16th ICCRTS: Collective C2 in Multinational Civil-Military Operations

Investigating Inter-Organizational Collaboration during the Haiti Relief Effort from a Macrocognition Perspective

Paper ID: #052

Primary Topic:	Topic 5: Collaboration, Shared Awareness, and Decision Making
Alternate Topics:	Topic 10: C2, Management, and Governance in Civil-Military Operations
	Topic 4: Information and Knowledge Exploitation

Susan G. Hutchins, **Ying Zhao**, **and Tony Kendall**
Graduate School of Operational and Information Sciences
Naval Postgraduate School, Monterey, CA

POC: Susan G. Hutchins
Graduate School of Operational
and Information Sciences
1411 Cunningham Rd.
Naval Postgraduate School
Monterey, CA 93943
831.656.3768
shutchins@nps.edu

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE
Investigating Inter-Organizational Collaboration during the Haiti Relief Effort from a Macrocognition Perspective

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School,Graduate School of Operational and Information Sciences,1411 Cunningham Rd,Monterey,CA,93943

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the 16th International Command and Control Research and Technology Symposium (ICCRTS 2011), Qu?c City, Qu?c, Canada, June 21-23, 2011.

14. ABSTRACT
On January 12, 2010, a massive earthquake ravished Haiti?s capital city of Port-au-Prince. Relief organizations, governments, and people from all over the world poured into Haiti to help address the devastating circumstances. Throughout the relief effort the communications that transpired between responders were recorded in the All Partners Area Network (APAN) collaboration system. APAN data from the Haiti relief effort was analyzed for this research where we employed an empirical process to evaluate a model of team collaboration. We analyzed the inter-agency collaborative communication by applying definitions of the macrocognitive processes included in a model of team collaboration to each thought unit posted by responders. Macrocognition is a nascent area of knowledge engineering that focuses on understanding how cognition emerges in natural environments. The goal for the research reported here is to understand the role of cognition in teams who are collaborating to solve unique, challenging, ambiguous, information-rich problems. Results indicate the task environment will influence which macrocognitive processes are used and we found evidence for several new macrocognitive processes. A more complete model of team collaboration can guide designers of collaboration tools to facilitate decision making as part of the overall task.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**43**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Investigating Inter-Organizational Collaboration during the Haiti Relief Effort from a Macrocognition Perspective

Abstract

On January 12, 2010, a massive earthquake ravished Haiti's capital city of Port-au-Prince. Relief organizations, governments, and people from all over the world poured into Haiti to help address the devastating circumstances. Throughout the relief effort the communications that transpired between responders were recorded in the All Partners Area Network (APAN) collaboration system. APAN data from the Haiti relief effort was analyzed for this research where we employed an empirical process to evaluate a model of team collaboration. We analyzed the inter-agency collaborative communication by applying definitions of the macrocognitive processes included in a model of team collaboration to each thought unit posted by responders. Macrocognition is a nascent area of knowledge engineering that focuses on understanding how cognition emerges in natural environments. The goal for the research reported here is to understand the role of cognition in teams who are collaborating to solve unique, challenging, ambiguous, information-rich problems. Results indicate the task environment will influence which macrocognitive processes are used and we found evidence for several new macrocognitive processes. A more complete model of team collaboration can guide designers of collaboration tools to facilitate decision making as part of the overall task.

INTRODUCTION

On January 12, 2010, Haiti experienced a 7.0 magnitude earthquake 10 miles from its capital city of Port-au-Prince. The global relief effort that followed was on a scale that to date has been unmatched. Relief organizations, responders from many governments, and people from all over the world poured into Haiti to help address the devastating circumstances. Throughout the relief effort the communications that transpired between air, ground, and ocean-based assistance crews were recorded in the All Partners Area Network (APAN) collaboration system. APAN data from the Haiti relief effort provided the data that was analyzed for this research. The goal for the research reported here is to understand the role of cognition in distributed teams who are collaborating to solve challenging, unique, dynamic, information-rich problems and to apply this understanding to make recommendations for collaboration support.

The research described in this paper focuses on the contextually bound processes entailed in sensemaking, managing uncertainty, and related cognitive processes entailed in responding to emerging events that occur in dynamic decision-making situations. For the research reported here we have examined team collaboration in the context of the Haiti Humanitarian Assistance/Disaster Relief (HA/DR) operation. We elected to analyze this data set as it represents a large set of real-world data with all the characteristics of interest for conducting an empirical evaluation of the model of team collaboration. That is, a problem where ad hoc teams are quickly assembled to deal with an emerging event that requires a collaborative effort to deal with the problem-solving event.

Macrocognition is an emerging field within the area of cognitive engineering that describes the way cognition occurs in naturalistic, or real-world, decision-making events (Cacciabue & Hollnagell, 1995). In this view of macrocognition, the focus is on cognitive task analyses of functions required to perform a task or achieve a goal (Klein, Ross, Moon, Klein, Hoffman, & Hollnagel, 2003). Macrocognition in teams (Letsky et al., 2008) further expands the concept by considering group cognition and the collective (team) cognitive processes that enable the externalization of internalized knowledge building. These cognitive functions are generally performed during collaborative team problem solving, where the emphasis is on building new knowledge. Macrocognition is differentiated from microcognition in several ways.

Microcognition places an emphasis on experimental control of tasks and theoretical accounts of specific phenomena while macrocognition emphasizes cognition and performance under actual working conditions. Macrocognitive phenomena generally occur over longer time periods, have ill-defined goals, and do not focus on the "basic" cognitive functions of microcognition (e.g., perception, attention and memory). Macrocognition encompasses cognitive processes involved in detecting problems, developing and sharing situation awareness, generating options, using analogues, mentally simulating courses of action, planning and re-planning, maintaining vigilance, and assessing risk (Klein et al., 2003).

The framework of collaborative problem solving developed as part of the Office of Naval Research (ONR) Collaboration and Knowledge Interoperability (CKI) Program (Letsky, Warner, Fiore, & Salas, 2007; Warner, Letsky, & Cowen, 2005) provides the conceptual foundation for this research. The emphasis on macrocognition in teams was initiated as part of a larger issue of how to understand and facilitate complex, collaborative activity – specifically in quick-response ad hoc teams. Both commercial and military communities are evolving in terms of the socio-technical systems employed, globalization, and ubiquitous information accessibility, which combined are changing the dynamics of team activity (Letsky & Warner, 2008). The CKI program seeks to develop a better understanding of internalized, non-quantifiable, mental processes at work as teams collect, filter, process and share information for problem-solving purposes.

The objective of the CKI program is to respond to emerging needs in both the military and business environments to better understand and improve the effectiveness of team decision making in complex, data-rich situations. The long-range program objective is to develop a range of cognitive science based tools, models, computational methods, and human-agent interfaces to help attain common situation awareness among distributed team members, engaged in asynchronous, quick-response collaboration for issue resolution, course of action selection, or decision making. Our objectives for the research reported here are to: (1) empirically evaluate the CKI model of team collaboration based upon analysis of real-world complex decision-making events, (2) determine which macrocognitive processes are used and, if necessary, refine the model based on empirical analysis, and (3) develop a better understanding of the cognitive processes employed when teams collaborate to solve problems.

The remainder of this paper is organized as follows: the background provides a brief review of the literature on collaboration and a model of team collaboration, and describes the lexical link analysis technique for identifying themes in a large data set; the method section describes the data analysis and coding plan; the results section discusses the qualitative and quantitative outcomes from our analysis; and the discussion section summarizes the results and conclusions then outlines avenues for future research.

BACKGROUND

Collaboration occurs "when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain" (Wood & Gray, 1991, p.11). This interactive process is performed in a collaborative team environment, with *collaborative* defined as the "cognitive aspects of joint analysis or problem solving for the purpose of attaining shared understanding sufficient to achieve situational awareness for decision making or creation of a product" (Letsky & Warner, 2008, p. 4). Benefits afforded by inter-organizational collaboration include better decision-making as a result of shared information, enhanced coordination among dispersed units, innovation resulting from the cross-pollination of ideas, and cost savings produced by sharing resources and the transfer of smart practices (Hansen & Nobia, 2004; Mankin & Fitzgerald, 2004). Team members can often provide several perspectives on an issue for generating, choosing, and implementing action plans.

The research reported on in this paper builds on a stream of research where we analyzed and coded transcripts or chat logs that transpired during five real-world problem-solving events and one laboratory experiment to empirically evaluate a model of team collaboration developed under the CKI Program. A model of team collaboration was initially developed that emphasizes the cognitive aspects of team collaboration and includes the major human decision-making processes used during team collaboration (Warner, Letsky & Cowen, 2005). An overarching objective of the research reported here is to test the current coding scheme which is included in the model. Schemes for coding communications data should be mutually exclusive, exhaustive, and equivalent.

Our previous research indicates a non-exhaustive set of macrocognitive processes in the model of team collaboration. Decision making – what we label *decision to take action* (DTA) – emerged during previous analyses of six task domains as a new macrocognitive process, indicating decision making is an essential macrocognitive process when teams are involved in responding to many complex, real-world tasks. Deciding to take action is viewed as both a macrocognitive *process* and a *product* of team collaboration (Klein, 1993). Many real-world tasks require making decisions over the course of the entire event – to accomplish the work, as opposed to the team making one final decision at the conclusion of the scenario. A decision can be defined as a "mental event that occurs at a singular point in time…that leads immediately or directly to action" (Hoffman & Yates, 2005, p. 77). From this perspective, a decision is a commitment to a course of action. Our analysis of a range of task domains indicates the types of tasks described by this model typically involve team members making decisions as part and parcel of the team's collaborative problem solving.

We maintain that decision making is an essential component of team collaboration for effective team problem solving when the team is *performing* the task as opposed to *planning* for a task to be executed in the future. This has been a consistent finding across six task environments analyzed: firefighters on Sept 11 responding to the attack on the world trade center (Hutchins, Bordetsky, Kendall, & Garrity, 2007), air warfare teams on a Navy ship (Hutchins, Kendall, & Bordetsky, 2010a), a boarding team conducting maritime interdiction operations (Hutchins &

Kendall, 2008); NORAD collaborating with the FAA on Sept 11 to ground all commercial air traffic (Hutchins & Kendall, 2010b), an Air Force team responding during a time-sensitive targeting scenario (Hutchins & Kendall, 2010c), and during an experiment involving UAV real-time planning and execution (Hutchins & Kendall, 2010b). Based on this consistent pattern of findings we have added *decision to take action* to our coding scheme.

