 is that decisions should be fast. While the importance of fast decisions should not be underestimated, of course, it does not seem to be an insight that originated with the OODA loop. Moreover, we should remember that no enemy was ever defeated by decisions alone. What is important are the military effects, and the extent to which these effects are delivered in a timely manner and at the correct location. This is not necessarily the same as making fast decisions (see Brehmer, 2005a, for an example), and to deliver effects in a timely manner, we have to consider other sources of delay in addition to these caused by slow decision making. Indeed, it may sometimes be better to buy more time for decision making by speeding up other aspects of the system instead. The second problem is that the OODA-loop does not give a very detailed account of the actual functions that are necessary for effective C2, a fact also noted by others (see, e.g., Bryant, 2003).

While the dominant military model of C2 may be Boyd´s OODA loop, the dominant model in research on C2 has been the *cybernetic model* (Builder, Banks & Nordin, 1999). Mayk and Rubin, (1988) list 15 such models, and new models have been added to the list after 1988, one of them my own (Brehmer, 2000). An important example is the HEAT model (Hayes, Strack & Bucioni, 1983). A recent example is the model proposed by Alberts and Hayes (2006).

Cybernetic models remedy the principal shortcoming of the OODA loop in that they also represent the effects of the action. They thus give a more complete picture of the delays that need to be handled in the C2 process. Most cybernetic models are nevertheless inadequate for two reasons. First, like the OODA loop, they depict the C2 process as essentially reactive, and thus leave no room for initiative (see Builder, et al., 1999). The second is that the existing cybernetic models are too general and give a poor representation of the functions that are required for successful C2. They might as well be models of a process plant as models of C2.

Most important, they do not represent the functions required for successful C2, and they thus give no basis for design of better C2 systems.

The Dynamic OODA loop, or DOODA loop[6] for short (Brehmer, 2005a) is an attempt to remedy both the shortcomings of the OODA loop and the cybernetic models. First, it includes a representation of the effects (like the cybernetic models, of which it is an example). Second, it incorporates the concepts required to break free from the purely reactive model of C2. Third, it provides a representation of the functions required for C2. Even though space limitations prevent a full argument, the OODA loop and existing cybernetic models can be seen as special cases of the DOODA loop, especially when it is instantiated as a process model rather than as a model of the requisite functions of C2. Be that as it may, the reason for the title of this paper is not this observation, but that one form of the DOODA loop, that which describes the functions (the F-DOODA, see below), is more fundamental than other DOODA loops that can be constructed on the basis of the logic design, viz., loops in terms of form or products, and the F-DOODA thus truly rules the familiy of DOODA loops. Hence the title of this paper.

The DOODA loop embeds the C2 system in a model of a military mission. In this mission system, it is itself a function, of course.

There are three principal forms of the DOODA loop, as would be expected from its origins in design logic. The basic DOODA loop is the Functions DOODA to be used for research in normative C2 science, and to guide design of C2 systems. The Product DOODA, and the Process DOODA loops belong in descriptive C2 science, and guide the evaluation of existing C2 systems as well as C2 systems under development We discuss each in turn..

The function DOODA (F-DOODA)

The functions in the F-DOODA are based on van Creveld´s historical analysis of C2, which yielded a list of eight functions (van Creveld, 1985, p. 8). We have, however, reinterpreted and repackaged his functions using concepts from modern cognitive science and cognitive psychology, and ordered them in a loop. The loop concept is implicit in van Creveld's analysis. It represents the fact that military missions are often extended in time, involving planning and replanning as the mission evolves. As a consequence, evaluation and assessment of effects is not a separate stage in the DOODA loop, but is handled by the loop concept.

The F-DOODA model is illustrated in Figure 2. It embeds the C2 system in a mission loop, placing the concept firmly among the cybernetic models of C2.

[6] The name is perhaps not so fortunate, for the DOODA loop has more in common with the cybernetic models of C2 than with Boyd's OODA loop.

