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Knowledge Management as a Supporting Concept to Effects Based Operations

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Abstract

Effects-based operations (EBO), which are based on a holistic understanding of the operating environment, differ from conventional operations with regard to the importance of integrating diplomatic, information, economic as well as the military instruments of power. Knowledge management (KM) is an essential concept to support EBO. The multi-national experiment 4 (MNE 4) was designed to assess and refine the EBO process, organization, and technologies (POT). The working KM definition for this experiment is the governing and facilitating of knowledge activities. The aim of this paper is to develop a methodology to evaluate the effectiveness of KM in supporting EBO.

The experimental hypothesis is that if the KM Plan (based on above definition) is implemented during MNE 4, then:

1. The governance and facilitation of knowledge activities will be robust (reliable, stable, and scalable) across the EBO POT; and
2. Governance and facilitation of knowledge activities will contribute positively to holistic understanding, decision-making, common intent, and mission completion.

This paper describes the KM concept, experimental design, and reports some experimental results from MNE 4. The paper concludes with a short discussion and recommendations for improvements to the multinational KM Plan.

INTRODUCTION

BACKGROUND

The Multinational Experiments (MNEs) are a set of experiments whose goal is to explore concepts and supporting tools for effects-based operations. Effects-based operations (EBOs) are defined as:

> *Operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims*. [1]

EBOs differ from conventional operations with regards to the importance of integrating the various instruments of power (including military and non-military as well as across participating nations) and basing the operation on a holistic understanding of the operational environment[1]. In other words, EBOs require both a broader and deeper understanding of the operational environment and an understanding of how available instruments of power beyond just force-on-force engagements can influence this environment. It requires the coordination and synchronization of the activities of various actors (governmental and non-governmental) that traditionally are not used to talk to each other and the planning of these activities based on the expected effects they will have on the operational environment.

MNE 3 was held in February 2004 and focused on effects-based planning[2]. A key conclusion of MNE 3 was: "The effects-based concept has the potential to make the coalition task force and NATO Response Force more effective instruments of power. However, the effects-based planning concept as developed for Multinational Experiment 3 is not operationally mature and requires further refinement."[2, 3]
The Multinational Experiment 4 (MNE 4) has been designed to address these refinements.

MNE 4 OVERVIEW

The aim of MNE 4 is: "To explore concepts and supporting tools for effects-based operations within a coalition environment involving stability operations with increasing levels of violence in order to assist the development of future processes, organizations and technologies at the operational level of command." [4] The MNE 4 experiment consisted of various limited objective experiments conducted between August 2004 and January 2006, followed by a main event experiment conducted over three weeks, between

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[1] A holistic understanding requires the analysis of the political, military, economic, social, infrastructure and information aspects of the operational environment and the dynamic of these aspects.
[2] Note that, as specified by the definition of effects-based operations, effects-based planning is only a limited part of EBOs, which also require effects-based execution and effects-based assessment.

27 February and 17 March 2006 (see [4] for details). Briefly, MNE 4 was a prototype refinement experiment using a human-in-the-loop virtual experiment method. For the main event, the experimental unit consisted of two operational level commanders and their functionally organized headquarter staffs. The two headquarter staffs operated independently. One was a Coalition Task Force (CTF) and the other a NATO Response Force (NRF). Participating countries within the CTF included Australia, Canada, Finland, France, Germany, Sweden, United Kingdom, and the United States. The CTF and NRF headquarters were organized differently and used slightly different sets of tools. However, both headquarters were required to plan, execute, and assess an effects-based operation whose goal is to provide stability in a precarious area of Afghanistan.

The effects-based operation (EBO) under scrutiny during MNE 4 went beyond the effects-based planning (EBP) concept explored during MNE 3. It included the following concepts: Knowledge-Based Development (KBD), Effects-Based Planning (EBP), Effects-Based Execution (EBE) and Effects-Based Assessment (EBA) (see ref. [1] for a definition of these concepts). The experiment also examined concepts required to support EBO, including multinational interagency group (MNIG), knowledge management (KM), and information operations (IO). For the main event, the headquarter staff was subdivided in various functional group, each assigned to one of the main concept (KBD, EBP, EBE, EBA) or one of the supporting concept (MNIG, KM, IO).

AIM

The aim of this paper is to describe the analysis of the knowledge management (KM) part of the Multinational Experiment 4 (MNE 4). In particular, it describes the KM experimental objectives, the experimental measures, and the analysis of these measures. Note that the focus of this paper is on the methodology used for the KM analysis: The paper will only provide a partial analysis of some of the experimental results obtained for the CTF headquarters during the MNE 4 main event.

OUTLINE

Before stating the KM measures, it is necessary to discuss our view of knowledge management. For this purpose, Section 2 provides a definition of knowledge and knowledge activities. These definitions are used to introduce the various activities that are embedded into knowledge management. As can be seen from this section, we consider a large view of KM encompassing many activities. Based on the introduced concepts, experimental hypothesis and objectives for the KM part of MNE 4 were designed. These objectives as well as the experimental measures necessary to test the hypothesis are explicated in Section 3. Due to the limited size of this paper, section 4 provides only a brief overview of the analysis of the measures done to support the objectives of the experiment. Finally, Section 5 reviews the conclusions of the experiment and brings forward recommendations for an improved KM Plan.

KNOWLEDGE MANAGEMENT CONCEPTS

KNOWLEDGE DEFINITION

While knowledge is a central part of daily life, it is hard to provide a clear-cut and precise definition of this concept. According to Allen Newell: "When a system has and can use a representation of something (an object, a procedure… whatever), then the system itself can also be said to have knowledge, namely, the knowledge embedded in that representation about that thing." [5] This definition of knowledge supports the Platonian view that abstract ideal representations are the source of all knowledge.

From this definition of knowledge, the difference between knowledge and information is explicit. While information can be transmitted through messages of one kind or another (e.g., oral, written, pictorial, or gestural), knowledge involves mental representations and possesses a value of confidence (belief that the representation is valid at least under given conditions) and usability (purpose of the representation).[3] For this reason, knowledge can only be imperfectly transmitted.

