# The M-OODA: A Model Incorporating Control Functions And Teamwork In The OODA Loop.

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#### Abstract

The objective of the present paper is to present a modified version of the OODA loop, the M-OODA. For the OODA loop to remain a useful tool in the context of documents defining the armed forces doctrine on C2, any modification has to keep explicit the high-level representation typical of the OODA loop, while accommodating dynamic and control concepts. The M-OODA incorporates explicit control and flow components more in line with the current understanding of military C2. It is based on a modular structure in which a module operates as a simple control system. A module is a task-goal directed activity formed of three core components. Next, a number of modules are structured in an OODA loop fashion and interconnected by feed-forward and feedback loops. Then, the model is adapted to a multi-tiered decision making process. Finally, an illustration of the M-OODA applied to teamwork in a C2 context is provided. The M-OODA model provides a compromise between that high level view of C2 decision-making, valued in military documents, and an expansion accommodating the basic C2 functions on information handling, processing, and communicating and the coordination and direction function in C2.

#### Introduction

The efforts at providing an acceptable model of decision-making in C2 have proven to be an enduring task. Repeated attempts at modeling C2 reflect the importance of such modeling for understanding C2 and contributing to the design of support tools and training efforts aimed at an improvement of C2. The present paper addresses a class of models defined as *descriptive* models. Descriptive models include a more psychologically valid description of the processes involved in a decision-making task. A good descriptive model will reflect the decision-making processes of the commander and the C2 team. It provides a description that "makes sense". It is very flexible and can take into account most constraints that are typical of an operational setting. Most of the time, descriptive models are not easily transformed into formal prescriptive terms. They will provide rather general predictions. By comparison, prescriptive models are theory driven. They are characterized by the formal representation of processes leading to some computational modeling of C2 decision-making. It is our contention that by adopting a principled modeling approach to C2 decision-making modeling, descriptive models can keep their high-level descriptive quality while providing a form of representation more consonant with formalization, mainly for the purpose of developing software support tools for the C2 process and in particular for the decision-making processes.

Dynamic decision-making in a complex task like C2 is often defined as a control task in which decision-making is continuous (Brehmer, 1982) and comprises a number of subtasks ranging from perception to action (e.g. Rasmussen's decision ladder; Rasmussen, Pejtersen, & Goodstein, 1994). Over the last 25 years, a number of descriptive models of C2 have been proposed based on that paradigm. For instance, early models like Lawson's (1981) or Wohl's SHOR model (1981) describe a set of processes spanning information sensing to action implementation processes. Mayk & Rubin (1988) provide a systematic analysis of C2 descriptive models. They describe 15 different block models that share some generic approach while each one is addressing C2 from a particular viewpoint. All the models are a form of representation of a basic perception-action loop operating in an environment.

## The OODA loop

The OODA loop, as described in Figure 1, is the prototypical descriptive model of decision-making in C2. The OODA loop in itself can be labelled a simple control system as described by Jagacinski and Flach (2003).



Figure 1. The classical version of the OODA loop model.

It identifies four processes: Observe – Orient – Decide – Act, organized into a loop. It is a very simple action cycle originating in observing the environment and terminating by acting on it. It has been developed in the context of command and control activities typical of military decision. An essential value of the OODA loop resides in its representation of decision-making in C2 as a dynamic system. The generic model presented by Mayk & Rubin (1988) is very similar in form to the OODA loop. The model has three basic processes: Observe, C3, and Action. The C3 process includes both Orient and Decide processes of the OODA loop.

## The OODA loop and military doctrine

Within military Command & Control, U.S. Army Field Manual (FM 6.0, 2003) defines Control as a regulation of forces and systems to achieve mission goals in accordance with the commander's intent. FM 6.0 considers information as the most important element of control since it transforms data into meaning. Control is further described in U.S. Air Force AFDD 2-8 (1999), as a set of processes for planning, directing and coordinating. In AFDD 2-5 on Information, control is defined as the processes by which commanders plan and guide operations. The commander's intent should specify the goals priorities and acceptable risks. Control operates through feedback for planning and directing purposes.