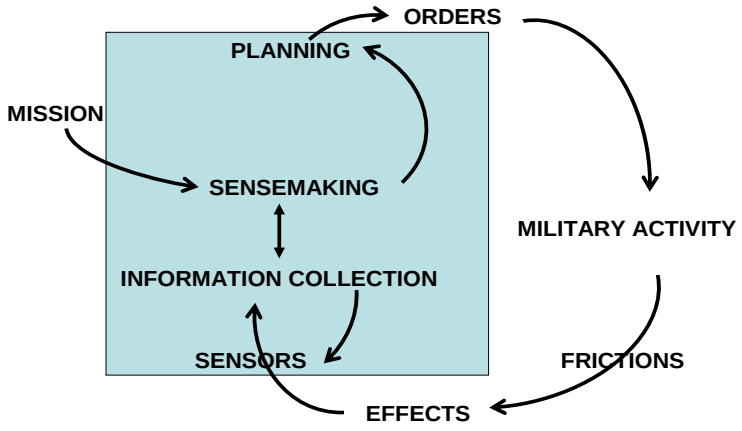

Figure 2. The Dynamic OODA loop. The C2 system (the blue box) is embedded in a mission loop which connects C2 and the environment.

The C2 system is what is in the blue box. It comprises three functions and the sensors. The first of the functions required for successful C2 is called *sensemaking*. It is conceptualised as the function that produces an understanding of the mission in terms of *what should be done* in the current situation. The inputs to this function are thus the *mission* and the data acquired by the *information collection function*. The product is a Course of Action (COA). The output of the sensemaking function represents the current understanding of what needs to be done, and this is the input to the original plan in the beginning of the mission and for possible replanning as the mission proceeds. In the earlier version (Brehmer, 2005a), the sensemaking function fed into a function called "command concept" which produces the commander's overall conception of the operation, i.e., his or her conception of what to do and how to do it on a very general level. However, this seems to be better captured by the COA concept. We will discuss the sensemaking function in more detail below.

The command concept function in the original DOODA loop was borrowed it from Builder, et al. (1999). They used it in two different senses, the first denoting the commander's overall conception of the operation, the other denoting a more detailed plan of what should be done. Following Builder, et al. our reason for including this concept was to break the purely reactive character of most cybernetic models: A military operation may actually start with the command concept, rather than with mission from some superior command Remember Napoleon standing in front to his maps planning his campaign in 1813! Builder, et al. give a number of additional examples. However, also in this case, sensemaking is required, and it seems more natural to capitalize of the general goal directed nature of the sensemaking function, and instead differentiate between missions that start with a task set by superior command and tasks that the commander sets for him or herself.

The *planning function* translates the product of the sensemaking function into *orders*, which are, of course, the most important output of the C2 system[7]. The orders are then translated into *military action*, the nature of which depends on the level under consideration. At the higher levels, the action is simply further DOODA loops, while at the lowest level, it is actual military actions, such as moving and firing. These actions are then filtered through the Clausewitzian *frictions* and result in *effects* on the battlefield which are picked up by the *information collection function* via the available *sensors* (some of which may be humans). The information collection function is under at least partial control of the sensemaking function to protect the commander and his staff from information overload. The information collection function provides input to the sensemaking function, and so it goes until the mission has been accomplished.

The relations among the C2 functions are *logical relations*, i.e., the arrows in the figure denote preconditions, not causal or temporal relations. Thus, sensemaking is a precondition for planning and the information collection function a precondition for sensemaking. Causal relations will be observed only at the level of form.

Some remarks on the C2 functions in the DOODA loop

To think of C2 in terms of information collection, sensemaking and planning is hardly new. What is new is the view that these are *functions*, rather than *processes* (although they, are, of course, embodied in processes in an actual C2 system) and the conception of what these functions need to accomplish, i.e., what the C2 system needs to to do at the level of form.

