Making Plans Alive

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Knowledge Systems for Coalition Operations, September 2010

Abstract

Over the years, researchers have expended considerable effort in attempts to improve military planning, most notably via the provision of automated planning support tools. While there have been some successes (e.g. the DART system which was used for movement planning during Gulf war), planning still remains a very human-orientated activity with little technical support. Why? A possible reason for this predicament is that researchers have not fully conceptualized the problem that planners face. For instance, a common approach has been to consider planning as a single process or a homogenous set of problems to be solved. Unfortunately, military planning is instead a set of heterogeneous and interrelated activities carried out by different sets of planners working at different times and locations. In addition, these sets of activities may be conceptually quite different from each other. It is therefore proposed that military planning should be viewed more appropriately as a capability, which consists of a set of diverse activities which are collectively aimed at producing a set of coordinated plans to achieve given high-level mission objectives. This perspective, while essentially human-centered, suggests where it is possible to provide beneficial automated support. This paper thus proposes a conceptual framework for providing automated support for aspects of the planning capability. It will describe the complex nature of military planning and proposes a pragmatic approach to providing planning support tools. This work is one part of the International Technology Alliance (ITA) research on collaborative shared understanding and problem solving over a network, where military planning is an example of distributed collaborative problem solving [1].

1 Introduction

> *"No matter how well one may fire a howitzer, plant a mine, manoeuvre a tank, pilot an aircraft or shape a ship's course, if the equation is wrong at the top it will eventually fail to produce the desired results."[1][2].*

Military operations, like many other major enterprises, have two intertwined phases: planning and execution. The former is intellectually the most demanding, and if not properly thought through, could seal the fate of the latter before it even commences.

Over the years, military planning has received considerable attention from researchers with the aim of providing automated planning support tools. For example, the ARPA/Rome Laboratory Planning Initiative was a large funded program which ran from 1989 to 1998 which demonstrated advanced concepts for planning and scheduling to support military crisis action planning [3]. This effort produced some notable successes including the Dynamic Analysis and Replanning Tool (DART) system which was used for movement planning during the first Gulf war [4]. Unfortunately, such point examples of success have not led to more generic successes in planning support tool provision. As a result, there is a dearth of specific planning support tools; and the planning activity remains primarily manual supported by standard office automation tools used mostly in the generation of written orders. One might reasonably ask why this should be so.

One explanation for this may be that researchers have perceived planning to be a single process or a homogenous set of problems to be solved, with automated solutions designed on the basis of such assumptions. Instead, military planning is a set of interrelated activities that are carried out by different sets of planners working at different times, in different locations, and with different perspectives [5]. These activities may be conceptually quite different (e.g., identifying the best location for a fuel dump, moving troops, deploying sensors, fire planning, determining courses of action). It is therefore argued that military planning is more appropriately viewed as a *capability* that consists of a collection of different activities jointly aimed at producing a set of coordinated plans to achieve given high-level mission objectives. This perspective, while essentially human-centered, can be used to help identify the key areas where automated support may be most beneficial. It preserves the human contribution to the planning process that allows for maximum utilization of human knowledge, creativity, experience, and situation awareness while offering automated support to increase planning effectiveness.

In this paper we present a conceptual framework for developing a human-centric military planning capability. Though the framework is primarily focused on facilitating planning knowledge generation and management, it uses constructs that could also be used by synthetic agents to support knowledge exploitation, particularly for dynamic planning and execution.

The paper starts with a description of some of the key characteristics of military planning that form the basis of our conceptual framework. Together, these implicitly provide a means of identifying requirements for support tools. To this end, the paper then presents some of research on the Collaborative Planning Model (CPM), a mechanism designed as a means to realize the conceptual framework [6].

2 Characteristics of Planning

2.1 Collaboration

Military planning is a collaborative activity involving a large number of military staff working in teams on different aspects of a plan[1]. For example, figure 1 shows how combat planning teams and other functional planning teams collaborate. These teams typically work in parallel. This way of working was first used by Napoleon (hence referred to as the "Napoleonic Staff System"), in which planners work collaboratively across functional areas and across echelons to ensure a coherent and synchronized set of plans[7].