In these documents, the OODA loop is referred to as a simple representation of these control processes. For one, AFDD 2-5 uses the OODA loop model as the basic set of processes describing a commander's decision-making capability. In the U.S. Navy doctrine document (NDP 6, 1995) on naval C2, the OODA loop is given a central position as the basis for describing the Decision-Execution cycle in C2. Finally, US Army FM 6.0 considers the OODA loop to be a valuable tool for illustrating a commander's decision-making processes, albeit admittedly simplistic. Our position is that given the current understanding of the Control component of C2, and the necessity for C2 systems to adapt to the commander's information requirements following mission objectives and situational constraints and affordances, the classical form of the OODA loop, still currently presented in the US armed forces documentation on C2 and information, lacks the power required to give a more adequate representation of C2 decision -making. A number of limitations of the OODA loop have been stated over the years. It is our opinion that for the OODA loop to remain a useful tool in the context of documents defining the armed forces doctrine on C2, any modification has to keep explicit the high-level representation typical of the OODA loop, while accommodating dynamic and control concepts.

# Modifying the OODA loop

While the OODA loop is a useful high-level representation of the basic processes in C2 decision-making it is limited by three basic difficulties:

- 1) It has no representation of the feedback or feed-forward loops needed to effectively model dynamic decision-making.
- 2) It is a very high-level representation with abstract concepts that do not provide the kind of details needed for the OODA loop to be used as an analytical tool for improving decision-making.
- 3) It is a strict sequential model with a single entry point and a single sequence of processes that cannot adapt to different levels of expertise in decision-making and to the diverse task context existing in real tasks.

Some attempts have been made to insert in the OODA loop features enabling dynamic control. An extended OODA loop, proposed by Fadok, Boyd & Warden (1995) has been developed and is presented in Figure 2.



Figure 2. The extended OODA loop (Fadok, Boyd & Warden, 1995).

As it can be seen, the Orient process seems to be the more important one in that extended version of the OODA loop. It is exploded into a number of factors. However, while the content of the Observe process is made more explicit, no new processes are included in the loop. Furthermore, one can readily see explicit data feedback and feed forward loops extending from the Orient process. These loops make the Orient process a central contributor for guidance of the early and late processes. The other two processes also send feedback to the Observe process. That late generation OODA loop is more complex. As is often the case in modeling, while the extended model is more representative of decision-making, it becomes more complicated and, consequently, less useful for communication purposes. For instance, the factors included in the Orient process are very diverse and in some cases difficult to estimate, as is the case, for the "Genetic Heritage" factor. However, it remains that it is a valuable effort to modify the classical version of the OODA loop.

Breton & Bossé (2002) also acknowledge the need to adjust the OODA loop to the dynamic aspect of decision-making. They propose a version of the OODA loop that includes an iteration process between the Observe and the Orient phases (see Figure 3). Again, it is the Orient process that is the target of the changes in the loop. Breton & Bossé are more explicit concerning the nature of the feedback they include in the loop. It is a control loop enabling an iteration of the Observe process. This iteration process is controlled by two criteria, which are the time constraint and the level of uncertainty. The iteration process is interrupted when the time available for analysis is over or when an acceptable level of uncertainty is reached. Then, the Decide process is activated and the selected course of actions is implemented in the Act process. The interest of that proposition lies in the more formal definition of control within the OODA loop processes.



Figure 3. The iterative version of the OODA loop (Breton & Bossé, 2002).

