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The Dynamic OODA Loop: Amalgamating Boyd's OODA Loop and the Cybernetic Approach to Command and Control

ASSESSMENT, TOOLS AND METRICS

Berndt Brehmer

Department of War Studies
Swedish National Defence College
P.O. Box 27805
SE-115 93 Stockholm SWEDEN
Telephone: +46 8 788 8495
Fax: +46 8 788 9454
e-mail: berndt.brehmer@fhs.mil.se

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Berndt Brehmer
Department of War Sciences
Swedish National Defence College
P.O. Box 27805
SE-115 93 Stockholm, SWEDEN

Abstract

This paper presents the Dynamic OODA loop, or DOODA loop for short, a generic model of Command and Control (C2) stemming from Boyd's OODA loop and cybernetic models of C2. The DOODA loop is formulated in terms of functions that must be accomplished for effective C2, and these functions are then studied in terms of (partially overlapping) processes. The DOODA loop preserves the prescriptive richness of the cybernetic approach in that it represents all the sources of delay in the C2 process envisioned by that approach, and thus escapes the limited focus on speed of decision making characteristic of discussions of C2 based on the OODA loop. The DOODA loop organises research on C2 and provides direction for studies aimed at finding ways of improving C2 effectiveness in that it specifies the functions that need to be accomplished for effective C2.

Introduction

Concepts are important in scientific work as well as in practice. They direct our thinking, and they make us focus on some phenomena at the expense of others, thus creating a form of "tunnel vision". In short, they lead us to pay attention to some possibilities and ignore others. This is as true in the study of command and control (C2) as in other fields. Hence, we have reason to scrutinize our concepts of C2, for it is important that they are adequate both for research on C2 and for the practice of C2. This paper analyses two of the dominant conceptions of C2: *Boyd's OODA loop* and *the cybernetic approach*, and proposes an amalgamation of the two that promises to eliminate most of the weaknesses of these conceptions while preserving their strengths. We first describe the main features of each approach. We then discuss their pros and cons. Finally, we present the proposed amalgamation, which we call the Dynamic OODA-loop, or *DOODA-loop* for short.

The OODA-loop

Boyd's OODA (Observe-Orient-Decide-Act) loop (Boyd, 1987) is clearly the dominant model of C2 today. Every self-respecting briefing on C2 issues has a reference to it[1]. It is part of the Doctrines for U.S. Air Force (U.S. Air Force, 1999), U.S. Army (U.S. Army, 2003) and U.S. Navy (U.S. Navy, 1995) as well as those of other defence forces, including that of the Swedish

[1] A search on the Internet using "OODA" gave 23 000 hits in English alone.

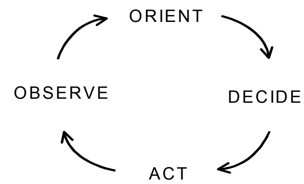

Figure 1. Boyd's OODA loop.

Armed Forces (Militärstrategisk doktrin, 2002). A good description of the development of the OODA-loop can be found in Hammond (2001).

Even though Boyd's OODA loop is by far the best known of the models discussed in this paper, it is useful to remind the reader of how the OODA loop originated because it illustrates important features of the concept.

The OODA loop was originally developed in an attempt to explain why American fighter pilots were more successful than their adversaries in the Korean war. It describes fighter combat in terms of four activities, or stages, see Figure 1. As the name implies the first activity, *Observe*, involves taking note of some feature of the environment. In the original version of the OODA loop, this meant detecting an enemy aircraft. The second activity, *Orient*, refers to pointing (orienting) one's aircraft towards the adversary, so as to be in a good position for entering the third stage, the *Decide* stage, which involves deciding what to do next. This leads to the fourth stage, *Act,* which involves implementing what has been decided, for example, pressing the trigger. Following the Act stage, a new observation is made, and so it goes. No explicit consideration is given to exiting from the loop. Perhaps Boyd did not see the need for this; if the Act stage is successful there is, of course, simply not anything more to observe, so the loop would stop for lack of input.

