13th ICCRTS: C2 for Complex Endeavors

"Machine Interpretable Representation of Commander's Intent"

Topic 9: Collaborative Technologies for Network-Centric Operations

Topic 3: Modeling and Simulation

Topic 8: C2 Architectures

Per M. Gustavsson (Saab) STUDENT
Training Systems and Information Fusion,
Saab
Storgatan 20,
SE-54130, Skövde,
SWEDEN
+46 31 794 89 39
per.m.gustavsson@saabgroup.com
(Point of Contact)

Michael Hieb (George Mason University)
Center of Excellence for C4I
George Mason University
4400 University Drive
Fairfax, VA 22030
USA
001-703-993-3990
mhieb@gmu.edu

Patric Eriksson
(Gothia Science Park /
De Montfort University)
CEO / Visiting Professor
Gothia Science Park
Box 133
54123 Skövde
SWEDEN
+ 46 500 44 89 60
patric@gsp.se

Philip More
(De Montfort University)
Professor of Mechatronics
Head of Research &
Commercial Development
Faculty of Computing
Sciences & Engineering
De Montfort University
Leicester LE1 9BH
UK
+44 (0)116 257 7053
prmoore@dmu.ac.uk

Lars Niklasson
(University of Skövde)
School of Humanities and
Informatics
University of Skövde
P.O. Box 408
541 28 Skövde
SWEDEN
+46 500 44 84 37
lars.niklasson@his.se

1 MACHINE INTERPRETABLE REPRESENTATION OF COMMANDER'S INTENT

2 ABSTRACT

The Network-Centric approach envisioned in the Global Information Grid enables the interconnection of systems in a dynamic and flexible architecture to support multi-lateral, civilian and military missions. Constantly changing environments require commanders to plan for missions that allow organizations from various nations and agencies to join or separate from the teams performing the missions, depending on the situation, as missions unfold. The uncertainty within an actual mission, and the variety of potential organizations that support the mission after it is underway, makes Command Intent (CI) a critical concept for the mission team. With new and innovative information technologies, CI can now be made available to the team of organizations in a coalition environment. Using a flexible and linguistically based approach for representing CI allows Intent to be interpreted and processed by all participants – both humans and machines. CI representations need to be able to express mission team's purpose, the anticipated End-State of the mission and desired key tasks. In this work, the expression of CI is developed to enable the structure and dynamics of collaboration support.

This paper presents the Operations Intent and Effects Model (OIEM) – a model that relates CI to Effects, and supports both traditional military planning and Effects Based Operations.

Keywords: Commander's Intent, Decision Support, Planning, Battle Management Language

3 INTRODUCTION

As new concepts and methods are developed to perform operations for complex endeavors, a new understanding of missions is being developed. While it is widely recognized that Situational Awareness is essential for operations involving a wide and diverse team of organizations, the agile development of plans and execution of actions is also important. The principles of Command Intent (CI), essential in US and NATO doctrine, can also be applied to complex endeavors, although the concept may be generalized to Intent as noted in (Alberts and Hayes, 2006).

In this paper, we elaborate on how to represent the well-understood concept of CI for a Coalition military operation. We present an innovative model (Operations Intent and Effects Model – OIEM) that shows how traditional planning can use the same representation as Effects Based Operations (EBO), describing the causality from Intent to Effects. This model of CI has the potential to be used in the next generation of advanced simulations and computer generated forces. Planning multi-lateral, civilian and military missions in a constantly changing environment requires organizations from various nations and agencies to join or separate from the team performing the mission, depending on the situation, as the mission unfolds. The uncertainty within an actual mission and the variety of potential organizations that support the mission after it is underway makes CI a critical concept that must be understood by the mission team.

A key capability of the systems is to establish connectivity faster than the current methods and mechanisms can. The challenge is to establish interoperability that not only enables multiple-protocols and multiple-information exchange models to co-exist in the system of systems environment but that the CI can be communicated between C2 systems and thereby enable collaboration across agencies, organizations and nations.

The outline of this paper is as follows: 1) an overview is presented of the concepts of CI and how it relates to collaboration; 2) a methodology (based upon the OIEM) is developed that relates Intent and causality for complex endeavors; 3) a new formalization of CI, that uses a Command and Control grammar to represent Effects and Expressives is described; 4) the paper ends with conclusions addressing future work regarding how CI can be implemented in agent-based systems such as Computer Generated Forces to facilitate collaboration.

3.1 An Overview of the Concept of Commander's Intent

Military strategy and tactics are traditionally called Doctrine. The concept of Doctrine represents the collected knowledge of an organization and is both a strict formalism and a guide for conducting military operations. In a Network-Centric paradigm a key aspect that leads to success in military operations is self-synchronization and understanding complex causes and effects. To enable self-synchronization the subordinates must be given the mandate to make their own initiatives, within the boundary of the mission. In Rethinking Command and Control by (Curts and Cambell, 2006) they address this fine line between delegating authority and maintaining and controlling hierarchy The one delegating authority must refrain from then directing the actions of subordinates, yet maintain some command structure and the subordinate must have the ability to work independently or with a team to achieve the mission goals. To create the needed empowerment for the commandeers information needs to be shared with everyone, autonomy is created by setting boundaries and hierarchy is replaced by self-directed teams (Curts and Cambell, 2006). CI acts as a basis for staffs and subordinates to develop their own plans and orders that transform thought to action, while maintaining the overall intention of their commanders. In the US Army Field Manual 6.0 paragraph 1-68 (US Army, 2003) CI is defined as below:

> *The commander's intent is a clear, concise statement of what the force must do and the conditions the force must meet to succeed with respect to the enemy, terrain, and desired end state. It focuses on achieving the desired end state and is nested with the commander's intent of the commander two levels up. Commanders formulate and communicate their commander's intent to describe the boundaries within which subordinates may exercise initiative while maintaining unity of effort. To avoid limiting subordinates' freedom of action, commanders place only minimum constraints for coordination on them.*

Military operations are governed by the planning process of the commander's staff and the result is disseminated to the subordinates of the organization for execution. In western military forces, NATO, and Partnership for Peace (PfP) countries, the doctrinal planning process is the Guidelines for Operational Planning (GOP) that has as its output a five-paragraph order. The five paragraph order consists of Situation, Mission, Execution, Service and Support and Command and Signal (Figure 1).

