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Formalizing Command Intent Through Development of a Command and Control Grammar (I-069)

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Abstract

Command Intent is currently incorporated in a number of decision models. However, there is no well-established method of modeling Command Intent, as there is with Situational Awareness. Battle Management Language (BML) is being developed as an open standard that unambiguously communicates Command and Control (C2) information, including orders that express Command Intent. On the one hand, C2 communications (orders and reports) have to be unambiguous – automatically processable in order to contribute to Network-Centric exchange of information, of knowledge and of intent. On the other hand, they have to be expressive enough to convey a Commander's goals and concept of operations.

In this paper, we will argue that it is possible to develop an formal, but also highly expressive language for tasking if it is based on a formal grammar that is imbued by linguistic principles such as completeness and coherence. This also means that approaches based on the exchange of information via a data model, i.e., the Multinational Interoperability Programme's Joint Command, Control and Consultation Information Data Exchange Model (JC3IEDM) cannot provide the expressiveness needed. To address this hypothesis we provide a grammar that formalizes Command Intent based on a well-known class of grammars, the Lexical Functional Grammar.

1 Introduction

As Command and Control (C2) moves into the 21st century it needs to transform many of its methodologies. Command Intent is a fundamental component of C2 that has remained unchanged in recent operations. However, the thesis of this paper is that Command Intent, as part of C2, must also be evaluated and new methods must be evolved to address the proliferation of new capabilities that can now be utilized to communicate and distribute orders and to command a wider range of automated forces

Previously, we have presented a formal language for C2, suitable for commanding and communicating with live forces, simulations and robotics [Schade & Hieb, 2006b]. We will refer to that work to show that Command Intent can also be expressed formally in the same language, gaining an increase in the measures identified by Alberts and Hayes for intent – quality of expressiveness; quality of commonality; and the degree to which intent is consistent with higher intent [Alberts & Hayes, 2006].

A formalization of Command Intent is particularly relevant for Network-Centric Operations, given the need for rapid coordination and collaboration between geographically distributed forces.

1.1 Understanding Command Intent

Albert and Hayes discuss intent in "Understanding Command and Control" and distinguish between intent, Command Intent, and Commander's Intent [Albert & Hayes, 2006]. Commander's Intent implies a single individual in command, while Command Intent is a newer term that implies a group or collective making decisions. The term intent is more general yet. In this paper we will use Command Intent, as the best term for discussing transitioning from a well-established command process relying upon written and verbal communication to a more flexible command environment, that can still support the same processes, but built upon a formal grammar.

The United States Department of Defence (DoD) defines Commander's Intent as [DoD, 2005]:

"a concise expression of the purpose of the operation and the desired end state that serves as the initial impetus for the planning process. It may also include the commander's assessment of the adversary commander's intent and an assessment of where and how much risk is acceptable during the operation."

The US Army in Field Manual 3-0, Operations [USA, 2001], similarly defines Commander's Intent as:

"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 the desired end state."

This is expanded in Field Manual 5-0, Army Planning and Orders Production [USA, 2005], which specifies that the Commander's Intent links the mission to the concept of operations, describing the end state and key task that are the basis for subordinates initiative, along with the mission. In addition, the Commander's Intent should convey a broader sense of purpose, giving the context of the mission. Doctrine also says that the mission and Commander's Intent should be understood in lower echelons (either one or two levels down).

In accordance with this definition, FM 5-0 breaks down Commander's Intent into these three elements:

- End State;
- Key Tasks;
- Expanded Purpose.

We will use these terms later in our work as a starting basis for our formalization of Command Intent.

While we will use the term Command Intent, which slightly expands this definition, it captures the essential elements of a mission's goal and objective. The DoD definition also assumes a formal planning process, which may not be present in future operations. As we are concerned with transitioning and putting into place a new C2 Language, we will concern ourselves with a design that accommodates both a formal planning process as well as situations where the planning is done in a more distributed and parallel fashion.

We find Command Intent is the input to many conceptual models as well as to many simulation systems. Our intent is to improve how Command Intent is represented and communicated to improve comprehensibility and to reduce ambiguity. The approach taken is to both develop a formal language so that command statements can be generated and automatically processed according to well-founded theoretical properties and to describe the context of the situation in enough detail to support the intent.

In *Power to the Edge*, Albert and Hayes describe the Battle of Trafalgar (1805) as "a genuine example of self-synchronized forces" [2003, p. 28ff.]. This description has an introduction in which the authors list the key characteristics of such a force. The first among these key characteristics is "clear Command Intent." Although it can be questioned whether the British fleet commanded by Lord Nelson was a self-synchronized force in all aspects – at least it had a very strict hierarchical command structure and cannot be seen as edge organization – Lord Nelson carefully explained his intent to his captains before the battle. And this clear and careful communication of his intent obviously was a key contribution to winning the battle.