Other work has addressed the issue of improving the underlying decision-making model and the related processes. Murphy & Glasgow (2000) have proposed a modified OODA based the Recognition Primed Decision-making model (RPD) (Klein, 1993) adapted to a de facto model of command-staff group process for current operations. It identifies five high-level processes: Monitor, Assess, Decide, Direct and Execute. The change in names of these processes reflects the generic processes included in Klein's model. Murphy & Glasgow go one step further and describe a number of activities, specific to a tactical operations centre, for each process. For instance, in the Decide process, on top of the Decide process in itself, three activities are to be completed if time permits: Solicit input from commander and staff, wargame and complete staff actions. That particular adaptation of the OODA loop is the result of the objective of Murphy & Glasgow to link more closely the OODA to military decision-making processes as they are defined for planning purposes, for instance. That effort would facilitate the translation of the OODA processes into tactics and procedures leading to an efficient OODA loop. On a more generic line. Mayk & Rubin (1988) present a list of more that 25 activities for the Observation process and 25 others for the Act process and an other 25 for the C3 process grouping both the Orient and Decide processes. These 25 activities are in fact verbs of action reflecting activities that could, on a conceptual or pragmatic basis, be linked to the basic OODA processes. While that may seem trivial, such an effort opens the OODA loop and makes it easier to adapt the model to specific situations at a more detailed level.

Leedom (2000) describes the Execution Decision Cycle (EDC) that is considered a more adequate model than the OODA loop for the design of support/automation tools. The EDC model is much more complex than the OODA loop. It expands the OODA loop on two basic aspects. First, it includes feedback/feedforward loops as well as explicit control nodes directing the flow of process with regards to parameters like time available, clearness of situation, scope of adjustment of selected COA and feasibility. Second, it adds a number of processes related to the testing of selected COA. The interesting feature of the EDC is that it is different from a classical process model typical of software design. In fact, it accommodates human decision-making processes within a form of flow model. The EDC model shares an objective with Murphy & Glasgow in making an effort to adjust a generic human decision-making model, Klein's RPD model (Klein, 1993), to current military procedures. Unfortunately, while Murphy & Glasgow remain within the OODA loop architecture, the EDC does not.

So, some attempts have been made to develop extended versions of the OODA loop. It is our opinion that while interesting, these developments are not principle based and that modifications of the original model can become quite complex. The next section will describe an extended version of the OODA loop based on architectural principles that could overcome the complexity problem. The objective of the present paper is to present a modified version of the OODA loop, the M-OODA. The M-OODA model provides a compromise between that high level view of C2 decision-making, valued in military documents, and an expansion accommodating the basic C2 functions on information handling, processing, and communicating and the coordination and direction function in C2. It is our contention that by adopting a principled modeling approach to C2 decisionmaking modeling, the OODA loop can be expanded while keeping its high-level description.

# The M-OODA model

The M-OODA model modifies the OODA loop based on the following principles:

- 1) It adopts a modular, or building blocks, approach in which each process of the OODA loop is represented as a generic module structured around three components: Process, State and, Control;
- It incorporates explicit control elements within and across modules enabling a bidirectional data/information flow between modules. It also includes a feedback loop within each module;
- 3) It provides a basic architecture for modeling a variety of team decision-making in with the OODA loop.

So, the M-OODA incorporates explicit control and flow components more in line with the current understanding of military C2. It is based on a modular structure in which a module operates as a simple control system. A module is a task-goal directed activity formed of three components. A number of modules are structured in an OODA loop fashion and interconnected by feed-forward and feedback loops. These loops enable communication and coordination means between modules. The M-OODA model is then a simple dynamic system enabling the control of the tasks/processes already identified as representing a commander's decision-making capability.

These modeling principles are in line with recent work on C2 modeling. McCorry & Morse (2000) presented an update of the DARPA Joint Force Air Component Commander (JFACC) program. The program aims at providing C2 with a prosthesis type of technology for decision-making support. For doing so they describe an approach based on a Multi Hierarchical Decomposition of a control node that is formed by a set of five processes that are almost identical to the OODA loop. The processes in the control node are interrelated with bi-directional communication links. From their modeling effort, a number of statements are highly relevant for deriving principles for the design of the M-OODA model. In the JFACC control model, each process of the loop is defined as a level. It then follows that each level requires different models with different levels of aggregation of time and objects. In the model, there is a systematic flow of state observation data that flows upward and downward from a level to another. That requires

systematic mappings between levels, since each level is modeled differently. Indeed, the transmission across levels has to take into account the properties of the target level. For instance, higher-level processes should be shielded from low-level state data, like velocity or position of an object entering at the bottom of the system. In fact, they claim that the upward transmission of information should be in terms of aggregated events and pictures. Similarly, the downward flow is a privileged channel for transmission of command information. Here again, an adequate mapping is essential for adapting the higher-level aggregation into low-level aggregation with higher temporal and spatial granularity, for instance. The M-OODA model adopts a similar point of view with systematic communication and control links between processes.