To guide the discussion about knowledge management, we will represent the concept of knowledge (K) related to a subject (S) as the interpretation of a proposition ($P(S)$) concerning that subject to which is associated a degree of confidence, μ:

$$K(P,S) = \langle P(S) \rangle_{\mu}$$

The accolades, $\langle \ldots \rangle$, are used to designate the interpretation and $P(S)$ designates the proposition. A proposition concerning a subject S is equivalent to saying that the subject, S, possesses an attribute or property P. The proposition corresponds to some type of information that is received.

The interpretation of the proposition depends on the individual's mental representation (or sense-making[4]) of the subject and of the attribute. These representations depend furthermore on both the individual's past experience, which is embedded in his/her overall knowledge, and the context in which the information is received. Since knowledge impacts the interpretation that defines the knowledge itself, this view of knowledge agrees with Von Krogh's self-constructionist view [8], also called *autopoiesis* (*poiesis*: from the Greek, meaning production or creation).

Finally, the degree of confidence, μ, is specific to a given interpretation. The degree of confidence captures the degree of belief related with the proposition. Knowledge that is considered matters of fact or supported by a scientific formalism will have a large degree of confidence, while knowledge that is trusted simply because it appears to be the most

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[3] Note that although most people agree about this difference regarding knowledge and information, most of the knowledge management studies done to this day focus on information management.

[4] Recent studies have indicated that instabilities of neural processes would be involved in representing and processing of information by the brain [6]. These studies support the view that the theory of complexity could be used to model sense making processes [7].

plausible explanation could have a much lower degree of confidence. In general, the degree of confidence depends on numerous factors including an individual strong set of beliefs and the source of the information. This representation of the degree of confidence is supported by Cox's conjecture which stipulates that a single number is both necessary and sufficient for its representation [9].

Using the definition of knowledge as introduced above, one can model an individual's knowledge with regard to a set of subjects $\{S_i, i = 1, ...M\}$ as an ordered set of knowledge elements: $\{K(S_i, P_j), i=1,...,M; j=1,...,N(S_i)\}$, $N(S_i)$ being the total number of properties of the subject S_i known to the individual. Note that an ordered set[5] is used to model the individual's knowledge rather than the simple union of knowledge elements since the interpretation associated with a given element, $K(S_i, P_j)$, depends on the overall knowledge and thus on the other elements of knowledge. The order of the knowledge elements depends on external factors such as the individual priorities and the fundamental beliefs of the individual.

Generally, depending on the purpose of the study, only a specific subset of an individual's knowledge will be modeled[6]. In particular, it might be useful to limit the knowledge set considered to the knowledge elements on which the individual's mind focuses on. Such limitations will allow one to analyze, for example, the knowledge management support to the individual to focus is thoughts or to recall other knowledge elements.

Finally, note that there are no requirements that the set of elements of knowledge be consistent or complete. An individual can have and most likely will, have only a limited knowledge of a subject and some elements of his knowledge can be inconsistent with others.

KNOWLEDGE ACTIVITIES

Knowledge management has the aim of managing the knowledge activities; or, in other words, to govern and facilitate the knowledge activities. Using the aforementioned concept of knowledge, one can formalize and categorized the various knowledge activities. There are activities that will introduce new elements in the individual knowledge sets, activities that will remove some elements, activities that will modify some elements (either the interpretation, or the degree of confidence), and activities that will change the order of the knowledge elements. These five categories will be called: knowledge creation, knowledge elimination, knowledge interpretation, knowledge formalization, and knowledge prioritization. Having introduced these categories, it is

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[5] The terms "n-tuple" or "list" are usually prefered in Computer Sciences since the term "set" is reserved for union of entities where the order of the union is irrelevant (see for example [10]).

[6] In fact, it might be utopist to try to model an individual's whole knowledge set. Furthermore, a clear-cut division of this whole set into knowledge elements can be impossible. However, it is assumed here that such a division is possible for the knowledge set of interest.

important to highlight that some specific activities might not easily be categorized. In particular, one should consider the following observations:

- The classification of knowledge activities, as defined above, leads to a clear distinction between information management and knowledge management. In particular, activities like information sharing and information distribution [9] are classified as information activities rather than knowledge activities. More precisely, information management is about how to get the information to the right person at the right time and only has an indirect influence on the knowledge formation; while, knowledge management is about what the individuals do with this information.
- The various knowledge activity categories are not independent. In particular, if the degree of confidence of a knowledge element is reduced below a given threshold, then the element is simply removed from the set of beliefs of the individual. In other words, this is equivalent to a knowledge elimination activity. Similarly, the modification of the interpretation of an element of knowledge has the same outcome as eliminating an element and creating a new one corresponding to the new interpretation.
- Most knowledge activities do not belong to a single knowledge activity category but rather have a mixed impact. A specific activity should be categorized based on its primary impact.

The following sub-sections describe more precisely the various knowledge activities.

Knowledge Creation

Knowledge creation activities are activities focusing on increasing the individual's knowledge. These activities can be subdivided into three groups:

- Some knowledge elements are recalled by the individual.
- New information is accessed and interpreted leading to new knowledge.
- New knowledge is obtained through a reasoning process on knowledge previously obtained. This reasoning process can be performed individually or with the support of other individuals inside a working group. Decision-making is an example of such activity where a new knowledge, "Option X is the best option," is obtained through the analysis of various options already known.

The knowledge creation activities can be governed and facilitated through knowledge management rules and also indirectly through information management. Information management supports the acquisition of new knowledge obtained by providing a knowledge based system (information sources) and various tools to efficiently access the information sources and share information between individuals. This is an indirect influence that concerns the management of information rather than knowledge itself.