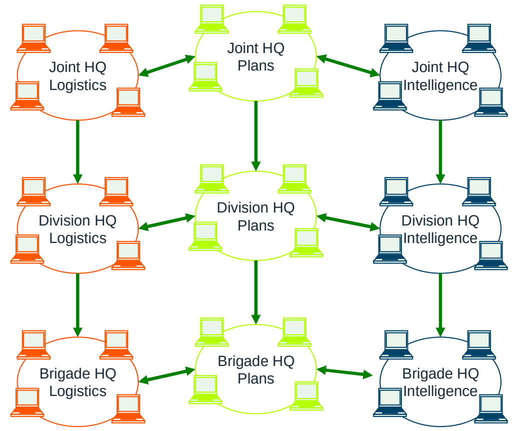

Figure 1: Collaborative Plan Development

The main battle (or maneuver) plan is developed by the *Plans* team who take inputs from the functional area teams (e.g., *Logistics* and *Intelligence*). For example, based on their assumed combat activities, the *Plans* team might get estimated figures for the fuel and ammunition requirements from the *Logistics* team. The functional areas will also produce their own supporting plans. While the combat plan is finalized, the *Logistics* team will start planning on how best to store and deliver the necessary fuel and ammunition to their own troops wherever they are likely to be on the battlefield during various phases of combat plan. Thus, these teams work in close collaboration to ensure synergy and consistency between their individual plans.

In order to generate timely and effective plans, there needs to be a shared understanding of the operational objectives and of the evolving plan between the *Plans* team and the functional planning teams at every echelon. A key aspect to achieving this shared understanding is an understanding of the primary reasoning of others as they go through their individual estimation processes. Currently, there are at least two impediments to successful collaboration: the increasingly distributed nature of the work and the eternal difficultly of communicating information without misunderstanding, in this case in regard to the content of plans that are shared.

The *Plans* team and functional planning teams are usually working at different locations with communications (voice and data) links. Each team gathers a large amount of data during planning, , which in turn generates new information, only some

[1] At the top level there is only one campaign plan. This plan will have a number of annexes describing the different supporting plans. At the tactical level, there will be different detailed mission plans for the combat and the supporting plans. However, all the plans are supposed to be coherent and coordinated.

of which is shared with other teams. Management and sharing of appropriate subsets of this information remains a challenge.

One of the possible reasons for less than optimal shared understanding between planners is the fact that plans are currently captured in a static representation such as text or diagrams [5]. These representations do not typically contain the rationale, constraints, or assumptions for the decisions related to the plan. Thus, based on associated research on possible causes of miscommunication in coalition operations which has demonstrated that context plays an important role in fostering shared understanding [8], the exchange of current representations only is not likely to lead to effective development of shared understanding between planning teams.

2.2 Specialisation

Two ways of categorizing planning are with regard to phase and organisational level (e.g. for phase this might be deliberate planning prior to deployment and crisis-action planning during operation [9] and for level and types of decision made this could be strategic, operational and tactical). The two categorizations are not entirely dissimilar as one can map, for instance, tactical planning to crisis-action planning. A fundamental flaw in both categorizations is the implicit suggestion that the different phases are discrete and can be conducted independently. Unfortunately, this is not the case. The plans generated by the *Plans* team and the supporting functional planning teams needs to be coherent and synchronized. Therefore, there is a close link between plans generated at different command levels and across the functional areas.

Figure 2 shows a high-level view of a typical military command organisation. Each node contains both the *Plans* team and supporting functional planning teams at that command level (the three horizontal teams in Figure 1). Each of the cells (peer groups at the same level of command) depicted in Figure 1 requires specialist knowledge. For instance, the Engineers might produce a combat supporting plan for building bridges and runways for aircraft, the Logistics unit might produce a plan for setting up maintenance areas and schedules for the provision of supplies in theatre.

There are at least two different type of information processing happening within the functional planning cells: provision of information for the combat estimate (e.g., there is sufficient ammunition to support a month's supply), and producing a plan and schedule for the delivery of supplies. The first is an analysis activity which feeds into the second, which is a planning activity.