Team Collaboration Tasks

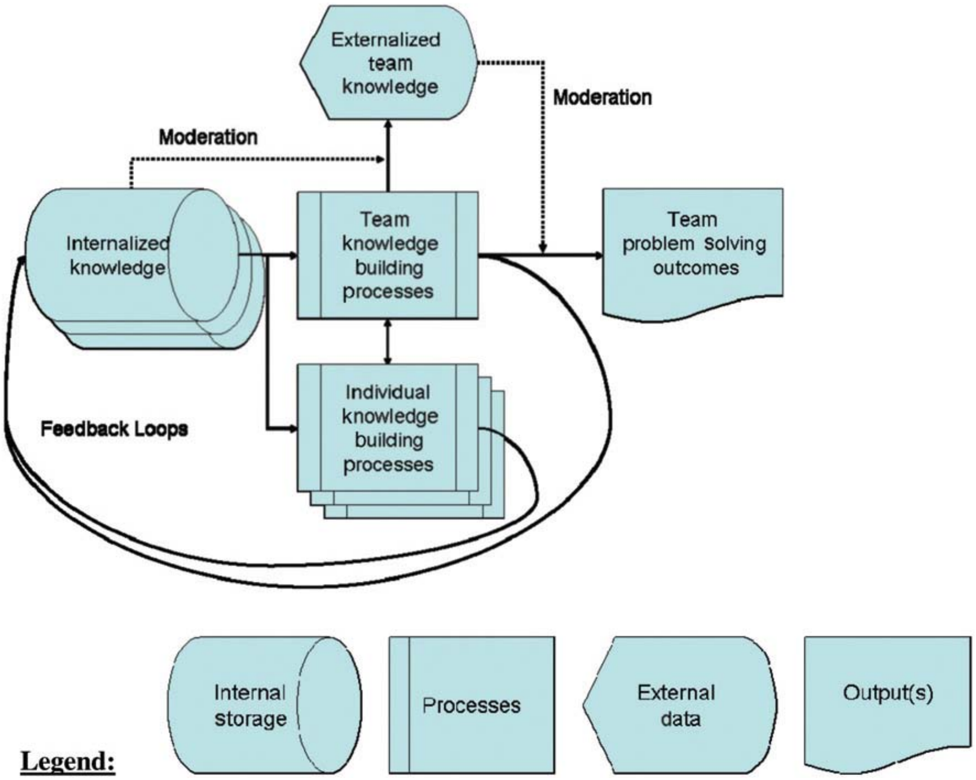
The types of problem-solving situations accounted for by the model of team collaboration (Fiore, et al, 2010) are ill-structured decision-making tasks that are characterized by time pressure, dynamically changing conditions, ambiguous and incomplete information, high uncertainty and high cognitive work-load (that is, a large amount of knowledge is brought to bear to solve complex problems), as well as human-system interface complexity. Information from multiple sources needs to be considered requiring collaborative analysis to ensure team members come to a shared understanding of the task, the environment, and reach consensus on a course of action.

Haiti Humanitarian Assistance/Disaster Relief (HA/DR) Operation

A wide range of diverse organizations partnered – including non-governmental organizations (NGOs), various military commands, Department of Defense agencies, public and private relief agencies and non-profit organizations – during the Haiti relief operation to form an alliance to cooperate, share information, and work together. Interorganizational collaboration has been defined as "the capability of an organization (or set of organizations) to enter into, develop, and sustain interorganizational systems in pursuit of collective outcomes" (Jansen, Hocevar, Rendon, & Thomas, 2009, p. 330). As described by Jansen et al (2009), the focus of this interorganizational collaboration is to accomplish a wide range of complementary or common goals and objectives, including, in this case, the common overall mission of providing humanitarian assistance and disaster relief. The extent of destruction in Port-au-Prince made rescue work difficult, and with many surrounding roads impassable and airports inoperable, the first shipments of foreign aid could not reach the people who most needed them.

Measurement Model of Team Collaboration

The primary purpose of this paper is to report on research conducted to empirically evaluate and, if necessary, refine a model of team collaboration developed by Fiore et al (2010). This model of team collaboration has evolved over the course of the CKI research program and the most recent version of the model is depicted in Figure 1. This revised version of the model was developed with an emphasis on the ability to measure the macrocognitive processes that transpire during team collaborative problem solving in a laboratory setting. While the traditional cognitive science approach has been to focus on individual-level constructs such as perception, attention, and memory, the Fiore et al. (2010) model emphasizes ways to reliably measure what team members are thinking as they interact.



(*Note*: multiple overlapping symbols indicate representations for multiple team members)

Figure 1. Model of Team Collaboration (From Fiore et al., 2010).

Definitions of the macrocognitive processes (Fiore et al., 2010) included in the model are listed in Table 1, which also includes examples from the APAN Haiti HA/DR event data of thought units coded as representing these macrocognitive processes. A thought unit refers to a "sequence of a few words conveying a single thought" (Welden, Jehn, & Pradhan, 1991, p. 559), or "the smallest message unit that can stand alone" (Keyton & Beck, 2010, p. 336).

Table 1. Macrocognitive Process Definitions used for coding with Examples from the Haiti APAN data.[1]

Stage I: <u>Individual Knowledge Building Process</u>: Actions individuals engage in to add to their existing knowledge such as reading, asking questions, accessing information on displays, providing messages to team members.
Individual Information Synthesis: Involves comparing relationships among information, context, and artifacts to develop actionable knowledge or affordances (e.g., pushpins and attached notes). - No coded examples for APAN data
Individual Information Gathering: Involves actions individuals engage in to add to their existing knowledge such as reading, asking questions, accessing displays, providing messages to teammates. • Does anyone know if the following docks located outside the general port area are functional?
Knowledge Object Development: Involves creation of artifacts, by the individual, that represents actionable knowledge or affordances (e.g., pushpins, attached notes). - No coded examples for APAN data
Stage III: <u>Team Knowledge Building Process</u>: Includes actions taken by teammates to disseminate information and to transform that information into actionable knowledge for team members.

Team Information Exchange: Involves passing relevant information to the appropriate teammates at the appropriate times. Relevant information is information that is useful in helping solve a particular task.

- "NAME" (USN Retired) has 250 water purification devices available in Puerto Plata, Dominican Republic, available for transfer to Port-Au-Prince.
- I think the main thing I'd recommend is that the NGOs you are speaking to get their needs communicated back into the system.

Team Knowledge Sharing: Involves explanations and interpretations shared between team members or with the team as a whole.

- SOUTHCOM has an ACOE [Army Core of Engineers] engineer team which did an assessment of the port of Port-Au-Prince, and they have determined that the entire Port-Au-Prince is unusable for large vessels.
- We can use trucks with lights and have ambulances available to transport patients a few hundred yards to hospital.

Team Solution Option Generation: Describes offering potential solutions to the problem.

- Killick CG base may possibly be used for offloading supplies, however, limited to small vessels estimated 47 ft or less shallow draft.
- Tactical solution – use 5k and 10k cargo nets as slings under rotary wing to deliver supplies to IDP [indigenous displaced personnel] areas and distribution points.

Team Evaluation and Negotiation of Alternatives: Clarifying and discussing the pros and cons of potential solution options. This could include clarifying pieces of information, verbally simulating the ripple effects of alternatives, attempting to persuade other teammates regarding the relative efficacy of alternatives.

- No coded examples for APAN data

Team Process and Plan Regulation: Discussing or critiquing the team's knowledge building process or plan.

- No coded examples for APAN data

Stage III: <u>Internalized Team Knowledge Products</u>:

Teammate Knowledge Similarity: The degree to which teammates' mental models of one another's relatively stable levels of skill, knowledge, experience, dispositions and/or habits converge.

- No coded examples for APAN data

Shared Situation Awareness: The degree to which teammates' awareness and interpretation of moment-by-moment changes in their collective situation converges.

- No coded examples for APAN data

Team Knowledge Objects: Creation of artifacts that represent actionable knowledge or affordances agreed to by the team.

- No coded examples for APAN data

Task Knowledge Stock: Accurate task-relevant knowledge held by team members. This would include knowledge about task strategy and equipment.

- No coded examples for APAN data

Stage IV: <u>Externalized Team Knowledge Products</u>: Refers to facts, relationships, and concepts that have been explicitly agreed upon, or not openly challenged or disagreed upon, by factions of the team.

Uncertainty Resolution: The degree to which a team has collectively agreed upon the status of problem variables (e.g., hostile/friendly).

- No coded examples for APAN data

Externalized Cue-strategy Associations: Describes the team's collective agreement as to their task strategies and the situational cues that modify those strategies (and how).

- No coded examples for APAN data

Pattern Recognition and Trend Analysis: The accuracy of the patterns or trends explicitly noted by members of a team that is either agreed upon or unchallenged by other team members.

- No coded examples for APAN data

Stage V: <u>Team Problem Solving Outcomes</u>: Assessments of quality relating to a team's problem solutions or plan.

Quality of Plan/ Problem Solving Solution: The degree to which the solution adopted by a problem solving team achieves a resolution to the problem (e.g., limit fatalities, limit destruction).

- No coded examples for APAN data
Efficiency of Planning Process: Efficiency of planning process describes the amount of time it takes a problem solving team to arrive at a successful resolution to a problem. - No coded examples for APAN data
Efficiency of Plan Execution: Describes the quality of the plan (e.g., number of lives saved) divided by the amount of resources used to accomplish this and the amount of time the plan takes to arrive at a successful resolution to a problem. - No coded examples for APAN data

[1](Definitions of macrocognitive processes from Fiore et al., 2010.)

Our previous analysis of several task domains indicates that several of the macrocognitive processes included in the model of team collaboration cannot be measured during certain types of real-world team collaborative problem-solving situations. The lack of evidence for several macrocognitive processes is attributed to two explanations.

The first is that in certain types of problem-solving environments, such as task domains that require dynamic decision making (Montgomery, 1993; Montgomery, 1989), teams do not employ some of the processes included in the model due to the rapid responses required to deal with emergent events. For example, Klein (1989) found that when decision makers use a recognition-primed decision-making strategy, usually the situation itself either determines or constrains the response options and that experienced decision makers make up to 90% of all decisions without considering alternatives. If the situation appears similar to one that the decision maker has previously experienced, the pattern will be recognized and the course of action is usually immediately obvious.

