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Characterizing Doctrine through a Formalization of C2 Processes

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Topics:

Topic 4: Collective Endeavors

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Abstract

Doctrine is fundamental – not only for military operations – but also for a wide variety of Civil Organizations. While Doctrine is well understood inside of the respective organizations, it is neither well understood outside, nor formally encoded, such that computer applications can consider it. This paper investigates a formalization of doctrine intended to better support collaborative planning and execution of operations, from military missions to disaster relief operations.

Previous work in formalizing the C2 process for Collective Endeavors has focused on defining a Management Language for C2. We have identified two essential elements that comprise such a Management Language (that applies to operations through space and time). These are a representation of the C2 Process (which we call Engineered Knowledge) and Grammars. These elements need to be particularized for a given domain. For a start we have created an XML Schema for a US and NATO Orders, Engineered Knowledge for several types of US Units, and a C2 Grammar that also applies for Multi-Agency Collaboration. In this paper we describe these elements and the methodology used to characterize different doctrines.

1 Introduction

Organizations operate according to their doctrine. Inside of an organization, its doctrine is well understood. It is our hypothesis that operating according to a doctrine can contribute to the organization's agility. However, in a collective endeavor in which all participating organizations rely on each other, the doctrines of these organizations certainly differ in some aspects. As a result, there is no common doctrine and even worse, misunderstandings will occur as every participating organization will operate according its own doctrine which is often unknown or misunderstood by the others. Thus, it is desirable to make the organizations aware of differences between their own doctrine and the doctrines of their partner organizations. Often, it is even necessary to align doctrinal aspects. This, however, presupposes that doctrinal aspects are made explicit. Doctrine can be made explicit by formally encoding it, such that not only the members of other organizations can understand an organization's doctrine, but that automatic applications can also consider this doctrine. This would contribute to the successful collaborative planning and execution of operations – complex missions as well as disaster relief operations. Finally, such an approach could result in a theory of doctrine that drives technology and applications, such that the agility of these operations can be significantly improved.

1.1 Examining Doctrine

An examination of the US Army's doctrine. Joint Publication (JP) 1-02, Department of Defense Dictionary of Military and Associated Terms, defines doctrine as: "Fundamental principles by which the military forces or elements thereof guide their actions in support of national objectives. It is authoritative but requires judgment in application."

U.S. Army Field Manual (FM) 3-0, Operations, provides the following on the role of doctrine:

> D-1. Army doctrine is a body of thought on how Army forces intend to operate as an integral part of a joint force. Doctrine focuses on how to think, not what to think. It establishes the following:
> - how the Army views the nature of operations,
> - fundamentals by which Army forces conduct operations,
> - methods by which commanders exercise command and control.
>
> D-2. Doctrine is a guide to action, not a set of fixed rules. It combines history, an understanding of the operational environment, and assumptions about future conditions to help leaders think about how best to accomplish missions. Doctrine is consistent with human nature and broad enough to provide a guide for unexpected situations. It is also based upon the values and ethics of the Service and the Nation; it is codified by law and regulations and applied in the context of operations in the field. It provides an authoritative guide for leaders and Soldiers but requires original applications that adapt it to circumstances. Doctrine should foster initiative and creative thinking.
>
> D-3. Doctrine establishes a common frame of reference including intellectual tools that Army leaders use to solve military problems. It is a menu of practical options based on experience. By establishing common approaches to military tasks, doctrine promotes mutual understanding and enhances effectiveness. It facilitates communication among Soldiers and contributes to a shared professional culture. By establishing a commonly understood set of terms and symbols, doctrine facilitates rapid dissemination of orders and fosters collaborative synchronization among units. It establishes the foundation for curricula in the Army Education System.
>
> D-4. Army doctrine forms the basis for training and leader development standards and support products. Training standards provide performance baselines to evaluate how well a task is executed. Together, doctrine, training, and resources form the key to Army readiness. Doctrine consists of
> - fundamental principles,
> - tactics, techniques, and procedures,
> - terms and symbols.

As can be seen, Doctrine is not an easy concept to formalize. However, as with our previous work with Intent (Hieb& Schade, 2007), we view it as necessary to formalize Doctrine to enable the next evolution of services and applications to better support those conducting complicated operations.

1.2 Examining Doctrine

Generalizing what we discussed in section 1.1 for the US Army, the doctrine of an organization is the set of the fundamental principles which an organization uses to achieve its objectives. These principles – and thus the doctrine as whole – are well-known to the organization. Normally, there are documents that explicitly define at least parts of the doctrine, but as a whole it has become second nature to the members and parts of the organization due to training and operations. Therefore, at its core, doctrine is implicit knowledge.

In this section, we take a look at the interaction between doctrine and agility in order to examine what aspects of doctrine improve agility. In general, doctrine is a two-edged sword with respect to agility. There are advantages as well as disadvantages. Let us start with the advantages. Alberts and Hayes (2003, p. 27) list four assumptions for self-synchronization, the ultimate goal of an agile organization:

- clear and consistent understanding of command intent;
- high quality information and shared awareness;
- competence at all levels; and
- trust (in information distributed, in subordinates, in superiors, and in equipment).

Doctrine helps to realize the first and last of these assumptions in an organization. Between the members of an organization, the doctrine of that organization especially builds trust. Everyone (as a part of the organization in question) knows how everyone else will react to specific circumstances because everyone will act according to the doctrine, at least if the situation is well-known and thus doctrinally considered. This is especially important when an organization conducts training for its operations, as the members of the organization gain experience both in the standard way that operations are conducted, as well as how other people in the organization behave. It would be difficult to have trust between different people when conducting complex operations if they had never trained together or even have not talked to each other about how to operate, but had only studied a type of operation in isolation (Blatt, 2005). In *The Iraq War* (Murray and Scales, 2003, p. 118) the authors state "The common doctrine, training and education gave commanders an inherent trust in the ability of disparate units to cooperate effectively on the battlefield."

Doctrine also provides the demanded quality of understanding of command intent. The command intent will be formulated according to doctrine and should be understandable by every member of the organization.