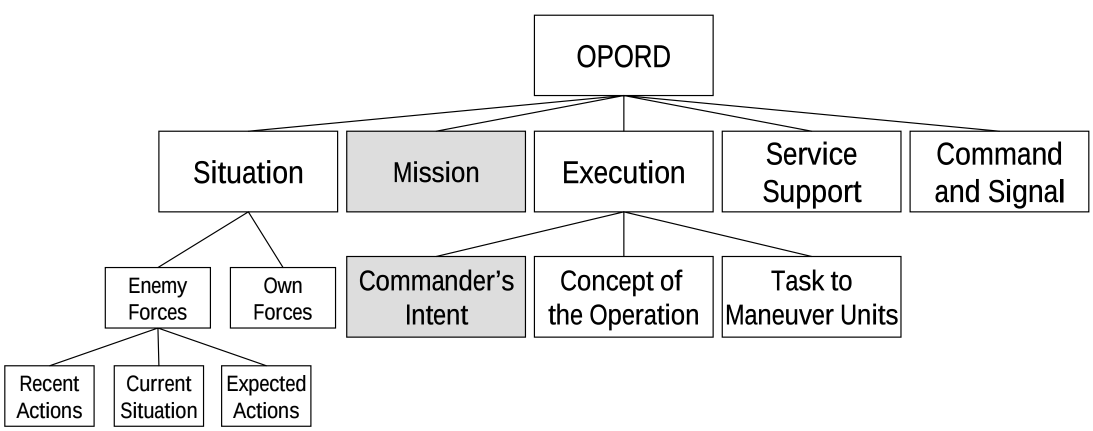

Figure 1. 5 Paragraph Operations Order (OPORD)

Situation describes an organization's own forces, adversary forces, and the environment. The adversary forces recent actions, current situation and expected actions. The expected actions, (or rather their effect) is what the commander assumes is the output from the adversary CI at the battlefield.

Mission describes the unit's essential task (or tasks) and is a short sentence or paragraph and purpose that clearly indicate the action to be taken and the reason for doing so. It contains the elements of who, what, when, where, and why, and the reasons thereof, but seldom specifies how.

Execution describes CI, Concept of the Operation, Tasks to maneuver units. CI focuses on the desired End-State and can be in narrative or bullet form; it normally does not exceed five sentences. The concept of operations focuses on the method by which the operation uses and synchronizes battlefield operating systems to translate the commander's vision and envisioned end state into action, it includes the scheme of maneuver and concept of fires. Tasks to maneuver units describe the missions or tasks assigned to each maneuver unit that reports directly to the headquarters issuing the order.

Service and Support describes support concepts, material and services, health and service support and personnel service support. The support concept describes the commander's priorities as well as the next higher level's support priorities.

Command and Signal describes the geospatial coordinates for command post locations and at least one future location for each command post. It identifies the chain of command if not addressed in unit Standard Operational procedures and lists signal instructions not specified in unit Standard Operational procedures.

CI is explicitly declared and represented in the execution part of the five paragraph order but there are also intent statements in the mission and in the concept of operations sections.

3.2 Intent and Planning

The Network-Centric planning process focuses on describing the CI in a manner to support flexibility for coordination and collaboration in a dynamic environment (Alberts and Hayes, 2007). Given the definition of CI presented above, we now look at a definition that gives some structure to CI:

> *The commander's intent links the mission and concept of operations. It describes the end state and key tasks that, along with the mission, are the basis for subordinates' initiative. Commanders may also use the commander's intent to explain a broader purpose beyond that of the mission statement. The mission and the commander's intent must be understood two echelons down.*
>
> *(US Army, 2003) Section 4-27*

This definition is broader than the definition of CI from FM 6.0 cited above in that it does not only describe the End-State but also the purpose. In Sources of Power (Klein, 1994), a view of CI is presented consisting of seven parts:

1) The purpose of the task (the higher-level goals);
2) The objective of the task (an image of the desired outcome);
3) The sequence of steps in the plan;
4) The rationale for the plan;
5) The key decisions that may have to be made;
6) Antigoals (unwanted outcomes);
7) Constraints and other considerations.

According to "The Human in Command" (Pigeau and McCann, 2000) CI also can be divided into *explicit* and *implicit* intent. So far we have discussed *explicit* intent which is shared between a commander and subordinates in the direct orders and it is a publicly stated description of the End-State as it relates to forces (entities, people) and terrain; the purpose of the operation; key tasks to accomplish. The *implicit* intent is developed over a longer time, prior to the mission, and consist of the expressives and the concepts, policies, laws and doctrine agreed to by military, civil, organizations, agencies, nations and coalitions.

In our work, we define ***Expressives*** as a component of CI that describes the style of the commander conducting the operations with respect to experience, risk willing, use of power and force, diplomacy, ethics, norms, creativity and unorthodox behavior.

Further there is a connection between CI and the three levels of situation awareness – perception, comprehension and projection – defined by (Endsley, 1995). Staff members need to perceive (*explicit intent*) and comprehend (*implicit intent*) CI, as well as understand how CI will impact future events in order to generate an effective campaign plan. Farrell describes this as common awareness that implies that team members with similar awareness of the environment and CI will produce effective team performance (Farrell, 2004).