Sensemaking. The central function in the DOODA concept of C2 is sensemaking. Indeed, it is a central aspect of C2 in any understanding of C2, and this is where most military disasters are born (Books on military disasters seem to represent a growth industry, so it is easy for the reader to pick his or her favourite example, see, e.g, Dixon, 1994, or David, 1997). This also seems to be the function in C2 that is least well understood, and indeed a function that often seems to be misunderstood, not least in many treatises on Information Age Warfare (none mentioned and none forgotten). Therefore, it may be useful to discuss it in some depth.

Like Weick (1995), who introduced the concept in modern day research, our conception of sensemaking is based on William James and pragmatism (e.g., 1907), rather than on cognitive psychology with its roots in British empiricist philosophy. But we have taken the concept further than Weick did, in going back to its roots in James's philosophy.

We reject the data → information → knowledge → understanding chain so common in discussions of C2 in general and Network Centric Warfare in particular. Sensemaking *uses data*, but it *is not based on data*. "Sense" does not flow automatically from data, and there can never be "enough data" to insure "sense". Instead, sensemaking must be a top-down process, starting with the mission to guide the further sensemaking process which is basically a form of explicit or implicit hypothesis testing (cf, Bryant, 2003, for a similar view, albeit one that is not based on James). That is data are used to test the provisional understanding but they do not produce that understanding. It cannot be otherwise, for understanding the battle space is subject to the same epistemological conditions as all understanding so was aptly expressed by Popper's (1963) statement: *truth is not manifest*. Therefore, no amount of data will be sufficient to produce truth (understanding). Understanding must be based on some conjecture or

[7] The planning function thus includes also the negotiation between a commander and his subordinates that precedes the final orders in mission command.

preliminary hypothesis that is then refined in the sensemaking process by testing it against data. Those not convinced by Popper's epistemological argument may remind themselves of the problem of achieving an understanding of the most central aspect of the sensemaking process, viz., understanding what the enemy's intentions are. These intentions are certainly not manifest; information about the enemy does come with the label: "These are our intentions", but remain a matter for conjecture.

Using data for testing is a matter of selection of *relevant* data, it is not a matter of collecting as much data as possible. It is not by knowing each and every feature of the battle space that we come to an understanding, it is by developing some conjecture and testing it. As a consequence, we do not find the concept of situational awareness very useful in conceptualizing sensemaking. Just being aware of the elements in the battle space will not lead to understanding. Defining a higher level of situational awareness as "being aware of the elements plus understanding" as Endsley (1995) does, just begs the question, unless we can specify the relation between data and understanding. So does the statement that understanding involves "fusing data with mental models" (e.g., Alberts & Hayes, 2006), unless one also specifies how the fusion is done: different conceptions of fusion will have different implications for what kind of support the commander and his or her staff need. In the DOODA perspective, support for sensemaking is support for hypothesis development, information collection, and hypothesis testing, not just a question of supplying more and more data. Data, although necessary for testing, is no substitute for the competence and creativity of the commander and his/her staff in developing conjectures to be tested.

The action component in sensemaking. Following William James, we include an *action component* in sensemaking. We do that for three different reasons. The first reflects our commitment to James's philosophy. The second has to do with what sensemaking in C2 is about and the third with what we can actually measure in empirical studies of sensemaking in C2.

Since "truth is not manifest" the sense we make in a given situation cannot be a picture of that situation as was assumed by the empiricist philosophers who provided the foundation for modern cognitive psychology as well as for our common sense understanding (see also Brehmer, 1980). As Piaget (1971) used to argue, understanding cannot be a picture because to create a picture we first need to know that which is to be pictured, that is, understanding must come before the picture. Thus, the picture concept seems to lead to an infinite regress. The value of our understanding (its "cash value" in James's (1907) well known phrase) can only come from its consequences. What these consequences should be must therefore be part of the understanding; we do not understand until we have also built up some expectation concerning what should follow from our understanding. This expectation must concern other observations that should be possible, given our current understanding. To make these observations will require some action on our part. Of course, not all possible consequences will be equally interesting. In the military case the most important expectation concerns what will happen when we put our plan into action, so the criterion of the sense achieved by the sensemaking function is the outcome of the action taken. This is, in fact, the *only* possible criterion of understanding. It is, of course, imperfect; a plan may fail for reasons that do not have to do with the truth of our understanding (remember the Clausewitzian frictions!), and it may succeed even if our understanding is grossly incorrect. Military history provides a plethora of examples of both. But this is a fundamental condition of life. Our understanding will always be incomplete and subject to revision, regardless of whether we are trying to understand our enemy or our teenage children.