However, there are disadvantages as well. Doctrine can cause problems. If situations occur that are not covered by doctrine, the members of the organization have to improvise. They might not be agile enough to do so because their doctrine does not provide an answer how to react to the uncommon situations and this might throw them out of balance. The second problem with doctrine appears if the organization has to collaborate with another organization. This second organization most naturally will also operate according to doctrine, but that doctrine is a different one. As their own doctrine has become second nature with the members of the organizations in question, all tend to assume that the members of the other organization will also operate with the same doctrine. This is especially true if the doctrines in question seem to be quite similar. In this case, often the assumptions about the members of the other organization on the basis of one's

own doctrine are correct. As a result everyone assumes that their own doctrine is the doctrine they have in common. If a clash happens no one might recognize it. Everyone still takes for granted that his collaborating partner from the other organization operates according to "common doctrine." The resulting misunderstandings can hamper the success of the collaboration, drastically. Hayes and Owen (2008) provide examples for some of this kind of misunderstandings in their analysis of the Golden Phoenix 07 exercise.

1.3 Implications of using Doctrine for Collaboration

In order to avoid misunderstandings in a collaboration, the doctrines of the participating organizations should at least be examined by the partners in the collaboration. In some critical aspects, it is even necessary to align them. In this section, we will discuss which aspects of the doctrines have to be aligned. In the following sections, we will introduce a formal language that can be used to carry out this alignment.

Let us start with terms and symbols. With respect to military operations, NATO nations have agreed upon a set of symbols to display the operational picture on a map. This set, as given by the APP-6A (APP-6A, 2009) even includes some symbols for operations other than war. There is a similar situation for terms. Most of the terms used in military operations as well as some terms used in operations other than war have a definition in the Joint Command, Control, and Consultation Information Exchange Data Model (JC3IEDM). Most of the NATO nations have agreed on the meaning and the usage of these terms. Civil organizations also have catalogues of symbols and terms as part of their doctrine, e.g., the Manchester Triage System (Mackway-Jones, Marsden & Windle, 2005). As a minimal step toward doctrinal alignment, all the catalogues of symbols and terms used by some participating organization must be accessible to all the organizations of the endeavor. In Section 5, we will suggest a simple mechanism to implement this. There are, however, some very basic terms, the organizations have to agree upon, namely how to denote time and space (date-time and coordinates).

1.4 Roadmap to the Paper

In principle, what is true for symbols and terms is also true for fundamental principles, for tactics, for techniques, and for procedures. What is necessary here is to specify and formulate them such that members of other organizations can check their meanings and the intentions behind them. We show this as knowledge acquisition methods given in Sections 2 and 3. Section 2 shows how doctrine can be represented in a generic manner. Section 3 describes the knowledge acquisition process and illustrates it for three different organizations, showing that the methodology can be used to represent doctrine of both military and civil organizations. There is one aspect that has to be agreed upon; how to communicate, that is how to exchange information and how to exchange requests and other directives. Again, we will suggest a method to handle this in Section 5. Before this can be done however, we first introduce some terms and some linguistic principles in Section 4, namely those that we want to exploit to formalize doctrine and to exchange doctrinal aspects and doctrinal knowledge among the organizations. We conclude with a discussion on how organizations can share and use this doctrine to improve collaboration.

2 Engineered Knowledge

We define Engineered Knowledge as the representation and organization of knowledge supporting Command and Control. Engineering Knowledge consists of both a process to create and maintain this knowledge and the specific relationships necessary to represent this knowledge for operational domains. An Engineered Knowledge Base is an instantiation of Engineered Knowledge for a particular domain, such as land warfare.

While the description of Engineered Knowledge applies to the military domain, and specifically to the area of land warfare, it is our opinion that the same process can be readily and directly applied to other situationally dependent, task-based operations. Examples of such operations are fire and police work, air traffic control, disaster relief and assistance, homeland security, etc.

Our hypothesis, stated in the introduction, is that Engineered Knowledge enables automated Command and Control (C2) and Decision Support Systems. In the future, we will examine whether our formulation of Engineered Knowledge can 1) identify Command Intent within context; 2) develop required Decision Support products; and 3) convey orders, reports; and C2 information. The fundamental data and information that is used in Engineered Knowledge is readily available in manuals, doctrinal texts, training material and a multitude of other sources. It is not, however, organized, associated and integrated in a readily usable fashion for Decision Support. This process normally occurs within the mind of the professional practitioner over years of study, training and operational conduct. Engineered Knowledge takes this highly individualized process of gathering, organizing, associating and integrating these various data elements, standardizes it and instantiates the results functionally within supporting decision support systems.

A Generalized Process for Creating Engineered Knowledge

In developing Engineered Knowledge the initial steps are to identify, for a specific domain:

- The organization to be supported, its roles, functions and operating entities;
- The position/functions within the organization to be supported;
- The information needs of the decision makers and supporting staff;
- The process or processes to be supported;
- The specific input and outputs of the processes; and
- The communications requirements and methods between and amongst the process and the positions/functions.

This identification and analysis process should be conducted by, or at least in conjunction with, a Subject Matter Expert (SME) that has extensive experience in the organization and its processes.

Building an Engineered Knowledge Base

After an initial examination of the domain is performed, as described in the preceding section, we describe the steps for building an Engineered Knowledge Base for a particular domain, in this case the US Army tactical forces. In the description below we refer to Command and Control

(C2) units. These can be individual commanders or command and staff sections that are doctrinally responsible for and authorized to process information, make decisions and/or issue orders.

In the following paragraphs we will give an example for each step for a US Army STRYKER Battalion from our current Geo-Enabled Battle Command implementation (Hieb et al. 2007a, Hieb et al. 2007b).

Step 1: Identification of C2 Processes and Formats:

First, the process and format of how information is passed from a sender to a receiver in the given domain is documented and deconstructed. In the military domain, some of the information passes from sender to receiver in accordance with well-defined message formats. These formats are used whether the message is written or verbal and they define the type and format of the information exchanged. In organizations that are not in the military domain, the information may not be documented or structured to the same degree as in the military. However, other organizations may have the equivalent of Standard Operating Procedures that can be used to identify the information communicated. This is an area where further research is needed.

For the US Army, FM 6-99.2, Reports and Messages, defines the reports and messages used to communicate. The formats are derived from Army Battle Command System (ABCS), United States Message Text Formats (USMTF), Allied Procedures Publications 9 (APP-9) formats as well as numerous unit Standard Operating Procedures (SOP)s. The Operations Order format complies with STANG 2014 – Formats for Orders and Designation of Timings, Locations and Boundaries (NATO, 2000).