In his analysis, Boyd found that the American pilots and their aircraft, the F-86 Sabre Jet, were superior to their adversaries in all four aspects covered by the OODA loop. Thus, the American pilots were better trained, making them better at deciding and acting, and they were flying an aircraft that was, in some (but certainly not all) respects better than that of their adversaries, having better possibilities for making observations and for faster orientation due to powered controls. That is, the American pilots were superior in the all four stages of the OODA loop, and this enabled them to "get inside" the enemy's loop and win the duel. Thus, the OODA loop did what Boyd set out to do: It provided an explanation for the superior performance of the American pilots.

In his later work, Boyd developed the OODA loop into a more general model of winning and loosing. This later version of the OODA loop is illustrated in Figure 2. It was intended to apply to various forms of combat, and not only one-on-one fighter engagements (see Hammond, 2001). As Figure 2 shows, Boyd achieved generalization of the OODA loop by elaborating the Orient stage from representing a physical orientation to representing a mental orientation and by introducing a number of feedback loops, thus actually placing the OODA-loop in the cybernetic camp.

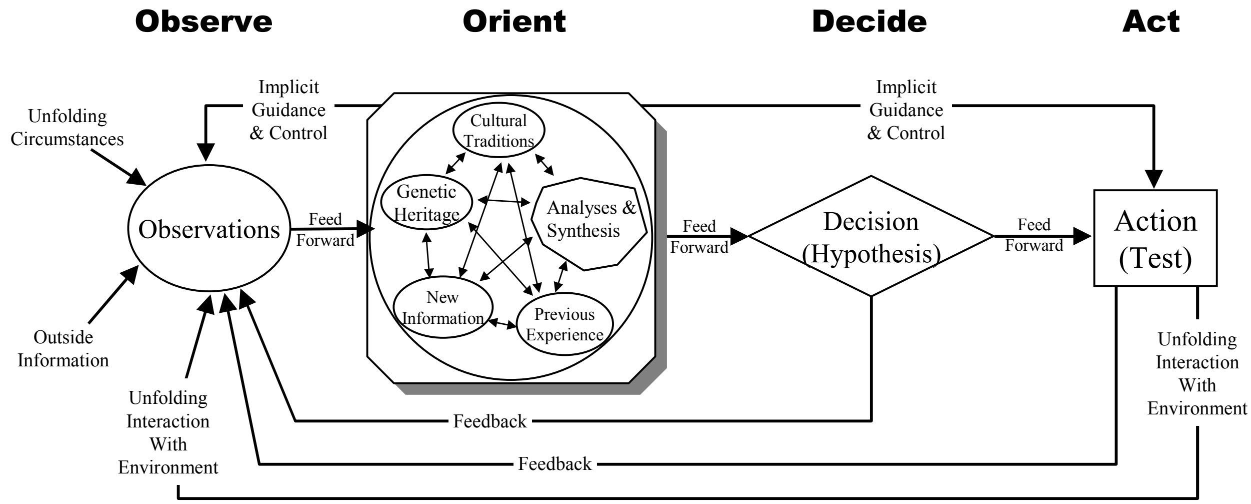

Figure 2. The modified OODA-loop. (Reproduced from J. R Boyd "An essay on winning and losing". http://defence and the national interest. d-n-i-net, 2001)

However, as a consequence, the OODA loop is no longer a loop, it is a stage model with multiple loops. With respect to the Orient stage, Boyd introduced a number of factors that affect the orientation achieved by the decision maker: Genetic heritage, cultural traditions and previous experience, as well as the mental processes of analysis and synthesis. These are not activities, as the elements of the original OODA loop (except for analysis and synthesis), but factors that affect the outcome of the Orientation stage. They point to factors that will explain how a decision maker will orient, and, perhaps, also what affects the speed with which orientation will take place. Orientation in the generalised OODA loop is a question of orienting in a more general way than just pointing one's aircraft in the appropriate direction, as was what Orientation meant in the original OODA loop. It is a question of being oriented mentally, and thus prepared, rather than just orienting physically.