The second reason for including the action component in sensemaking is that action is what C2 aims at; it is not aimed at contemplation or knowing in the abstract; it concerned with finding a course of action that will achieve the mission. Finding the requisite COA is the goal of the commander and his staff; before they know what to do, it cannot be said that they have understood the mission and the situation. The action component is thus a necessary aspect of understanding in C2, as well as the basis for the test of its "cash value". The goal of the commander and his/her staff is given by the mission, and that mission thus specifies what is an interesting and useful test of understanding in the context of C2. That is, the commander and his/her staff cannot just be content with tests of their understanding involving any new observations that is possible, as the scientist can in testing his/her theories. It is, of course, important that the understanding developed be consistent with all observations that can be made before it is put to the final test in a military operation. This is, of course, what staff work is all about. Sensemaking in military circumstances is a collective process, where the commander and his/her staff bring their different perspectives and information to bear on the final product (Jensen & Brehmer, 2005).

The third reason for including the action component in the concept of sensemaking is to create a useful operationalization of the concept for empirical work. It is hard, and perhaps impossible, to find ways of actually measuring the understanding, or sense, achieved by the commander and his/her staff, if for no other reason than that so much of it will be implicit. Among professionals sharing a culture and training, there is no need to spell out everything that is involved and all consequences of the sense achieved. Consequently, it will be hard to measure the sense achieved from what is said or drawn on the maps for not everything will be there, and questioning the commander and his/her staff is not likely to give all of their understanding or all implications of their understanding. However, the Course of Action selected can be observed and evaluated as an, albeit imperfect, indicator of the sense that was achieved. This is, of course, an interesting indicator only because of the two first reasons: if action were not part of the sense, and if the important action were not the COA selected, it would, of course not make any sense to measure sense in terms of the COA.

Information collection. The DOODA concept does not include a separate representation of information as does most models of C2. Data may exist independently of the people in the C2 system, but information certainly does not. Information is data that make a difference, and this means that they must make a difference to someone with a purpose for which the data make a difference. What is information will depend on this purpose and person's background. Hence, it is an idle exercise to try to characterise information independently of the users. We can only characterize information in terms what the users do with it. An outsider may, of course, make his or her own classification of the available data and what they can be used for, this has meaning only if the person who makes the classification shares the purpose of the actual user. In a way, therefore, all data are used in a "pull" mode, even if they are pushed to the user. This does not mean that each and every piece of data will be become information only if the user asks for this piece specifically. Data may also meet general needs that are not expressed explicitly and be collected as a matter of routine, such as data relating to the enemy's activities.

Even though the information collection function collects data, it is nevertheless called information collection function to remind us that it is used by the commander and his/her staff to collect data for a purpose, i.e., data that, to them, is information.

Planning. The planning function is given a more limited meaning than that in most contemporary C2 systems, where planning tends to encompass both sensemaking and planning. Here, the planning function is seen as a function that elaborates the result of the sensemaking function into effective orders. It thus involves decisions about the specifics, such as who should be given a mission, what weapons systems should be used, solving problems of logistics, and the like.

The Product DOODA (P-DOODA)

The functions specify what should be done. How it is done is a matter for the form of the C2 system, i.e., the organization, methods, processes, procedures and support systems. The form produces products that can then be used to assess the extent to which it succeeds in achieving the functions. This leads to the second DOODA-loop, which we call the Product DOODA loop, or P-DOODA for short, see Figure 3. The products may not be produced in any complete and well defined form that can be used for evaluation purposes, and it may therefore be necessary to find *indicators* that enable us to evaluate the products.