Firefighters, as well as team members in many other domains collaborate on the 'front end' of the problem – that is during situation assessment and subsequent development of situation awareness, but typically do not collaborate on how to respond to an event due to time pressure. For example, we saw little evidence for *team evaluation and negotiation of alternatives* by team members during dynamic decision-making problem-solving task domains because many responses are guided by standard operating procedures, and the stored schemas of highly experienced operators.

A second reason our analyses have consistently provided a lack of evidence for some macrocognitive processes included in the model is that the processes included in the *Internalized Team Knowledge Products Stage* (stage III, in Table 1) require direct interaction with team members to gather data required to measure certain processes. These cognitive processes – *Teammate Knowledge Similarity*, *Shared Situation Awareness*, and *Task Knowledge Stock*, are amenable to measurement in laboratory settings but it is typically not feasible to obtain measurements on participants during a complex high-fidelity exercise or during a real-world event. Our focus has been on analyzing transcripts or chat logs obtained after the real-world event has transpired, such as the transcript from the Fire Department of New York on September 11, 2001, and the Haiti HA/DR effort reported on in this paper.

In a similar vein, *Team Problem Solving Outcomes* (stage V, in Table 1) requires performance assessment metrics to assess the *Quality of the Plan/Problem Solving Solution*, *Efficiency of Planning Process*, and *Efficiency of Plan Execution.* Performance metrics for the types of task domains we have studies o not exist. Measurement strategies to assess how the team performed overall, such as quality of the plan/problem solving solution, and efficiency of planning process, are not available and developing these types of measures would require a major effort in itself.

Additional Macrocognitive Processes used for Analysis

A consistent pattern was evident across the task domains we previously investigated where the majority of thought units were coded as representing two of the cognitive processes: T*eam Information Exchange* (TIE) and *Team Knowledge Sharing* (TKS). The percentage of communications coded as TIE and TKS, in previously reported data, and for the current data, are shown in Table 2. The high percentage of communications coded as TIE motivated us to attempt to unpack this category by investigating if other cognitive processes might be occurring.

Table 2. Percentage of Communications Coded as Team Information Exchange and Team Knowledge Sharing across Task Domains.

Task Domain	Team Information Sharing	Team Knowledge Exchange
Maritime Interdiction Operation	60.0[1]	5.0[2]
Air Operations Center	51.5[1]	10.3[2]
NORAD	52.9[1]	3.7[2]
UAV Dynamic Re-planning	58.00	4.29
Haiti HA/DR Effort	81.00	5.90

Note: [1]In a previous version of the model this macrocognitive process was labeled *Team Information Exchange*.
[2]In a previous version of the model this macrocognitive process was labeled *Team Knowledge Sharing*.

Since we are focusing on tasks performed in "the wild" we culled from the naturalistic decision-making (NDM) literature related to macrocognition to develop an additional list of macrocognitive processes that could be used for coding the present set of data. Based on a review of the macrocognition literature related to NDM we elected to include additional macrocognitive processes in a revised coding scheme. (More detail is provided in the Method section.) These macrocognitive processes and their definitions listed in Table 2.

Sensemaking. Sensemaking is an essential cognitive function performed by a variety of domain practitioners across a wide range of real-world tasks (Klein, Phillips, Rall, and Peluso, 2007). The sensemaking process begins when a person becomes aware of a weakness in their current comprehension of a situation, often experienced as a surprise, in response to unexpected changes or as a failure of expectations. Sensemaking is a critical process for teams engaged in real-world domains were practitioners deal with complex, dynamic, evolving situations that are "rich with various meanings" (Klein, et al, 2007, p. 114). The data these practitioners use to develop an understanding of the situation are often highly ambiguous and very complex and the dynamic events require the decision maker to dynamically update their understanding as the situation evolves over time. The frame that is adopted by the practitioner will affect what data are attended to and how these data items are interpreted. When the practitioner notices data that do not fit the current frame, the sensemaking cycle of continuously moving toward better explanations is activated. Sensemaking incorporates consideration of the following criteria: plausibility, pragmatics, coherence, and reasonableness (Klein, et al, 2007).

Anticipatory thinking is described as a critical macrocognitive function of both individuals and teams (Klein, Snowden, & Lock Pin (2007). Anticipatory thinking is form of sensemaking that is future oriented such as forming expectancies about future events (e.g., Weick & Sutcliffe, 2001). Active attention management where the operator focuses attention on likely sources of critical information is a key characteristic. *Assessing Risk* refers to an evaluation of the potential consequences for risk or a danger to reach a desired end-state. *Problem Detection* is defined as a form of sensemaking that recognizes issues arising from the current situation and the outcome that could be detrimental if not addressed. *Using Analogs* refers to comparing the current situation with past experiences to solve the current situation. *Planning and Re-planning* involves a process where team members build a list of actions that will be performed to solve a problem and adjust as developments occur.

Table 3. Macrocognitive Processes from the Naturalistic Decision-Making Literature.

Macrocognitive Process	Definition
Anticipatory Thinking (AT)	To foresee and make mental preparation by employing one's mind to a hypothetical scenario or problem (contingency preparation)
Assessing Risk (AR)	Evaluation of the potential consequences for risk or a danger to reach a desired end-state
Problem Detection (PD)	A form of sensemaking that recognizes issues arising from the current situation and the outcome that could be detrimental if not addressed
Planning and Re-planning (PR)	A process where team members build a list of actions that will be performed to solve a problem and adjust as developments occur
Sensemaking (SM)	The process of framing and reframing current inputs to the problem in a continuous process that helps us filter and interpret the data
Using Analogues (UA)	Comparing the current situation with past experiences to solve the current situation

In the following sections we describe the collaboration tool that was used during the Haiti HA/DR effort – All Partners Area Network (APAN) – and a method for the analysis of text files – lexical link analysis (LLA). Use of the LLA results provided a systematic way to select a subset of the large amount of APAN data from the Haiti HA/DR effort for our subsequent analysis. We selected several themes that were identified by LLA – the 'water' and 'hospital' themes – to analyze from initiation to completion.

All Partners Area Network Collaboration Tool

The All Partners Area Network (APAN) is an internet-based tool which was designed to facile-tate information sharing between participants during disaster relief efforts and was used in the Haiti relief effort. APAN is a web site that combines the benefits of unstructured collaboration (wikis, blogs, forum) and structured collaboration (file sharing, calendar) with social networking to facilitate information sharing with multinational partners, NGOs, and US Federal and State agencies. Over 1700 different individuals utilized the site during the relief effort (Pierce, 2010).

APAN has recently been revised and the version used in the Haiti relief operation was the Transnational Information Sharing Cooperation (TISC). This version of APAN was created in 2008 to meet the needs of the US Pacific Command (PACOM), who oversees a vast operational area with many different countries. The goal of this tool is to facilitate the free flow of information between relief organizations and the military throughout PACOM's Area of Responsibility (AOR) (Ives, 2010). In particular, the site was to be used in areas without sophisticated technical capabilities – a working internet connection is all that is required to use the site.

The simplicity of the site was one of the major reasons for its adoption among relief workers. The site was designed to be easy to use in order to facilitate use by personnel who may not be technologically savvy (Pierce, 2010). Another benefit of this tool is that it enables relief providers to advertise their services allowing the user to pick and chose what they need. An example of this was with the Sacré Coeur hospital in Milo, Haiti. The hospital was not damaged in the earthquake, but many people did not know this and thus the hospital was severely underutilized. The hospital admitted only 6 people in the four days following the disaster. Hospital personnel announced the availability of beds on APAN and the US military responded by airlifting severely injured patients to the hospital and increasing its hospital admittance to 250 within a few days (Technology Links Medical Aid and Survivors, 2010).

Lexical Link Analysis

Lexical link analysis (LLA), a tool for the analysis of structured or unstructured text files, based on an automated parsing of documents, to develop themes for the examined database based on the frequency of occurrence of key words (Gallup & Wood, 2010). These themes are characterized by one, two, or three key words, where themes such as ‘water’, ‘hospital-supplies’, or ‘injuries’ are thus discovered. The LLA is composed of two components, lexical analysis and link analysis. Lexical analysis is a form of text mining in which word pairs are extracted from a specific set of documents, such as Blog and Forum. Link analysis is a subset of network analysis that explores associations between objects, revealing the crucial relationships between objects. Link analysis “discovers” and displays a network of word pairs.

A LLA was performed on the APAN data to identify themes that emerged and what organizations were involved in each theme over the course of the Haiti HA/DR operation (Zhao, 2010). The APAN data was from a Microsoft Structured Query Language (MSSQL) database and the sources that were analyzed included: (*i*) Official documents and briefings: 167 PDF file attachments related to HAITI HA/DR from 1/13/2010 to 5/26/2010; (*ii*) SITREP: 150 Situation Report documents; (*iii*) Forum: 1173 posts from 1/13/2010 to 6/3/2010; and, (*iv*) Blogs: 3900 blog messages.

Forty themes were generated by identifying noun-verb word pairs where noun and verbs next to each other were found in documents. Weights were assigned to word pairs according to themes and documents for each day. Results of the LLA provided a systematic way to select a subset of the huge amount of APAN data for analysis for this research. For example, all information exchanges that concerned “water” were tagged as related to the “water” theme and were subsequently analyzed from the initiation of that theme through the conclusion of information exchanges pertaining to water.

METHOD

The ONR CKI Program Manager was provided a complete set of the APAN data from the Haiti HA/DR Effort. ONR went through its institutional review board (IRB) process to obtain permission to use this data and to distribute the data to researchers conducting under the CKI program. We also went through the Naval Postgraduate School IRB process to obtain approval for use of this data.

Selecting Data for Analysis

Data representing two themes were selected based on the results of the LLA – 'water' and 'hospital', and all communications associated with these themes were analyzed and coded to empirically evaluate the measurement model of team collaboration. This step served two purposes. First, it provided a systematic way to select a subset of the vast amount of data included in the overall APAN data set, which includes communications between some 1700 responders over a 5-month time period. Second, it also provided a way to isolate all communications related to a particular topic, such as 'hospital,' 'water,' or 'security.' We analyzed the data, using definitions of the macrocognitive processes included in the model of team collaboration to gain insight into the inter-agency collaboration that transpired between the various responders who represented a large number of organizations during this large-scale effort.

Data Analysis and Coding

One pair of coders, as part of the research for their master's thesis, analyzed two themes; each coder analyzed and coded all thought units associated with the water theme and the hospital theme. A thought unit refers to a sequence of words that convey a single thought (Welden et al, 1991).Cohen's kappa coefficient was used to calculate the percentage of agreement between the two coders.