Information management can also facilitate the decision-making and analysis process by establishing appropriate working groups, facilitating the development of Communities of

Practice (CoP) and provide supporting tools like Expert Systems[7] and Consensus Ranking software (for example, FIDO [13, 14, 15]). Knowledge management, on the other hand, can support knowledge creation by setting contexts that help the individual to recall useful knowledge.

Most of the research in information and knowledge management concerns the governing and facilitating of knowledge creation activities. In particular, Pavitt [16] summarized five important discoveries with regard to knowledge creation:

- Groups outperform individuals for brainstorming and recalling processes.
- Based on Wegner's theory of transactive memory [17], an efficient communication allows groups to know everything known by their members.
- Groups do not perform as well as rational models predict. In particular, actual group performance is expected to lie between the Condorcet group and the ideal rational group performance [18].
- The degree of underperformance, compare to the ideal rational group, increases with greater group size.
- Group interaction is not an especially efficient method for pooling members' knowledge. In particular, researchers have observed that the knowledge-sharing processes can breakdown under given conditions and have identified ineffective group interaction leading to such breakdowns (see [19] for the study of interaction within small groups).

Knowledge Elimination

Knowledge elimination is obtained by reducing an individual's topic of focus. Knowledge management can facilitate knowledge elimination by helping the individual focus on the most important elements of knowledge and reminding him/her of the objectives of his/her tasks. It can also be facilitated through information management by filtering the information sent to the individuals.

Note that knowledge elimination is different from convincing an individual that some of his/her knowledge elements are false. This process corresponds to a knowledge formalization/knowledge creation process where the degree of belief in a knowledge element is decreased (knowledge formalization) and then the individual is convinced of the opposite propositions (knowledge creation). In fact, knowledge elimination is closely linked to knowledge prioritization activities where the priority of knowledge elements is modified.

[7] Expert Systems are software designed to support problem solving which possess the following characteristics: 1) The use of symbolic reasoning; 2) The use of heuristic methods for the representation and manipulation of information [12]. Expert Systems emerged from the field of Artificial Intelligence.

Knowledge Interpretation

Knowledge interpretation activities are processes where new information is assimilated and amalgamated within existing knowledge elements. Note that this process will affect the whole knowledge set. The interpretation activities can be influenced by the way the information is displayed. For example, the sentence '*The colleagues I met for coffee occasionally questioned me about knowledge management*' is ambiguous and can lead to alternative interpretations. After re-structuring the sentence as '*The colleagues I occasionally met for coffee questioned me about knowledge management*', a precise interpretation of the sentence can be ensured.

To facilitate an appropriate interpretation of the information, information management should provide rules to ascertain that the individuals in the organization adequately formulate their knowledge before sharing it. The management of the interpretation activities can be particularly difficult when the individuals differ largely in cultures and speak different languages. Thus, some issues can be expected with regard to the knowledge interpretation in EBO due to the diversity of organizations with different cultures (military, diplomatic…) that have to share information. Glossaries and a management team knowledgeable about the culture of the various organizations involved in the operation can help to reduce the risk of misinterpretations.

Knowledge Formalization

Knowledge formalization activities impact on the degree of confidence associated with the knowledge elements. Knowledge formalization can be managed by facilitating verification and validation processes of the individual's knowledge elements. This can be done, for instance, by informing the individual about the sources for the various information that was provided to him (KM), by encouraging a critical approach when faced with new information (KM), by facilitating the individual's access to subject matter experts (IM), and by providing confirmation theory-based Expert Systems that could help the individual to identify the evidence that support or oppose specific information elements (IM).

Knowledge Prioritization

The various types of information received by an individual is not all of the same importance. The individual must be able to discard irrelevant information and identify critical information. This prioritization process is greatly influenced by the way the information is displayed. For example, a red flag can be associated to important e-mails (KM), the most relevant information inside a text can be highlighted (KM), and the important information to an individual can be emphasized for him (IM). Current research in information technology is looking at developing more sophisticated tools to support the prioritization of the information and attention focus (see for example [20]).

EXPERIMENTAL SET-UP

MNE 4 KNOWLEDGE MANAGEMENT ACTIVITIES

For MNE 4, the knowledge activities were governed and facilitated by ensuring the implementation of the following activities:

- The development of business rules and policies for knowledge activities;
- The selection and integration of suitable resources (personnel, software and hardware) to support the various knowledge activities.
- The establishment of an organization to ensure the good working conditions of the tools provided; and,
- The development and distribution of a training package (including information about the processes, organization, and tools) for all participants of MNE 4.

The approach to implement those activities was explicated within a KM Plan [21] that was developed by the Canadian Forces Experimentation Centre following multi-national workshops [22].

KM Plan

The KM Plan was completed in October 2005. It provides a conceptual definition of knowledge management (KM is the governance and facilitation of knowledge activities) and proposed an organizational structure to support the KM activities for MNE 4. In this sense, it has aspects of both a strategic plan (describing the goal of knowledge management) and an implementation plan (proposing an organizational structure to support the knowledge management).

The KM Plan starts by identifying current knowledge issues with regard to military operations: “Operational commanders are faced with data and information overload yet they lack the means to synthesize data and information to provide the key knowledge elements required for timely and effective operational decision-making.”

Having argued for the need of knowledge management, the KM Plan then proposes a definition of knowledge management and a classification of knowledge activities. The knowledge activities, as defined by the KM Plan, are based on Nissen’s work [9] and differ slightly from those introduced in the previous section. In particular, the KM Plan makes no strict difference between knowledge management and information management. For this reason, knowledge management and information management were jointly analyzed, and observations as well as recommendations with regard to both, IM and KM, are provided in this report.