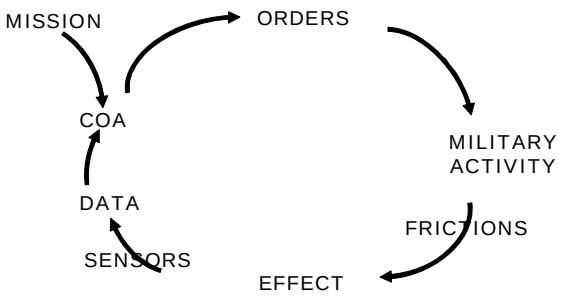

Figure 3. The Product DOODA (P-DOODA).

As discussed above, the product relevant to evaluating the sensemaking function is the COA. As noted above, despite its name, the information collection function produces only data, Thus, it must be evaluated in terms of the data that it makes available to the commander and his/her staff. The planning function produces orders, and should be evaluated in terms of these orders. Here, we make no distinction between the plan and the orders, for a plan that does not result in orders will not lead to any military activity.

Planning and execution. The exact content of the products will differ, depending on whether we are examining the initial planning stage or the execution stage. This may be formulated as a difference in questions answered by the sensemaking function during the two stages. In the initial stage, the question is: *Will this COA work?* The data sought will therefore be data needed to test the plan. The tests will mainly be *tests of coherence*, i.e., tests that provide information about the extent to which the COA under consideration is consistent with what is and can be known at the time, and will rely on the expertise of the various staff members and the data available to them. In the execution stage, the focus changes.

The relevant question now is: “Is the plan working?”, or rather “*Do we need a new COA?*”. The data collected in this stage will be specified by the expectations generated by the plan concerning what should be observed at different points in time. If these data are not consistent with expectations, it is “back to the drawing board”: a new or modified COA must be developed by the sensemaking function. It is thus important that the initial sensemaking generates the relevant expectations that lead the information function to supply the data needed to evaluate how the plan progresses.

The Form DOODA

The products in the P-DOODA result from the form of the system, i.e., the organization, methods, processes, procedures, and systems that comprise the actual C2 system. A number of factors contribute to the form that a C2 system takes, as illustrated in Figure 4, such as technology, doctrine, organization, the level at which C2 is executed, etc.

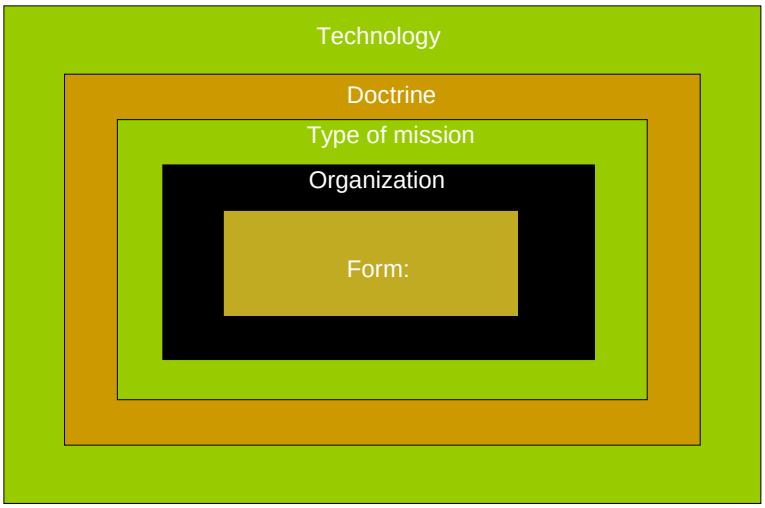

Figure 4. The form of the C2 system is determined by a number of factors, among them technology, doctrine, type of mission, and organization.

The actual form of the system may not have any direct process counterparts to the functions. Indeed, most C2 systems tend to be designed so that there is only one integrated process, e.g., the Military Decision Process (MDMP) or some national variation on it. This process is supposed to achieve the functions and produce the products that are required. There are thus many possible instantiations of the F-DOODA at the process level. Regardless of its form, each C2 system must nevertheless be evaluated in terms of the extent to which it achieves the functions, so the first goal of empirical work aimed at evaluation must be directed at finding the relevant products in the P-DOODA.

