SUPPORTING MEGA-COLLABORATION:

A FRAMEWORK FOR THE DYNAMIC DEVELOPMENT OF TEAM CULTURE

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Dedicated to my husband, who has supported my efforts with great patience.

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ABSTRACT

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This research project, inspired by the nationwide crisis following Hurricane Katrina, identifies *mega-collaboration* as an emergent social phenomenon enabled by the Internet. The substantial, original contribution of this research is a mega-collaboration tool (MCT) to enable grassroots individuals and organizations to rapidly form teams, negotiate problem definitions, allocate resources, organize interventions, and mediate their efforts with those of official response organizations. The project demonstrated that a tool that facilitates the exploration of a team's problem space can support online collaboration. It also determined the basic building blocks required to construct a mega-collaboration tool. In addition, the project demonstrated that it is possible to dynamically build the team data structure through use of the proposed interface, a finding that validates the database design at the core of the MCT. This project has made a unique contribution by proposing a new operational vision of how disaster response, and potentially many other problems, should be managed in the future.

CHAPTER ONE: INTRODUCTION

1.1 Problem Statement – Responding to Disaster

On August 29, 2005, Hurricane Katrina, the costliest and most devastating hurricane ever to strike the United States, came on shore near the city of New Orleans. Katrina was only a Category 3 storm by the time it made final landfall, but it was pushing waves it had kicked up the previous day as a Category 5 storm. The 30-foot storm surge breeched levies in New Orleans, flooding most of the city. Less than a month later, Hurricane Rita also passed near the city, prolonging the flood. Between them, these storms left nearly two thousand people dead and over half a million more displaced (Knabb, Rhome & Brown, 2005). This was the most extreme situation that the United States has had to face in the modern era.

During the height of the crisis, the situation seemed chaotic, filled with frustration and finger-pointing. However, now that we are looking back several years later, it is possible to see a pattern in the response to this disaster that may well presage the future of collaboration between private resources and government authority in addressing major societal problems. It was a pattern characterized by the spontaneous gathering of information and resources, enabled by private-sector use of information and communication technologies (ICTs). But it was also a pattern characterized by the limited ability of government authorities to convert the information and resources into effective action – ability that was constrained by the need for common ground with which to give the information context. It was a pattern of massive and spontaneous private initiative, making effective use of modern technology, but overwhelming the capacity of

government structures to take advantage of it. However, the successes and failures of the Katrina response provide intriguing hints of how the ICTs that are already expanding private-sector capabilities may someday also contribute to the solution of the authority-interface problem. It was the intention of this research to examine how such a solution might be facilitated.

Recent years have seen the growth of two divergent empowerment models representing the communication and coordination methods used in confronting extreme societal challenges, such as the response to disasters. The first is a top-down, unitary-chain-of-command model, exemplified in the United States by the National Incident Management System (NIMS). The second is a bottom-up, community-based collaboration model, enabled by the growth of information and communication technology (ICT), which we call the *mega-collaboration model*. In a top-down organizational structure, the head decides on a goal and initiates a "chain of command" that can be many layers deep (Lupia, 2001). The mega-collaboration model, however, empowers people through a bottom-up process. The power to act is spontaneously generated by groups of people working together. Both top-down and bottom-up methods are based on shared goals. However, for top-down methods, the goal is elaborated from the vision of the head; for bottom-up methods, it emerges from the visions of many people.

Jakob Nielsen first used the term "mega-collaboration" in 1997 to refer to situations where a public good results from the ICT-enabled mass action of many people, even though each action is performed only for the sake of the individual performing it (Nielsen, 1997). The term referred originally to unwitting actions, such as raising someone's search-engine rating by linking to their website. However, in the months after

Hurricane Katrina struck New Orleans, the world witnessed a new kind of mega-collaboration, evinced by blogs, news articles, and government investigative reports (Newlon & Faiola, 2006), where ICT-enabled volunteers intentionally worked together to respond to the crisis. Denning (2006) detailed the characteristics of the "Hastily Formed Network" (HFN) put in place for emergency response, and compared HFNs from several recent disasters. Palen and Liu (2007) completed an extensive ethnographic survey of the phenomenon, describing it as "an emerging form of societal-scale computer supported cooperative activity that extends and challenges our knowledge of computer-mediated interaction" (p. 1).