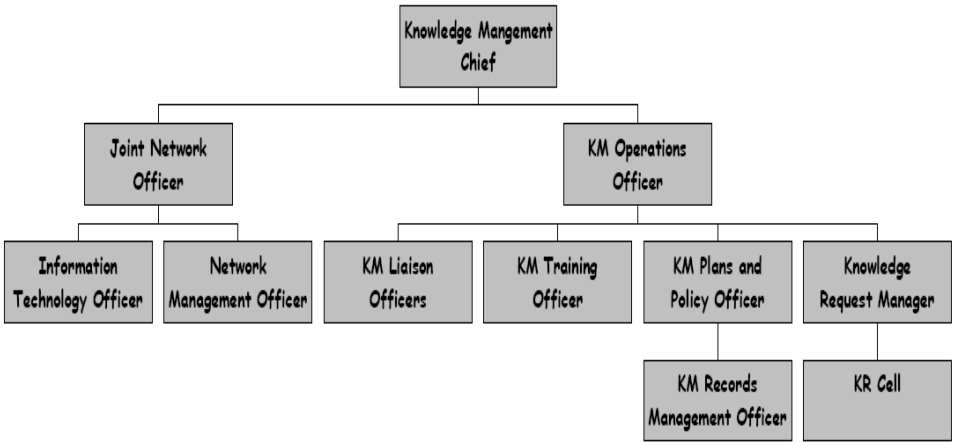

Figure 1. Knowledge management organization as proposed by the KM Plan.

The KM Plan ends by proposing a list of knowledge management activities, tools and organization to support the knowledge activities. The knowledge management team in support of the CTF headquarter staff should include a knowledge management chief, a KM operations officer, KM liaison officers, a KM training officer, a KM plans and policy officer, a KM records management officer, a knowledge request manager, a knowledge request cell, a joint network officer, an information technology officer, a network management officer (see Figure 1). A precise description of the roles and responsibilities of the KM team is to be found in the KM Tactics, Techniques and Procedures, but the KM Plan mentions the following activities:

- KM will institute and manage a knowledge request (KR) function. This function is to be used for the collection of new information; that is to say, information that does not reside within the databases (or knowledge base) to which the MNE 4 participants have accessed (note that the maintenance and the storage of information within the databases are activities under the responsibility of the Knowledge Base Development (KBD) team and not the KM team). These KRs will be prioritized in accordance with Commander's guidance;
- Collaborative Information Environment (CIE): The CIE is defined as “The aggregation of individuals, organizations, system capabilities, processes and infrastructure for the common purpose of creating and sharing data, information and knowledge necessary to plan, execute and assess CTF operations and to enable the CTF Commander to make better and faster decisions than the adversary.” KM will be responsible for the design and maintenance of the CIE.
- Knowledge Base (KB) Interface: A separate staff is devoted to the KB and to the Knowledge Base Development (KBD) activity, however, the KM staff will perform two key interface functions:
    - Develop and implement Business Rules for the content of the KB (i.e., formats and templates); and,
    - Develop and implement Business Rules for access (input and retrieval) to the KB (push/pull, alerts, etc.).

- Visualization: Visualization is a key enabler of information and knowledge transfer, and the KM team will support the development and implementation of an effective data display.
- KM Training: KM will institute a training regime so that all MNE 4 personnel are familiar with applicable KM policies and procedures, as well as promulgating all new/amended policies. This training will take place in advance of and during MNE 4, and be given in situ and by distributed means.
- DIME Linkages: KM will facilitate linkages among all CTF headquarter staff and information sources. This includes all Diplomatic, Informational, Military, and Economic (DIME) elements such as subject matter experts (SME), centers of excellence (COE), regional advisors, agencies, non-governmental organization (NGOs), universities and national contacts. It will include the processes and procedures for utilizing knowledge from communities of interest (COI), both standing and *ad hoc*; and,
- Network/Information Technology:
    - KM will use the JFCOM architecture for the execution of MNE 4 over the Combined Federated Battle Lab Network (CFBLNet); and,
    - A Help Desk service will make use of existing JFCOM technical resources supported by MNE 4 personnel.

For more details on the various KM functions, the reader is referred to the KM Plan [21]. These functions facilitate and govern the various knowledge activities. For example, the KR function should facilitate the knowledge creation by providing access to new information and an effective visualization should facilitate the interpretation of the information.

EXPERIMENTAL HYPOTHESIS AND OBJECTIVES

Hypothesis

The hypothesis to be tested for the KM part of MNE 4 is the following:

If the KM Plan is applied and adhered to during MNE 4, then:

1. *The governance and facilitation of knowledge processes will be robust (reliable, stable, scalable, not constraining) across the EBO processes, organizations, and technologies implemented in MNE 4; and*
2. *Governance and facilitation of knowledge processes would contribute positively to the decision-making process.*

Objectives

Experimental objectives were developed based on the experimental hypothesis. In other words, to test the hypothesis, the following objectives need to be fulfilled:

1. Evaluation of the ability of the CTF staff to perform the various knowledge activities.
2. Evaluation of the use of the KM resources.
3. Evaluation of the adherence to the KM Plan, in particular the adherence to the business rules.
4. Assessment of the ability of the KM supporting organization to govern and facilitate the knowledge activities.

EXPERIMENTAL MEASURES

To fulfil the experimental objectives, a list of quantitative and qualitative measures was developed. These measures fall into three categories: data to be obtained from the IT systems, observations to be made by analysts, and survey questions that will be distributed to the MNE 4 participants. The measures can be classified according to the experimental objectives and are as follows:

1. **Ability of the CTF staff to perform the knowledge activities.**
   Measure the ability of the CTF staff to access information.
   Measure the ability of the CTF staff to share information.
   Measure the decision-making ability of the CTF staff.
   Measure the ability of the CTF staff to formalize information.
   Measure the ability of the CTF staff to interpret the information received.
   Measure the ability of the CTF staff to prioritize the information.
2. **Use of the KM resources.**
   Measure the use of the Knowledge Request process.
   Measure the use of the portal and other information sharing tools.
   Measure the workload of the KM staff.
3. **Adherence to the KM Plan and the business rules.**
   Determine if the KM processes were followed (training received, meeting done, KM documents delivered).
   Comparison of actual roles and responsibilities of the KM staff with expected ones.
   Measure of degree of adherence to the business rules.
4. **Governance and facilitation of the knowledge activities.**
   Measure the quality and responsiveness of the KM services (training, KRs, portal design, facilitation of meetings).
   Subjective measure of job satisfaction by the KM staff.