Boyd's OODA loop has frequently been criticized on two grounds. Specifically, its critics point out that it neither describes decision making in general, nor military decision making in particular (e.g., Bryant, 2004), and that it does not apply outside the aviation context (e.g., Bateman III, 1998). Both of these criticisms apply to the generalized OODA loop as well. Although the generalised concept includes some of the factors that determine the outcome, it is not a model of the C2 *process* as such. The main point of the latter line of criticism, i.e., that the OODA loop only applies to fighter combat, is targeted at the action part. The point here is that the OODA loop is too simple a description of what takes place in, for example, an army context. In that context, "action" must be characterised as activities on a number of levels and requires a new series of cycles, such as the RUDE (Receive-Understand-Disseminate-Execute) cycles proposed by Bateman III (1998, see also Rosseau & Breton, 2004, for an interesting development of the OODA loop that takes these kinds of problems into account).

I find both of these criticisms, although correct on their own terms, to be misguided. Boyd clearly never aimed at developing a general theory of decision making, nor a theory of command and control (he did that elsewhere in his briefing “An organic design for command and control” which is part of “Discourse on winning and losing”). Nor was he concerned with a general description of military activity across services. Instead, as suggested by the title of his well known briefing “A discourse on winning and losing”, he wanted to find the conditions that led to success or failure in combat, to winning and losing, as he put it. He thought, in the case of one-on-one fighter engagements over Korea, that he had found the explanation why the American pilots were so much more successful that their adversaries in their faster OODA-loop, or, to use the expression that has since become a mantra in discussions of C2: they were able to get inside the OODA-loop of their adversaries. In his later development of the OODA-loop, Boyd generalised this, thus joining the tradition from Liddell Hart (e.g., 1927), and others, in emphasising speed as a condition for winning.

The emphasis on speed in discussions if C2 based on the OODA loop has focussed on one factor contributing to this: fast decisions, perhaps aided and abetted by the information technology merchants whose products seem to promise exactly this. This is unfortunate, but perhaps unavoidable, for no other recommendation could come from the OODA loop. This is because it does not include a representation of the environment that is affected by the decision maker’s actions (Brehmer, 2004). Such a representation is, however, part of the cybernetic approach. We now turn to that approach, which will give us a richer picture on what could lead to winning and losing.

The cybernetic approach to C2

As noted by Builder, Banks and Nordin (1999), the *cybernetic approach* has dominated research on command and control. A variety of cybernetic models have been proposed (see, for example, Levis & Athans, 1988). Here we focus on three somewhat different examples of such models that give the essence of the approach.

The first of these models is that of Lawson (1981), see Figure 3. In contrast to the OODA-loop, it is labelled a process model of command and control. This suggests that it is intended to be a description of C2. While all the terms in the OODA loop represent activities that *people* (fighter pilots) do (people observe, orient, decide and act), Lawson’s model includes an explicit representation of the environment where the acts have their effects, as well as a desired state which gives a goal and thus a possibility for exiting the loop, in addition to a number of activities that are presumably done by people. These are, however, at a different level than those considered in the OODA loop. The activities in Lawson’s model are described in generic terms and could as well have been used to characterise an electro-mechanical, or computerised, control system in, say, a process plant. Thus, Lawson’s model is a general model of *control* rather than a specific model of C2. In the model, the environment is seen as a source of signals that must be sensed[2], processed and compared to a desired state. On the basis of the results of these comparisons, a decision is made that leads to some act that affects own forces and new signals

[2] ”Sense” in Lawson’s model refers to the *detection of a signal*, rather than to the understanding of some event or process in the environment and it is thus fundamentally different from sense is the sensemaking process discussed later in this paper.

are generated (presumably as a consequence of the interaction between own forces and the enemy). These signals are then sensed, and so on.