Conveying a clear intent is only helpful if the subordinates are allowed to operate with some degree of autonomy. The idea is that subordinates should do whatever has to be done to fulfil the Command Intent and to reach the goals formulated by it. Regling [1983, p. 384] proposed that Napoleon failed because – among other reasons – his marshals were not educated to such a degree of autonomy. Learning from the Napoleon wars, Helmuth Graf von Moltke established and formalized the concept of mission command to the Prussian army. He demanded that subordinates would act against a given order if that would serve the intended purpose [cf. Dupuy, 1977; Regling, 1983]. With respect to network centric operations, Storr [2003] argues that the "information age […] creates conditions where such a command philosophy [mission command] is the essential bedrock for success" [Storr, 2003, p. 93]. Obviously, this command style deeply depends on a very clear formulation of the Command Intent.

1.2 Expressing Command Intent in Current Operations

There are various forms of orders used for commanding forces of different services. The most common form is the Operations Order, which is used by Coalition, Combined and Joint commands. However there are other formats such as the Air Tasking Order, used by national Air Forces. In this paper, we will use the Operations Order as our example. However, we intend that our work extend to other Order formats as well.

STANAG 2014 specifies the standard form of an Operations Order for the North Atlantic Treaty Organization (NATO). This five paragraph format is similar to US and representative of other nation's formats. Military doctrines have leveraged these standards, such that professional

soldiers know, by heart, how an Operations Order should be structured and how such an order should be read and interpreted. Command Intent is a key part of the format of the Order.

Operations Orders are generally structured such that they have 5 sections (paragraphs) in the following order:

1) Situation
2) Mission
3) Execution
4) Service Support
5) Command and Signal

In the 5 Paragraph order, the Command Intent statement is found at the start of the Execution Paragraph, followed by the Concept of Operations and then task-oriented directions to the forces commanded. Command Intent statements of the higher Commands will be repeated in the Situation Paragraph in the section that describes friendly forces.

However, the Command Intent (and much of the Operations Order) is formatted as "free text" and as such is extremely difficult to process automatically. While a trained military professional has little problem dealing with this "free text", current automated systems handle it as a single data field and do not understand Command Intent such that they can represent or communicate it. This paper will provide a formal grammar for Command Intent to overcome this problem.

1.3 Structuring Command Intent for Network-Centric Operations

Command Intent clearly is the start of the Command and Control process. It is also perhaps the most important element to determine a successful outcome of a military operation. Work on structuring Command Intent is aimed at providing a more analytic and rigorous framework for the development of both conceptual models and also the tools and services that implement C2 processes. We would assert that there are no C2 services in Network-Centric environments that are not affected in some way by Command Intent.

Future C2 services that directly deal with Command Intent include automated decision aids, such as course of action development and analysis tools, mission rehearsal simulations, and mission planning tools. Command Intent is a necessary input to future models and simulations that will execute scenarios for a wide variety of purposes. A structured Command Intent would facilitate higher-level reasoning and better behaviours than are presently possible, with only task-specific commands available.

While the proposal in this paper is to use a structure for Command Intent in modelling C2, this should not be construed as proposing to change the way that Command Intent is doctrinally used by military commanders. We would recommend that military commanders use written and verbal processes as they have traditionally used. When time permits and the tools are available, this Command Intent can be put into the structure given here, and made available to automated systems and services. The original written or verbal form can be carried along with the Command Intent structure so that humans can have this available for additional clarification when desired. Thus, the original doctrinal Command Intent can be preserved with no cost or degradation.

The Command Intent structure presented here is an initial version and will be revised, along with the C2 Tasking and Reporting Grammars presented previously [Schade & Hieb, 2006b]. Command Intent presents extremely difficult problems in capturing its essence as will be explained below and there are many conceptual modeling issues that remain to be solved.

The result we are working towards is a clear and unambiguous language derived from doctrine already defined for military messages. Being unambiguous and thus processable by systems, this language can be used for the communication among C2 systems, it can be used to control agents in simulations, and it could even be used for communication among C2 systems and future robotic forces. In addition, the incorporation of standards for military messages will contribute to understanding and interoperability in their meaning.

Regarding the semantics of this language (including Command Intent), The Multinational Interoperability Programme (MIP) has already produced semantics for C2 terms suitable for coalition operations. This is documented in NATO – the Joint Command, Control and Consultation Data Exchange Model (JC3IEDM) [MIP, 2007].

The JC3IEDM consists of both a Data Model and an Exchange Mechanism. The Data Model is intended to represent the core data types identified for exchange across multiple functional areas. It lays down a common approach to describing the information to be exchanged in the command and control domain. Thus, the approach is generic and not limited to a special level of command, force category, etc. In general, JC3IEDM describes all objects of interest on the battlefield, e.g., organizations, persons, equipment, facilities, geographic features, weather phenomena, and military control measures such as boundaries using a common and extensible data modeling approach. Besides the Data Model there is an Exchange Mechanism that uses a replication protocol that allows the exchange of data between two systems that employ the JC3IEDM.

With the advent of the JC3IEDM defining standard semantics to C2 terms on the one hand and providing a data exchange mechanism on the other, the additional effort of developing a language may be thought to be unnecessary. However, in [Schade & Hieb, 2006b] we presented an analysis on why just relying upon a data model is insufficient for military communication.