EXPERIMENTAL ANALYSIS

This section describes the analytical results obtained from the data gathered during the experiment. Due to the limited size of this paper, most data are not displayed explicitly and the focus is on the measures supporting our major conclusions. The section is divided according to the experimental objectives[8].

QUALITY OF KNOWLEDGE ACTIVITIES

Information Access

The participants of MNE 4 had access to four different databases: ONA, Helix, Mindmaps, and Xythos. The content of the databases varied slightly but most information could be found in more than one database. The various databases could be reached by the participants from a portal. The portal served as an interface between the users and the databases. Documents could be loaded onto Xythos and documents could be open by a participant using portal's functions. A knowledge request template could also be found on the portal to request information not found on the databases.

After testing the portal search engine and making some observations of the players' ability to find documents on the portal, it became obvious that the access to the information was an issue particularly during the first week of the experiment. The main reason for this issue was the poor quality of the search engine. The result of a search provided only a very limited list of the relevant documents that were known to be available on the portal. Figure 2 shows the number of instances where a participant requested the location of a document from another participant using the text function of the chat rooms available. Note that these requests represented only a subset of all 'document location' requests since similar requests could also been done verbally or using emails.

The number of requests for documents location started on the 28th February – the 27th February was mainly used for briefs and situational update. As the workload increased during the first few days, the number of requests increased until the 3rd March when the number of requests drastically dropped. For the subsequent weeks, the number of requests stayed low indicating that the participants became familiar with the folders structure and knew where required documents where stored and did not depend on the search engine. Note that during the last week, a direct link to Xythos search engine was made directly available on the portal. This search engine performed much better than the one built onto the portal.

[8] The adherence to the KM Plan and business rules will be discussed elsewhere. This analytical review will focus on the quality of the knowledge activity, the use of the knowledge management support and the quality of the governance and facilitation.

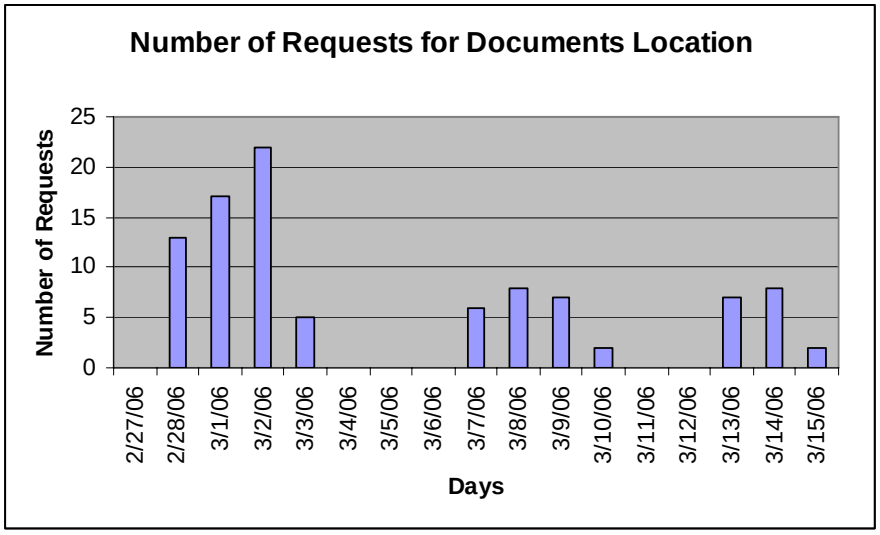

Figure 2. Number of requests for documents location.

Information Sharing

To evaluate the information sharing process, the participants were requested to rate the level of difficulty associated with various factors in terms of their preventing information sharing in this exercise. The 10 following factors were considered: technical difficulties, language, procedural barriers, cultural difference, organizational culture, time constraints, priorities, approachability of the commander, lack of knowledge of who needs what information, influence and power. For each factor, a large distribution of response was obtained going from 'Low level of difficulty' to 'High level of difficulty'. Although, there was a low level of agreement among the participants regarding the level of difficulty linked with each factor, a better agreement was observed in the rank of the factors. Thus, a consensus ranking tool, FIDO (see [15]), was used to analyze the ranking of these factors. The following order was obtained (starting with the most important hindrance to information sharing): 1. Technical difficulties, 2. Procedural barriers, 3.Time constraint, 4. Lack of knowledge of who needs what information, 5. Priorities, 6.Organizationel culture, 7. Influence and power, 8. Culture difference, 9.Approachability of Commander, 10. Language.

Observations support the importance of the first four factors as knowledge sharing hindrance. In particular, due to technical difficulties, many meetings had to be interrupted or suspended for minutes. Similarly, there was limited time to integrate into the database all the new information developed or coming from external sources. This time constraint led to a lack of conciseness of the information being shared.

Decision-Making Process

The decision-making process was evaluated both through surveys and observations. The KBD team and the KM team were the team for which the decision-making process was judged to be particularly weak. Indeed, observations of the decision-making process

showed a lack of decision-making rigor that requires an initial brainstorming with the development of generic options, an evaluation of the pros and cons of each option, the development of a common representation, and the free expression of concerns and doubts. In particular, for the KM team, it was observed that the decisions were often taken rapidly without team consensus leading to the same issues coming back at further meetings. Different factors can explained the lack of good decision-making:

- Technical difficulties: Many studies show that the decision-making process of a dispersed team requires elaborated tools (see for example [19]). The technical difficulties experienced with the tools did not support a good decision-making process.
- Lack of tools knowledge: Many decisions made by the KM team were concerned with modifications of business rules and process to better suit the tools available. The development of a list of options would have required an expert who would have known the ins-and-outs of the tools; this was not always the case.
- The lack of knowledge management principles in the KM Plan did not help for the evaluation of the pros and cons of the identified options.