The architecture of the M-OODA model is based on the concept of building block. That approach bears resemblance with the model proposed by Curts & Campbell (2001) in the context of applying Object Oriented Data Bases (OODB) concepts to the OODA. Their model has a formal architecture in which functional building blocks can be assembled to form large-scale processes or databases. These basic blocks have three components: Processes, Attributes of processing and Functions. Then, it appears that applying the building block approach to the M-OODA is of interest since that approach has shown to be adapted to formal representation in the context of the design of software support tools. The M-OODA modules resemble the OODB blocks except on two points. First, given the commitment in the M-OODA to the control processes in C2, the third component of the M-OODA module is not a generic function but a more specific control function. Second, the modules are designed as simple control systems, which is not the case in the OODB model.

# The M-OODA Basic Module

The basic module is the core component of the M-OODA model. A module represents a task-goal directed activity supported by a set of components. It can be seen as the basic structural element of a goal-directed system. The module has components whose function is to produce the expected state following the appropriate process according to preset control criteria. On top of that, a module has components for interaction with other modules and the general environment. In the M-OODA model, iteration processes are added within and between all the different modules part of the process. These feedback loops make possible backward communication between the M-OODA parts. These loops have two purposes. First, within a module, they support an iteration request based on a set of criteria included in the control component. Second, they enable communication between the different modules. With these loops, the flow of activities in the M-OODA model is dynamic and multi-directional. Figure 4 presents the structure of a basic module. As can be seen, a module has a set of 8 elements: the module name, three core components, two feedback loops and input/output connections. Each element of the module will be described in the following paragraphs.



Figure 4. The Structure of the basic module.

*Module Name.* The module name corresponds to the specific process included in the module. A module name is composed of an operation and an object on which the operation is applied. Actually, the name of the module reflects the general goal (G) of the module within the M-OODA model. For instance, in the Data Gathering module, the goal is to gather data from the environment. Thus, module name is more than a simple label; it is a high-level determinant of the nature of the process, resultant state and related control criteria within a module.

*Input.* In most cases, inputs (I) are mainly outputs from other M-OODA modules. Information from the environment can also contribute to the Input of a given module. Depending on its goal and on the current situation, the relative importance of these two sources will vary. While we acknowledge that a module operates in a general environment where objects are present and actions occur independent of the specific task goal, we limit the input to the states represented in the M-OODA model.

*Process.* The process (P) is the core active component of a module. It is a goal-directed action applied on an input. Its properties depend on the nature of the goal. A process will generate a state in the module. The process is given a generic name that is closely related to the action included in the module name. For instance, in the Situation Understanding (SU) module, processes such as understand, identify, organize, and form hypothesis can be used to represent the module goal-oriented activity. This goal is achieved by an agent that can be a human, an automaton or a combination of both. The Process is actually viewed as a generic component that can be subdivided into sub-processes. For instance, a process could be *Select a course of action*. It is obvious that such a label covers a number of sub-processes that would model that specific process.

*State*. The state (S) is the result of the process activity. It is a structured representation with properties depending on the nature of the process from which it originates and of the input that was fed to the process. The granularity of the aggregation in time and space is likely to vary with the specific processes. The general properties of the state are also constrained by the module goal.