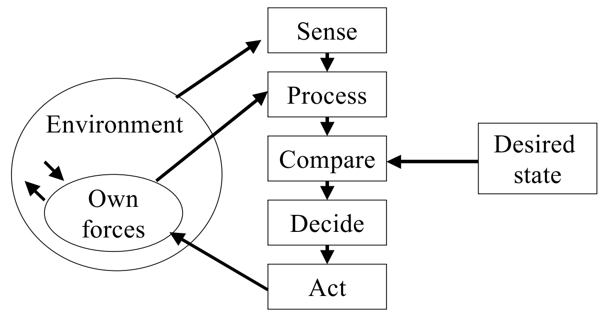

Figure 3. Lawson's model (After Lawson, 1981)

A second example is Wohl's well known SHOR (Stimulus-Hypothesis-Option-Response, Wohl, 1981) model, see Figure 4. It differs from Lawson's model in that its terms refer to psychological entities, using the Stimulus-Response framework then popular in psychology, and process descriptors like "perception" and "hypothesis". This model apparently has roots, not only in control theory, but in psychology as well, and it may be seen as a step towards a model with a greater descriptive accuracy. Wohl's model is nevertheless only superficially different from Lawson's model.

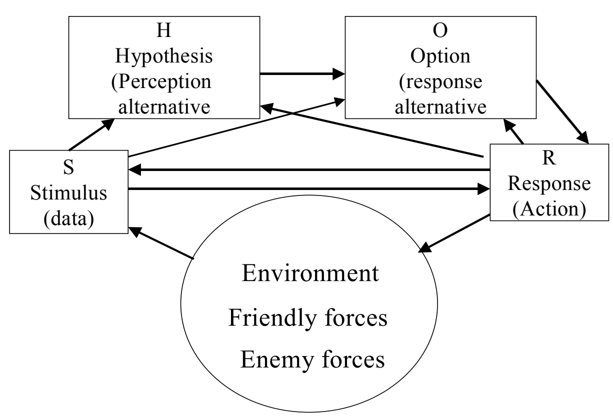

Figure 4. Wohl's SHOR model

Both Lawson's model and Wohl's SHOR model are advanced as descriptive models of C2. This is also true of my own Dynamic Decision Model of C2, see Figure 5 (Brehmer, 2000, 2004) which is our third example. This is a kind of model also used to represent decision making in some System Dynamics approaches (e.g., de Rosnay, 1979). It illustrates the strengths and weaknesses of the cybernetic approach quite clearly.

As illustrated in Figure 5, there are four salient events in this approach: Information, Decision, Action and Result, all of which are connected in a feedback loop. Thus, the process is triggered by information, which leads to a decision, which leads to some action that has a result (a change in the decision maker's environment) that leads to new information that triggers a new decision, and so on. All of the events are events that can be observed. The model does not refer to any psychological processes that may explain why a given decision is made. The model in this form leaves something to be desired when it comes to descriptive accuracy with respect to the C2 process.

Like the OODA loop, a loop of the kind illustrated in Fig. 5, would go on forever; because there is no representation of a target value, so there is no natural stopping point. This problem

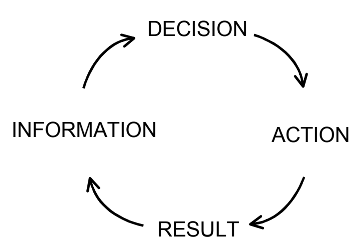

Figure 5. The Dynamic Decision Model of C2 (Brehmer, 2004)

is handled in Lawson's model above in the comparison process that carries out a comparison between a desired state and the actual state. Such a comparison process could easily be added to the Dynamic Decision Loop, perhaps as part of the Decision component, but it is harder to see how the problem could be handled in the SHOR model. Being cast in an S-R framework, that model has no use for mentalistic terms like decision making.