So while we present this initial work on Command Intent in order to advance understanding of how it can be structured, this work fits into the development of a C2 language that leverages the C2 tasking and reporting grammars [Schade & Hieb, 2006a; 2006b] and the strong semantics of the MIP.

1.4 Organization of the Paper

In Section 1, the concept of Command Intent has been investigated, first from a conceptual point of view, then from an operational point of view, and finally in regard to structuring Command Intent within a C2 language. Section 2 presents the theory taken from Computational Linguistics that underlies our work with C2 grammars and Command Intent. We need *formal* grammars and language to ensure that the C2 expressions can be processed, automatically. Our previous work in C2 grammars for tasking and reporting is reviewed in Section 3. In Section 4, the syntax for Command Intent is introduced, built upon the C2 grammars. Section 5 presents an example of how the Command Intent syntax would be used for an Operations Order from a MIP Exercise.

Section 6 discusses related work regarding Modeling and Simulations (M&S). Section 7 looks forward to future work.

2 Linguistic Principles

To construct a clear and unambiguous language to express Command Intent, linguistics offers the concept of a formal language as well as principles for integrating semantics.

A formal language is the set of all expressions that can be generated by a formal grammar. In general, a grammar consists of a lexicon and a set of rules. The lexicon provides the words of the language, and the rules determine how to construct longer expressions, e.g., sentences, using these words. In order to specify the semantics of the language, one has to give meaning to every word of the lexicon. In addition, one has to determine how to concatenate the meanings of the words to form the meaning of an expression if the rules allow the generation of this expression. In principle, this means to give meaning not only to the words but also to the rules. For example, if the terms "two", "hostile" and "sniper" are put together by a rule to form the phrase "two hostile snipers", the respective rule has to ensure that "hostile" is treat as a modifier to "sniper" that assigns a specific value to the object referred to by "sniper", and that "two" is treated as a specifier to "hostile snipers" that provides a count of objects referred to by "sniper" and have the value "hostile" to describe their affiliation.

Linguistics uses the term "constituent" for expressions that are part of a sentence but nevertheless form an information unit. For example, in the sentence "the 43rd Spanish Cavalry Regiment advances to phase line Star" there are two constituents besides the verb, namely "the 43rd Spanish Cavalry Regiment" and "to phase line Star". The first constituent refers to the executer of the action and the second provides the destination. Obviously, the sequence "Regiment advances to" does not form a constituent. Constituents fill semantic roles within a sentence [cf. Sowa, 2000]. In the example, the roles filled are "agent" (the initiator of the action denoted by the verb = executer) and "destination" (the spatial goal assigned to this action). Semantic roles can be seen as labels assigned to the information units. A role describes the function of the constituent in question in the context of the whole sentence. It can be said that semantic roles are the (formal) linguistic mirror images of the 5 Ws: Who, What, Where, When, and Why. However, there are more than five semantic roles. E.g., the roles *origin*, *path*, *destination*, and *location* all are Where-constituents. More than one constituent of the same W-type may appear in a sentence. E.g., in "the company marches from Alpha to Omega via route Dover", there are three Where-constituents, namely an *origin*, a *destination*, and a *path*.

Verbs come with a frame [cf. Fillmore, 1976; FrameNet Website]. The frame determines which kind of constituents are demanded (obligatory or mandatory constituents) and which are allowed (optional constituents) by the verb. The linguistic principle of completeness demands the occurrence of the obligatory constituents, and the linguistic principle of coherence prohibit the occurrence of constituents that are not at least optional. To incorporate these principles in the formal grammar is essential to assign the correct meaning to the grammar's rules. E.g., in the sentence "the platoon rests towards north" a constituent of type *direction* is connected to the verb "rest" although "rest" neither demands nor allows such a constituent. A direction does not make sense with the doctrinal definition of "rest", which means that a unit is stationary and inactive.

The linguistic principles mentioned, namely the use of constituents, the use of verb frames, and the principles of completeness and coherence, are ideally supported by Lexical Functional Grammar [Kaplan & Bresnan, 1982; Bresnan, 2001]. Therefore, we modelled a grammar for military communication in general and for Command Intent in particular on LFG. LFG analysis of an expression consists of at least two steps. In the first step, the so-called c-structure is derived – "c" for "categorical". The c-structure is a classical phrase structure [Sells, 1985]. Phrases, including those that form constituents, are organized within a syntactic tree by phrase structure grammars. The syntactic tree is the result of a pure syntactic analysis of the input expression. In the second step, the syntactic tree is transformed into the f-structure – "f" for "functional". This second step is indicated by the "F" in LFG; the "L" points to the frames that are stored together with the verbs in the lexicon. They are exploited for the building of the f-structure. F-structures are represented as feature-value matrices. F-structures also connect syntax to semantics. The meaning of an expression can be derived from them if the meaning of the lexical items is known. The representation of f-structures as feature-value matrices simplifies the transformation into XML representations. It also allows for further processing by unification, a standard algorithm in the field of computational linguistics [Shieber, 1987]. For example, military expressions like the Command Intent can be enhanced by unification-based information extraction or processes based on an ontology about military operations.