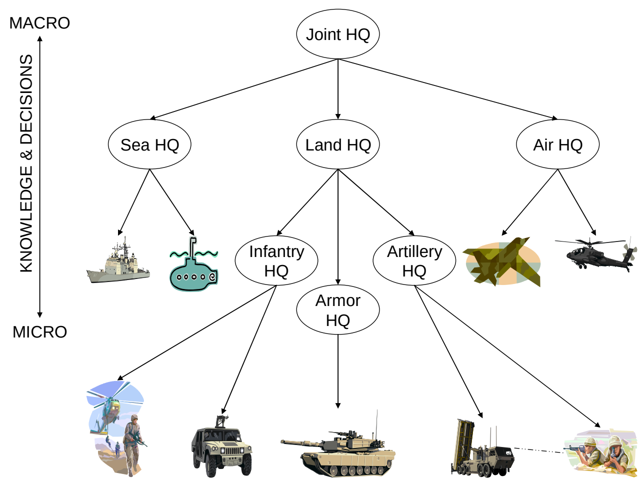

Figure 2: Knowledge and decisions levels in Command

While there is difference in specialization between peer groups, there is also a significant difference in the type of information the teams at different command levels (superior and subordinate nodes) use and the type of decisions made. At the higher command level, granularity of information processing and outputs are relevant to macro-level decisions (e.g. this will be primarily a ground operation with close-air support provided by the Navy). As planning progresses down the command-chain, the level of information processed is more detailed (e.g. covering the specific land assets to be used). At the higher joint-level (where, for example the campaign plan is developed) one would look at terrain from the perspective of deciding force composition. At a lower-level battalion HQ, relevant battlefield terrain would be examined for suitability for setting up maintenance areas, determining movement plans and identifying locations to engage the enemy.

Figure 2 is an illustration of a typical hierarchical military structure. For the purpose of designing planning support tools one needs to understand the more detailed information processing occurring within a node and between nodes. The planning teams (*Plans* team and supporting functions) working at the same command level use different domain knowledge. Therefore there a number of plans which collectively form a coherent set of synchronized activities aimed at achieving higher-level objectives. These sets of plans are then fleshed out in greater detail as planning goes down the command chain.

The implication for planning support tools is that they need to support the specialist functions of different planning cells. Furthermore, they should facilitate information management so the information gathered at the higher-level is gradually built upon as the elaboration process moves down the command hierarchy and more detailed information is gathered and incorporated.

2.3 Communication

Figure 3 illustrates typical areas of responsibility for Plans cells and an Operations cells. The Plans cell tends to look at longer-term future plans, while the Operations cell focuses on current plans and their execution.

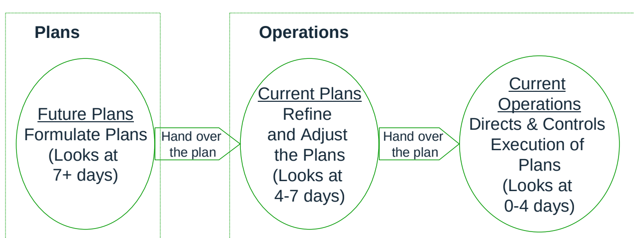

Figure 3: Plans-Operations interactions

There are two key communication channels: between the planning teams, and between the planning teams and operations teams. The issues related to the former were discussed in the previous two sub-sections. The latter requires more attention as communication is across a different and more challenging type of boundary. In addition, the hand-over (of plans) process is often rushed due to time pressures (e.g., paper copies of the plans are handed over without detailed background briefings on the issues, constraints, and assumptions that were considered during the planning process).

The lack of transfer of contextual information subsequently creates problems when the Operations cell needs to amend the plan. Because the Operations cells were not involved in the development of the plan, they also do not have the knowledge-forming benefit of long deliberations that went into the plan formulation stage. Therefore, during the handover of the plan to the Operations staff, a detailed and comprehensive brief should ideally be conducted. Unfortunately, due to frequent pressure on time, this is often not possible.

Effective transfer of knowledge from the Plans cell to the Operations cell is essential; both for the purpose of generating correct Operational Orders and undertaking replanning[2] in light of a changing situation. As most of the replanning occurs during the execution phase, the responsibility for making the necessary changes falls to the Operations Cell (as Planning teams are by then busy generating plans for the next phase of the battle). Thus, initial planning and subsequent replanning are generally undertaken by different staff [5].

Like planning, replanning is also a knowledge intensive activity and ideally should exploit the understanding that was generated during the planning stage. A large proportion of this understanding is not transferred in the communicated plan. Currently, there are no proper mechanisms for representing and communicating this understanding in a way that can be adequately utilized in the replanning process.

2.4 Changing Situation

The constantly changing situation that causes plans to be rapidly invalidated is fact of life that the planning community is acutely aware of. Indeed, the mantra that *plans are nothing, planning is everything* is used to emphasize the fact that the situation (your own, the enemy, and the environment) is constantly in a state of flux as a result of your own, enemy, and third party actions. The usual consequence is that plans need frequent updating to stay current. However, such dynamic forms of planning are difficult to execute in military theatres of operation due to lack of both time and knowledgeable resources. According to General Rabin, "it would not do to wait for detailed planning to be completed before starting a move; such a delay is harmful and should not be tolerated." [10].