Although the cybernetic models are developed as descriptive models of C2 in general, and C2 decision making in particular, they also identify conditions of winning and losing, as does the OODA-loop. In the cybernetic approach, the problem of winning and losing is interpreted in terms of control or the loss thereof. A most important precondition of control is the ability to handle the various delays in the loop so as to be able to get inside the opponent's dynamic decision loop and present him with a situation to which he has no time to adequately

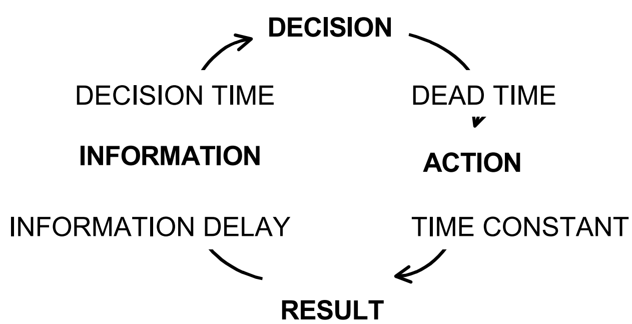

Figure 6. Sources of delay in the dynamic decision loop.

react. The relevant sources of delay are shown in Figure 6.

In the OODA loop, only one source of delay has been considered. This is because the OODA loop only represents the Information → Decision part (if one assumes that Information and Observation are synonymous, which amounts to assuming that everything that can be observed will be observed (but not necessarily oriented to)), and the Decision → Action part of the dynamic decision loop. The dynamic decision loop identifies other forms of delay as well. These are the delays identified by control engineers: *dead time*, which is the time between the initiation of an act and that when the act starts (the time required to get military action started), the *time constant*, which is the interval between the moment when an act starts and that when it takes effect (the time required to actually produce results), and *information delay*, which is the interval between the moment when a result has been achieved and that when the decision maker is made aware of this result (the time between the moment when some result has been achieved and that when the commander becomes aware of this result). In addition there is what we may call the decision time, the time from information to decision, which corresponds to the Observation → Orientation → Decision aspect of the OODA-loop. In most cases, this is probably the shortest delay in the loop. This is important to remember, because it suggests that speeding up the decision process is not the only alternative, and perhaps not even the best alternative, if one wants to beat the enemy by getting inside his dynamic decision loop. It may be more profitable to work on other delays in the loop than the decision time. One example, taken from a study by Johansson (1999) will have to suffice.

In the Six-Day War, the Israeli Air Force was rightly praised for its fast planning and targeting process, i.e., its fast decision process in OODA loop terms, compared to that of its Arab adversaries. The question is, then, what the Arab air forces would have gained by imitating the Israeli C2 procedures and processes. Not much, as it turns out, for the Arab air forces were also slower in other respects. For example, while the Israeli air forces had a turn around time from landing to refuelling, rearming and taking off again, that was a matter of minutes, the corresponding time for e.g., the Egyptian air force, was two hours. Thus, even if the Egyptian air force had adopted Israeli C2 procedures, the Israeli air force would still have been within its dynamic decision loop, if not its OODA-loop.

By identifying additional sources of delay, the cybernetic models lead to a richer understanding of the causes of winning and losing. What is important is getting inside the opponent's *dynamic decision loop*. Getting inside the opponent's OODA loop is just an aspect of this, but it is not sufficient in itself, and perhaps not even the most important aspect, for other sources of delays may well be more important, as the example above suggests. There is reason, therefore, to work on these delays as well, and it may, perhaps, be more to gain from doing so than from trying to speed up the decision process, something that may well decrease the quality of the decisions. One could well argue that the total effect could be better from working on these other sources of delay, and allowing more time for careful decision making, than from speeding up the decision process (Brehmer, 2004).

Some common features

Both Boyd's OODA-loop and the various cybernetic models emphasize time. According to these models, time is the dominant concern in warfare. The important thing is to be fast. This was also emphasized by Clausewitz (1976), but only for the attack. For defence, Clausewitz maintained that one should be slow. This is because time is used differently in attack from how it is used in defence. In the attack, the reason for being fast is to disturb the adversary's decision process by preventing him from orienting, a dominant theme also in modern manoeuvre warfare theory (Lind, 1985). In the defence, one wants to be slow so as to make the attacker spend his resources and reach his point of culmination before one counterattacks. The importance of speed in the attack was also emphasised by Liddell Hart (1927). One may say, therefore, that neither the OODA loop nor the cybernetic approach provide any really new insights into the causes of winning and losing.