Step 2: Identify the Organizational Structure.

Second, the structure of the organizations involved is documented and deconstructed in order to determine which units can direct other units, and which units pass non-directive information to other units. This involves documenting the echelon and task organization (C2) structure of US Army units. Multiple units may be of the same type (they contain similar assets and capabilities) but exist in different organizational structures. This is given in Figure 1.

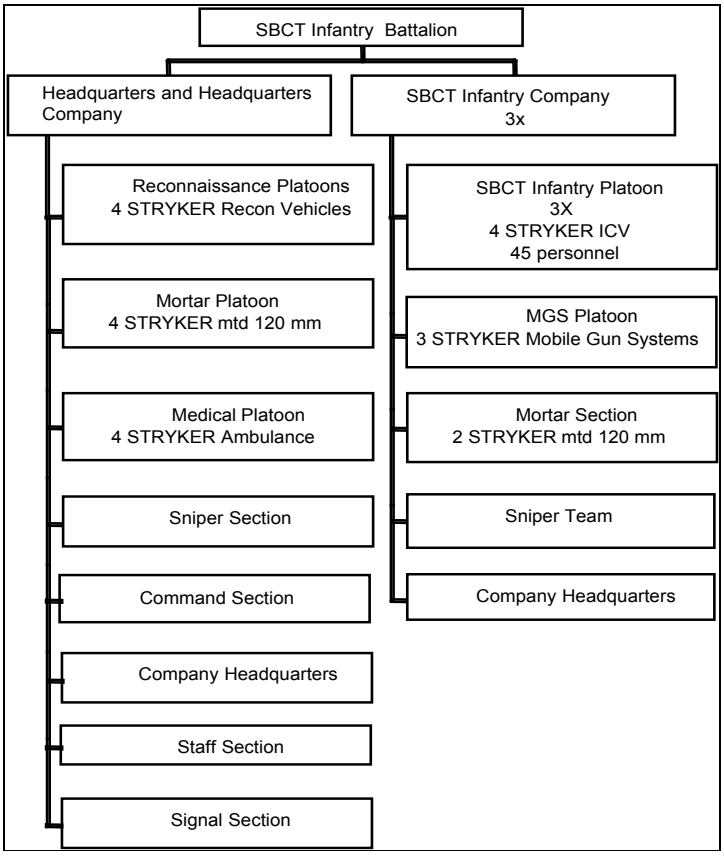

Figure 1: Stryker Brigade Organization

A STRYKER Brigade Combat Team (SBCT) Infantry Battalion (Inf Bn) consists of a Headquarters and Headquarters Company (HHC) and three identical SBCT Inf Companies (Co) [A, B, and C]. Subordinate to the HHC is a Reconnaissance Platoon (Plt), a Mortar Plt, A Medical Plt and a Sniper Section (Sec). During operations these four elements report directly to the SBCT Infantry Battalion. Each SBCT Inf Co consists of three identical SBCT Inf Plts [1, 2, and 3], a Mobile Gun System (MGS) Plt, a Mortar Sec, and a Sniper Team (Tm).

From this we can identify that there are eleven unit types (based on function and size (echelon)) with some unit types having multiple instantiations as in Table 1.

Table 1: Unit Type Table

Unit Type	Number of Instantiations	Takes Direction from
SBCT Inf Bn	1	
SBCT Inf Bn HHC	1	SBCT Inf Bn
SBCT Inf Co	3 [A, B, C]	SBCT Inf Bn
SBCT Inf Plt	9 [1/A, 2/A, 3/A, 1/B, etc.]	SBCT Inf Co
MGS Plt	3	SBCT Inf Co
Mortar Sec	3	SBCT Inf Co
Sniper Tm	3	SBCT Inf Co
Recon Plt	1	SBCT Inf Bn
Mortar Plt	1	SBCT Inf Bn
Medical Plt	1	SBCT Inf Bn
Sniper Sec	1	SBCT Inf Bn

The next five steps discuss developing the Engineered Knowledge Base to support tasking units.

Step 3: Identify the Actions the Unit is Capable of Performing.

In order to facilitate one unit directing another unit there must be an understanding of what actions each of the individual unit types are capable of accomplishing. In a non-automated environment, it is assumed that this knowledge of what the directed unit is capable of doing resides within the unit doing the directing. This is not always the case, specifically if there is a change to the organization and non-habitually related units are assigned to a new directing unit. This is the "What" in terms of the 5 "W"s. We use the concept of the 5 "W"s to model military operations (Carey et al., 2003).

The US Army has a very well defined doctrinal base consisting of Field Manuals (FMs) that describe how the Army is organized and operates. It also has Army Readiness and Training Evaluation Program (ARTEP) Mission Training Plans (MTP). There are ARTEP-MTPs for each type of unit and echelon. You can think of an ARTEP-MTP as an owner's manual for the unit type. It describes all the actions that particular unit type is capable of performing, as well as the conditions and standards that the unit should train to. For each of the unit types described for the SBCT Infantry Battalion above, there is an ARTEP-MTP associated with it. Additionally the Army identifies Tactical Tasks that units can perform. These Tactical Tasks are specified in FM 7-15, The Army Universal Task List (AUTL). We can extract from the appropriate ARTEP-MTPs and from FM 7-15 all the tasks that the eleven unit types in step two are capable of performing. If we include some additional information in our listing, such as a definition or description of the task, a source document, etc. it can facilitate expanded uses in applications. This is shown in Table 2.

Table 2: Task Table

Task	Definition	Task Source
Clear Enemy Forces	Clear requires the commander to remove all enemy forces and eliminate organized resistance within an assigned area.	FM 7-15
Conduct a Cordon and Search in an Urban Area	The unit establishes a cordon of the designated area without being detected by the insurgents or sympathizers. The unit conducts the search and captures all insurgents and enemy material within the cordon.	ARTEP-7-22-MTP

Step 4: Associating a Unit Type to Actions that a Unit is Capable of Performing.

Fourth, to formalize the knowledge of what a unit is capable of doing a relationship is created that relates the actions a unit can perform to a specific unit-type and position in its organization (e.g. an Infantry Brigade, and Engineer Battalion, etc.). We are concerned with echelon level here because a specific unit's capabilities, even of the same unit type as its subordinate units, maybe greater than the capabilities of the subordinate units. This is a "Who" to "What" relationship as shown in Table 3.