Organizing data. The APAN data was originally from a MSSQL database and was exported as excel spreadsheets by NPS students. Data included people's names, organizations, email addresses, etc. Investigators replaced all personally identifiable information (PII) by substituting all personal identifiers of chat/blog respondents when the data set was received. Prior to coding, the data was unitized by separating each thought units on a separate line in the excel spreadsheet. Each thought unit was given a separate code. A thought unit is not equivalent to a sentence, as one sentence may contain several thought units and several sentences may contain one thought units.

Practice coding. Students independently practiced coding 200 lines from a separate data set to gain experience in applying the definitions of the macrocognitive processes included in the model of team collaboration. Raters discussed their respective coding with the lead researcher to calibrate their use of the macrocognitive process categories. They then completed additional practice coding on 200 lines of APAN data – on a separate theme – prior to their coding the data reported here to ensure they were calibrated. Following this training period they independently coded the data from the forum and blogs related to the water and hospital themes, subsequently reviewed their coding, calculated percent agreement, and resolved any differences in coding.

Inter-Rater Reliability. Both coders coded 682 and 538 thought units for the 'water' and 'hospital' themes, respectively. Cohen's kappa coefficient indicated high levels of agreement between coders for both sets of data. Inter-rater agreement was 72.0% and 70.0%, for the water theme and the hospital themes, respectively.

New Macrocognitive Processes

As discussed in the background section, we were motivated to unpack the macrocognitive category that contained the majority of team communications, *Team Information Exchange* (TIE). The research team reviewed the NDM literature related to macrocognition to determine additional cognitive processes that might be used to differentiate the large number of communications that were coded as TIE. Macrocognitive processes included in our coding scheme included sensemaking, anticipatory thinking, problem detection, assessing risk, planning and re-planning, and using analogues. After reviewing the definitions found in the literature we arrived at a consensus on definitions for the macrocognitive processes listed and defined in Table 2 (in the background section), and they were added to the list of macrocognitive processes to be used for analyzing and coding the APAN data.

RESULTS

Table 4 presents the percentage of communications between aid workers in the water and hospital themes coded as representing the macrocognitive processes in the measurement model of team collaboration. The pattern of results is strikingly similar for both themes and is similar to results obtained during previous use of the coding scheme in the measurement model of team collaboration. As can be seen, the vast majority of team members' communications concerned knowledge construction, that is, *Team Knowledge Building* –specifically *team information exchange*, highlighting the importance of this process during the Haiti relief effort. *Team Information Exchange, and to a lesser degree*, *Team Knowledge Sharing*, and *Team Solution Option Generation* are used by team members to develop an understanding of the complex problem and to refine and maintain their understanding as the highly dynamic situation evolves. Of particular interest is the large number of speech turns coded as *Team Information Exchange* (tie): TIE involves passing relevant information to the appropriate teammates at the appropriate times. Relevant information is information that is useful in helping solve a particular task.

Table 4. Percentage of Communications Coded as Macrocognitive Processes.

Code	Macrocognitive Process Categories	Percentage of Thought Units	
Individual Knowledge Building		**Water**	**Hospital**
IIG	Individual Information Gathering	4.10	3.60
IIS	Individual Information Synthesis	0.00	0.00
KOB	Knowledge Object Development	0.00	0.00
Team Knowledge Building			
TIE	Team Information Exchange	81.00	81.80

TKS	Team Knowledge Sharing	5.90	5.60
TSOG	Team Solution Option Generation	1.80	1.50
TENA	Team Evaluation and Negotiation of Alternatives	0.00	0.00
TPPR	Team Process and Plan Regulation	0.00	0.00
Internalized Team Knowledge			
ITK	Teammate Knowledge Similarity	0.00	0.00
SSA	Shared Situation Awareness	0.00	0.00
TKR	Team Knowledge Objects	0.00	0.00
IK	Task Knowledge Stock	0.00	0.00
Externalized Team Knowledge			
UR	Uncertainty Resolution	0.00	0.00
ECSA	Externalized Cue-strategy Associations	0.00	0.00
PRTA	Pattern Recognition and Trend Analysis	0.00	0.00
Problem Solving Outcomes			
QOP	Quality of Plan/ Problem-solving Solution	0.00	0.00
EPP	Efficiency of Planning Process	0.00	0.00
EPE	Efficiency of Plan Execution	0.00	0.00
Decision to Take Action			
DTA	DTA (Issue Course of Action)	0.00	0.00
RTA	DTA (Request Take Action)	7.30	7.40

Team's Use of Additional Macrocognitive Processes

It is noteworthy that the third most frequently used cognitive process was a subcategory of *Decision to Take Action, that is, Request Take Action* (the last entry in Table 4), reflecting how decision making is often required to effectively respond during a real-world event.

Tables 5-8 present examples of instances where thought units were coded with one of the macrocognitive processes from the NDM literature. As reflected in Table 5, in all cases the thought unit was coded using one of the initial set of macrocognitive processes included in the model of team collaboration and then when appropriate was coded with an additional category. In the vast majority of cases where coders assigned a second code these thought units were initially coded as *team information exchange* (TIE). For example, Table 5 provides examples of thought units coded as *team information exchange* that were also coded as *anticipatory thinking* (AT). In the first example, the person is anticipating the need for additional beds for patients and is letting other relief workers know that the hospital where he is working will be able to accommodate 100 additional patients in the coming days. In the second example of *anticipatory thinking* the relief worker informs others that he has "perhaps twelve hours of working materials to keep going," anticipating a shortage of necessary material that same day.

Table 5. Examples from the 'Hospital' theme coded as Anticipatory Thinking.

	Thought Unit	Model Code	NDM Code
1.	We have capacity for 10 patients immediately and probably 100 more in the coming days.	TIE	AT
2.	At this point, like I was saying, we have perhaps twelve hours of working materials to keep going.	TIE	AT

3.	The use of CAP (combat air patrol) will avoid the logjam at PAP [Port-au-Prince] and is an effective innovation in putting the supplies and aid where they are needed.	TIE	AT

Note: AT = Anticipatory thinking

Table 6 provides examples of thought units coded as *problem detection* (PD) from the hospital theme. *Problem detection* refers to a situation where the person recognizes an issue arising from the current situation where the outcome could be detrimental if not addressed. These involve instances where the person is informing others of the need for (1) security, (2) contact with the only operational hospital, (3) medicine, (4) food and water, (5) security, and (6) additional medical care. In all these instances of *problem detection*, labeling these instances of *team information exchange* provides a greater degree of specificity beyond *team information exchange.*

Table 6. Examples from APAN data Hospital theme coded as Problem Detection.

	Thought Unit	Model Code	NDM Code
1.	Improvement in delivery method will aid some and can be implemented immediately but the final solution will require security on the ground.	TIE	PD
2.	Unfortunately the situation is critical and although US choppers are flying overhead regularly there is as yet no contact between one of the few remaining, standing hospitals in the country and the US military.	TIE	PD
3.	We have run out of antibiotics and analgesics.	TIE	PD
4.	500 children 40 miles N/NE of Port-au-Prince that have about 24 hours of food and water left!!!	TIE	PD
5.	The rumor is that force protection – a Force protection requirement – is impeding aid delivery.	TIE	PD
6.	Again, we have over a thousand patients that are ready for surgery.	TIE	PD
7.	The hospital administrator for Bernard Mevs Hospital located near the Port-Au-Prince airport has reported an escalating number of pediatric malaria cases requiring treatment.	TIE	PD
8.	The hospital official noted a limited supply of anti-malarial pharmaceuticals available.	TIE	PD
9	From OCHA [Office for the Coordination of Humanitarian Affairs]: The Haiti emergency is also a high-risk environment for sexual exploitation and abuse.	TIE	PD
10.	At this point, like I was saying, we have perhaps twelve hours of working materials to keep going.	TIE	PD
11.	In these operating rooms, we don’t have oxygen, we don’t have general anesthesia, we don’t have narcotic pain medicines in enough quantity.	TIE	PD
12.	Again, we have over a thousand patients that are ready for surgery.	TIE	PD
13.	“WEBSITE” does not seem to have contacts for hospitals in Haiti and seems to provide maps only in PDF format.	TIE	PD
14.	I saw your post and thought perhaps partners may know of someone who can assist us.	IIG	PD
15.	The problem we are facing is with discharge.	TIE	PD

Note: PD = Problem detection

Table 7 provides examples of thought units coded as *problem detection* (PD) from the water theme.

Table 7. Examples from APAN data Water theme coded as Problem Detection.

	Thought Unit	Model Code	NDM Code
1.	The U.S. has supply agreements with Luxembourg (attached), though it appears they exclude North America.	TIE	PD
2.	At this moment my condition is very difficult with the orphans because we can't have food, water, and medicines and food supplies because we don't have money on hand to do that.	TIE	PD
3.	But the roads are not yet all named in the Montagne Noire area.	TIE	PD
4.	We safely dropped shelter boxes (emergency tent/filtration/blanket survival kits) Friday but gents, this is food and I fear for their safety.	TKS	PD
5.	Last contact with the orphanage revealed little to no food, no access to water and a deep concern about possible criminal activity in the area.	TIE	PD
6.	Jumping the water from US to Haiti is the only missing piece of our puzzle!	TIE	PD
7.	They didn't have radios, batteries or generators and the earthquake silenced landlines and mobile services, leaving Haitians in the dark in more ways than one.	TIE	PD
8.	MSC or airlift needed ASAP.	TIE	PD

Table 8 provides examples of thought units coded as *Sensemaking* (SM) from the hospital theme.

Table 8. Examples from APAN data Hospital theme coded as Sensemaking.

	Thought Unit	Model Code	NDM Code
1.	This one was very interesting in that the need on the ground if Haiti changed based on UNICEF WASH.	TIE	SM
3.	The comforting doll is "Like Them."	TIE	SM
4.	Dr. "name": This question of security and the rumors of security and the racism behind the idea of security had been our major block to getting aid in.	TKS	SM

Note: SM = Sensemaking

Lastly, an example of *using analogies* (UA) occurred where the person compared the current situation in Haiti with previous HA/DR efforts where "a single website was needed to support the predictable exchange of information in emergencies at the country level." A second example is the following: "I believe there is such hunger that food brings out the beast in any uprooted survivor of a 12 day old disaster."