*Control.* The criteria-based control (C) component is a flow control function gating the delivery of the output to other modules and enabling iterations of the process within the module. Control can interrupt, iterate the process or exercise no gating function depending on the mode of operation required. It can accept a given level of state quality depending on task-goal criteria. Since they are goal related, the control criteria should be different from one module to another. According to Breton & Rousseau (2001), different types of uncertainty are related to the different components of the OODA loop. Vagueness, beliefs, value and feasibility are types of uncertainty respectively associated with Observe, Orient, Decide and Act. On top of all possible criteria, time and quality can be the most important ones.

*Output.* The Output (O) is the current status of the state resulting from the process that reaches an acceptable level of quality based on the criteria-based control component. The resulting output becomes the input for a subsequent module.

*Internal feedback loop.* The internal feedback loop (IL) is an iteration request based on a set of criteria included in the control component. The iteration request can be based on the need for improved quality in state or for increased quantity of state content, focus on repeated processing of part of the input, or need for updating the content of state.

*External feedback loop.* The external feedback loop (EL) enables communication between modules. We label <u>target module</u>, the module towards which the EL is directed. There are two kinds of EL: The Request loop (R-El) and the Transfer loop (T-El). The R-El is a loop originating in the need for an improved input to a module in order to enable an adequate or maximal state. It is thus a request addressed to the modules that control the input to a given module. That request will then be adapted internally, within the target module, in terms of an internal control loop. The T-El is a passive transfer of the status of the current module to other modules or other non-task-goal related processes. It produces a form of broadcast in the system. It takes the form of a feedback or of a feed-forward loop depending on the position of the target modules. The transmission of commander intent would flow downward through the T-EL. Table 1 gives a summary of the parameters defining each component of a module.

Component	Parameters		
Module name	M: [object, operation]		
Input	I: [physical signal, OODA state, non-OODA input]		
Process	P: [action verb].		
State	S: [object, representation, goal-determined properties, process-		
	specific properties]		
Control	C: [time, quality, goal-related criteria].		
Output	O: [current State]		
Internal loop	IL: [state quality criterion, state completeness criterion, update		
	monitoring]		
External loop	R-El: [time, information criterion, number]		
	T-El: [State status, control status, command information].		

Table 1. Summary of the parameters associated with each component of the basicModule

# A Modular Architecture for the OODA Loop Model

The M-OODA loop is a modification of the classical OODA loop. The modular architecture refers to the organisation of a set of modules to model the OODA loop. In the M-OODA loop, the specific modules are defined by the four high-level processes of the OODA loop. Three modifications of the OODA have been applied in the M-OODA architecture. First, the four original processes of the OODA have to be renamed according toe the requirements of the Module name component of the M-OODA. Second, the structure of the model must allow for dynamic and multi-directional processing. Third, a common and general architecture should be adopted to represent the process related to the different processes in the M-OODA model. These modifications are described in more details in the next sections.

The classical version of the OODA loop includes four different processes that are included in the M-OODA loop. The main goal for that choice of four processes is to keep intact the high-level representation of decision-making of the OODA. The first aspect of the M-OODA architecture is to adapt the OODA processes to the concept of goal-oriented processing as reflected by the Module names. That leads to a change in the labels associated with the OODA processes in accordance with the specifications of the Module Name in a module.

<b>Original OODA Loop Processes</b>	M-OODA Loop Processes
Observe	Data-Gathering (Dg)
Orient	Situation-Understanding (Su)
Decide	Action-Selection (As)
Act	Action-Implementation (Ai)

Table 2. Modifications to the Processes labels of the OODA loop

The M-OODA module names are presented in Table 2 in relation with the original processes of the OODA-loop. The M-OODA loop is developed by representing each OODA process with a basic module as described above. The M-OODA shares with the classical OODA the sequential operation of the modules. In such a model, the output of a module is strictly linked to the input of the next. It is that Output/Input connection that enables the sequential operation of the M-OODA cycle. The M-OODA architecture is presented in Figure 5.



Figure 5. The M-OODA loop.