Other Knowledge Activities

The quality of the other knowledge activities will not be described in details in this paper. However, it is interesting to note that there was very little knowledge formalization (influencing the degree of belief) performed during MNE 4. Instances where contradicting information elements were shared among the CTF staff have been observed.

USE OF THE KNOWLEDGE SUPPORT RESOURCES

Use of the Knowledge Request

The knowledge requests were used by the participants to obtain information that had not been found in the databases. To perform a knowledge request (KR), a participant had to access the knowledge request page on the portal; fill-in the template for his request specifying the required information, the media to be used for the answer, and the time by which the information is required; and send the request to his knowledge management liaison officer (KMLO) who would review the request and then send it to the knowledge request manager (KRM). The KRM would verify that the information is not available in the databases, prioritize the KR and attribute a tracking number. The KRM would then forward the KR to the Assistant KMO KR. Through consultation between the KRM and Assistant KMO KR, a decision would be made on how to classify the KR. There were two types of classification: *standing* KRs and *ad-hoc* KRs. Standings KRs were requests that needed to be answered on a regular basis (e.g., the information would be requested on a daily basis). In contrast, ad-hoc KRs needed to be answered only once: a regular update of the information was not requested. For standing KRs, a location on the portal, where the information would be stored, was selected by the KRM and Assistant KMO

KR and the URL address send to the KR originator. In the case of ad-hoc KR, the Assistant KMO KR would look for an appropriate information source to answer the KR. This source was either the Intel group, the System-of-System Analysis group (part of the knowledge based development cell), the multi-national interagency group or the experimental control team, which are not part of the experimental players but would control the information that should be used for the experimental scenario. Once the KR was answered, the answer would be forward to the originator who would then close the KR if satisfied by the answer.

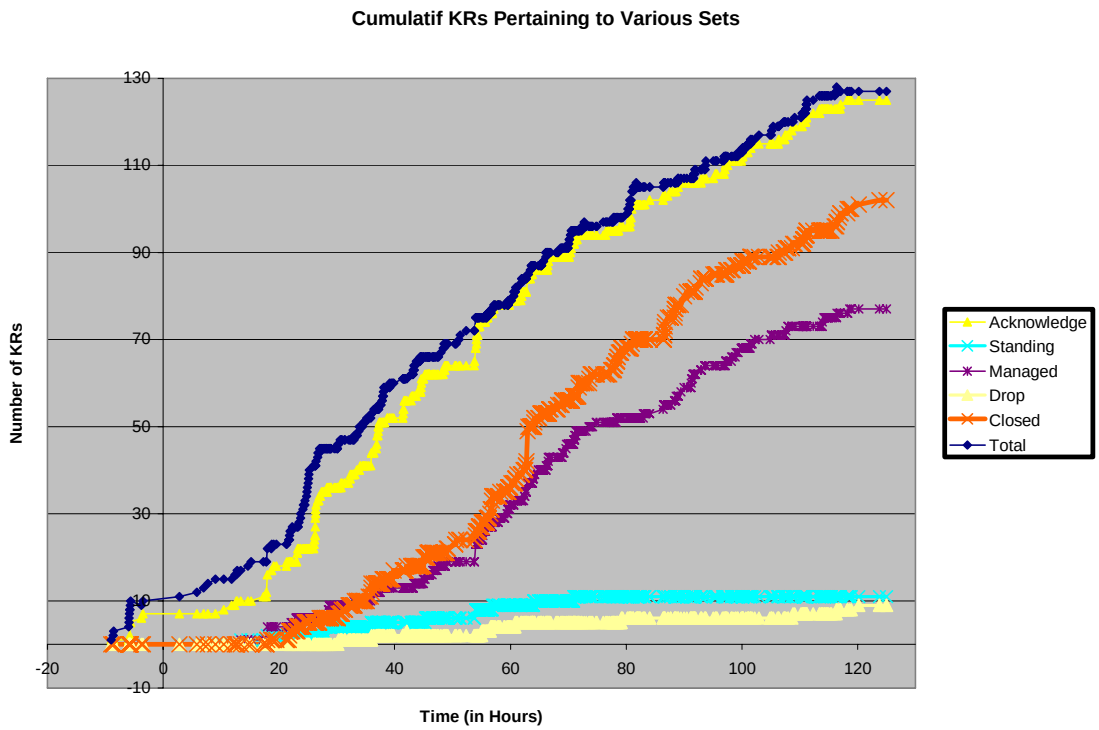

Figure 3. Evolution of the knowledge requests with time.

Figure 3 shows the evolution of the knowledge request during the experimental period. The x-axis shows the time in hour. The KR started on the 23rd of February during the training session ahead of the start of the experimental play (0 h on the graph). Note that only the working hours are shown on the graph. Thus '9 h' displays the end of the 27th of February and '9 h 1 min' corresponds to the first minute of experimental play on the 28th of February.

The graph shows a very linear behavior for the total request. After the first 50 hours, the KRs were quickly acknowledge as shown by the gap between the number of acknowledge KRs (yellow curve) and the number of total KRs (blue line) closing down. The number of managed KRs represents the sum of the answered KRs and standing KRs for which a location for the information had been selected. The graph shows that the gap between the total number of KRs and the managed KRs was increasing slightly with

time. Some KRs were also simply dropped by the originator due to the complication of the KR process or the delay for getting an answer. When the established KR process was not followed by the originator (e.g., the originator would send the KR directly to the Assitant KMO KR rather than sending it to his KMLO), the KRM or Assistant KMO KR would request from the originator that he follows the established process. Following this request some originator decided to drop the KR and try to access the requested information through a different source. One can also observe from the graph that the number of closed KR surpassed the number of managed KRs by the KR cell. There are two reasons for that. First, the dropped KRs were closed before the KR having been managed. Second, some KRs were closed after the answer was found by the originator in some databases.