Table 3: Unit Type to Task Relationship Table

Unit Type	Task
SBCT Inf Bn	Clear Enemy Forces
SBCT Inf Bn	Conduct a Cordon and Search in an Urban Area
…	…

Step 5. Identifying the Reasons that a Unit would Accomplish an Action.

Fifth, the reasons a particular unit performs a particular action (or task) are identified. To a large extent these reasons for performing a specific action are dictated by the action and the conditions under which the action is performed. In most cases there are a limited number of effects that the action can achieve and can be defined as actions that affect the unit itself, friendly units, hostile units, neutral elements, or other physical aspects of the environment (terrain, facilities, equipment, material, person). This is the "Why" in terms of the 5 "W"s.

For the Engineered Knowledge Base for the SBCT, as we conducted research to identify the actions that each unit type can accomplish, we also searched other related doctrinal manuals to identify the reasons a unit would conduct a specific action. In this case that reason was identified and associated to the doctrinal definition. In other cases there were more general descriptions such as: to **enable** another friendly force to accomplish its mission, to **allow** some other action, etc. In this case the reason was recorded with its appropriate Webster's definition. Our Why Table, Table 4, has approximately 170 entries identified in the doctrinal research of FMs that support the tasks in the ARTEP-MTPs and FM 7-15. We have found over several years that listing is fairly stable. As with the task table, adding some additional information such as a definition to the table can facilitate future applications.

Table 4: Why Table

Why	Definition	Source
Protect	The preservation of the fighting potential of a force so the commander can apply maximum force at the decisive time and place.	FM 3-0
Capture	The action objective has been captured or acquired and is available for use or interrogation.	Adapted OED (JC3IEDM)
Allow	To let do or happen.	Webster
Cause	To make happen.	Webster
…	…	…

Step 6: Associating a Reason for Doing an Action to an Action.

Sixth, as in the case of relating actions to unit types, we can also create a relationship table that associates actions for the specific reasons for performing that action. This is a "What" to "Why" relationship as shown in table 5.

Table 5: Task to Why Relationship Table

Task	Why
Clear Enemy Forces	Protect
Clear Enemy Forces	Allow
Conduct a Cordon and Search in an Urban Area	Capture
…	…

Steps 7 and 8: Identify Geospatial Products and their Association to Actions.

Seventh, for any action that a unit is capable of performing there may be a geospatial aspect to the action. In this step, these geospatial "products" are identified for a given domain. Each action is examined to determine what these geospatial requirements are. In a number of cases these requirements can be categorized into standard products which can be globally applied across a large selection of actions and therefore computed based solely on the general location of the operation. In other cases, there are standard products that can be associated to specific types of actions.

Eight, a relationship is created that identifies which types of geospatial products are associated to the specific actions units can perform. As we extended the concept of the Engineered Knowledge into the realm of actionable geospatial information we developed a new class of objects, Tactical Spatial Objects (TSOs) (Hieb et. al. 2007a, Hieb et. al. 2007b). A TSO is defined as an analytical product extracted from terrain data. A TSO is described in terms of the aspects of terrain that directly support the planning and execution of operations. TSOs are meant to be linked to operational tasks taking into account the effects of terrain and weather. For example an Attack by Fire TSO can be developed from analysis of the terrain and weather data to identify the terrain that supports a unit type's conduct of an Attack by Fire task based on the weapon systems available to the unit type and the identified Objective or Engagement Area. This Attack by Fire TSO would provide options to the commander from which he then decides where to locate the

position thus assigning the appropriate 2525B graphic control measure for the Attack by Fire task. For the Engineered Knowledge Base for the SBCT we defined a set of TSOs specific to the SBCT actions. Then we associated each TSO type to an action.

3 Building Specific Languages for Different Doctrines

In this section we will discuss extending the process addressed in Section 2 for the U.S. Army SBCT Infantry Battalion to two other organizations, one a military organization from a different country (German Tank Battalion), and the American Red Cross.

Step 1: Identification of C2 Processes and Formats:

Example 1: German Panzerbataillon (Tank Battalion). The German military has standardized formats for their communications (cf. HDv 100/200 *Führungsunterstützung im Heer*, sections 654-677), and as a NATO member they comply with STANAG 2014.

Example 2: American Red Cross. The American Red Cross has standardized reporting formats such as the "Statistical and Cost Report of Disaster Operation (Form 2066)."

Step 2: Identify the Organizational Structure.

Example 1: German Tank Battalion. The structure we will address in this example is that of the German Tank Battalion. The German Tank Battalion has directly subordinate to it a Headquarters Company, and four identical tank companies. These organizations would be added to the Unit Type Table. Figure 2 shows the German Tank Battalion's Organizational Structure.

Example 2: American Red Cross. In this example we will look at the general structure of the Red Cross. The International Red Cross and Red Crescent Movement is composed of the International Committee of the Red Cross and International Committee of the Red Crescent. Each of these committees represents the 186 National Societies. In the United States the American Red Cross is in the process of reorganizing into 10 Divisions. Each Division is composed of regions. The Couth Central Division has 5 Regions, one of which is the Greater Kansas City Region. The Kansas City region is further divided into six Chapters: St. Joseph, Wyandotte, Leavenworth, Douglas, Pettis, and the Greater Kansas City Chapter. Each Chapter covers one or more counties, for example the Leavenworth Chapter covers just the Leavenworth County whereas the Douglas Chapter covers multiple counties. These organizations would be added to the Unit Type Table. Figure 3 shows the Red Cross Structure.