Awareness, intent, and planning are part of the decision making processes. In military applications the commonly referred decision making model is the OODA (Observe-Orient-Decide-Act) loop model (Richards, 2001, Boyd, 1996, Boyd, 1987). In this profound theory of warfare, Boyd describes the essential parts to achieve mastery over an adversary by introducing a human behavioral cycle of decision making. However the OODA-loop often is criticized for just dealing with one commanders decision loop, not explicit declaring the connections with higher and lower command and not appropriate for collaborative decision making. In work by (Brehmer, 2005) the Dynamic OODA-Loop is presented that describes a decision making model that uses the OODA-Loop and extends it to collaborative decision making and command chains. The Dynamic OODA-Loop does not change the original idea of a decision process that not only is faster than the adversary's, but also provides a commander with assessments methods of his own and his adversary's strengths, weaknesses, abilities and capabilities in the on-going situation. Thus, awareness is reached and each of the decisions made, together with the actions executed, moves towards the commander's desired goal. Boyd describes this ability as what a commander needs to get inside the adversary's moral-mental-time cycle to achieve decision advantage. In the Joint Vision 2020 (Joint Chief of Staff, 2000) this ability is termed Decision Superiority:

> *Decision Superiority – better decisions arrived at and implemented faster than an opponent can react, or in a non-combatant situation, at a tempo that allows the force to shape the situation or react to changes and accomplish its mission.*

To achieve better decisions CI needs to be disseminated to all subordinate commanders. Of course the best way of disseminating the intent is for the commander to do it face-to-face to all subordinates, allowing the receiver as well as the commander to use all of their senses for interpretation. But when tempo is crucial the commander does not have the time to be everywhere. The use of video conferencing is being one possible way of solving this problem. Still if there is a multi-national, multi-doctrinal component in the operation, there is a good chance that misinterpretations may occur. One step further is to develop a Lingua Franca that creates unambiguous statements of the CI. The structure needs to be suitable for dissemination between commanders so that the interpretation is as unambiguous as possible providing the ability for commanders and subordinates from different nations and agencies to interact. For a simulation context the CI must be expressed in such way that it can be interpretable by machine and executed in simulations. Then the formalized CI will be a basis for collaborative planning.

3.3 Effects and Commander's Intent

CI, properly formulated, will express a desired End-State. To detect, measure, and assess that a desired End-State is reached there is a need to observe the effects from actions taken. Observers, human or machine, will interpret the information and form an understanding that is used in the decision making process. Implementation of the decisions then causes a new plan and that starts a new turn in the OODA-loop. The commander will observe (perceive) and orient (interpreter, comprehend) the effects differently because of sensing ability, domain knowledge and previous experience resulting in decisions (projection, intent) that leads to actions and effects that may or may not help to shape the situation further and accomplish the mission.

The coordination of actions to establish effects in the most effective area at the most effective time to move towards a desired End-State is the core of Effect Based Operations. The described End-State is the overall intent of the operation. In the book, Effects Based Operations (EBO) (Smith, 2003), states that the EBO approach combines the strategic, operational and tactical objectives to be attained together with how Network-Centric and effect based operations help to realize those objectives. Network-Centric Warfare has been driven by the technological advances in collecting, processing and disseminate information, that has made it possible to enhance information sharing and collaboration on tasks in command and control systems. The new technology combined with organizational and doctrinal adoption, changes the conditions for collaboration between systems and individuals. EBO shifts the focus from weapons and targets towards focused actions to shape the behavior of enemies and allies. To stress the concept further (Alberts, 2007) describes three new key concepts for future Command and Control namely agility, focus, and convergence. As stated in the introduction of his work "agility is the critical capability that organizations need to meet the challenges of complexity and uncertainty; focus provides the context and defines the purposes of the endeavor; convergence is the goal-seeking process that guides actions and effects".

In the work of (Farrell, 2007), an approach is introduced of using Control Theory on Effect Based Thinking (EBT) and modeling "operations" as a Feedback Control System. In this work Farrell describes the key functions needed for EBT. Information plays a central part since it is the basis for the entire planning and assessment process. The description of situations, plans, orders, actions, effects, reports etc. are all information that must be expressed in such a way that it is interpretable for both humans and machine.

3.4 Where Are We Now

Even though processing, e.g. data mining, filtering, aggregation and fusion techniques, of information has evolved; this is not enough to keep up with the pace of collection and dissemination. The collection and dissemination of information enables literally anyone to share information. Although that information can be shared in joint, civil-military, multi-lateral, peacekeeping, information, security and multi-agency operations, it does not imply that the receiver can interpret (perceive and comprehend) the information and make use of it in decision making Even if the information is interpreted correctly the methods and procedures in implementing operations calls for a shift from describing the actions towards describing the desired Effects and desired End-State. The doctrine that subordinates initiative shall be as unlimited as possible and that echelons shall self-synchronize with other echelons require that the collaborative environment allow C2 information to be shared, and especially CI.

The information exchanged must then be as clear as possible, with a minimum of ambiguity, and understandable. Clear means that the information expressions are concise and conforms to agreed doctrine, procedures and methods. A minimum of ambiguity means that there is an explicit structure that the information can be put into and then parsed out of with only one clear and definite outcome results from the parsing. Understandable means that the semantics used in the information are available and common to all of the recipients.

What if a clear unambiguous representation suitable for collaborative environments were available? What would it be?

4 THE OPERATIONS INTENT AND EFFECTS MODEL

The Operations Intent and Effects Model (OIEM) is a Command and Control model of Command Intent that combines: CI; a Decision-making process (OODA-Loop); A planning process based on NATO Doctrine; an information fusion model (JDL) (Steinberg and Bowman, 2004, Llinas et al., 2004); Doctrine; and the Expressives of the commander. The model is an expansion of a generic C2 Model, such as (Curts and Charles, 1996), in that it introduces CI as a key component in order, planning and for assessment. The purpose is to combine a formalism of CI with Expressives and doctrine to produce a representation for decision support.