3 Formal Grammars for Tasking and Reporting

As has already been mentioned, we developed grammars for tasking [Schade & Hieb, 2006a; Schade & Hieb, 2006b] and reporting [Schade & Hieb, 2006b; Schade & Hieb, 2007] following the linguistic principles given above. The set of the expressions that can be generated by applying the lexicon and the rules of these grammars therefore build a Language for tasking and reporting. The paper at hand provides a complementation to these grammars such that Command Intent also can be expressed unambiguously. We will start our description of the grammars by presenting the most important aspects of the grammars for tasking and reporting to provide the basis for adding Command Intent.

For the C2 grammars described, we use the attributes and the values provided by the standard data model JC3IEDM as lexicon elements. With other words, the standard data model provides the words of the C2 Language. Only in those few occasions in which the model lacks a term, we opted – and will opt – for adding the term to the data model. Therefore, it can be said that the development of BML provides some beneficial influence on the development of the data model.

Since the lexicon of our grammars is grounded in the JC3IEDM, the description of the C2 grammars is mainly a description of the rules used to concatenate the words to expressions. With respect to the tasking grammar, these expressions are single orders which are used assign specific tasks to specific units. With respect to the reporting grammar, these expressions are single lines of a report.

3.1 The Rules for the Tasking Grammar

As has already mentioned in subsection 1.2, the format of orders is defined by the NATO standard STANAG 2014 "Format for Orders and Designation of Timings, Locations and

Boundaries." An Operational Order is divided into five sections 1) Situation, 2) Mission, 3) Execution, 4) Administration and Logistics, 5) Command and Signal, and the respective annexes. Section 3 is used to "summarize the overall course of action," "assign specific tasks to each element of the task organization," and "give details of coordination." The tasking grammar as it has been presented so far [Schade & Hieb, 2006b] scopes the assignment of single specific tasks to specific units as well as the giving of details of coordination. Therefore, the head rule of the tasking grammar is:

(1) S → OB* C_Sp* C_T*

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

According to the linguistic principles as given in Section 2, basic order expressions are composed of a verb and its frame. The verb denotes a task. These tasking verbs are taken from JC3IEDM's table "action-task-activity-code." Thus, the rules to expand OB have the general form as given in (2a). (2b) and (2c) give examples.

(2a) OB → Verb Tasker Taskee (Affected|Action) Where
Start-When (End-When) Why Label (Mod)*

(2b) OB → ***advance*** Tasker Taskee Route-Where
Start-When (End-When) Why Label (Mod)*

(2c) OB → ***defend*** Tasker Taskee Affected At-Where
Start-When (End-When) Why Label (Mod)*

Tasker is to be expanded by the name of the one who gives the order. Taskee is to be expanded by the name of the unit that is ordered to execute the task. Start-When and End-When are to be expanded by temporal phrases expressing when the execution of the task has to start and when it has to be finished. End-When is optional as indicated by the parentheses. Tasker, Taskee, Start-When, and End-When appear in each basic order rule.

Affected in (2a) has to be a term in the expression if someone, e.g., the enemy, will be directly affected by the task; in linguistic terms this is called the patient. Whether Affected is part of a rule depends on the tasking verb. For example, it is there in the case of ***attack*** or ***defend*** because the executing unit is tasked to attack the enemy or to defend against the enemy. It is not there in the case of advance. The tasking verbs come with frames that express which kind of constituents are required, e.g., a constituent of type Affected. This grants keeping the principles of completeness and coherence. Action is similar to Affected. It only appears if the task affects an action, as a task of type ***assist*** does – the unit is tasked to assist the execution of another task by another unit. In addition, the type of the Where is also determined by the verb. It is currently an At-Where or a Route-Where. An At-Where denotes a location, and a Route-Where a path to a location. A Route-Where can be expanded to more complex concatenations of constituents as in "**from** LocationA **to** LocationD **via** LocationB **and** LocationC."

A basic rule ends with Why, Label and the optional Mod. Why represents a reason why the task specified by the rule is ordered. Label is a unique identifier for its task. By this identifier the task can referred to in other expressions, especially in temporal coordinations. The optional Mod (for modifier) is a wild-card that represents additional information that can be used to describe a particular task, e.g., formation – to specify a particular formation for an advance, or speed – to specify the speed of a road march. The Why is of specific importance in association with Command Intent and is discussed in the next section after the formalization of Command Intent.

An example of (2b) is in (2d) for the following task:

> Multi-National Division (West) commands 13th Dutch Mechanized Brigade to perform a Fast Tactical March to PL TULIP by or behind ROUTE DUCK.

(2d) ***advance*** MND-West M_BDE13(NL)
along DUCK **start at** Phase1A **in-order-to** surprise label_3_11

The rules for spatial coordination are for appointing control features, and the rules for temporal coordination are for establishing timetables and phases. More details to these rules as well as more examples for the basic rules are given in [Schade & Hieb, 2006a; 2006b].