Generating solutions during time-critical tasks is an important aspect of collaboration. Table 9 provides examples of thought units coded as Team Solution Option Generation (TSOG).

Table 9. Examples of Team Solution Option Generation.

	Team Solution Options Generated
1.	One idea might be to set up Comms between the hospital and the USNS Comfort which I believe will be in port today.
2.	A good idea perhaps if at all possible is have someone take some GPS coordinates of the landing field and post it here.
3.	My driver offered to wrap every medical worker in 5 Haitians to make sure they'd feel safe.
4.	Suggestion for military to consider: Would help a lot if military came across as focused primarily on humanitarian aid, less on security.

Inter-Rater Reliability

The high Cohen kappa coefficient achieved indicates the two coder's agreement is substantial. This high inter-rater reliability indicates the macrocognitive process definitions used by the coders are objective. Table 10 presents the results of the kappa analysis, for the water theme data, in the form of a pivot table which compares coder 1 codes with coder 2 codes. Coder 1 codes are displayed in the columns and coder 2 codes are read across rows. The diagonal cells of the matrix indicate agreement between the coders whereas the values in the other cells indicate the difference between what each of the coders chose. The pivot table also highlights which codes the coders disagreed upon. For example, under the *team information exchange* (TIE) category, coder 1 and coder 2 had assigned a total of 540 and 506 TIE codes, respectively, to the data. However, both coders matched selections for 488 of the TIE codes.

Table 10. Pivot Table for Coders Analysis of Water theme.

Water Cohen Kappa Results									
Row Labels	IIG	RTA	TIE	TKS	TSOG	UR	MISC	NC	TOTAL Coder 2
IIG	24	0	2	0	0	0	1	0	27
RTA	1	34	6	1	0	0	0	0	42
TIE	0	10	488	6	2	0	0	0	506
TKS	0	0	27	19	1	0	0	0	47
TSOG	0	1	7	2	5	0	0	0	15
UR	0	0	0	0	0	0	0	0	0
MISC	0	0	10	0	0	0	35	0	45
NC	0	0	0	0	0	0	0	0	0
TOTAL Coder 1	25	45	540	28	8	0	36	0	682

Table 11 presents the results of the Kappa analysis, for the hospital theme data.

Table 11. Pivot Table for Coders Analysis of Hospital theme.

Hospital Cohen Kappa Results									
Row Labels	IIG	RTA	TIE	TKS	TSOG	UR	MISC	NC	TOTAL CODER 2
IIG	13	5	3	0	0	0	0	0	21
RTA	0	32	8	0	0	0	0	0	40
TIE	1	5	380	7	0	0	0	0	393
TKS	0	1	18	15	0	0	0	0	34
TSOG	1	2	8	0	2	0	0	0	13
UR	0	0	0	0	0	0	0	0	0
MISC	0	0	8	0	0	0	29	0	37
NC	0	0	0	0	0	0	0	0	0
TOTAL Coder 1	15	45	425	22	2	0	29	0	538

DISCUSSION

A sequential analysis method was used to unpack the way cognition unfolded over the course of the Haiti HA/DR operation for a highly-dynamic, complex, large-scale problem-solving event. Several of the macrocognitive processes included in the model cannot be captured or coded with the type of data we have analyzed, that is, a set of communications or chat log entries that occurred in a real-world setting, but were received after the event. Since the data we focus on is data captured either from "the wild" or in high-fidelity experiments, we have no ability to measure things such as *Teammate Knowledge Similarity*, *Shared Situation Awareness, Quality of Plan/ Problem Solving Solution*, and *Efficiency of Planning Process* because they require (1) obtaining specific types of data directly from team members, such as via survey administration, or (2) assessing the team's performance, which often is not possible as, in many cases, there are no performance assessment metrics for these real-world tasks.

We took the approach of adding new cognitive processes to our coding scheme in an effort to discover other macrocognitive processes that might be employed by collaborating teams. Specifically we were interested in cognitive processes that are currently coded as *Team Information Exchange*. The addition of macrocognitive processes from the NDM literature was an exploratory effort to discover whether additional cognitive processes are employed during complex, information-rich, problem-solving events. We saw evidence for these additional processes, that is, sensemaking, anticipatory thinking, problem detection, assessing risk, planning and re-planning, and using analogues.

Developing a more comprehensive understanding of the macrocognitive processes involved in team collaboration has several practical advantages. First, conceptualizations that provide the theoretical foundation for a model of team collaboration that take into account consistent findings based on empirical research in real-world work domains are likely to be more accurate. Second, the way team cognitive processes influence team functioning was listed among the top ten critical research questions in team research (Salas & Wildman, 2009). Third, a more complete model of team collaboration can guide designers of collaboration tools to facilitate decision making as part of the overall task.

Decision Making is Part of Problem-Solving

Many dynamic and evolving tasks that involve team problem solving include decision making; that is, team members take action, or request other teammates to take action, in addition to developing new knowledge and agreeing on a final solution. Actions are frequently part of the overall information gathering process and have diagnostic functions (Orasanu & Connolly, 1993).

CONCLUSIONS

Developing a more comprehensive understanding of the macrocognitive processes involved in team collaboration has several practical advantages. First, conceptualizations that provide the theoretical foundation for a model of team collaboration that take into account consistent findings based on empirical research in real-world work domains are likely to be more accurate.

Second, the way team cognitive processes influence team functioning was listed among the top ten critical research questions in team research (Salas & Wildman, 2009). Third, a more complete model of team collaboration can guide designers of collaboration tools to facilitate decision making as part of the overall task.

Decision to Take Action is recommended as a new category to be added to the set of macrocognitive processes included in the Fiore et al. (2010) model of team collaboration. Deciding to take action is viewed as both a macrocognitive *process* and a *product* of team collaboration. We assert that decision making is a critical element of team problem solving when a team is executing a task, in contrast to conducting a planning task. When team members collaborate to solve a problem they make decisions and implement those decisions as part of performing the task.

For the task domains discussed here, a constant interplay exists between sharing information – to develop new knowledge and maintain situation awareness—and deciding on actions that are required, and implementing those actions, followed by monitoring the situation and continuing to build new knowledge on the unfolding situation. Execution of the mission, or problem-solving task, would come to a screeching halt without this continual, iterative cycle of developing knowledge of the situation and responding to the current situation.

REFERENCES

Fiore, S. M., Rosen, M. A., Smith-Jentsch, K. A., Salas, E., Letsky, M. & Warner, N. (2010). Toward an Understanding of Macrocognition in Teams: Predicting Processes in Complex Collaborative Contexts. *Human Factors,* Vol. 52 No. 2, 203-224.

Genzlinger, N. (2011, January 11). Lawlessness and the Need to Survive in Shaken Haiti. *The New York Times.*

Gallup, S. P., & Wood, B. P. (2010). Transnational Information Sharing Cooperation (TISC) Letter of Observation (LOO) on SOUTHCOM Communities of Interest (CoIs). Naval Postgraduate School Report. Monterey, CA.

Gyokeres, T. S. (2010, March 23). Air Force Captain Looks Back On Efforts to Re-establish Air Ops in Haiti. Retrieved April 3, 2011, from US Southern Command: http://southcom.mil/appssc/news.php?storyId=262

Hansen, M. T. & Nohria, N. (2004). How to build collaborative advantage. MIT *Sloan Management Review*. *46*(1), 22-30.

Haviv, R. (2006, February 2). Glimmers of Hope in Cite Soleil. Retrived April 8, 2011, from Washington Post: http://blog.washingtonpost.com/haitisstruggle /2006/02/glimmers_of_hpe_in_cite_solei_1.html

Hocevar, S.P., Thomas, G.F., & Jansen, E. (2006). Building collaborative capacity: An innovative strategy for homeland security preparedness. In Beyerlein, Beyerlein & Kennedy (Eds.), *Advances in interdisciplinary studies of work teams: Innovations through collaboration*, (pp. 263-283). (Vol. 12). New York: Elsevier JAI Press.

Hoffman, R. R. & Yates, J. F. (2005). Decision(?)Making(?). *IEEE Intelligent Systems*, July/August 2005. pp. 76-83. www/computer.org/intelligent.

Hutchins, S. G., Bordetsky, A., Kendall, T., & Garrity, M. (2007). Empirical Assessment of a Model of Team Collaboration. In *Proceedings of the 8th International Conference on Naturalistic Decision Making*. Asilomar, CA. June 4-6, 2007.

Hutchins, S. G., Bordetsky, A., Kendall, A., & Garrity, M. (2007). Evaluating a model of team collaboration via analysis of team communications. In *Proceedings of the 51st Human Factors and Ergonomics Association Annual Meeting*, Baltimore, MD.

Hutchins, S. G., & Kendall, A. (2008). Patterns of Team Collaboration Employed to Solve Complex Problems. In *Proceedings of the 52nd Annual Meeting of the Human Factors and Ergonomics Society*, New York, September 22-26. Santa Monica, CA.

Hutchins**,** S. G., Kendall, A., & Bordetsky, A. (2008). Understanding Patterns of Team Collaboration Employed to Solve Unique Problems. In *Proceedings of the 13th International Command and Control Research & Technology Symposium*, June 17-19, Bellevue, WA, www.dodccrp.org.

Hutchins, S. G., & Kendall, T. (2010a). The Role of Cognition in Team Collaboration during Complex Problem Solving. In K. L. Mosier and U. M. Fischer (Eds.), *Informed by Knowledge: Expert Performance in Complex Situations.* pp. 69-89. Abington, UK: Taylor and Francis.

Hutchins, S. G., and Tony Kendall, T. (2010b). Analysis of Team Communications to Understand Cognitive Processes used during Team Collaboration**.** In *Proceedings of the 15th International Command and Control Research & Technology Symposium*. Santa Monica, CA, 23-25 June. www.dodccrp.org.

Hutchins, S. G., & Kendall, A. (2010c). Understanding Cognition in Team Collaboration through use of Communications Analysis. In *Proceedings of the 54th Annual Meeting of the Human Factors and Ergonomics Society*, San Francisco, CA. September 28-October 1. Santa Monica, CA.

Hutchins, S.G., and Kendall, A., Letsky, M. (In review). Macrocognition and Team Collaboration during Complex Problem Solving: It's all about Decision Making.

Ives, B. (2010, February 19). *Portals and KM: US Military Enterprise 2.0 Platform is Helping Coordiante Haiti Relief*. Retrived April 2, 2011, from Bill Ives TypePad.com: http://billives.typepad.com/portals_and_km/2010/02/uus-military-enterprise-20-platform-is-helping-cooridinate-haiti-relief.html

IHRC, (2011, January 12). *Haiti one year later: The progress to date and the path forward.* A Report from the Interim Haiti Recovery Commission.