QUALITY OF THE GOVERNANCE AND FACILITATION

Quality of the KRs

The participants who initiated knowledge requests, a total of 42 individuals, were asked to evaluate the quality of the KR answer and the timeliness of the answer. The distribution of the participants' evaluation is displayed in Figure 4 separately for each functional group of the CTF headquarters. The satisfaction level was chosen between 1 and 7; 1 being 'Very Displeased', 4 'Neutral', and 7 'Very Pleased'. The red boxes display the distribution of the answers received on the 16 March and the blue boxes those for the 9 March.

a) b)

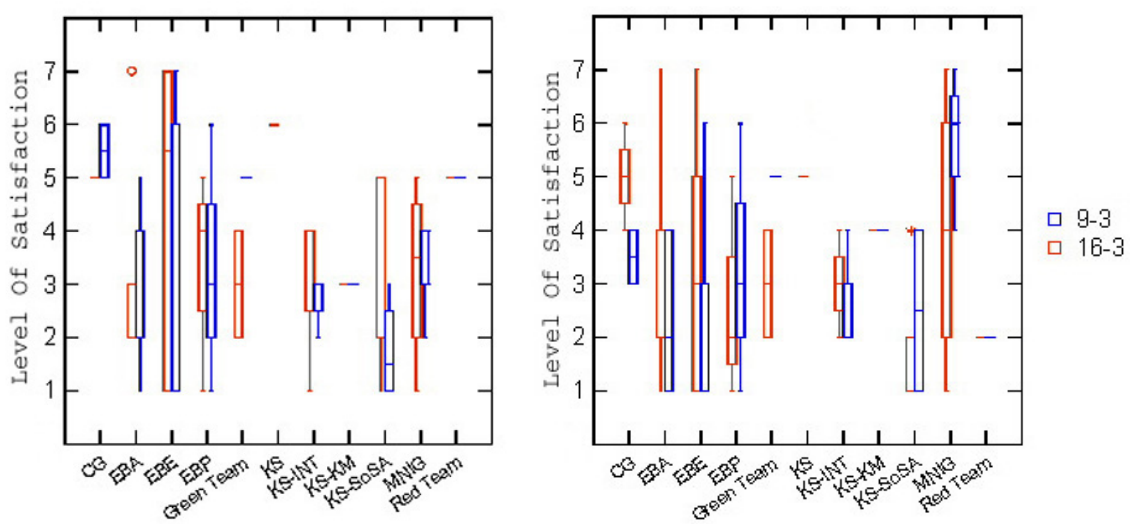

Figure 4. Participants evaluation of the KRs answer (a) and the timeliness of the answer (b).

The number of respondents per group, including all participants that responded at least on 1 day, was as follows: 3 in the Command Group (CG), 7 in EBA, 7 in EBE, 6 in EBP, 2 in Green team, 1 in Knowledge Support (KS), 3 in KS-INT, 1 in KS-KM, 6 in KS-SOSA, 5 in MNIG, 1 in Red Team. The line inside the various boxes display the median of the response received. The edge of each box shows the 25 percentile and 75 percentile of the

distribution of the responses received (i.e., 50% of the responses received lie within the boxes. Finally, the extremity of the lines added at each end of the boxes provides the 12.5 percentile and 87.5 percentile. Note that in the cases where the 12.5 percentile coincide with the 25 percentile, the line at the lower end of the box will not be displayed. Similarly, if there is only one respondent, only a single line will appear (no box). Additional symbols like a circle are used to indicate outliers.

Three main observations can be made from the graphs: 1) There is a wide spread of opinion regarding the quality of the answers to the KR; 2) A majority of the participants were dissatisfied with both the answer received and the timeliness of the response; 3) A majority of participants have indicated no change of level of satisfaction on the 16 March compared to the 9 March for both the quality of the answer and its timeliness.

To validate the responses received from the survey, an analysis of the KRs answer was done. The KR answers were classified according to three categories: 1) No answer provided, 2) Poor answer provided, 3) Adequate answer provided. From the 105 submitted KRs, 36 had not been answered, 14 received a very poor answer and 55 had received a useful answer. Furthermore, there was a wide spread of the required time to answer the KR: The fastest answer took 40 minutes while the longest answer took 9 days (excluding week-ends). This analysis indicates indeed the spread of the survey answers and the limited satisfaction of the players.

An analysis of the response time of the staff involved in processing the KRs was done to determine some causes for the time required to answer the KRs. Figure 5 displays the cumulative distribution of the response time for the staff involve in processing the KRs. Different curves are used for each staff. The x-axis displays the experimental elapsed time in hour. The graph shows that the KMO KR was the most efficient with 90% of his response time within a 90 min interval. Note that the staff responding to a KR does not mean he provided an answer to the KR but simply that he replied to a KR that was pushed to him. Obviously, a longer time delay is expected for those staff that had to gather the information needed to answer the KR: like the MNIG or Control (CNTL).

The analysis of the response time indicates that a weak link to the process of the KR was the Intel player. The Intel player had a long response time (usually between 2 and 12 hours) and did not provide any answer to the KRs. His reply would usually be limited to suggesting possible source for the information. Both Control and MNIG also had long response time and the issue with these two teams was due to the delay to gather the information necessary to answer the KRs.