3.2 The Rules for the Reporting Grammar

The head rule for reporting says that a reports consists of arbitrary many basic reporting expressions (RB):

(3) S → RB*

The general form of a basic reporting expression depends whether the report is about military operations (task report), events (event report) or status (status report). The respective rules are given in (4a) to (4i).

(4a) RB → Task-Report Verb Executer (Affected|Action) Where When (Why) Certainty Label (Mod)*
(4b) RB → Event-Report EVerb (Affected|Action) Where When Certainty Label (Mod)*
(4c) RB → Status-Report Hostility Regarding (Identification Status-Value) Where When Certainty Label (Mod)*

(4d) Executer → Taskee
(4e) Executer → Agent
(4f) Executer → Theme

(4g) Agent → Size Hostility Unit_type
(4h) Theme → Count Hostility Equipment_type

(4i) Regarding → (position | status-general | status-material | status-person)

Rule forms (4a) and (4b) are quite similar to the rule form for basic order expression as given in (2a). The differences are as follows: Neither (4a) nor (4b) has a Tasker. For (4a) this is because the reporter may not know the unit that has ordered the task he is reporting on, especially if it is an action performed by the enemy. For (4b) this is because events happen and it does not make sense to say they are "commanded" by an organization.

Rule form (4a) has a generalized Taskee named Executer in order to allow constituents like "four hostile snipers" (that express the Who). (4b) has no Executer; it uses verbs (EVerb) from another JC3IEDM table, namely "action-event-category-code" that contains verbs like "flood" or "peace conference".

The rules for Executer are given in (4d) through (4f). The reporter normally does not know the name of the unit executing a task. Therefore, Executer may be expanded by the name of the unit – in the cases it is known to the reporter – (by rule 4d), by the type of the unit – e.g., *a hostile infantry battalion* – (by rule 4e), or by referring to equipment – e.g., *four hostile battle tanks* – (by rule 4f).

Obviously, these rules have to be expanded further. Rule (4g) is for the expansion of Agent – introduced in (4e). Rule (4h) is for the expansion of Theme – introduced in (4f).

In (4c) Regarding takes the role of a verb. Regarding defines what the status report is about. As shown in (4i), status reports can be given about the operational status of a unit (by using the key word status-general in Regarding), about the status of a unit's personal (by using the key word status-person) and about the status of a unit's material (by using the key word status-material). In addition, the position of a unit can be reported (by using the key word position). Regarding is accompanied by a term that indicates whether the unit is friendly or hostile (friend, hostile, neutral). This term can also be "own" to indicate that the status report is about the reporting unit. In addition, all the rule forms for basic report expressions contain Certainty. It is used to specify the certainty of the report from the sender's perspective. The Reporting Grammar and its rules have been described in detail in [Schade & Hieb, 2007].

The tasking grammar and the reporting grammar provide the basis for the formalization of Command Intent as will be discussed in the following section.

4 Communicating Command Intent within a Network-Centric Environment

Obviously, a military professional views the process of communicating Command Intent as a special prerogative. Many view the decision making process of a military commander as more of art than science. There are many nuances in the expression of Command Intent that are difficult or impossible to convey in a formal language. These include qualifiers modifying tasks or purposes as well as emotional cues.

As an example, there are many stories where a commander will not give written orders to a subordinate for a particularly difficult mission. Instead, the commander may feel that his Command Intent may only be conveyed personally, as when a commander will travel to a

subordinate to convey a task such as "defend to the last man". In these cases, some of the Command Intent is conveyed "between the lines" and not explicitly stated. In a coalition force, those subordinates that do not speak the language used as their mother tongue will probably not catch the nuances mentioned above. The illocutionary force [Austin, 1962] of the command thus is not conveyed to these coalition officers. This is even more true for automated systems.

In Network Centric Operations, Command Intent must be communicated to a potentially wide range of recipients (coalition officers, automated situational awareness systems, decision support systems, robotic reconnaissance units, etc.). The Command Intent in these cases must be as clear as possible, without ambiguity, and understandable. Clear means that the expression is concise and conforms to the doctrinal guidance given for the C2 process. Without ambiguity means that there is an explicit structure that the Command Intent can be put into and then parsed out of. It also means that only one clear and definite outcome results from the parsing. Understandable means that the semantics used in the Command Intent are available and common to all of the recipients.

The approach taken below is an initial structuring of the Command Intent to meet the requirements of automated systems. Again, the structure below is NOT intended to replace the human to human process of command. If a written order is produced then the structure below should be able to capture the essential elements of the Command Intent. The written portion can be saved and sent to the humans involved in the operation, while a structured version can be sent to non-human elements. While many will be uncomfortable with structuring the Command Intent in this way, we wish to point out that presently, there is no specified methodology of communicating Command Intent to systems.