The OIEM model, shown in Figure 2, consists of a State→Order→Action→Effect→State diagram showing the linkage between the desired End-State to appropriate action. The OODA-Loop is a well-known model that is simplistic enough to capture the necessary parts. The Orient-Decision phase can be utilized in Decision Making models such as Classical Decision Making (von Neumann and Morgenstern, 1944), i.e. normative models of rational behavior, Judgment Decision Making (Edwards, 1954, Meehl, 1954), i.e. model of observed rational behavior by modeling the deviation from rational, or Naturalistic Decision Making (Klein, 1999, Klein, 1994), i.e. representing the actually observed behavior.

The OIEM consists of two parts: 1) the Model, shown in Figure 2, that describes the OIEM causality and introduces an Intent-Effect representation for planning; 2) The Dissemination, shown in Figure 3, describes the impact of CI in a command structure taking into account the Doctrine, and Expressives of a Commander. The model and dissemination supports collaboration between teams and actions in complex endeavors.

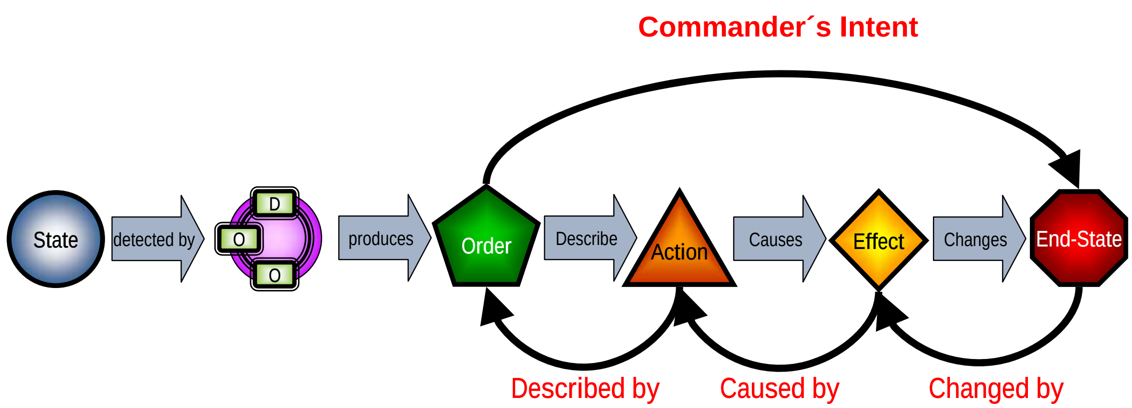

Figure 2. The Operations Intent and Effects Model

The flow in the diagram in Figure 2 is, at a top level, that a State is detected by a Decision Making Process that produces an order that describe *Actions* that cause *Effects* that change the state into the desired *End-State*. The detection of the initial state (the state prior to the decision making and the time the *Order* is given) means that the system where the decision making-takes place must to be able to perceive and comprehend the situation, and from reasoning and projection etc. produce a plan that consists of an order that describes *Actions* to be executed. The *Effect* from the actions then changes the initial state to another state. The Act in the OODA-Loop is expanded to visualize the causality relation in the Model (Order->Action->Effect->End-State).

In a planning scenario the commander uses a Decision Making (DM) process and produce an order, e.g. OPORD. The order expresses the *End-State* by using a representation of CI that is as unambiguous as possible, the curved arrow between *Order* and *End-State*. The arrow labeled *changed-by* expresses the *Effect* needed to transition between two states, here the initial state and the *End-State*. An *Effect* can then have one or more *Actions* associated with it and are represented by the curved arrow *caused-by*. The *Actions* are then described in the *Order*, the curved arrow *described-by*.

The OIEM can also be used to assess the *Effects* needed to reach the desired *End-State*. These effects are provided by *Actions* that are delivered by some force and equipment with a particular capability. Thus a chain can be formed where the *End-State* is the focus in planning the actions to deliver the needed *Effect*. With unlimited time at hand multiple choices can be evaluated in depth using multi-hypothesis simulation techniques, but in certain situations there is no time for extensive simulations.

Following the concept of Naturalistic Decision Making (Klein, 1999) one approach is to identify the desired *End-State* and backtracking – chaining from the *End-State* to *Effect* to *Action* to the ability and capability of the force at hand, to find the first solution that might fulfill the mission. The solution found is then assessed towards situations that might break the chain. A solution is a sequence of actions that together or alone cause the effect needed to change the state to the desired *End-State*.

Using the OIEM above provides a model that simulation systems can use for both forward and backtracking planning corresponding to both traditional planning and EBO. In a collaborative planning process the commander then expresses the *End-State* and the other staff members then can assess what effects that are necessary to fulfill so that the *End-State* is reached. With a set of desired *Effects* the search for an appropriate action with corresponding force is looked for.