The problem with the two approaches lies elsewhere, however. As pointed out by Builder, et al. (1999) the cybernetic approach is fundamentally flawed in that it paints a picture of C2 as basically reactive. This is true also of the OODA loop. It puts the commander in a position where no self-respecting commander would want to be, namely in the situation where he or she can only react to what the enemy does. In this respect, one might add, these models are also out of date with modern forms of process control, where control is no longer only feedback driven, but a mixture of feed-forward control based on models of the process and feedback control to update the models.

A further problem is that neither the OODA loop nor the cybernetic models give a good account of the processes involved in C2. They therefore provide little guidance with respect to how the

C2 process can be improved. For that purpose, we need a descriptively adequate account of C2 at a sufficient level of detail. We now turn to the Dynamic OODA loop as our answer to this challenge.

The Dynamic OODA (DOODA) loop

The Dynamic OODA loop, or DOODA loop for short, is intended to be a general model of C2. It is reasonable, therefore, to first ask what the possibilities of creating a general model of C2 might be. A look at history shows that the way C2 is exercised has changed dramatically from the times of Alexander, especially as a result of the introduction of new forms of information technology; Alexander did not lead his troops in the same way as von Moltke or General Westmoreland (see van Creveld, 1985 for a historical account of how technology has changed both how C2 is exercised and what is commanded). Therefore, we cannot build a general theory of C2 on a study of the process of C2 at any point in time. We need a different level of generality. The level of *functions* provides that level. That is, we must start by asking, not how C2 is exercised, but what its function is, i.e., what one is trying to achieve, and what functions need to be fulfilled to enable the commander to achieve the C2 function, i.e., what his C2 system must achieve to enable the commander to achieve C2.

To find these functions, we turn to history to assess what, if anything, have remained constant in the dance of change. Fortunately, this job has been done for us by van Creveld, one of the leading military historians, in his book *Command in war* (van Creveld, 1985). He lists the following eight functions that we take to be the defining characteristics of C2 (op.cit., p. 7):

- Gathering information on own forces, the enemy, the weather and the terrain
- Finding means to store, retrieve, filter, classify, distribute and display the information
- Assessing the situation
- Laying down objectives and working out alternative means for attaining them
- Deciding what to do
- Planning
- Writing orders and transmitting them as well as verifying their arrival and proper understanding by the recipients
- Monitoring the execution by means of feedback, at which the process repeats itself

The last bullet is important. It suggests that our C2 model should be a loop, or dynamic feedback model. However, despite this, van Creveld's list of functions does not lead to the traditional reactive cybernetic model, for it also emphasises laying down objectives as an important function. The list therefore gives a good starting point for developing an alternative to the OODA-loop and to the traditional cybernetic models that is more descriptively adequate. However, being descriptively adequate is not enough. We also want the model to be prescriptively adequate, that is, it should be consistent with what we know about winning and losing combat.

To evaluate our concept in this respect, we must turn to military theory. The most modern version of that theory is the manoeuvre warfare theory (e.g., Lind, 1985). This theory emphasises that the condition for winning is that of achieving "system shock", i.e., rendering the enemy powerless to act by acting faster, and attacking him where he does not expect it and is particularly vulnerable. Good understanding of the situation and the ability to act fast and decisively are therefore desirable characteristics.