Our approach is to build Command Intent out of the grammars described above in Section 3. We will show how the Command Intent can be broken into doctrinally derived elements that can then be represented by elements already defined in the Tasking and Reporting Grammars. The additional structure is not a complete grammar by itself. While this approach does not address all of the other elements of Command Intent (qualifiers and emotions), it will stay within the bounds of the formal system described by the existing grammars. This is the next step in specifying a complete formal language for military communications.

4.1 Command Intent Grammar Rules

In order to create the grammar rules for Command Intent, the doctrine stated in the US Field Manual FM-5 in Section 1.2. We use this as it is the most structured description of Command Intent. The Command Intent is composed of three terms: End State, Key Tasks, and Expanded Purpose. Therefore the basic rule for Command Intent is (5).

(5) $CI \rightarrow$ [Expanded Purpose] [Key Tasks] [End State]

The End State describes the resulting situation that is achieved when the mission is accomplished. Therefore we model the End State as it would be reported at the successful conclusion of the mission. This State can be represented by a combination of basic report expressions, consisting of task, event and status reports (6). The Key Tasks are tasks and conditions that are essential to accomplishing the mission, thus Key Tasks can be formulated as

both basic orders and basic reports (7). The Expanded Purpose is similar to the End State, but expresses more general aspects of the resulting situation. In short, the End State is about the resulting situation form the military perspective whereas the Expanded Purpose also considers other, e.g., political, consequences and results. Being the description of a state, Expanded Purpose again is represented by basic report expressions (8), but these will include more reports of event type that refer to political situations, such as "POW return" or "peace conference."

(6) [Expanded Purpose] → RB*
(7) [Key Tasks] → (OB|RB)*
(8) [End State] → RB*

As given by (6) to (8), the components of Command Intent are formulized by the use of basic order expressions and basic report expressions. There are however two aspects that have to be taken into account. First, the Command Intent describes key tasks in the Key Tasks section. This is to emphases these tasks. In contrast, the basic order expressions in the execution segment of an operation order assign tasks to units. Therefore, the Taskee, the unit that has to execute the task in question, is referred to in the basic order expressions used for representing the execution part of an order. The basic order expressions as used in Command Intent do not need to explicit the unit that will be ordered to execute the key task in question. Indeed, this unit might be chosen by the receiver of the operation order. It will be chosen in accordance to his superior's Command Intent. The unit that is assumed to execute a key task best will have to execute it. To sum up, the basic order expressions used for the formulation of Key Tasks in the Command Intent do not include the name of the unit that will execute the task. Instead there is a place holder called OPEN.

Second, purposes and states as described by basic report expressions for End State or Expanded Purpose often will include negation. E.g., we would like to formulate that after accomplishing the mission that enemy no longer has troops in a certain position or area. Therefore, we have to add a negation operator "neg" that can be added to any basic report to negate the statement of this report.

4.2 The Why

According to Field Manual FM 3-90, appendix C, in mission statements there is the Why that provides the mission's purpose. Within the BML grammar, basic order expressions also have a Why in order to model the BML expressions according to the doctrine. FM 3-90 offers a list of verbs to express the Why, namely divert, enable, deceive, deny, prevent, open, envelope, surprise, cause, protect, allow, create, influence, and support. Some of these verbs are values of JC3IEDM's table "action-task-activity-code", namely, divert, deceive, deny, envelope, and support; the others are not. From a linguistic perspective, the verbs also can be divided into two groups, namely those that can be used with an argument that is an object, like "in order to deceive the enemy", and those that need another task as argument, like "in order to enable task DELTA". The latter verbs tend to be those ones that are not values of the JC3IEDM.

In order to define a Why that is consistent with the doctrine, we suggest that the Why can be expanded as follows:

(9a) Why → **in-order-to** PVerb (TaskLabel)
(9b) Why → **in-order-to** cause EndStateLabel
(9c) Why → **in-order-to** enable ExpandedPurposeLabel

Some of the purpose-verbs given above can be taken directly as Why. These cases are covered by (9a). For example, one can have the verb "destroy" here. In some cases, the purpose of a task is to influence another task. In particular, this rule can be used to make explicit the dependencies between the tasks of a course of action. For example, if a course of action is divided into three phases, and a unit has to execute task1 in phase 1, task2 in phase 2, and task3 in phase 3, normally the completion of task1 is a pre-condition to task2, and the completion of task2 is a pre-condition of task3. Therefore, the Why of task1 is "in order to enable task2", and the Why of task2 is "in order to enable task3". The tasks are chained together by their Whys. The Why of the last task of a course of action, however, has to point to a part of the desired End State (9b) or the Expanded Purpose (9c). In other words, this Why connects the course of action to the Command Intent.

There is an alternative to approach the chaining of the tasks as has just be described. The temporal structure of the phases is provided by the time table formulated by temporal coordination rules (C_T). Therefore, the chain of tasks can be inferred. If the systems that would interpret the BML expressions would have a component at their disposal to do this reasoning the Why of all the tasks in such a chain can point to the same End State or Expanded Purpose, namely the one that would appear only in the final task of the chain otherwise.