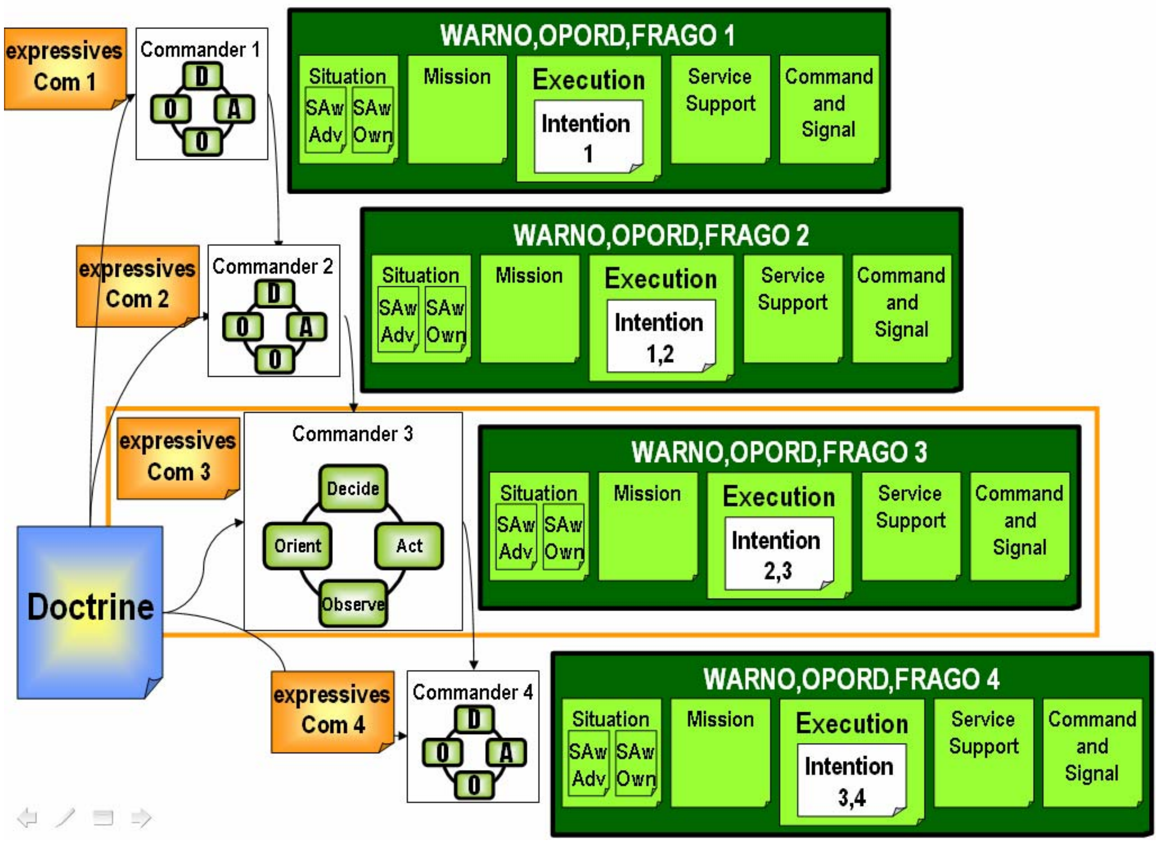

Figure 3 Intent and Chain of Command

Figure 3 visualizes Intent as it propagates through a military command structure. In NATO doctrine, intent is known two levels up. In the order issued by Commander 3, the intention of commander one is no longer present (i.e. following the guidelines from the field manuals). The Situation part changes and gets more and more detailed and specialized for the lower echelons. The CI links the orders together. The subordinate commander forms the plan according to the higher commander's order and passes the original CI together with his intent further in his OPORD.

The model expands the Generic Command and Control Process in Figure 4 (Curts and Charles, 1996, Curts and Cambell, 2006) in that The Generic C2 Process "assess->evaluate->select->plan->order" is not directly assessing a desired End-State (i.e. CI) but rather the objectives and mission statement. A good commander would, however, assess the current situation in the context of the commander's End-State but would he assess the situation towards the superior commander's End-State? Furthermore the Generic C2 Process model gives the impression that a plan is formed by the mission, objectives and the current situation which is not a proactive planning process such as effect based approaches. The OIEM in Figure 2, visualizes the Intent as a description of the desired End-State that is clearly and, as unambiguous as possible, defined in the Order.

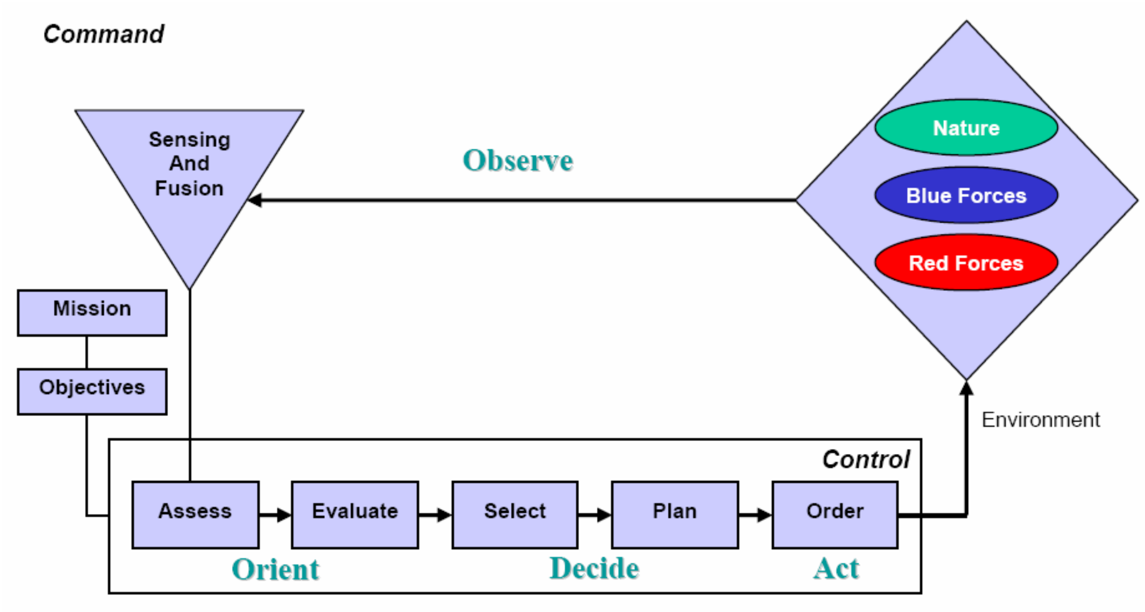

Figure 4. Generic Command and Control Process (Curts and Charles, 1996)

5 FORMALIZING COMMANDER'S INTENT

One of the goals of developing an unambiguous representation, as is addressed in this paper, is make CI more widely available to establish subordinates initiative. Future planning systems will need to make use of a machine interpretable format of intent. To describe CI so that it can be provided to a command structure there needs to be a reference in every order pointing towards the intent. The intent should be represented in each order so it can be interpreted by a commander or by a Computer Generated Force. The proposed representation follows the initial development by (Schade and Hieb, 2006) but expands the structure for Intent and introduces both Effects and Expressives to enrich the model. This allows the language to be used not only in representation of goal states in a CGF to determine if the effect/intent has occurred, but also in operational information fusion systems as the hypothesis to look for.