Jansen, E., Hocevar, S. P., Rendon, R. G., & Thomas, G. F. (2009). The Theory and Measurement of Interorganizational Collaborative Capacity in the Acquisition and Contracting Context. Naval Postrgradaute School Technical Report, NPS-AM-09-051, Monterey, CA.

Kendall, T., & Hutchins, S. G. (2009). Use of a Team Collaboration Model in Assessing Knowledge Management Technology. In *Proceedings of the 9th International Naturalistic Decision Making Conference*, British Computer Society, London, UK.

Keyton, J., & Beck, S. J. (2010). Perspective: Examining Communication as Macrocognition in STS. *Human Factors*, Vol. 52 No. 2, 203-224.

Klein, G. A. (1989). Recognition-primed decisions. In W. R. Rouse (Ed.) *Advances in man-machine systems research* (Vol. 5, pp. 47-92). Greenwich, CT: JAI Press.

Klein, G., Phillips, J. K., Rall, E. L., and Peluso, D. A. (2007). A Data-Frame Theory of Sense-making. In Hoffman (Ed.), *Expertise Out of Context*. Lawrence Erlbaum Associate, New York.

Klein, G., Ross, K. G., Moon, B. M., Klein, D. E., Hoffman, R. R., & Hollnagel, E. (2003). Macrocognition. *IEEE Intelligent Systems*, *18*(3), 81-85.

Lakhani, N. (2011, January 10). A Year After a Massive Earthquake, Rape and Squalor Prevail in Haiti. *Canberra Times (Australia).*

Letsky, M., & Warner, N. (2008). Macrocognition in Teams. In M. Letsky, N. Warner, S. M. Fiore, & C. Smith (Eds.). *Macrocognition in Teams.* London: Ashgate.

Mankin, D., Cohen, S., & Fitzgerald, S. P. (2004). Developing complex collaboration: Basic principles to guide, design, and implementation. In M. M. Beyerlein, D. A. Johnson, & S. T. Beyerlein (Eds.), *Complex Collaborative Capacity: Building the capabilities for working across boundaries* (pp. 1-26). New York: Elsevier.

Orasanu, J., & Connolly, T. (1993). The reinvention of decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 3-20). Norwood, NJ: Ablex.

Pierce, D. (2010, January 21). *Pentagon's Social Network Becomes a Hub for Haiti Relief.* Retrieved March 28, 2011, from Wired Magazine: http://www.wired.com/dangerroom/2010/01/pentagons-social-network-becomes-hub-for-haiti-releidf/#ixzz0dGxabYQ

Robson, S. (2010, February 28). *Rebuilding Haiti's Demolishd Port Is No Small Task for U.S.* Retirieved april 3, 2011, from Stars and stripes: http://www.stripes.com/news/rebuilding-haiti-s-demolished-port-is-no-small-task-for-u-s-1.99687

Salas, E., & Wildman, J. L. (2009). Ten critical research questions: The need for new and deeper explorations. In E. Salas, G. F. Goodwin, C. S. Burke (Eds). *Team effectiveness in complex organizations: Cross-disciplinary perspectives and approaches. The organizational frontiers series*. (pp. 535-546). New York, NY: Routledge/Taylor & Francis Group.

Sawer, P. S. (2010, January 16). Haiti Earthquake: Looting and gun fights break out. Retrievd April 8, 2011, from London Telegraph: http://www.telegraaaph.co.uk/news/worldnews/centralamerica and the caribbean/haiti/7005554/Haiti-earthquake-looting-and-gun-fights-break-out.html

Technology Links Medical Aid and Survivors. (2010, February 24). Retrieved April 5, 2011, from US Southeren Command: http://www.southcom.mil/appssc/blog.php?id=72

Warner, N., Letsky, M., & Cowen, M. (2005). Cognitive Model of Team Collaboration: Macro-Cognitive Focus. In *Proceedings of the 49th Human Factors and Ergonomics Society Annual Meeting*, September 26-30, 2005. Orlando, FL.

Welden, E., Jehn, K. A., & Pradhan, F. (1991). Processes that mediate the relationship between a group goal and improved group performance. *Journal of Personality and Social Psychology*, *61*, 555-569.

Wood, D. J., & Gray, B. (1991). Toward a comprehensive theory of collaboration. *Journal of Applied Behavioral Science*, 27, 149-162.

Zhao, Y. (2010). Lexical Link Analysis for APAN Haiti Humanitarian Assistance/Disaster Relief. Presentation for Naval Postgraduate School, Decision Information Systems Experimentation (DISE) Research Group. Monterey, CA.

NAVAL
POSTGRADUATE
SCHOOL

Investigating Inter-Organizational Collaboration during the Haiti Relief Effort from a Macrocognition Perspective

Susan G. Hutchins, Ying Zhao, and Tony Kendall
Graduate School of Operational and Information Sciences

21-23 June 2011

Background
Objective

- Evaluate CKI measurement model of team collaboration
  - Based upon analysis of real-world complex decision-making events
  - Determine which macrocognitive processes are used and, if necessary, refine the model based on empirical analysis
  - Develop a better understanding of the cognitive processes employed when teams collaborate to solve problems
- Test the current coding scheme included in the model of team collaboration
  - Apply definitions of macrocognitive processes included in CKI model of team collaboration
  - Schemes for coding communications should be mutually exclusive, exhaustive, and equivalent
- Examine a range of real-world task domains

Method

- **Macrocognition -** emerging field within cognitive engineering that describes the way cognition occurs in naturalistic, or real-world, decision-making events (Cacciabue & Hollnagell, 1995)
- **Macrocognition in teams** expands the concept by considering group cognition and the collective (team) cognitive processes that enable the externalization of internalized knowledge building. (Letsky et al., 2008)
- **Focus on cognition in collaboration contexts**
  - Focuses on contextually-bound processes
    - Sensemaking, managing uncertainty, and related cognitive processes entailed in responding to emerging events that occur in dynamic decision-making situations
  - Teams collaborate on **short-term situations which require rapid action to be taken against specific missions**
- **Content analysis –** analyze, code team comm's
  - Unique, information-rich, ambiguous, time-compressed scenarios

Technical Approach

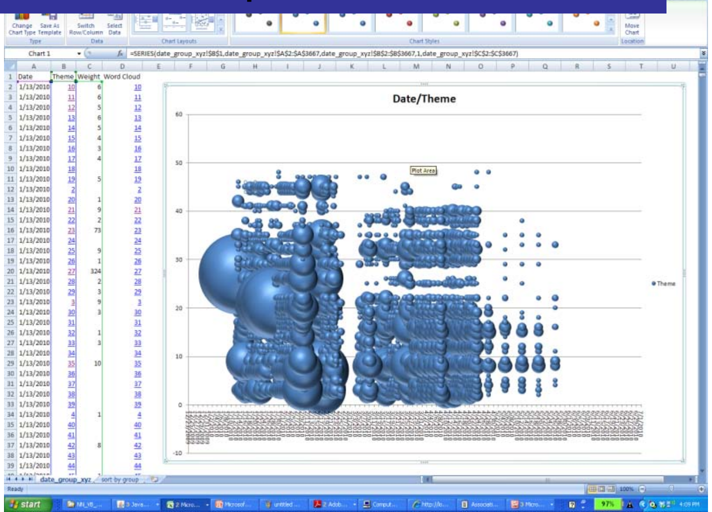
- Analyzed APAN data from the Haiti HA/DR effort in FY11
  - Communications between air, ground, and ocean-based assistance crews were recorded in the All Partners Access Network (APAN) collaboration system
  - Internet-based tool designed for information sharing during disaster relief efforts
    - » Wikis, blogs, forum, file sharing, chat, …
  - > 1,700 individuals used APAN during relief effort
  - Multinational partners, NGOs, and US Federal and State agencies
  - Period covered: Jan 13, 2010 – May 26, 2010
- Lexical link analysis was performed on APAN data
  - Identified terms that emerged and organizations involved over the course of the Haiti HA/DR operation
  - MSSQL database included: 1173 Forum posts and 3900 Blog messages
- Systematic way to select a subset of the vast amount of data in APAN data set
  - Provided a way to isolate all communications related to a particular topic, such as 'hospital,' 'water,' 'logistics,' and 'security'
- Applied definitions of macrocognitive processes included in the model

Technical Approach

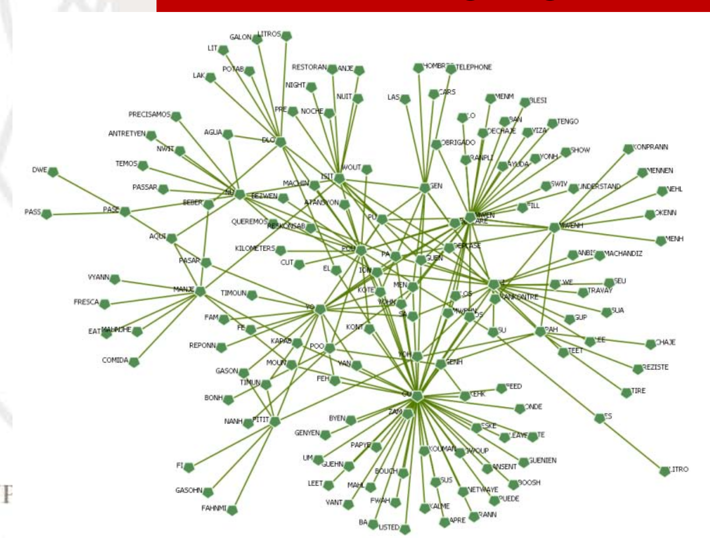
Lexical Link Analysis

- Analysis of structured and unstructured text files (Gallup & Wood, 2010)
  - Automated parsing of documents
  - Develops themes for examined database based on frequency of occurrence of key words
- Lexical analysis – text mining, word pairs extracted from documents, e.g., Blog and Forum (Zhao, 2010)
- Link analysis – reveals relationships between two objects
  - Discovers and displays a network of word pairs
- Generated 40 themes using LLA

Themes line up w/ the timeline



Theme – Language Basic Skills



Collaboration

- Collaboration occurs
  - "When a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain" (Wood & Gray, 1991, p.11)
- Interactive process performed in a collaborative team environment
  - *Collaborative* defined as the "cognitive aspects of joint analysis or problem solving for the purpose of attaining shared understanding sufficient to achieve situational awareness for decision making or creation of a product" (Letsky & Warner, 2008, p. 4).
- Benefits afforded by inter-organizational collaboration
  - Better decision-making as a result of shared information
  - Enhanced coordination among dispersed units
  - Innovation resulting from the cross-pollination of ideas
  - Cost savings produced by sharing resources and the transfer of smart practices (Hansen & Nobia, 2004; Mankin & Fitzgerald, 2004).