The eight functions, together with the loop concept, make it possible to specify a C2 model with these characteristics: there are eight things that must be done right, eight functions that must be achieved, and they must be done faster and, hopefully also better, than the enemy does them. This may not seem very different from what the OODA loop recommends, and this is hardly surprising. The OODA loop was one of the parents of modern manoeuvre warfare theory, at least as formulated by Lind (1985) and his followers. However, as noted above, just having a faster C2 process is not enough. No enemy was ever defeated by decisions alone, and fast decisions will come to nothing if other delays are not taken into account as well. We must be inside the enemy's dynamic decision loop, not just his OODA loop. This suggests that the new model should take the dynamic decision loop as its point of departure, rather than the OODA loop, to adequately model also these delays.

As noted above, although the dynamic decision loop provides a more adequate description of the conditions of winning and losing than the OODA loop, it is not descriptively adequate, because it does not include an account of what commanders and their staffs actually need to achieve (in addition to being fast) and how they must do it. That is, we must first find the functions required for successful C2 and the processes that are required to achieve these functions. The DOODA loop illustrated in Figure 7 takes us towards that goal. It takes the OODA loop and the dynamic decision loop, as well as van Creveld's eight functions as points of departure and translates them into a set of functions that, based on our current understanding, are required for effective C2.

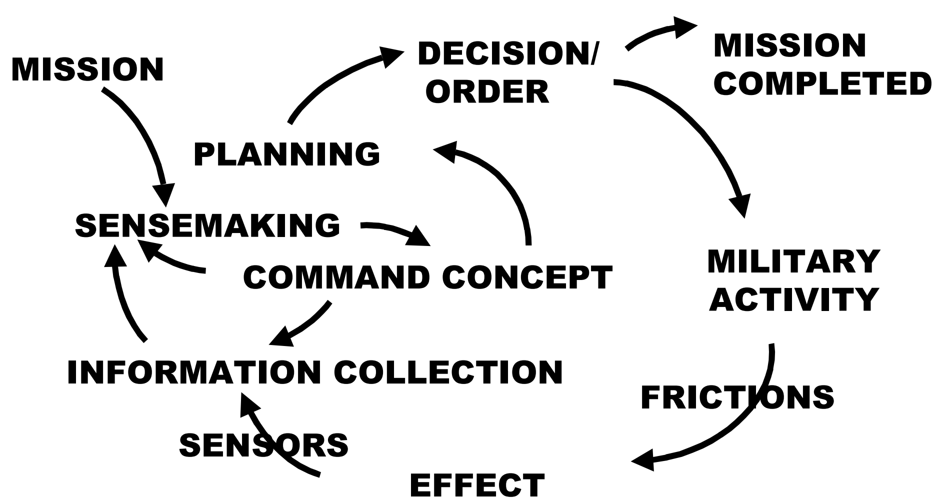

Figure 7. The Dynamic OODA loop (DOODA loop).

The DOODA loop preserves all of the steps of the dynamic decision loop, and thus allows us to represent all the important delays in the C2 process. It differs from the dynamic decision loop, first, in that the Act stage has been renamed MILITARY ACTIVITY to remind us that, in anything but one-on-one combat, the act stage in military circumstances is highly complex and may, in turn, be composed of a number of sub-processes, such as the RUDE cycles proposed by Bateman III (1998) and, second, in that a number of stages have been added between the INFORMATION COLLECTION stage and the DECISION stage to reflect the fact that C2 decisions are not based on raw information but that the information must be processed into *understanding* and *planning* before a decision can be made. The addition of these stages represents our acknowledgement and interpretation of the second, third and fourth bullet in the list based on van Creveld (1985) above. To cover these aspects, we have introduced SENSEMAKING, which, following Weick (1995), we consider a form of understanding in terms of what can be done (Jensen & Brehmer, 2005). Sensemaking, in the present context, involves making sense jointly of the mission received from superior command and the situation, so that the situation is understood in terms of what can be done to accomplish the mission under the circumstances at hand. The concept of sensemaking differs from the individually oriented concepts of *situation awareness* (Endsley, 1995) and *situation assessment* (Klein, Orasanu, Calderwood & Zsambok, 1993) in that it is seen as the result of the collective activity of the commander and his staff, and in that it is aimed at action. One possible outcome of the sensemaking process is, of course, that the mission has been accomplished, and that no further action is required, as indicated in the figure.