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[2] Replanning is used here to refer to plan repair or amendment.

As an alternative to dynamic planning, the military employ the approach of developing contingency plans. Unfortunately, due to the open-ended nature of military problems, it is not possible to produce contingency plans for every possible eventuality. Thus in reaction to a change of situation, the normal approach is to adapt the contingency plan closest in nature to the situation at hand. Obviously, this is not a terribly effective means of handling unpredictable situations, especially as certain changes will unfold new goals [11], for which there may be no appropriate contingency plans available. It is therefore not possible to amend the plan without some understanding of the evolving goals. As a result execution involves improvisation and a lot of peer-to-peer coordination. For example, during the 1967 Arab-Israel conflict, of the four day campaign by the Southern command "only the first day was planned in detail, the remaining days were pure improvisations" [10].

Replanning, like planning, is a complex cognitive task that requires both time and effort. Unfortunately, in theatre both of these are at premium, hence improvisation is the norm. This is obviously very risky and could negatively impact operational effectiveness. Aitken et al. [5] have investigated the possibility of providing automated planning support tools to help dynamically replanning during execution. This approach, however, relies on the availability of necessary information from the planning stage.

3 HUMAN-CENTRIC FRAMEWORK

3.1 Requirements

From the planning characteristics described above we can distil the following requirements for planning support tools:

1. A tool must support coordinated activities carried out by different teams, which may not be co-located (collaboration, specialization)
2. A tool must support the diversity in information requirements and processing done in each of the teams (collaboration, specialization)
3. A tool must support both planning and replanning[3] which involve different types of information processing[4] and is carried out by different staff, e.g., Planning or Operations (communication)
4. A tool must support replanning during the execution phase to account for the dynamic nature of the battlespace. Due to time constraints there is a need for automated support for replanning (changing situation)

3.2 Solution Options

Before looking at the possible planning support options, it is assumed that all planning teams will be using some form of planning support tools[5]. The measure of usefulness of a solution approach is whether it is able to adequately meet the above requirements. The following are the main options:

- *Single Planning Tool* – the same tool is used by all planning teams. This is not a good option as it meets none of the requirements.
- *Common Planning Tools* – superior and subordinate planning teams use same planning tools, which are different for different functional areas. This is a possible option, but it will not adequately meet the second requirement. Also, if the common tools are used by superior and subordinate cells, there will be strong tendency over plan by the superior cells.
- *Different Planning Tools* – different planning teams use tailored tools to meet their needs. This approach only partially satisfies the above requirements, assuming tools are able to exchange data. It however falls short on addressing the issue of how one fosters shared understanding and ensures coherence in the plan generated by different teams.

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[3] Replanning here refers to plan repair or modification in light of a changed situation. This activity normally falls within the execution cycle.
[4] Planning involves generation and selection of courses of action (COAs) whereas replanning will involves modification of the current COA.
[5] In this paper we have not differentiated planning support tools in terms of what functionality they provide. The assumption is that these tools will provide all necessary support to generate COAs and produce hard copies of Operational Plans.

- *Different Planning Tools Linked with a Common Representation* for planning concepts – different planning teams use tailored tools to meet their needs. This approach does satisfy the above requirements.

3.3 Proposed Framework

It is proposed that for the generation of timely and quality plans human planning teams need to be supported by a network of planning support tools. These tools should be tailored to the needs of individual planning teams. The only requirement on the tools is that they use a common representation of the planning concepts[6]. The common representation can be the basis of the tool, or if an existing tools has its own semantics, then interoperability can be achieved by creating a mapping between the ontologies. So what is shared between teams are planning concepts, as illustrated in Figure 4.