The characteristics of these products must then be related to the characteristics of the form that produces them. A second step in the evaluation of an existing C2 system is therefore to identify the processes that produce the relevant products, and find ways of characterizing these processes. Our work on the sensemaking and its effects (Jensen & Brehmer, 2005) provide an example. In this work, we have developed a number of measures of the characteristics of the sensemaking process, reflecting the extent to which information is exchanged in a staff, and how the commander organizes the work. These measures have them been combined into an overall measure of sensemaking effectiveness that has been shown to predict the quality of the plans developed by the team. Interestingly, the characteristics of the sensemaking process proved to more predictive of plan quality than the amount of data that was available. That what is done with the data is more important than the amount of data is, of course, just what we would expect from our perspective on sensemaking described above.

Type of mission. The type of mission for which the C2 system should be used is, of course, an important factor in determining its form. Today's missions tend to be complex and involve not only military components. Indeed, the complexity of the missions often require broader competence than that possessed by the military alone, and therefore the missions require co-operation between both military and civilian components. Moreover, such missions do not always have a military commander, and the usual military perspective of coordination of resources will not work, a perspective of cooperation is required instead (Ahlqvist, Brehmer & Buxrud, 2001).

This changes the nature of the sensemaking process, for it must now be aimed at achieving some form of agreement among the civilian and military components about what is to be done (see Brehmer, 2006). This perspective is also relevant in the new Information Age warfare concepts, such as NCW, where self synchronization is the result of an agreed COA, not one that has been decided by a commander, nor one that can be enforced. The concept of "command intent" proposed by Alberts & Hayes for these kinds of operations seem appropriate. Finding a form that will facilitate such agreements and the development of command intent is an important problem for future research on C2. The DOODA concept is neutral in relation to this and other questions of organization and technology. It assumes that that the same functions much be achieved in all cases of C2, but how these are achieved is a matter of form and will vary with organization and technology.

Evaluation of the C2 system

The P-DOODA supplies the information that we need to to evaluate a C2 system, while the F-DOODA shows what we need to evaluate. The functions themselves cannot, of course, be measured, they are theoretical constructs. Only the products relating to the functions can be evaluated. An important task for research on C2 therefore, is to develop measures of the quality of the products of the various functions. Such an evaluation should be scenario independent if the functions have been properly specified, and the conditions for achieving them are known. Moreover, it should be possible to predict how well the C2 system would work under given circumstances, provided that we know the extent to which the functions are achieved.

The products of the system alone do not explain the outcome of a military mission, of course, the frictions and the enemy also have their say in this. This does not mean that the C2 cannot, and should not, be evaluated in terms of outcomes, only that such evaluations are inherently ambiguous. Indeed, since the ultimate goals of C2 is to defeat the enemy and overcome the frictions, evaluations in terms of outcomes are highly relevant, but evaluations of C2 systems

are not limited to evaluating them in this way. Before being put to this ultimate test, they can, and should, be evaluated in terms of products and form, as explained above.

Putting the DOODA loop to work

The DOODA concept is currently used both in the development of new C2 systems in the Swedish Armed Forces and in research in our laboratory. Here, we restrict our discussion to its use in research.

As mentioned above, we have taken steps towards finding ways to measure the quality of plans by means of expert judgments (see Thunholm, 2003, for examples) and to characterise the sensemaking processes as assessed by observer judgments (e.g., Jensen & Brehmer, 2005). This has made it possible to relate the quality of the plans produced by planning teams to the quality of their sensemaking processes, where sensemaking is studied as a collective process.

This work has enabled us to make some first studies of the relations among processes and products. The results point to a strong relation between the quality of the sensemaking process and the quality of the resulting plans (Jensen & Brehmer, 2005). This suggests that sensemaking is indeed the central function. Current work is directed at studies of how a command concept develops, and at assessing the relations among different function in the DOODA loop. A concrete model of sensemaking based on the principles outlined above is also in development.

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