5.1 Battle Management Language

The Battle Management Language (BML) was formally defined in (Carey et al., 2001) as "…the unambiguous language used to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture" (Figure 5).

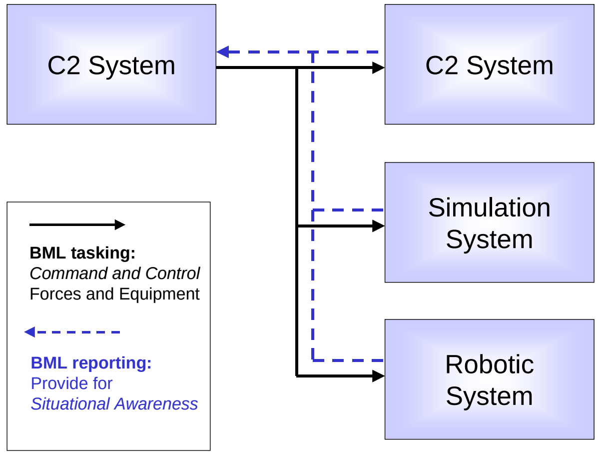

Figure 5 – BML Tasking and Reporting

Using BML, it should be possible for C4I systems, simulation systems, and emerging robotic forces to communicate unambiguously with any of these other types of systems. Such system-to-system communication is demanding enough when it involves systems within the same organization. It grows even more complex and demanding when incorporating other organizations and nations.

5.2 Guiding Principles of BML

There are two guiding principles that must be followed in order for a BML implementation to function correctly. (1) BML must be minimally unambiguous and (2) BML must not constrain the full expression of the CI. These principles are very difficult to simultaneously satisfy, as they conflict with one another to some extent. Many systems that convey a CI do so by allowing free text comments to accompany a data transmission. In this way, natural language messages can be employed by the commander to express his ideas. The difficulty here, of course, is that natural language messages are very difficult to disambiguate, especially when relaying those messages to constructive or robotic forces for automated interpretation. To satisfy all of these requirements, a BML must be rich enough in structure to accommodate system interoperability for a complex domain.

5.3 Command and Control Grammar

In the initial work in formalizing BML, (Schade and Hieb, 2006) present tasking and reporting grammars and in the continued work they present a general approach to a Command and Control Grammar providing rule for intent, reporting and tasking (Hieb and Schade, 2007). In their recent work "A Linguistic Basis For Multi-Agency Coordination" (Hieb and Schade, 2008), examines linguistic-based representations of intent in non-military organizations. The basic structure is the usage of context-free grammar, the principal approach used in the field of computational linguistics for automatically processing sentences in a written or spoken language.

Starting with reports, the C2LG says that reports consist of arbitrarily many basic reporting expressions (RB):

(1) S $\rightarrow$ RB*

The general form of a basic reporting expression uses the same form as the tasking rule given in (8). Depending on whether the report is about task operations (task report), events (event report), or status (status report) the respective rule forms are given in (2a) to (2c).

(2a) RB → **Task-Report** Verb Executer (Affected|Action) Where When (Why) Certainty Label (Mod)*

(2b) RB → **Event-Report** EVerb (Affected|Action) Where When Certainty Label (Mod)*

(2c) RB → **Status-Report** Hostility Regarding (Identification Status-Value) Where When Certainty Label (Mod)*

The Verb in (2a) is taken from the action-task-activity-code table and describes an action. The Executer is expanded into:

(3a) Executer → Taskee

(3b) Executer → Agent

(3c) Executer → Theme

Taskee in (3a) is to be expanded by the name of the one who performs the task. The Agent in (3b) is used when the id of the executer is unknown and is expanded in rule (4) where Size is the specific value that represents the relative size of the commonly accepted configuration of military formations and is taken from "unit-type-size-code", Hostility is taken from "object-item-hostility-status-code" and is the specific value that represents the perceived hostility status or is referring to the reporting unit itself (coded as "own") finally Unit_type is taken from "unit-type-arm-category-code" and represents the designation of a military branch.

(4) Agent → Size Hostility Unit_type

The Theme in (3c) is used when only the equipment is known and is expanded in (5) to Count which is an integer number describing the amount of equipment, Hostility as previous defined above and Equipment_type that is taken from several tables in JC3IEDM, e.g. aircraft-type-model-code, surface-vessel-type-category-code, vehicle-type-category-code etc.

(5) Theme → Count Hostility Equipment_type

Affected in (2a-b), is a non-terminal to be expanded by the name of the one to be affected by the task. Whether Affected is part of a rule depends on the tasking verb. Action expands to the label of another report or task. The Where in (2a-c) is either an At-Where or a Route-Where. When is a time that can be absolute or relative. Certainty expands to denote the certainty of the sender regarding the report and is taken from "reporting-data-credibility-code".

EVerb in (2b) is taken from the "action-event-category-code" and represents the general class or nature of activity.

(6) Regarding → (position | status-general | status-material | status-person)

In (2C) Regarding expands to the rule (6). Identification depends on to what the report is regarding, in a status-general case the identification is the name or the type of the unit and the Status-Value a value is taken from JC3IEDM's table "organisation-status-operational-status-code". For reports about the status of a unit's personnel use a Count together with a value from JC3IEDM's table "person-type-rank-code" as Identification and the respective Status-Value denotes the physical status of persons, i.e. "person-status-duty-status-code", "person-status-physical-status-code", and "person-status-physical-status-qualifier-code".