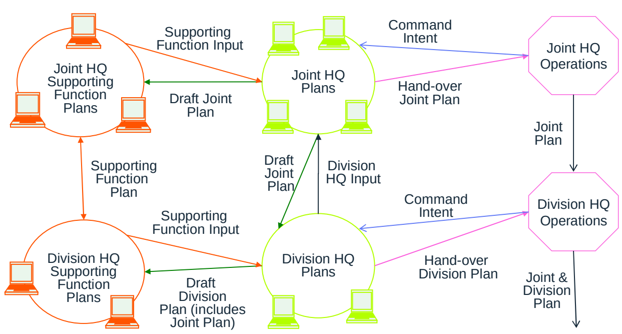

Figure 4: Flow of Plans

In Figure 4, "Joint Plan" includes all of the information that the Joint HQ Plans cell has generated during the planning process. This is held digitally so different planning teams are able to selectively visualize and amend the plan as necessary. As such, the plan is alive. In contrast, the current military planning process involves exchange of paper copies of "plans", which consist of just the final, static, abridged outputs of the planning process [5].

[6] Example of planning concepts include: Objectives, Tasks, Activities, Effects, Units, Agents and Main Effort.

The information flow process is as follows: once command intent is received, the Joint HQ Plans cell will generate a joint plan, which is sent to the Supporting Functions cell and Division HQ for their inputs. Once the joint plan is finalized, it is handed over to the Joint Operations cell for execution. The plan flows down the command hierarchy, and at each level it is fleshed out with more details. This process continues until it is finally executed. However, as noted the previous section, plans are continually modified during the execution cycle. With a digital version of the plan it becomes feasible to employ synthetic agents to carry out plan modifications, particularly in time-constrained situations (e.g. dynamic planning and execution).

Example benefits of digitizing plans includes:

- Increased shared understanding between planning teams, as they are now able to see significantly more underpinning information (e.g., assumptions, constraints, rationale) in the plans.
- Decrease in information load as synthetic agent technology can be used to quickly process information (e.g., route planning) leaving humans to focus on important tasks. This will improve the timeliness for generating plans.
- Improve plan quality by making it easier to verify and validate plans using modeling and simulation tools.

The proposed approach is based on the proposition that a comprehensive and reliable plan representation scheme can be developed. This is a research question and is the subject of ongoing research in the International Technology Aliiance (ITA) Program described in the next section. Other challenges include knowledge acquisition (how to get planning teams to encode their thought processes into the system), visualization (visualizing relevant parts of the plan), plan version control (as plans are continuously modified by different planning teams), sharing plans (exchanging only changes elements of the plan to reduce network traffic).

4 Plan Representation using the CPM

There is a research strand within the ITA program investigating how to improve shared understanding in distributed teams collaboratively solving a common problem over the network [12]. The research has taken Military Planning as an example of collaborative problem solving.

One of the activities in the research strand is developing a representational scheme for military planning. This plan representation language is called the Collaborative Planning Model (CPM). The CPM is a representation ontology developed to support military planning by distinctly representing goals, plans, constraints, and human rationale associated with decisions made while creating the plan [13]. The CPM ontology is represented in a Web Ontology Language (OWL 1.1) and is capable of representing planning concepts typically present in "static" documents (e.g., objectives, tasks, decision points, resources) as well as assumptions, constraints and human rationale associated with decisions made while creating plans [13].

While a useful machine understandable representation, raw OWL is not a human friendly representation [13]. To address this we have taken two approaches. Firstly we have developed a human-readable Controlled Natural Language (Controlled English [14]) that can be mapped to and from OWL. Secondly we have explored plan-specific visualization by creating three independently-developed tools with the ability to create, edit, visualize and exchange plans in CPM: the IBM Visualiser, the Boeing Graphical Plan Authoring Language (GPAL) Tool, and the Honeywell PlanEditor. Two of the tools (Visualizer and PlanEditor) were developed explicitly for CPM, while one tool (GPAL) was developed independently with its own semantics and extended to allow for the exchange of plans in CPM. The tools provide a graphical representation of the spatial and non-spatial aspects of the plan, including a display of the plan on a map and the relationships between entities such as objectives and tasks; facilities for editing the plan including objectives, tasks, resource requests, and assignments; capabilities to import and export plans in CPM/OWL; and the display and capture of the rationale for properties of plan entities.

4.1 Initial CPM Evaluation

Initial functionality of CPM was evaluated in September 2008 by three UK military officers [15]. A brigade level plan was produced on the Visualizer by one military officer. The plan was then forwarded to the battlegroup commanders (the other two officers). The battlegroup planning was done on two different laptops, one with Visualizer and other with the PlanEditor. The battlegroup plans were then merged on another laptop to identify resource conflicts. This exercise demonstrated the feasibility of using a common plan representation to collaborative problem solving using different tools [15]. However, since the tools used for this exercise were designed for CPM, the findings were deemed to be limited. Additionally, only UK planning was represented, and it was important to understand if the CPM could repesnt US planning concepts. Finally, this evaluation only addressed battle planning, and thus functional planning was not represented.