We have also added Builder, et al.'s (1999) COMMAND CONCEPT, first, to acknowledge that the information actually used is only a subset of the information that is available, and that this subset has been chosen by the commander and his staff, based on their emerging concept of the operation that informs them about what they need to know, and, second, to escape the purely reactive character of the traditional cybernetic loop model. Following Builder, et al. we see the command concept as the commander's overall concept of how an operation is to be conducted. The command concept provides guidance for the planning process, which then leads to a more detailed concept of how the commander's intent is to be achieved, as a basis for the decision about what to do (which we see as the commitment to a given course of action) and the subsequent orders (which may consist in missions or directives given to subordinate commanders depending on what the situation requires and on the command philosophy to which that the commander subscribes). It also helps the commander and his staff to cope with the mass of information that will be received during the actual operation.

Deciding on a command concept is probably the most important decision in the C2 process, and when that concept has been decided upon, other decisions in the loop become a question of making a commitment to a given course of action developed on the basis of the command concept.

The term SENSORS is introduced between the effect and the information to acknowledge that the commander and his/her staff do not have access to the world *in toto*, but that the information they can access is filtered by the sensors available to the commander, including, of course, people, e.g., subordinates. The term FRICTIONS between MILITARY ACTIVITY and EFFECT points to all the factors that will prevent the effect from turning out exactly as the commander intended. Such a term could have been added also on the information side of the figure (and, perhaps, in other places as well), but the figure is cluttered enough as it is.

The arrows are an important feature of the DOODA loop. They represent the fact that, conceptually, a given function requires that other functions have been accomplished. Thus the arrows specify logical relations among the functions, and they should not be given too strict a temporal interpretation at the process level. At that level, there may well be overlap between the processes that accomplish the different functions. For example, there is likely to be considerable overlap between SENSEMAKING and PLANNING, as sensemaking is a form of understanding that involves knowing what to do, albeit not requiring a fully developed plan, but the results of the planning process are nevertheless likely to contribute to the sensemaking process, and, of course, vice versa. This goes also for SENSEMAKING and COMMAND CONCEPT.

The arrows in the model in Figure 7 represent our current best understanding of the likely relations among functions. An important question is whether we can identify and isolate the processes that accomplish the functions in the DOODA loop. Selected parts of the model are now being subjected to test (see Jensen & Brehmer, 2005, for a first example involving sensemaking in planning teams, and Thunholm, 2005a, b, for studies of the development of command concepts and plans). For 2006 we are planning experiments that will involve larger parts of the model, enabling us not only to assess the arrows, but the relative importance of the different functions to the overall C2 function as well.

The DOODA loop is intended to be a generic model of military C2, applicable at every level of C2. The formulation of the DOODA loop in terms of functions in aid of the overall C2 function contributes to this aim. The actual processes required to accomplish these functions will, of course, differ depending on the level under consideration, and the technology available to support the C2 process, as van Creveld (1985) reminds us.

The DOODA loop achieves three goals for us. First, it guides our research on C2. Specifically, it points to those functions that need to be met in order to have effective C2. In our research, we try to identify the processes that accomplish these functions, and to find ways of improving them by new procedures or new forms of information technology. Our work with ROLF 2010, a "Command Post of the Future" for the Swedish Armed Forces (Brehmer & Sundin, 2005) provides an example of this work. Second, the model provides a way of systematising research on C2, turning the explosion of research in the area into an implosion where we are able to think in terms of a limited number of concepts, rather than in terms of a very large number of individual results. Finally, the DOODA loop serves as source of hypotheses about winning and losing. Here, it provides a much richer source of hypotheses than the original OODA loop that only seems to require faster and faster decisions in a world that seems to far too complex to allow even slow decisions. It is regrettable that this has required a more complex model than either of its parents, and this may seem like a Ptolemaic development. If so, we can only patiently await our Copernicus.

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