5 Network-Centric Scenario

In this section we give both a general example of structuring Command Intent taken from an Operations Order and also a specific example from a MIP exercise taken from an Army Corps Order.

5.1 Example of Structuring Command Intent

Below is a general Commander's Intent statement as might be seen in a typical Army Operations Order from Paragraph 3. The forces involved, Multinational Force (MNF) and its units Response Force A (RFA) and Response Force B (RFB), as well as specific terrain and control measures are nominal.

3. EXECUTION.

The purpose of this operation is to enable establishment of regional military stability in operations zone A. This will require our forces to maneuver rapidly from an attack position along river B to seize objectives C and D, destroy enemy forces occupying key terrain in operations zone A and secure the international border. Destroy enemy forces that engage our forces or occupy positions on key terrain along our axes of advance. The key to our success during the attack will be that our forces gain a twofold surprise by courageous and insistent attacking while the enemy is still deploying his forces and by aggressive reconnaissance of suspected and known enemy locations along the axis of advance to identify and destroy hostile reinforcing forces as early as possible.
At the conclusion of the operation, our forces will have:

- Destroyed enemy occupying key terrain in zone A;
- Established hasty defensive positions in objectives C and D;
- Established our forces on the international border

This statement of Command Intent follows the recommended guidelines of including an expanded purpose, key tasks and an end state. The formal version of this Command Intent follows this structure due to applying rule (5). In the formalization, TP1, TP2, and TP3 are nominal points in time; nlt means "not later than" and RPTFCT is the JC3IEDM term for "reported as fact"; stabilized area is put into quotation marks because in JC3IEDM's table "control-feature-type-category-code" a respective value is missing. In (11c) as well as in (11d) the objective to be occupied is mentioned twice because it expands Affected and At-Where. In natural (human) communication it would be sufficient to mention it only once, but in the formulization it has to be in both places in order to avoid ambiguity.

The subsections of the Intent will be as follows:

(10) [Expanded Purpose]
(10a) **Task-Report** ***establish*** MNF "stabilized area" **at** Zone A **start at** TP3 RPTFCT **in-order-to** secure label-ep1;

(11) [Key Tasks]
(11a) ***reconnaissance*** MNF OPEN **at** Axis-of-Advance **start at** TP1 **in-order-to** locate Enemy label-kt-1;
(11b) ***attack*** MNF OPEN Enemy **along** axis-of-advance **start at** TP2 **in-order-to** surprise label-kt-2;
(11c) ***occupy*** MNF OPEN objective C **at** objective C **start at** TP2 **end nlt** TP3 **in-order-to** secure label-kt-3;
(11d) ***occupy*** MNF OPEN objective D **at** objective D **start at** TP2 **end nlt** TP3 **in-order-to** secure label-kt-4;
(11e) ***secure*** MNF OPEN **at** "international border" **start nlt** TP3 **in-order-to** enable label-es-4 label-kt-5;

(12) [End State]
(12a) **Task-Report** ***destroy*** MNF Enemy **at** Zone A **start at** TP1 **end a**t TP3 RPTFCT **in-order-to** secure label-es-1;
(12b) **Task-Report** ***establish*** MNF defensive position **at** objective C **start nlt** TP3 RPTFCT **in-order-to** secure label-es-2;
(12c) **Task-Report** ***establish*** MNF defensive position **at** objective D **start nlt** TP3 RPTFCT **in-order-to** secure label-es-3;
(12d) **Status-Report** ***own position*** MNF **at** "International Border" **at** TP3 RPTFCT label-es-4;

5.2 MIP Example

The following scenario is from a Multinational Exercise and was used to describe division tasks. In this case, we will use the Army Corps Order as the source of our example. The original order was used in the "Integrated Operational Test and Evaluation" exercise of the "Multilateral Interoperability Programme (MIP)," September 8th to 26th, in the city of Ede in the Netherlands.

In the exercise, the order in question was released from the NATO Multinational Corps (MNC) and directed to – among others – the Multinational Division-West and Multinational Division-West. In the formalization, TP4, TP5, and TP6 are nominal points in time. The following shows some of its content:

3. EXECUTION.

> MNC Commander's Intent. My intent is to direct two-division movement from Tactical Assembly Area (TAA) to blocking positions along PL TULIP. In the event of incursion by BRADYLAND forces, MNC forces will not allow their progress north of the buffer zone. Keys to success include safe arrival at PL TULIP, construct and occupy blocking positions along PL TULIP, to prohibit the advance of enemy forces beyond the northern boundary of the buffer zone. The main effort is the counterattacks to eject the BRADYLAND forces from GENERICLAND and restore the international border. The end state is achieved when the UN recognized border between BRADYLAND and GENERICLAND is re-established.

In this statement of Command Intent, one cannot easily separate the three elements of Expanded Purpose, Key Tasks and End State. However, with some interpretation, the three elements can be determined as follows. The Expanded Purpose is to establish security in GENERICLAND and prevent the BRADYLAND forces from advancing into the buffer zone. The End State is clearly stated as when the border is re-established. And the Key Tasks are movement, hasty occupation and possible counterattacks.