In a 5 paragraph order execution section consists of the command intent, the assignment of single specific tasks to specific units, as well as giving of details of coordination. Therefore, the basic rule of the tasking grammar is:

(7) S → CI OB* C_Sp* C_T*

This rule means that a tasking expression consists of the command intent (indicated by CI), basic order expressions to assign tasks to units (OB), spatial coordination (C_Sp), and temporal coordination (C_T). The asterisk indicates that arbitrarily many of the respective expressions can be concatenated together.

(8) OB → Verb Tasker Taskee (Affected|Action) Where Start-When (End-When) Why Label (Mod)*

The general form of OB is described in (8) and Tasker is to be expanded by the name of the one who gives the order. Why describes the mission purpose and is expanded to:

(9a) Why → in-order-to PVerb (TaskLabel)

(9b) Why → in-order-to cause EndStateLabel

(9c) Why → in-order-to enable ExpandedPurposeLabel

In (Schade and Hieb, 2006), CI is represented by grammar rules as follows:

(10) CI → [Expanded Purpose] [Key tasks] [End State]

(11a) [Expanded Purpose] → RB*

(12a) [Key Tasks] → (OB|RB)*

(13a) [End State] → RB*

Where End-State (13a) describes the resulting state of the mission and therefore is described as an BML report, Key Tasks (12a) is described as either Orders or Reports and the Expanded Purpose (11a) describes not only the military objectives but also political, economical and diplomatic. The Expanded Purpose, Key Tasks and End-State also need to be able to express task-reports, event-reports and status-reports that are ***not*** allowed to happen. The rules (11a-13a) are then changed to include an optional ***No*** that negates the RB.

5.4 Representing Commander's Intent

In a multi-doctrinal and multi-national context where the commander knows that subordinates come from other cultures with different experiences and using different doctrines there is a need to express the common ground for the CI. The commander must be able to express CI in such a way that, regardless of the force carrying out the order the effect is the same, meaning that the methods and actions can be different but that the effect leads to the End-State.

With the introduction of *expressives* a commander can use the expressives in an operational collaborative environment where the subordinates do not know the style of the commander. An example is when the Nordic Battle Group (NBG) commander knows that there are units from other nations that do not have the same doctrinal set of methods and procedures. The NBG commander might want to express that the style of the intent is to use low violence. If this traditionally implicit intent was not explicit stated it could not necessarily be derived from the OPORD.

A second usage of expressives is in a simulated environment where the goal of the Computer Generated Forces (CGF) is to utilize the CI and there is a need to communicate the implicit intent amongst the simulation models in order to get them to interact and react so that the correct Effect that leads to the desired End-State is chosen.

With the extension of expressives of CI (10), and making the Expanded Purpose and Key Tasks optional, the grammar representation of CI in OIEM is:

(14) CI→ (Expanded Purpose) (Key Tasks) [End State] (Expressives)*

(15) Expressives → Style Level

The Expressives term in (14) is expanded in (15) to a Style that can be one of experience, risk willing, use of power and force, diplomacy, ethics, norms, creativity and unorthodox behavior. Each of the styles has a corresponding level associated with it. Both the Style and Level needs to be expanded into the JC3IEDM structure. The NBG commander can then express the use of Low Violence by: Expressives → use of power and force Low

The real challenge lies in decoupling the hard connection between Order->Action->Effect express the relations amongst all the states in the OIEM model (Figure 2). The goal is to allow subordinates initiative and that commanders participating and commanding multi-national forces to have the freedom to choose how to implement the order governed by the CI. The C2LG provides the glue between Order and Action by rule (8), between Order and CI by rule (10) and with the extensions in rule (14) implicit intent can be expressed.

However the C2LG does not cover Action to Effects and Effects to End-State. The need to communicate Effects leading to a certain End-State becomes important when using Effect-Based Thinking (EBT) planning process, e.g. feedback system based on control theory (Farrell, 2007). As an example, a team of people, such as a Multinational Interagency Strategic Planning (MNISP) Headquarters (HQ), analyses and decomposes the desired situation into desired Effects (physical and non-physical), links them to desired Actions (based on available resources), synchronizes the desired Effects and Actions, and develops an Effects Based plan. The HQ members need to be able to collaborate by communicating the Effects, End-State and chains among each other. Since there are several agencies with their methods and procedures and several participating nations it is more likely that there will be a whole lot of doctrinal clashes. Yet another example is that in a planning process that includes the Subordinate Commander (SC) the order together with the expressed CI is the foundation for the SCs planning. The SC performs a planning phase and the result is communicated to the HQ. However, if only the Orders are communicated there is a risk for misinterpretation since the methods and procedures of the SC may not be the same as the HQ. It is not enough to just communicate the expressives of the subordinate since the expressives do not tell why a certain Action is selected and to which Effect it contributes. There is a need to represent the Action and Effect and Effect to End-State to support EBO. The suggested grammar statement is:

(16) E → Effect Verb Executer Affected Certainty Label (mod)

Rule (16) defines an effect by describing the connection between Effect and Action. Actions can be described by Verbs from “action-task-activity-code” in JC3IEDM. Executer is expanded according to the rules (3a-c). Affected is expanded to the name of the one to be affected by the task. The Affected follows the same structure as executer in that it can be a known unit, an agent or a theme. Certainty is the probability that the Action will cause the Effect. With a probability measure in the rules (16) the planning staff can assign the likelihood of success but also a way of using the expressives to set different probabilities depending on which Executer that will perform the action. Future research needs to be performed to describe the connection between End-State and Effect. Effect is similar to a “Why” term in the tasking grammar above (9a-c).

The following example illustrates the usage of rule (16) to express Effect and Actions.