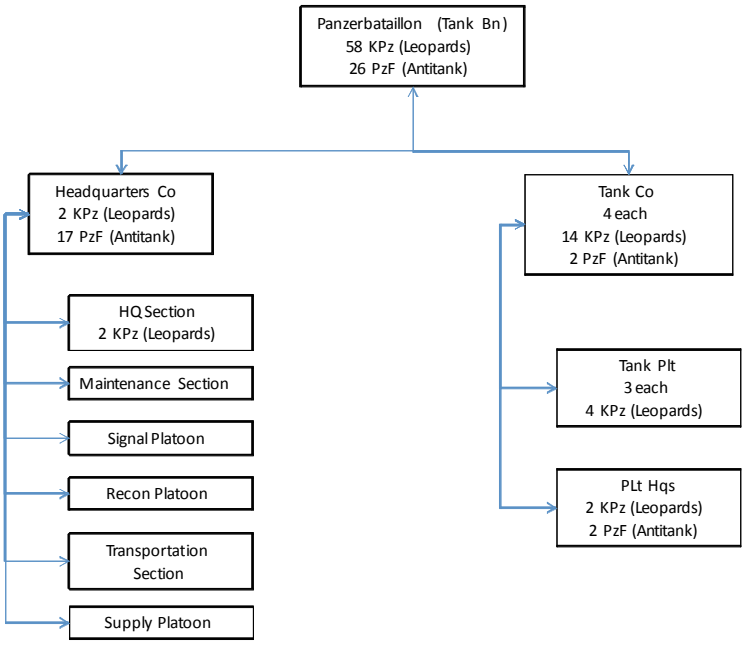

Figure 2: German Tank Battalion Structure

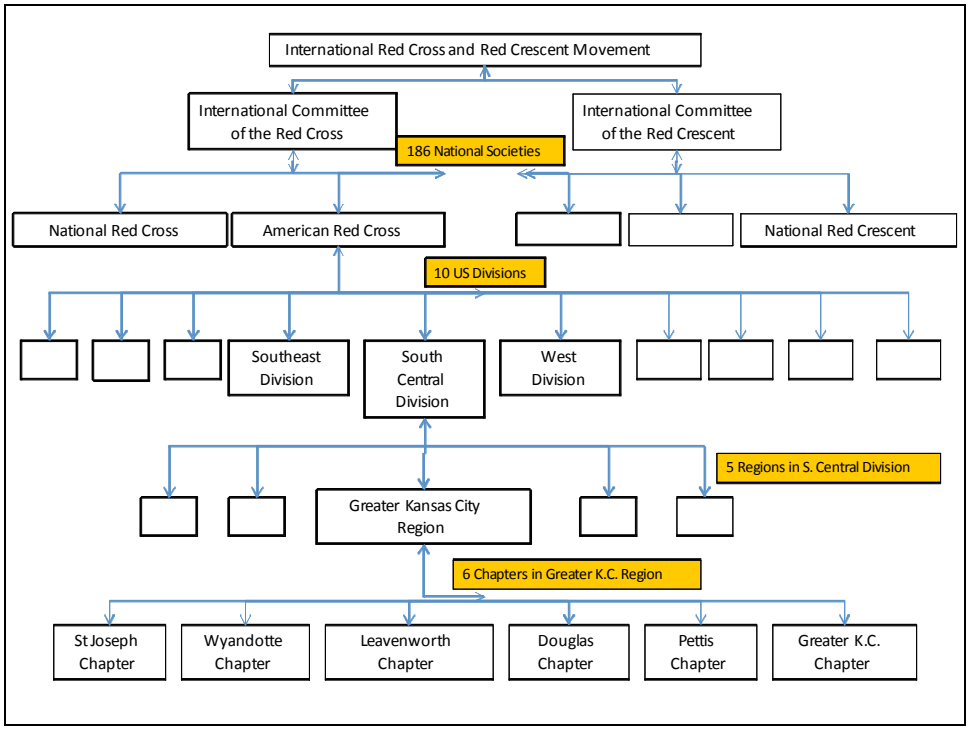

Figure 3: American Red Cross Organization Structure

Step 3: Identify the Actions the Unit Types are Capable of Performing.

Example 1: The German Tank Battalion. The German Tank Battalion has doctrinal publications that they use in their military training that describes the capabilities and uses of their equipment and unit types. Examples are HDv 100/100: *Truppenführung* (Army Doctrine 100/100: How to Lead Troops), and HDv 221/100: *Das Panzerbataillon* (Army Doctrine 221/100: The Battle Tank Battalion). From these we can develop a listing of actions that each type of unit would be capable of performing. Some of these tasks may be the same as those from the US Army example. This listing of actions would have to be compared to the list of actions that currently exist in the Task Table. If the action already exists and is sufficient then we would use it, if not we would add any newly identified actions to the Task Table. For example, the German Tank Battalion can conduct the task "Attack, main" as defined in AAP-6.

Example 2: Red Cross. The American Red Cross has a number of doctrinal documents and manuals that define what it believes is the "best way of doing things." This includes it Congressional Charter, which describes its organization, purpose, membership and governance. The American Red Cross has a Code of Business Ethics and Conduct as well as mandatory classes that employees and volunteers must complete in order to fill specific roles. Example of these classes include: Disaster Action Team Workshop, Disaster Supplies and Logistics, Feeding and Sheltering, etc. Additionally there are three documents in the Disaster Services Program Guidance Series: Foundations of the Disaster Services Program, Disaster Response Handbook, and Disaster Operations Management Handbook (Disaster Services Program Guidance) (October 2006), which addresses actions such as Initiation, Assessment, Scaling Up, Implementation, Oversight, and Scaling Down. Attachment I to this document is the Operations Management Activities / Tasks Summary. There are also a number of Group/Activity Handbooks which are procedural manuals for each of the activities in the seven Disaster Services Human Resources Contingency Groups. These tasks and others identified in the training material would be added to the Task Table. For Example the task, "Provide sheltering on a scale commensurate with the community risk and requirements for at least five days. At a minimum, the chapter should be able to open and sustain two shelters."

Step 4: Associating a Unit Type to Actions that a Unit is Capable of Performing.

Example 1: German Tank Battalion: We would relate the actions that now exist in the Task table to the appropriate unit types using the Unit Type to Task Relationship table the same way as the US Army example above.

Example 2: Red Cross. We would relate the actions that now exist in the Task table to the appropriate organization (unit) types using the Unit Type to Task Relationship table the same way as the US Army example above.

Figure 4 shows an example of this association for the three types of organizations described. Note that this example shows all three examples within the same database. This is but one way of implementation.