This will be modelled as

(13) [Expanded Purpose]
(13a) **Status-Report** neg ***hostile position*** combat-unit **at** BUFFER ZONE **at** TP6 RPTFCT label-ep-a;
(13b) **Task-Report** ***establish*** MNC "stabilized area" **at** GENERICLAND **start at** TP6 RPTFCT label-ep-b;

(14) [Key Tasks]
(14a) ***move*** MNC OPEN **from** TAA **to** PL TULIP **start at** TP4 **in-order-to** enable label-kt-b label-kt-a;
(14b) ***occupy*** MNC OPEN combat zone **at** BUFFER ZONE **start nlt** TP5 **in-order-to** enable label-es-a label-kt-b;
(14c) ***counterattack*** MNC OPEN Enemy **at** BUFFER ZONE **start nlt** TP5 **in-order-to** enable label-es-a label-kt-c;

(15) [End State]
(15a) **Task-Report** ***establish*** MNC border **at** "UN Recognized Border" **end nlt** TP6 RPTFCT **in-order-to** secure label-es-a;

6 Related Work

Relevant work to a formal C2 Language is an emerging standard from the Modeling and Simulation community – known as "Battle Management Language" (BML) [Carey et al., 2001]. While the original BML had specific goals related to interfacing M&S systems to C2 systems it is

apparent that a BML is of greatest value if it is also used for sharing information in a network-centric fashion among C2 services. A persistent issue with the original BML work was the lack of formal syntax and semantics – in other words, the lack of a formal language description. In the following we describe the previous work done with BML. From this description, it can be seen how BML inspired the development of a formal grammar and how the specific rules for the formal grammar will be integrated into current initiatives.

6.1 Developing a Battle Management Language for M&S

A major drawback of using computer-simulated training is the need for large contingents of support personnel to act as workstation controllers and provide the interface between the training unit and the simulation. The group of workstation controllers is often as large as, or even larger than, the training audience. While this enables training opportunities, it is still resource-intensive and lacks the degree of fidelity that actual combat operations present to the commander and staff. What is needed is a standard representation and tools that can be used to automate the simulation interface to C2 services. A BML would address this need.

Each major simulation used today to represent military operational forces has a language to task simulated units. Unfortunately, each of these is specific to its own simulation and often is driven by technical constraints of the simulation system and not by operational necessities of the warfighter, e.g., [Hieb et al., 2004].

Taking the widest possible interpretation, BML has been defined [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.***

The objective of the BML work is to define an unambiguous language to describe the commander's intent in a way that soldiers and systems can understand and make use of it. The resulting language should be applicable not only to simulation systems, but also to operational command and control systems, and robotics.

We have previously described both Army and Joint BML prototypes as described in [Hieb et al., 2004]. These prototypes investigated: 1) eliminating "free text"; 2) use of BML to link a C2 application to a simulation in a doctrinally consistent manner; 3) representation of doctrinally correct tasks and units; and, 4) employment of a scenario useable by both the C2 application and the simulation.

This work was the foundation for several other BML initiatives with Air Operations and Coalition Forces, as well as a new initiative using BML to assist terrain and environmental reasoning with a Geospatial BML (geoBML) [Hieb et al., 2006].

6.2 Current Coalition Initiatives

The Simulation to Command and Control Information System Connectivity Experiments (SINCE) program is investigating interoperability issues by conducting multinational C2 experiments, supported by C2 and Simulation systems, designed to address the transformation of collaborative planning and interoperable execution in a coalition environment [Mayk et al., 2005].

Within the Simulation Interoperability Standards Organization (SISO), a Coalition BML (C-BML) Study Group investigated a potential standard for BML. The Study Group conducted a number of technical meetings involving a membership of over 100 persons from 11 different countries resulting in a comprehensive study. As a result of this study's recommendations, in 2006, a Product Development Group (PDG) was formed in SISO to standardize BML [Blais et al, 2005].

In parallel to the C-BML Study Group activities, the NATO Modeling and Simulation Group (NMSG) established a 12 month Exploratory Team (ET-016) on C-BML [Tolk et al., 2004]. The team, led by France, endorsed the requirement for a C-BML and has established a 3-year Technical Activity Program (Group MSG-048) for 2006-2009.

Our linguistic approach is part of both the SISO standardization and the NATO C-BML initiative.

7 Conclusions

The work on Command Intent presented here is part of a larger initiative to develop a formal C2 language for communicating both tasking and reports. The Command Intent Syntax builds upon C2 Grammars for Tasking and Reporting [Schade & Hieb, 2006b]. These grammars are intended to be general enough for multiple domains, but able to be specialized as required. Many challenging research tasks remain to be solved. Near term tasks will be to work with the SISO and NATO M&S groups to develop the Grammars and assess the Command Intent syntax through experimentation. Longer term tasks are to assess the conceptual component of the language to see how well it addresses Network-Centric principles and frameworks. In the area of linguistics, modality, negation and disjunction remain as research topics.

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