5.5 Example One

In order to achieve the Effect of destroying the enemy an Attack task can be utilized. The attacking force need to have the basic ability to perform the task, but also the capability to make it happen. In the example the size of force varies to provide the requested effect, however with various certainties. The Certainty is here a numeric which is opposite the previous usage were the value comes from the “reporting-data-credibility-code” in JC3IEDM

E → in-order-to Destroy Attack Infantry-Division Infantry-Battalion 90% label-DBINF-1

E → in-order-to Destroy Attack Infantry-Battalion Infantry-Battalion 70% label-BBINF-1

E → in-order-to Destroy Attack Infantry-Company Infantry-Battalion 20% label-CBINF-1

In the above statements, *Effect* expands to in-order-to Destroy, *Verb* expands to Attack, *Executer* expands to an *Agent* that expands to Infantry-Division, and *Affected* expands to *Agent* that expands to Infantry-Battalion.

5.6 Example Two

This example illustrates the variation of action to achieve the same effect.

E→ in-order-to Suppress Deception-Electronic 2 Jas 39 Gripen Air Defence-Company 80% label-SRJ-1

E→ in-order-to Suppress Destroy 2 Jas 39 Gripen Air Defence-Company 90% label-SRJ-2

In the above statements, *Executor* is expressed as a *Theme* per rule (5) as in ”2 Jas 39 Gripen”.

Whilst the certainties are notional, the power of expressing Effects and Actions with the probability of success provides CGFs and commanders to use the effect as a base for communicating the choice of actions. In a CGF system the selection mechanism can be built to use the certainty as the selection criteria. Commander’s can express the own forces capability to provide the requested effect and communicate it to staff members or other collaboration partners.

6 CONCLUSIONS

We conclude with some observations on the OIEM model and plans for future investigations.

6.1 Effects Based Search for Appropriate Actions

In this paper the OIEM Intent Causality model is introduced showing the connection between Order->Action->Effect->End-State together with an implementation using the C2LG Grammar.

The OIEM supports the vision by (Alberts, 2007) of a goal-seeking process that guides actions and effects, in that it allows templates to be constructed that describes Effects from various Actions and force structures enabling planning systems to search from End-State and Effects . The context and purpose of the endeavor is described through the use of the OIEM representation of CI and Effect, with a model of dissemination to subordinates that provides a shared CI. The proposed OIEM Causality Intent Model and formalism provides a capability to restrain the complexity and uncertainty in complex operations.

The representation allows the use of templates of effects from various action and force structures so that planning systems can search from the End-States rather than performing exhaustive simulations. The hypothesis found can then be used in simulation and reduce the number of possible scenarios to evaluate in simulations framework. Such reduction of search space then allows the planning tools to be used in missions where the planning phase needs to be as short as possible.

When describing the desired effect a decision support system ought to search for the actions that deliver that effect as well as the force that can deliver it. If the effect can be further narrowed, for example to a Why statement in the End-State description, then the system could find all the tasks and forces that have the ability to achieve that effect (such as "suppress enemy radar"). Thus instead of working with tasks and actions as the input, the system would work with effects as an input.

6.2 Collaborative planning and operations

In a situation were there is a need to communicate the plan and intentions to staff members, joint and coalition forces and other agencies the information must be as unambiguous as possible, this paper’s focus is on providing such mechanism for CI and providing a model showing how CI for can be modeled and formalized.

The Effect to Action mapping allows the commander's to express their selected actions towards an effect and their belief that they will succeed. This can be used at higher level command to assess the plans and together with the proposed representation which is suitable for both human and machine interpretation allows human analysis, machine analysis (e.g. simulation, reasoning) as well as the combination of both.

It is presumed that with the ability to communicate desired End-States, effects and actions between members in a staff or between organizations from different nations the capability for each of the participants to assess what effects they can deliver that supports the whole mission and leads to the end-state will be increased.

6.3 Future Work

While this paper presents a model and formalism to express CI, experiments need to be conducted to assess how the theory described actually works in real systems. The test bed under consideration is the OIEM demonstration environment that is similar to that used in the NATO Modeling and Simulation MSG-048 – Coalition Battle Management Language (Pullen et al., 2006, Pullen, 2007, Pullen et al., 2007, Pullen et al., 2008b, Pullen et al., 2008a, Nico et al., 2008) A representation of CI and Effects will be implemented in a Command and Control System and a CGF. This will require an execution engine that makes use of CI and Expressives to model the behavior. The control logic in the model also needs to assess how close it is to the end-state. With such a test-bed a formal proof of the formalism and dissemination model can be conducted, as well as assessing the concept for agile planning.

In a C2 system or CGF there is need to be able to describe an End-State and then find effects that can move the current state towards the End-State. A CGF commander then needs to be able to find the actions that together provides that effect and as an output delivers a list of possible actions that can be made. Developing a system design that combines the grammar and engineered knowledge with search mechanisms a starting point is to base the design on the OIEM.

In the paper suggest performing searches using End-State and Effects. To build such templates of End-State coupled to Effect and Actions some sort of repository needs to be developed. A starting point for such a work is to look into the domain of engineer knowledge and how the Business Intelligence and the search engine community systems build up their repositories.

When CI is explored and developed there is yet an even greater challenge to address, namely deploying the concept of CI, Effect and Actions into Civil and Non-Governmental Organizations. A future research areas is how the models and formalism presented in this paper can form a Crisis Management Language (Gustavsson et al., 2006) or a Multi-Agency Operational Language (Hieb and Schade, 2008).

One topic is to test the applicability of the suggested model and grammar representation in some planning tool or process. The "Operations" Feedback Control System (Farrell, 2007) is based on Control Theory and models the effect-based thinking (EBT) and gives the EBT concept some structure. The work would be to test the applicability of the suggested representation of End-State, Effect, Order and Reports using the same fundamental grammar and information structure presented in this paper and how it can be used as the representation in an "Operations" Feedback Control System.

7 ACKNOWLEDGEMENT

The authors thank the Swedish Armed Forces Land Warfare Centre for their cooperation in providing availability to their supply of standard scenarios.

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