Method

Selecting data

- Large set of real-world data with all the characteristics of interest for conducting an empirical evaluation of the model of team collaboration
  - Ad hoc teams are quickly assembled to deal with an emerging event that requires a collaborative effort to deal with the problem-solving event
- Data representing four themes was selected based on LLA
  - Water, hospital, security, logistics

Data analysis and coding

- One pair of coders coded two themes: Water, hospital,
- Second pair of coders coded two themes: Security, logistics
- Cohen's kappa used to calculate percentage agreement
  - 72% and 70% agreement for water and hospital themes

Organizing data

- Data unitized by separating each thought unit on separate line
  - A thought unit refers to a **"sequence of a few words conveying a single thought"** (Welden, Jehn, & Pradhan, 1991, p. 559)
  - **"the smallest message unit that can stand alone"** (Keyton & Beck, 2010, p. 336)

Method

Practice coding

- Coders independently coded 200 lines from separate data set
- Raters discussed respective coding w/ researcher to calibrate their use of the macrocognitive process categories
- Then completed additional practice coding 200 lines of APAN data on a separate theme

Independently coded data from forum and blogs for their two themes

- Reviewed respective coding, calculated percent agreement, resolved any differences in coding

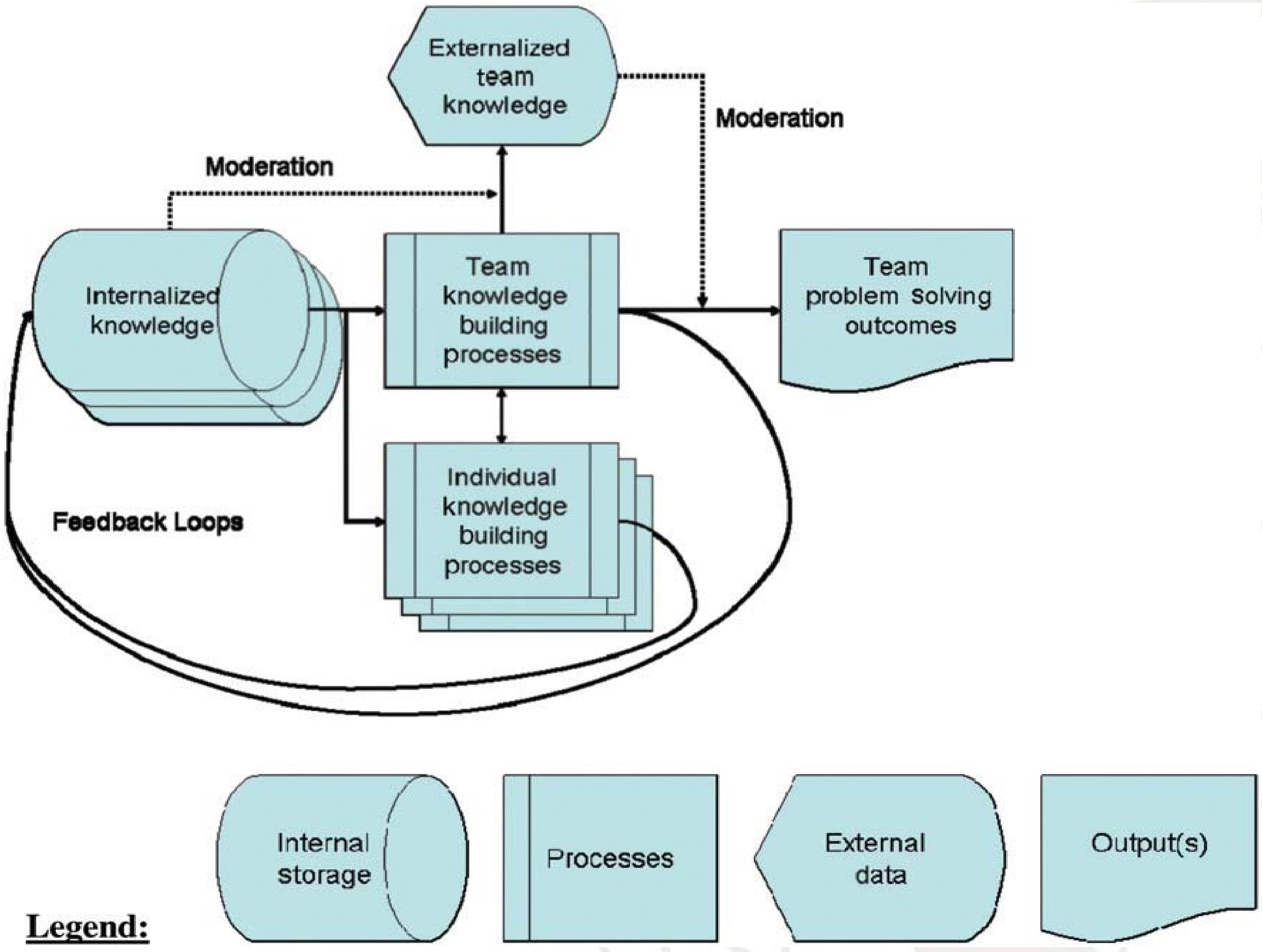
Motivated to unpack the macrocognitive category that contained the majority of team communications, *Team Information Exchange* (TIE)

- 81% of water and hospital theme thought units coded as TIE
- Research team reviewed the NDM literature related to sensemaking to determine additional cognitive processes that might be used to differentiate the large number of communications that were coded as TIE

Method

Measurement Model of Team Collaboration

(From Fiore, Rosen, Smith-Jentsch, Salas, Letsky, & Warner, 2010)



Method

- **A consistent pattern is evident across task domains** previously investigated where the majority of thought units were coded as representing two of the cognitive processes: *Team Information Exchange* (TIE) and *Team Knowledge Sharing* (TKS)
- ***Team Info Exchange:*** passing relevant information to the appropriate team member
- ***Team Knowledge Sharing*:** explanations and interpretations shared between TMs

Percentage of Communications Coded as Team Information Exchange and Team Knowledge Sharing across Task Domains

Task Domain	Team Information Exchange	Team Knowledge Sharing
Firefighters 9-11	42.0[1]	27.0[2]
Maritime Interdiction Operation	60.0[1]	5.0[2]
Air Operations Center	51.5[1]	10.3[2]
NORAD	52.9[1]	3.7[2]
UAV Dynamic Re-planning	58.00	4.29
Haiti HA/DR Effort	81.00	5.90

Note: [1]In a previous version of the model this macrocognitive process was labeled *Task Knowledge Development*.
[2]In a previous version of the model this macrocognitive process was labeled *Team Knowledge Development*.

Include Sensemaking Processes

- Focus on tasks performed in "the wild" – culled from NDM literature related to sensemaking to develop additional list of macrocognitive processes that could be used for coding the present set of data
- **Sensemaking:** An essential cognitive function performed by a variety of domain practitioners across a wide range of real-world tasks (Klein, Phillips, Rall, and Peluso, 2007)
  - Begins when person becomes aware of a weakness in their current comprehension of a situation, often experienced as a surprise, in response to unexpected changes or as a failure of expectations
  - Sensemaking is a critical process for teams engaged in real-world domains where practitioners deal with complex, dynamic, evolving situations that are "rich with various meanings" (Klein, et al, 2007, p. 114)
    - Data practitioners use to develop an understanding of the situation are often highly ambiguous and very complex and the dynamic events require the decision maker to dynamically update their understanding as the situation evolves over time
  - The frame that is adopted by the practitioner will affect what data are attended to and how these data items are interpreted
    - When the practitioner notices data that do not fit the current frame, the sensemaking cycle of continuously moving toward better explanations is activated. Sensemaking incorporates consideration of the following criteria: plausibility, pragmatics, coherence, and reasonableness

Method

Macrocognitive Processes from the NDM Sensemaking Literature

Macrocognitive Process	Definition
Anticipatory Thinking (Klein, Snowden, & Lock Pin, 2007) (Weick & Sutcliffe, 2001)	A critical macrocognitive function of both individuals and teams. A form of sensemaking that is future oriented such as forming expectancies about future events. Active attention management where the operator focuses attention on likely sources of critical information is a key characteristic
Assessing Risk	Evaluation of the potential consequences for risk or a danger to reach a desired end-state
Problem Detection	A form of sensemaking that recognizes issues arising from the current situation where the outcome could be detrimental if not addressed
Planning and Re-planning	A process where team members build a list of actions that will be performed to solve a problem and adjust as developments occur
Sensemaking	The process of framing and reframing current inputs to the problem in a continuous process that helps filter and interpret the data
Using Analogues	Comparing the current situation with past experiences to solve the current situation

Results

- **Previous research indicates non-exhaustive set of macrocognitive processes**
- **Decision making** – what we label *Decision to Take Action* (DTA) – **emerged during previous analyses of six task domains as a new macrocognitive process**
  - Decision making is an essential macrocognitive process when teams are involved in responding to many complex, real-world tasks
- **Dynamic decision-making tasks require decisions throughout the entire scenario** (Brehmer, 1992)
  - Deciding to take action is viewed as both a **macrocognitive *process*** and a ***product*** of team collaboration (Klein, 1993)
  - Decision maker continuously engaged in monitoring environment, reassessing the situation, and trying to understand what is unfolding until a decision is called for
    - This view sees **knowing <u>when</u> to act as critical as knowing <u>what</u> to do** (Warwick & Hutton, 2007)
- **Many task domains require an interleaving of knowledge building, decision making and taking action to accomplish the mission**
  - Opposed to the team making one final decision at the conclusion of the scenario
- **Analysis of range of task domains indicates types of tasks described by model typically involve team members making decisions as part of the team's collaborative problem solving.**