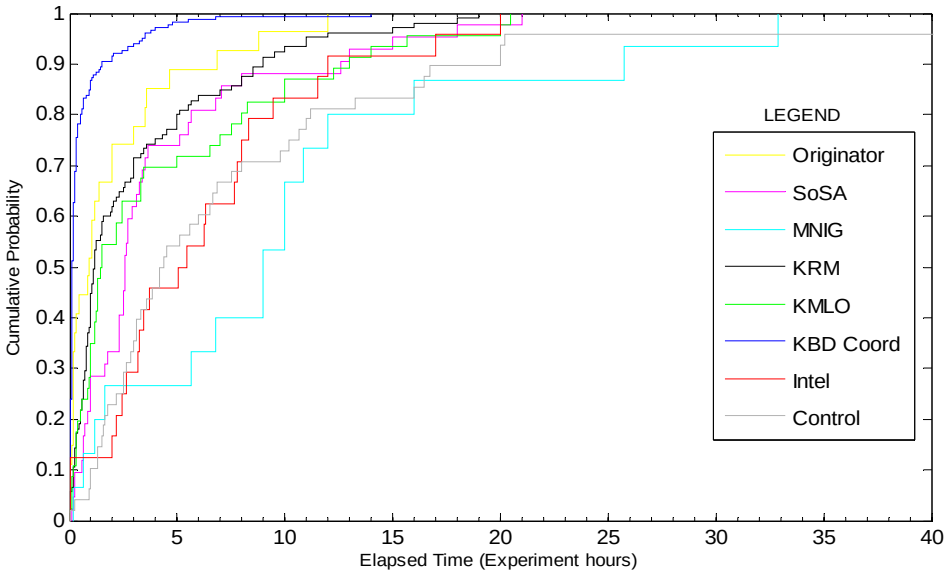

Figure 5. Distribution of the response time for the staff involved in processing the KRs.

CONCLUSION

This paper proposed knowledge and knowledge management concepts. These concepts were used to define a set of measures for evaluating knowledge management. This framework was applied to assess the knowledge management support to MNE 4.

Most MNE 4 knowledge activities were limited due to technical difficulties. The analysis also showed that a better integration and collation of the information available were needed to support the knowledge access. Furthermore, one of the least supported knowledge activities was certainly the decision making process. There was no expert system available and very few principles to guide the participants to make decisions in uncertain situations. These observations lead us to conclude that the KM Plan should not only propose a KM organization with roles and responsibilities and business rules but should also elicit good KM principles.

The Knowledge Request support was used by all teams of the CTF headquarters with an average of about 11 requests per day. However, a large portion of the participants who used the KR support was dissatisfied in terms of the quality and timeliness of the response. The analysis of the KRs indicates the need for a simple KR process with a need to limit the number of participants involve in treating a given KR. Each participant involved should also take an active role in processing the KR.

Finally, the overarching conclusion from a KM perspective is that the EBO process necessitates a large load of information to be collected, organized and processed, which requires a good set of supporting tools, process and organization. The MNE 4 experiment allowed us to partially evaluate the KM Plan and the quality of the KM support. Additional experiments are required to further refine the KM process particularly with regard to the decision-making support.

REFERENCES

1. *Operational Implications of Effects-based Operations.* USJFCOM J9, Joint Doctrine Series, Pamphlet 7, 17 November 2004.

2. Multinational Experiment 3 – Final Report. USJFCOM J9, April 2004.

3. Farrell, P.S.E. *et al*. *CFEC Analyst Final Report for Multi-National Experiment 3*, Technical Memorandum, TM 2005-149, June 2005.

4. Wahl, M. *MNE 4 Experiment Design Document*. USJFCOM J9, July 2005.

5. Newell, A. *The Knowledge Level*. Artificial Intelligence, 18, p.1 (1982).

6. Ashwin, P., and M. Timme. *When Instabilities Makes Sense*. Nature, Vol. 436, p. 36 (2005).

7. McElroy, M.W. *Integrating Complexity Theory, Knowledge Management and Organizational Learning*. Journal of Knowledge Management, Volume 4, No. 3, pp. 195-203 (2000). [Available at http://www.emerald-library.com].

8. Von Krogh, G. *Care in knowledge creation*. California Management Review 40, p. 133 (1998).

9. Cox, R. *Probability Frequency and Reasonable Expectation*. American Journal of Physics, Vol. 14, p. 1 (1946).

10. Davis, M.D., R. Sigal, and E.J. Weyuker, *Computability, Complexity, and Languages*. Academic Press, London, 1994.

11. Oxendine, Lt. E. and M.E. Nissen. *Knowledge Process and System Design for the Carrier Battle Group*. Journal of the KMCI, Vol. 1, no.3, p. 89 (2001).

12. Krause, P. and D. Clark. *Representing Uncertain Knowledge*. Kluwer Academic Publishers, Dordrecht, Netherlands, 1993.

13. Emond, E.J. and D.W. Mason, *A New Technique for High Level Decision Support*. Project Report PR 2000/13, June 2000.

14. Offiong, J. and P. Comeau. *Fundamental Investigation of Defence Objectives – Decision Support to the Strategic Capability Planning Process*. ORD Project Report PR 2000/20, November 2000.

15. MacLean, D. Fundamental Investigation of Defence Objectives User Guide for FIDO Version 1.0. DRDC-CORA, Technical Report PR2000/25, December 2000.

16. Pavitt, C. (2003). *Why We Have to Be Reductionists About Group Memory*. Human Communication Research, Vol. 29, p. 592.

17. Wegner, D.M. *Transactive Memory: A Contemporary Analysis of the Group Mind*. In Theories of Group Behavior, Springer-Verlag, New York, U.S.A., pp. 185-205 (1987).

18. Sorkin, R.D., C.J. Hays, and R. West. *Signal-Detection Analysis of Group Decision Making*. Psychological Review, Vol. 108, no.1, p. 183 (2001).

19. Soller, A. Understanding Knowledge-Sharing Breakdowns: A Meeting of the Quantitative and Qualitative Minds. Journal of Computer Assisted Learning, Vol. 20, p. 212 (2004).

20. Roda, C. and J. Thomas. *Attention Aware Systems: Theories, Applications, and Research Agenda*. Computers in Human Behavior **22**, pp. 557-587 (2006).

21. Coalition Task Force Headquarters Knowledge Management Plan for the Multinational Experiment IV. Version 0.88. CFEC, June 2005.

22. Bernier, M., P.S.E. Farrell, and A. Elford. *Knowledge Management Workshop 1 Proceedings*. DRDC-CORA/EX-ORT, Technical Note TN 2005/01, February 2005.