It is composed of four modules, each one associated with the processes of the OODA. Each module is specified by the three basic components (P, S and C). The EL and IL loops are links that maintain the same properties no matter the specific module. Furthermore, as defined in the basic module, I/O connections are redundant representations of the state component when described strictly within the M-OODA. In each module, P, S and C are given a generic label in order to simplify the representation of the M-OODA. As stated before, P can be seen as, in fact, an organized network of sub-processes that can be active depending on the specific task-goals and current constraints in the environment. We assume, for simplicity, that EL can link a given module with any previous one, as represented with the red dotted arrows in Figure 5.

Outputs with high level of familiarity can initiate automatic process in subsequent module. For instance, when a familiar output, produced by the DG module is fed into the

SU one, it triggers an automatic recognition which also triggers the activation of wellknown and familiar set of actions from the AS module. This automatic answer is fed into the Action Implementation (AI) module. In this very familiar situation, attentional resources are only required to execute the DG and AI modules. SU and AS can be executed on an automatic, non-controlled mode.

A detailed description of the core components of each module is given in Table 3. We do not claim that the table provides an exhaustive and necessary description of the components specific to each module. Actually, the extensive list of processes presented in Mayk & Rubin (1988) could expand the number of processes already listed in Table 3. However, it provides a very good approximation of these components. We have made an attempt at describing the specificity of each core component within each module. We have also made an effort to keep these specific components at the level of a model. Furthermore, there is no assumption as to the nature of the agent associated with particular processes within a given module. In fact, an agent, human or automaton, with a specific set of skills and resources owns a specific module.

Module	Process	State	Control
Data Gathering	Sense, encode, register,	World	Vagueness,
	data translation,	representation,	completeness,
	transduce, scan, fuse,	object/background,	fuzziness, time
	detect, monitor	scene organization,	available, quality
		multimodal-	of picture
		integration	
	Understand, identify,	Mental model,	Belief in
	categorize, classify,	schema, episode,	interpretation,
Situation	organize, schematize,	familiarity	familiarity of
Understanding	recognize, form	estimation,	schema,
	hypothesis, simulate		uncertainty on
			meaning
Action Selection	Select, choose, identify	Decision, list of	Risk assessment,
	options, apply rules,	actions (course of	completeness of
	consult,	actions), risk	options, cost
		evaluation,	assessment, gain
		expected gain,	estimation,
		selection rules	familiarity of
			situation
	Act, planning, resource	Set of Actions,	Feasibility,
	management, constraints	schedule,	acceptability,
Action	identification, milestone	milestones, plan,	resource
Implementation	definition, project	mission, orders	availability
	management, taking		
	action,		

 Table 3. Specifications of the core components of the M-OODA.

To summarize, the M-OODA loop is a simple adaptive network of modules. The control nodes with the feedback/feedforward loops make the OODA loop sensitive to time pressure and requests from higher-level processes for specific information. The control module also serves the function of mapping the demands from other modules to the reality of a given module. This is an important function that recognizes the need for such a mapping. Then, the OODA loop keeps its valued high-level representation while accommodating dynamic adjustments compatible with command and control requirements. In its current status, the M-OODA is a framework that could be adjusted to specific requirements. Each core component could be modeled and further complexified for the purpose of modeling a specific aspect of C2 decision-making. The M-OODA can be seen as a layered system in which different parts can be exploded for more details. That layered aspect is an emerging property of the M-OODA and makes it compatible with complex decision-making models or data fusion models, for instance. An other important property of the M-OODA is that it is compatible with team decision-making. The next section will present an extension of the M-OODA for team, or multi-tiered decision-making.

#### The M-OODA team model

#### Modeling principles

## 1) The basic structure

There are two levels of team representation that can be modeled in the M-OODA architecture. The first level, the between module level, assumes that the modules are not all owned by the same agent. For instance, the DG module might be under the control of a given agent and the next two would be controlled by a different one. In that case, the only aspect of the M-OODA architecture that would be of relevance is the feedback/feedforward loops. These loops would make possible the required communication between agents. The other level, the within module level, deals with the presence of multiple agents within the same module. It does not reflect the mere number of agents but more specifically the diversity and specificity of different agents linked to different processes. In that case, these different agents will be taken into account by inserting more than a single building block within a module. The type of DM in operation in a given setting will determine the way agents are organized across and within DM subtask modules. That will lead to Team DM models with different architectures. An appropriate subset of Team Functioning Elements is then invoked to handle the required interactions between agents.