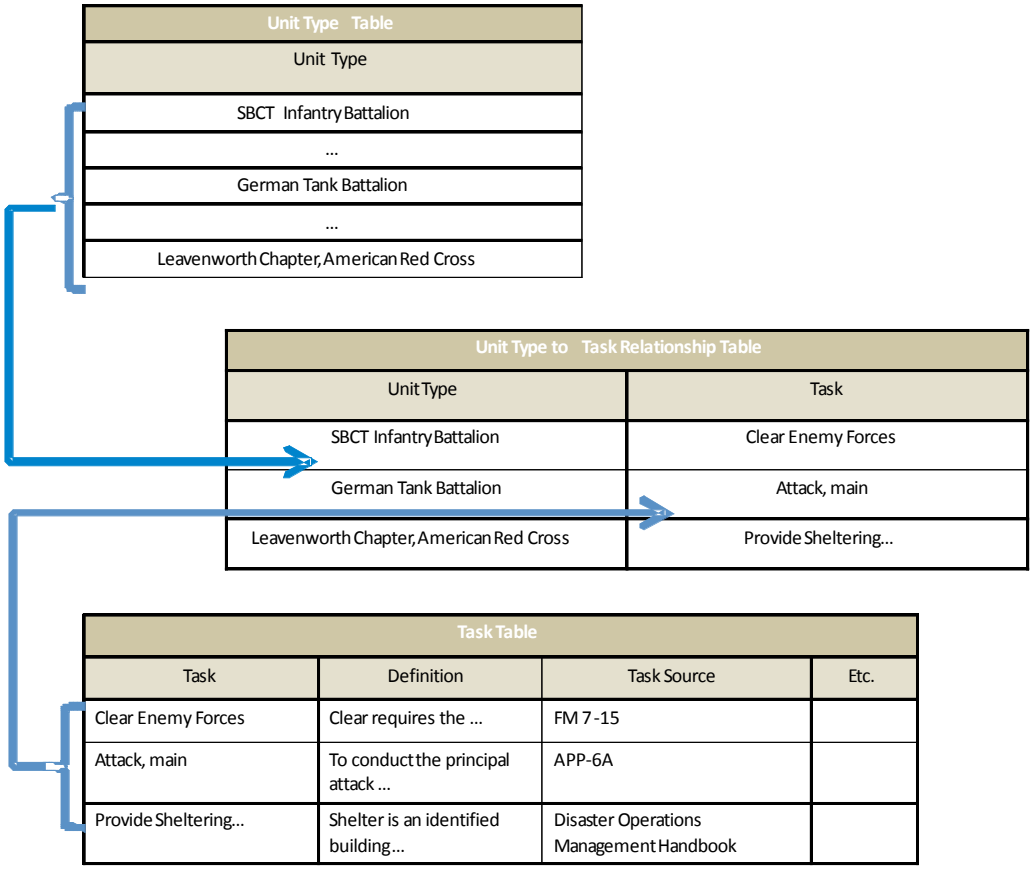

Figure 4: Who to What Association

Step 5. Identifying the Reasons that a Unit would Accomplish an Action.

Example 1: German Tank Battalion: Since the German Tank Battalion is still a military unit there will probably be very few additions required to the Why table.

Example 2: Red Cross: Since the Red Cross is a completely new type of entity there will probably be several additions required to the Why table. As an example the term "comfort: to sooth in time of grief and fear" (Webster's II New Riverside University Dictionary)

Step 6: Associating a Reason for Doing an Action to an Action.

Example 1: The German Tank Battalion: We would associate the actions that have been associated to the German Tank Battalion units to the appropriate reasons in the Task to Why Relationship table in the same manner.

Example 2: Red Cross: We would associate the actions that have been associated to the Red Cross units to the appropriate reasons in the Task to Why Relationship table in the same manner.

Figure 5 shows an example of this association for the three types of organizations described.

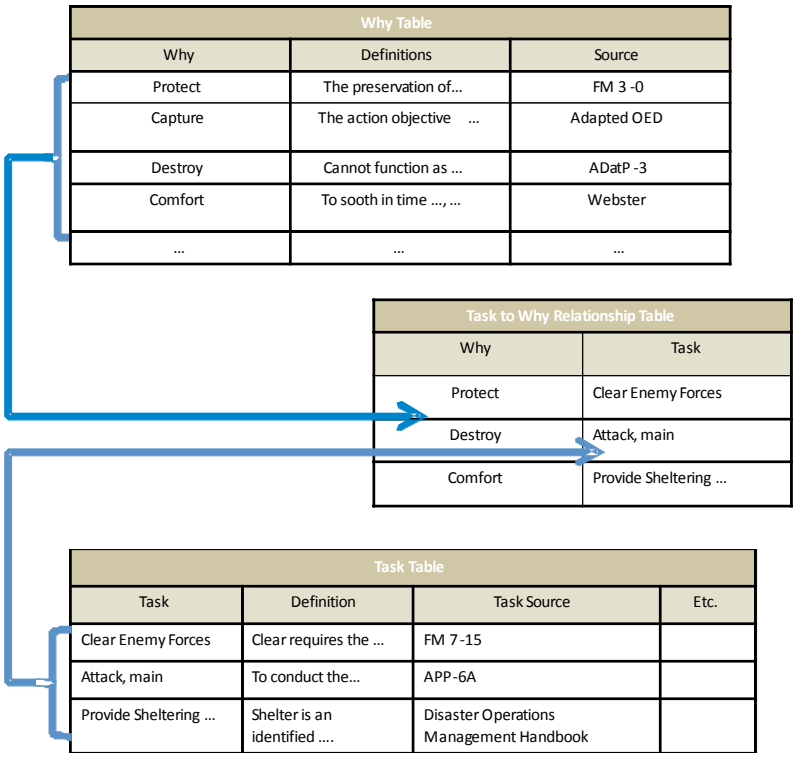

Figure 5: Why to What Association

Steps 7 and 8: Identify Geospatial Products and their Association to Actions.

Example 1: The German Tank Battalion. We would associate the actions that have been associated to the German Tank Battalion units to the appropriate TSOs in the same manner as for the SBCT Inf Battalion. Since the German Tank Battalion conducts ground military operations, many of the TSOs developed for US Army would be applicable. Input variables such as weapon ranges would be unique to the German Tank Battalion.

Example 2: Red Cross: We would associate the actions that have been associated to the Red Cross units to the appropriate TSOs. Since the Red Cross actions differ greatly from the US Army, relevant TSOs would need to be identified and constructed.