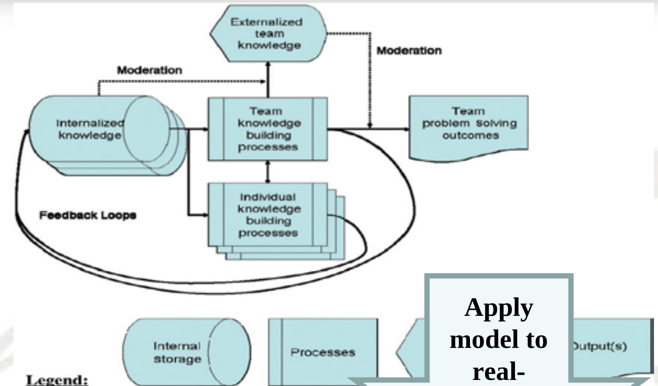
Decision Making is Part of Problem Solving

- **A decision** can be defined as a **“mental event that occurs at a singular point in time…that leads immediately or directly to action”** (Hoffman & Yates, 2005, p. 77).
  - From this perspective, a decision is a commitment to a course of action.
- **Decision making is an essential component of team collaboration for effective team problem solving when team is *<u>performing</u>* the task as opposed to *<u>planning</u>***
- Consistent finding across seven task environments analyzed:
  - Firefighters on Sept 11 responding to the attack on the world trade center
  - Air warfare teams on a Navy ship
  - Boarding team conducting a maritime interdiction operation
  - NORAD collaborating with the FAA on Sept 11 to ground all commercial air traffic
  - Air Force team responding during a time-sensitive targeting scenario
  - Experiment involving UAV real-time planning and execution

	FDNY	Air Warf	MIO	AOC	NORAD	Haiti
Course of Action (COA)	12	22	2	4.7	1.2	--
Request Take Action (RTA)	7	5	9	2.8	4.1	7.4
Total Percent	19	27	11	7.5	5.3	7.4

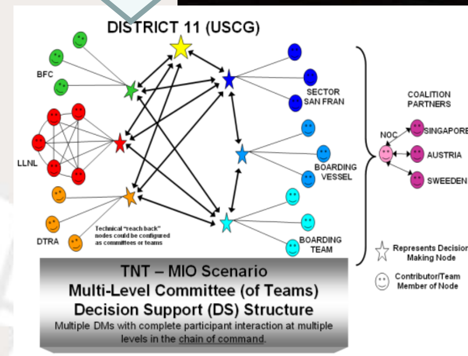
Results

- **Examined a wide range of task domains**:
  - Firefighters on 9/11
  - Air warfare decision making on US Navy ship
  - Maritime Interdiction Operations (MIO)
  - NORAD/FAA on Sept 11, 2001
  - Air Operations Center Dynamic Targeting Exercise
  - UAV planning and execution
  - Haiti HA/DR Operation
    - Security -722 thought units; Relief Logistics 1,260
    - Water & Hospital - 1,220 thought units
- **High inter-rater reliability**:
  - Firefighters, 9/11 - 89.3%
  - Air Ops Center dynamic Targeting – 89%
  - FAA/NORAD – 77%
  - Haiti HA/DR – 72% and 70%,Water & hospital themes
- Results indicate **task environment will influence which processes are used**
  - C2 teams collaborate on situation assessment but often use RPD decision strategy to determine COA



Apply model to real-world scenarios

Better under-steam decision making



A more complete model of team collaboration can guide designers of collaboration tools to facilitate decision making as part of the overall task.

NAVAL POSTGRADUATE SCHOOL

Results of analysis of APAN data for Water and Hospital Themes

Code	Macrocognitive Process Categories	Percentage of Thought Units	
	Individual Knowledge Building	**Water**	**Hospital**
IIG	Individual Information Gathering	**4.10**	**3.60**
IIS	Individual Information Synthesis	**0.00**	**0.00**
KOB	Knowledge Object Development	**0.00**	**0.00**
	Team Knowledge Building		
TIE	Team Information Exchange	**81.00**	**81.80**
TKS	Team Knowledge Sharing	**5.90**	**5.60**
TSOG	Team Solution Option Generation	**1.80**	**1.50**
TENA	Team Evaluation and Negotiation of Alternatives	**0.00**	**0.00**
	Decision to Take Action		
COA	DTA (Issue Course of Action)	0.00	0.00
RTA	DTA (Request Take Action)	**7.30**	**7.40**

TIE – passing relevant info to appropriate TMs at the appropriate time

Accomplishments

Examples from the 'Hospital' theme coded as Anticipatory Thinking.

	Thought Unit	Model Code	NDM Code
1.	We have **capacity for 10 patients immediately and probably 100 more in the coming days.**	TIE	AT
2.	At this point, like I was saying, **we have perhaps twelve hours of working materials to keep going.**	TIE	AT
3.	The use of CAP (combat air patrol) will avoid the logjam at PAP [Port-au-Prince] and is an effective innovation in putting the supplies and aid where they are needed.	TIE	AT

NAVAL POSTGRADUATE SCHOOL

Problem Detection: a form of sensemaking that recognizes an issue arising from the current situation where the outcome could be detrimental if not addressed

	Thought Unit	Model Code	NDM Code
1.	Improvement in delivery method will aid some and can be implemented immediately but the final solution will require **security** on the ground.	TIE	PD
2.	Unfortunately the situation is critical and although US choppers are flying overhead regularly there is **as yet no contact between one of the few remaining, standing hospitals** in the country and the US military.	TIE	PD
3.	We have **run out of antibiotics and analgesics.**	TIE	PD
4.	500 children 40 miles N/NE of Port-au-Prince that have about **24 hours of food and water left!!!**	TIE	PD
5.	The rumor is that **force protection** – a Force protection requirement – **is impeding aid delivery**.	TIE	PD
6.	Again, we have over a thousand patients that are ready for surgery.	TIE	PD
7.	The hospital administrator for Bernard Mevs Hospital located near the Port-Au-Prince airport has reported an **escalating number of pediatric malaria cases requiring treatment**.	TIE	PD
8.	The **hospital official noted** a **limited supply of anti-malarial pharmaceuticals available**.	TIE	PD
9.	From OCHA [*Office for the Coordination of Humanitarian Affairs*]: The Haiti emergency is also a high-risk environment for sexual exploitation and abuse.	TIE	PD
10.	At this point, like I was saying, we have perhaps twelve hours of working materials to keep going.	TIE	PD
11.	In these operating rooms, **we don't have oxygen, we don't have general anesthesia, we don't have narcotic pain medicines in enough quantity.**	TIE	PD
12.	Again, we have over a thousand patients that are ready for surgery.	TIE	PD
13.	"WEBSITE" does not seem to have contacts for hospitals in Haiti and seems to provide maps only in PDF format.	TIE	PD
14.	The problem we are facing is with discharge.	TIE	PD

Results

Examples from APAN data Water Theme Coded as Problem Detection

	Thought Unit	Model Code	NDM Code
1.	The U.S. has **supply agreements** with Luxembourg (attached), though it appears they **exclude North America**.	TIE	PD
2.	At this moment my condition is very difficult with the orphans because we **can't have food, water, and medicines and food supplies** because we don't have money on hand to do that.	TIE	PD
3.	But the **roads are not yet all named** in the Montagne Noire area.	TIE	PD
4.	We safely dropped shelter boxes (emergency tent/filtration/blanket survival kits) Friday but gents, this is food and I fear for their safety.	TKS	PD
5.	Last contact with the orphanage revealed little to no food, no access to water and a deep concern about **possible criminal activity** in the area.	TIE	PD
6.	Jumping the water from US to Haiti is the only missing piece of our puzzle!	TIE	PD
7.	They didn't have radios, batteries or generators and the earthquake silenced landlines and mobile services, leaving Haitians in the dark in more ways than one.	TIE	PD
8.	MSC or airlift needed ASAP.	TIE	PD

Results

- Analysis of a range of task domains indicates that several macrocog processes cannot be measured during certain types of real-world problem solving
- Two explanations:
  - Many tasks require dynamic decision making (Montgomery, 1993; 1989)
    - Rapid responses are required to deal with the event
    - When TMs use RPD strategy, usually the situation itself either determines or constrains the response options and experienced decision makers make up to 90% of all decisions w/o considering alternatives (Klein, 1989)
    - If the situation appears similar to one that the decision maker has previously experienced, the pattern will be recognized and the course of action is usually immediately obvious.
    - Firefighters, as well as TMs in many other domains collaborate on the 'front end' of the problem, but do not collaborate on how to respond to an event due to time pressure.

Little evidence for *team evaluation and negotiation of alternatives* by team members during dynamic decision-making problem-solving task domains because many responses are guided by standard operating procedures, and the stored schemas of highly experienced operators.

Results

- Many cognitive processes included in the model are not amenable to measurement when working with real-world teams
  - Analyze chat logs or transcripts from large-scale real-world events and exercises
    - Typically not possible to administer surveys or collect data to measure many processes in model
  - See little evidence for many processes included in the model, such as Knowledge Object Development
- Some macrocognitive processes included in the *Internalized Team Knowledge Products Stage* (stage III) require direct interaction with team members to gather data required to measure certain processes.
  - *Teammate Knowledge Similarity*, *Shared Situation Awareness*, and *Task Knowledge Stock*, are amenable to measurement in lab settings but it is typically not feasible to obtain measurements during a or during a real-world event
- *Team Problem Solving Outcomes* (stage V) requires performance assessment metrics to assess the *Quality of the Plan/Problem Solving Solution*, *Efficiency of Planning Process*, and *Efficiency of Plan Execution*
- Performance metrics for the types of task domains we have studied do not exist
  - Developing measurement strategies to assess how the team performed overall, would require a major effort in itself

Conclusions

- Content analysis was used to investigate inter-organizational collaboration
- Added new processes to coding scheme in an effort to discover other macrocognitive processes that might be employed by collaborating teams
  - Specifically we were interested in cognitive processes that are currently coded as *Team Information Exchange*
- Exploratory effort to discover whether additional cognitive processes are employed during complex, information-rich, problem-solving events
  - Evidence for these additional processes, that is, sensemaking, anticipatory thinking, problem detection, assessing risk, planning and re-planning, and using analogues
- Developing a more comprehensive understanding of the macrocognitive processes involved in team collaboration has several practical advantages
  - Conceptualizations that provide the theoretical foundation for a model of team collaboration that take into account consistent findings based on empirical research in real-world work domains are likely to be more accurate
  - The way team cognitive processes influence team functioning was listed among the top ten critical research questions in team research (Salas & Wildman, 2009)
  - A more complete model of team collaboration can guide designers of collaboration tools to facilitate decision making as part of the overall task