2) Team Functioning Elements (TFE)

TFEs are interactions between team agents associated with the quality and efficiency of teamwork. The set of TFE selected for the Team DDM models is taken from the NATO RTA IST-019 TG006. It includes Human Communication (HC), Tool Communication (TC), Coordination (Co), Task Allocation (TA), Task Balancing (TB) and Information Distribution (ID). That set covers more than communication and coordination between team members. It also addresses task adjustments and tool communication requirements. The TFEs are included in the M-OODA architecture as additional components. They will

appear as links between building blocks representing a given team decision-making arrangement.

## Applying the M-OODA Team Decision-Making Architecture

The M-OODA will be applied, for the sake of illustration, to a multi-tiered decisionmaking (MTDM) process, typical of large military groups, presented by Leedom (2000). He provides a schematic representation of the C2 structure of command posts (CP) of the III US Army Corps. An adaptation of Leedom's MTDM is presented in Figure 5. It shows three levels of a group composed of Tier 3, Tactical CP (Support staff sections), Tier 2, Main CP (Principal staff advisor), and Tier 1, a commander. Briefly, the Tier 3 Support level is formed of specialized teams collecting specific information with the appropriate devices. These teams, in Figure 5, provide support for Tier 2 functions that can be approximately described as follows: G2, Intelligence from all sources; G3, Planning and co-ordination of operations; FSE, Fire support; ALO, Air liaison; the last team is simply a set of diverse support units. The Tier 2 Advisor team is composed of staff officers (field grade officers and NCOs) receiving the specialized information and sharing that information in order to produce a tactical, or operational, picture that will be reported to the commander for decisions to be taken.



Figure 5. Multi-Tiered Decision-making. (Adapted from Leedom, 2000).

Figure 6 shows a M-OODA model of MTDM. It has been developed to represent the following basic aspects of MTDM:

- 1) Tier 3 is the Tactical CP, formed by a set of specialized teams working in parallel and feeding data/information to the next level. It is modeled as a Data Gathering module and the set of teams is represented, for sake of simplicity by three building blocks. Each of these blocks is assumed to be a team in itself.
- 2) Tier 2 is the Main CP, formed by a team of advisors, who receive independent inputs from the Tier 3. Commonly, their task is to provide a shared state/picture and possible courses of actions to the commander. Again, only three members are

represented and the shared state is explicitly modeled. Tier 2 is modeled as a Situation Understanding module.

- 3) Tier 1, since it concerns a single individual who is responsible for making a final decision, is modeled as a simple Action Selection module.
- 4) For the sake of completion, an Action Implementation module is included, although no effort has been made to model the team structure of that module.



Figure 6 A M-OODA model of multi-tiered decision-making.

A simple examination of Figure 6 gives an immediate sense of the increase in complexity of team decision-making. The increase in efficiency resulting from specialized teams working in parallel is somewhat diminished by the cost in coordination and proper task allocation and task balancing. There is an increased overall cost in organizational coordination. Furthermore, the model provides an explicit description of the issues involved in the transfer of information from the DG module to the SU module. Since each team, in the DG module, is controlled by specific criteria that are likely to be

different, in part, from one team to the other, asynchronous communication and differences in quality of outputs to the SU module are to be expected. While none of these points are in themselves new, the interesting aspect of the M-OODA team model is that it can represent, with the same set of modeling basis, complex decision-making processes. It provides a way to adapt the OODA loop while keeping intact its essential architecture.

## Conclusion

We have presented a descriptive model of decision-making in C2, the M-OODA, based on the classical OODA loop. It provides a means to model decision-making at the required level of complexity while maintaining the coherence of the model. The modular concept, based on building blocks, has been showed to be a potential useful tool to describe the decision-making process in C2.

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