4 A Formal Approach based on Linguistic Principles

Section 2 examined the concept of doctrine and Section 3 described a method of knowledge acquisition for doctrine. In the process of acquiring doctrine, the doctrine was defined in a particular form that we call Engineered Knowledge. However, in order to make the doctrine of an organization in an endeavor available to the other organizations participating in the endeavor, doctrine needs to be communicated among the organizations. In the past, we have developed a grammar based on the Lexical Functional Grammar to define a formal language for communication among organizations participating in an endeavor [Schade & Hieb, 2008]. It deals

with the exchange of taskings, requests and reports. In the following section, we will provide an overview of this grammar and its language. We will then describe an addition to the language that will allow the exchange of the doctrinal propositions of the Engineered Knowledge described in Section 3. Doctrinal aspects expressed in a formal language become explicit. Members of all participating operations can study these aspects; they become shared [cf. Farrell 2004] and can be taken into account. When the Engineered Knowledge is expressed formally it also can be processed automatically. Thus, these doctrinal aspects can be taken into account in decision support modules. Note that it is also possible to express Engineered Knowledge of an organization not part of the endeavor – for example a neutral organization in a simulation system used for decision support.

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 treated 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 "*4 people rescued at Building 2109*" there are two constituents besides the verb, namely "*4 people*" and "*at Building 2109*". The first constituent refers to the affected of the action and the second provides the location. Obviously, the sequence "rescued at Building" does not form a constituent. Constituents fill thematic (semantic) roles within a sentence (cf. Sowa, 2000). In the example, the roles filled are "patient" (the one or ones affected by the action) and "location" (the spatial essence assigned to the action). Thematic 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 thematic roles are the (formal) linguistic mirror images of the 5 Ws: Who, What, Where, When, and Why. However, there are more than five thematic roles. E.g., the roles *origin, path, destination*, and *location* all are spatial constituents and thus of type Where. This, however, makes sense as in a sentence more than one constituent of the same W-type may appear. E.g., in "the unit relocates from Alpha to Omega via route Dove", there are three Where-constituents, namely an origin, a destination, and a path.

In order to deal with doctrine, a formal language can be used in two ways. First, it can be used to express doctrinal aspects directly. Doctrinal aspects expressed in a formal language are explicit. Members of all participating operations can study these aspects; they become shared [cf. Farrell 2004] and can be taken into account. Doctrinal aspects expressed formally even can be processed automatically. Thus, these aspects can be taken into account in decision support modules. Note that it is possible to express assumed doctrinal aspects of an organization not part of the endeavor – for example a neutral organization in a simulation system used for decision support. Second, the formal language can be used in the communication among the collaborating organizations in order to synchronize the actions. In this case, the language is about the actions. However, it can

be designed with properties that help the organizations to understand their partner organizations intent (Hieb & Schade, 2007). This can be done by offering and providing access to situationally relevant doctrinal aspects of the organization one communicates to. In the following section, we will give rules for both variants of the formal language.

5 A Language for Complex Endeavor Communication

In this section, we will describe a formal language for complex endeavor communication. We will start by showing how taskings, requests and reports are expressed in that language and we will then proceed to the expression of doctrinal statements that express the Engineered Knowledge. In the past, we designed a formal language for military communication (Schade & Hieb, 2006a, b, 2007) and its underlying grammar, the Command and Control Lexical Grammar (C2LG). This language has been used by NATO MSG-048 "Coalition Battle Management Language" for giving orders to simulated units by using C2 systems (Pullen et al., 2008a, 2008b, 2009; de Reus et al., 2008). In Schade & Hieb (2008) we discussed how this language can be broadened to allow communication among different kinds of organizations in a complex endeavor. This was illustrated by an earthquake relief operation example. This language can be further enhanced such that it provides access to relevant doctrinal resources of the communication partner during communication in a running operation. We will present this enhancement in following (subsection 3.1). In addition, the rule formats of the C2LG can also be used to express doctrinal aspects to make them explicit. This will be presented in subsection 3.2. In addition, subsection 3.3 will introduce formats that can be used to negotiate agreements about those doctrinal aspects the organizations have to or would like to agree upon.

5.1 Taskings, Requests, and Reports

Communication in among the participating organizations of a complex endeavor uses two basic kinds of speech acts, directives and reports. By reports, the sender informs the addressee about something. Information is exchanged. Directives have the purpose of having the addressee perform an action. In the military field, directives normally are either orders (if the sender is superior to the addressee) or requests. In the communication between different organizations participating in a complex endeavor there are also have requests, but not have orders. If one organization is formally coordinating the efforts, it has some legitimacy to assign tasks to others but not the legitimacy that stems from a military command hierarchy. We coined the term "tasking" (in contrast to "order") to denote this kind of directives. In Schade & Hieb (2008) we extrapolated the format for a basic directive expression, abbreviated DB, from C2LG's format for basic order expressions (Schade & Hieb, 2006a, b) as given in (1):

(1) DB → CatT: Verb Sender Addressee (Affected|Action) Where
Start-When (End-When) Why (Mod) Label

In this rule form, CatT denotes the kind of directive. Its values are "order", "tasking", or "request," respectively. Verb is the verb that denotes the task that the sender wants to be executed, e.g., advance or assist; Sender is the one who directs the task; Addressee is the one who is supposed to execute it; Affected and Action denote who is affected by the task (either an object – Affected – such as a wounded in the case of rescue, or another task – Action – such as a

rescue action in the case of assist); Where is the location the action should take place (that can be a location as in the case of rescue or a route as in the case of advance); Start-When is the point in time when the task should start; End-When is the point in time when it should have ended (this constituent is facultative); Why provides a reason for the task (it is linked to the intent); by Mod some modifiers can be added, and Label is a kind of ID that can be used to refer to this directive. More details are given in Schade & Hieb (2006a, b, 2008). The categorization term (CatT) expresses if the directive is meant as an order, a tasking, or a request by setting CatT to the value order, tasking, or request, respectively.

While this notation looks quite different than the Engineered Knowledge in Section 3, the Verb is a task, and is equivalent to the "What" in the Engineered Knowledge. The other terms in the grammar can be mapped in a similar way.

For example, a SBCT Infantry Battalion sends the request given in (2) requesting shelter for displaced civilians to a Red Cross unit. Since, in this example, the SBCT Infantry Battalion uses the JC3IEDM's annex E as a doctrinal catalogue of terms, the term "provide accommodation" should be linked to this annex. Then a member of the Red Cross can check what the SBCT Infantry Battalion's doctrinal interpretation of a "provide accommodation" task is (and whether this agrees to his own interpretation). The check will give "to provide room for receiving people, especially a place to live or lodging" and the Red Cross unit might infer that performing a "provide sheltering" from their list of action will be an appropriate answer to the request.