4.2 Dry-run for Second Evalution

In preparation for a detailed evaluation of CPM's capability to represent collaborative human generated battle and functional plans at two levels of command of a joint US-UK operation, we carried out a dry-run with the help of two US and a UK military officers over one and half days in March 2010. This exercise suggested that CPM is able to represent most of the US planning concepts, and that at the conceptual level there was not any significant difference between US and UK[7].

While not formally examined, we had the opportunity to develop and share plans between the Visualiser and GPAL. This finding was interesting considering that the G-PAL ontology is different from the CPM, but the G-PAL system can import and export CPM plans [16][17].

4.3 Future Challenges

Evaluations [15] of the CPM has highlighted potential challenges that must be met when achieving shared understanding in more complex multi-level collaborative planning, including issues of representational semantics, rationale, configuration management, visualization utilizing context and filtering, plan interoperability, and interfaces.

The continuing challenge in building the CPM is to ensure that it contains the representational semantics needed to capture all the relevant

[7] Most of the identified differences were purely linguistic as suggested by [8].

constructs within the planning process. Thus it must have both broad and deep semantics that can support the range of planning from pre-deployment to dynamic ad-hoc re-planning during execution. Ideally as plans are modified, there would be some form of audit trail to further enable someone to uncover the history of the plan to better understand its current state.

Recent discussions with US planners during “dry run” planning session revealed that the rationale in the form of dependencies between tasks was important; in addition the presentation of draft plans was also accompanied by statements of rationale [18]. There are still many issues to be addressed in the construction of rationale in the CPM: the multiple sources of rationale information, structured vs. unstructured rationale, the capture of rationale in formalisms like Controlled English, and the utility of context in creating and interpreting rationale.

Given the complexity of coalition plans, it is difficult, if not impossible, for every planner to understand all details of the entire plan. In fact, each plan participant has his or her own role in planning process, and therefore may only need to understand a small portion of the plan, along with additional contextual (including situational) information that is not necessarily included in the plan itself [15][19]. This has implications for how to share plans or portions of plans between functional teams and between levels, how to visualize plans at different planning levels, and how to provide information during the planning process. In our approach, the same planning element will be used for every situation or context [19]. What changes from context to context is not the representation of specific planning elements but what attributes, features, or relationships should be represented. Context aware representation speaks directly to the task-specific concerns and interests of specific group of users and, as such, it will selectively represent aspects of the plan and feature representations in which the user operates. Thus shared understanding may not require an understanding of the total plan, only those parts relevant to the planner’s task in hand.

Configuration management involves identifying plan revisions at given points in time, systematically controlling changes to the plan, and maintaining the integrity and traceability of the plan throughout the lifecycle[15]. Configuration management poses a challenge in multi-level planning environments. As the plan evolves and different versions of plans are generated, the problems worsen. Planning constraints and version restrictions can be encoded in CPM/OWL that can facilitate the sharing of knowledge about configurations, across various systems. Additionally, as more plans are created, it would be possible to create libraries of partial plans that could be used starting a new plan. How to archive and index such a partial plan library is another challenge to be addressed.

It will be necessary to reconcile different military vocabularies. Experience in discussion with military experts suggests that the terminology and concept definition in different nationalities and areas of planning can be conflicting and confusing. Traditionally, terms are introduced by defining them in terms of others, and we propose a similar approach. CPM seeks to define generic concepts, that are not necessarily one-to-one with military terminology (due to the confusions of the latter), but that have a logical meaning. We then propose to map key military terminology onto the more generic CPM concepts, thus different cultures could share understanding of the same underlying concepts.

Finally, interfaces must support all phases of the military mission, from pre-deployment planning through execution to post operation activities. While the CPM allows for entities and modeled concepts to follow a plan through all phases, there still remains the challenge of how to effectively capture data along the way to support the capture of rationale, planning alternatives considered and discarded, and other elements of the problem solving process.

ACKNOWLEDGMENTS

Research was sponsored by the U.S. Army Research Laboratory and the U.K. Ministry of Defence and was accomplished under Agreement Number W911NF-06-3-0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the U.S. Army Research Laboratory, the U.S. Government, the U.K. Ministry of Defence or the U.K. Government. The U.S. and U.K. Governments are authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation hereon.

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