(2) request: provide accommodation SBCT Inf Bn Red Cross **at** Melkar Square **start** at now label 2-b-103;

5.2 Expressing Engineered Knowledge in the C2LG

One approach when different types of organizations operate together would be to provide links to catalogues of doctrinal terms and symbols that can be used during an endeavor. Members of the participating organizations could then check whether they agree with their partners on the meaning of terms and symbols used in communication. Our hypothesis stated at the start of the paper is that a formalization of doctrinal aspects of operations can support advanced planning and execution.

To use this formalized doctrine, Engineered Knowledge should be made known to the partners at the beginning of the operation and then agreed upon prior to being used in the operation. In this subsection we will suggest language expressions to allow these doctrinal statements and doctrinal agreements. For the language, we again will use a format similar to the one given for basic directives.

We define a doctrinal statement as an expression that makes an aspect of the sender's doctrine explicit. It is sent to all participating organizations at the beginning of a collaborative endeavor and it holds for the whole endeavor. Therefore, that doctrinal aspect can be implemented in the systems of the organizations such that planning and executing tasks as part of the endeavor can automatically take these aspects into consideration. A doctrinal statement consists of multiple (at least one) basic doctrinal statement, abbreviated DSB. The basic statements follow the form given in (3).

(3) DSB → doctrinal statement: Org Aspect Relation Argument* Label

In this format, Org stands for the organization for that the expressed doctrinal statement holds, normally the sender of the statement; Aspect expresses the doctrinal aspect this statement is about; Relation refers to a relation by which that aspect can be expressed, and Argument denotes an argument to that relation. Since some relations will have more than one argument, Argument is marked by *. To illustrate this format, (4) provide examples of doctrinal expressions sent to partner organizations during an endeavor.

(4a) doctrinal statement: SBCT Inf Bn ***organizational structure*** CMDCTL HHC Mortar Plt label-ds-168;
(4b) doctrinal statement: American Red Cross Leavenworth Chapter ***action capability*** able to perform provide sheltering label-ds-269;

Example (4a) is a doctrinal statement by a STRYKER Brigade Combat Team Infantry Battalion (SBCT Inf Bn) about a part of its organizational structure (the doctrinal aspect in question). It says that its Headquarters and Headquarters Company (HHC) has its Mortar Platoon (Mortar Plt) under command and control (Relation: CMDCTL), also cf. Figure 1. Example (4b) expresses that the Leavenworth Chapter of the American Red Cross is able to provide sheltering (Aspect: action capability; Relation: able to perform; Argument: provide sheltering), also cf. Figure 5.

In order to implement the complete language to express Engineered Knowledge as doctrinal statements, its still is necessary to define the lexical items of that language, especially the lexical items to denote the doctrinal aspects that can be expressed and the relation terms for these aspects.

6 Conclusions

Once doctrine has been codified into Engineered Knowledge, the question then becomes "How can it be shared across the disparate organizations?" Hayes and Owen (2008) outlined seven attributes that were observed and relevant data collected on during the Golden Phoenix 07 exercise. One of these was Organizational Familiarity and Trust which was defined as: "Organizational Familiarity and Trust involves knowledge of the capabilities of other participating organizations and the respondent's degree of confidence in the fact that they could obtain support from the organization if needed." The sharing of Engineered Knowledge would go along way towards satisfying Organizational Familiarity and Trust. It is unlikely that all organizations that might be tasked to work together in response to a disaster (local, state, federal, other governmental organizations, and Non-Governmental Organizations (NGOs)) would have their Engineered Knowledge collocated in the same location. Therefore, there needs to be a means for organizations to exchange this information by either pushing their information to others or allowing others to pull the information.

As an example, consider the C2 challenges that Multi-National Brigade (East) (MNB(E)) faced in Kosovo in 2005. MNB(E) was the U.S. commanded brigade responsible for the south eastern portion of Kosovo. MNB(E)'s higher headquarters was HQ Kosovo Forces (KFOR), a NATO headquarters. MNB(E) had subordinate to it three U.S. battalions, a Greek Battalion (with an

Armenian unit attached to it), and a Polish/Ukrainian battalion that had a Polish headquarters, two Polish companies, two Ukrainian companies, and a Lithuanian platoon. In their area of operations they had to deal with the United Nations Mission in Kosovo (UNMIK) organizations that were working to re-establish civilian control. This included local governments in each of the municipalities as well as the CIVPOL (UNMIK Civilian Police responsible for policing Kosovo as well as training/supervising Kosovo's new police force (UNMIK-P)). Additionally there were other governmental organizations such as Organization for Security and Cooperation in Europe (OSCE), USAID (the U.S. State Departments aid organization), as well as non-governmental organizations (NGOs) such as the Red Cross, Red Crescent, Doctors Without Borders, etc.

All together there were nearly fifty organizations, all working towards a similar goal of restoring Kosovo to a safe and secure environment, but working within their own organizations goals and doctrines. It was common for MNB(E) and multiple other organizations to work together to solve problems such as conducting cordon and search operations where US forces provided the cordon and UNMIK-P provided the search force so that prosecutions could result or MNB(E) providing transportation and security to support the United Nations High Commission on Refugees (UNHCR) conduct a resettlement of refugees or displaced civilians back to their local communities. Applications and services based on Engineered Knowledge would have been useful tools in representing each organization's doctrine.

Doctrine, as noted above, can be viewed as constraining in a Network-Centric Environment. However, in order to build advanced planning services and automation to support complex endeavors, our hypothesis is that it will be necessary to address doctrine and intent, not as implicit concepts, but explicitly and formally. This starts with a body of knowledge about an organization that is developed in the context of how an organization operates. We have described one approach to building this knowledge, which we call Engineered Knowledge. After Engineered Knowledge is built about an organization, we believe that C2 communications can be exchanged via a formal language like the C2LG. Using a formal language has the potential to abstract up from the many data models and unique message formats now in use. We have used the C2LG in the area of Simulation Interoperability (Pullen et al., 2008a) and built Engineered Knowledge for Geospatial Battle Command (Hieb et al. 2007a, Hieb et al. 2007b). While in the early stages of this research, key issues currently being addressed are how to share and understand Engineered Knowledge as well as how to develop applications that can best use a formal grammar for C2.

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