Congress mandated the use of the NIMS model for disaster response in 2002 (Palen & Liu, 2007). However, the mega-collaboration model has also seen much use. HFNs coordinating immense humanitarian responses were in evidence following the World Trade Center attack in 2001, the Indian Ocean tsunami in 2004, and the Pakistani earthquake in 2005, as well as after Hurricane Katrina (Denning, 2006). The months following Hurricane Katrina's landfall saw a massive flow of information through hundreds of thousands of blogs, listbots, and bulletin boards, soliciting and channeling private-sector resources from individual donors to Katrina victims (Bloggers Blog, 2005; Craigslist 2005).

Unfortunately, these two models do not coexist peacefully. While the mega-collaboration model was the star of the Hurricane Katrina response (Newlon & Faiola, 2006), the NIMS model suffered by comparison. In fact, Palen and Liu (2007) noted that the NIMS model works poorly in situations with many victims or volunteers. The presence of such divergent sources of empowerment results in organizations that differ

substantially in cultures, methods, and outcomes. This fundamental difference leads to inefficiency, interference, or even deadlock when these different groups try to work together. Neither model is necessarily sufficient by itself to provide complete disaster recovery, but with no way to dovetail official and spontaneous activity, the conflict between central control and grassroots empowerment can add to the general chaos of a disaster instead of reducing it (Newlon & Faiola, 2006).

1.2 Relevant History – Past Analysis of the Problem

The Katrina Response – What Went Wrong?

Much of the public inquiry on Katrina has concentrated on what went wrong with the response effort. However, a few of the major findings concern problems that this research counts as merely part of the underlying emergency, such as the failure of some people to evacuate, the failure of some responders to have enough initial resources, and the massive damage to emergency response infrastructure. Such things will always happen in a disaster of this magnitude. Human nature and economics both dictate that we plan for the expected, not the worst imaginable extreme. People had been talking about the possibility that New Orleans might flood for years before it actually happened (Nussbaum, 2004). However, the expense of maintaining evacuation facilities for over half a million people throughout those years could never have been justified. So, how do we handle the worst-case scenario when it finally arrives? This is where ICT-empowerment is likely to make the greatest difference by facilitating the flow of information needed for an ad hoc response.

A number of the Katrina findings speak to problems with the management of information in a crisis. In a report released February 1, 2006, the Government Accountability Office (GAO) critiqued the preparedness and response of government, at all levels, to Hurricanes Katrina and Rita. This report decried the "multiple chains of command," the "myriad of approaches and processes for requesting and providing assistance," and the fact that volunteers and donations were not well integrated into the response and recovery activities (Walker, 2006). In a report released on February 15, 2006, the House of Representatives Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina summed up the results of their Congressional investigation with the following quote, "The preparation for and response to Hurricane Katrina show we are still an analog government in a digital age" (Executive Summary, p. 2). The committee concluded that the biggest problem was a failure of initiative. Their report noted that sparse and conflicting information was too often used as an excuse for inaction rather than an incentive to gather more information, and that information passing through a long chain of different entities degraded in timeliness and relevance as it was reinterpreted for each internal audience. In addition, the report noted that this failure of initiative was also a failure of empathy, highlighting the need to reach more people on their own terms (Davis et al., 2006).

What were the stumbling blocks to the Katrina response? Surely everyone had email. What sorts of things kept the central authorities from coping with the unanticipated scale of events? In analyzing the findings of the Congressional investigation (Davis et al., 2006), it appears that many of the problems resulted from the fact that the incompatible internal cultures of the agencies involved formed barriers to the flow of information

between them. For instance, the Mississippi Adjutant General complained that the Red Cross failed to establish a formal operations section, as required by NIMS, and thus could not be integrated into the Incident Command System (ICS). This militaristic requirement on a volunteer organization resulted in a very significant barrier to the flow of information. The ICS was the primary interface between the disparate command and control structures that had jurisdiction during the crisis. So, almost every failure in the Katrina response could be traced to an ICS problem of some sort. The fact that non-governmental organizations (NGOs) were not integrated into the ICS played a role in these response failures.

However, integration into the ICS obviously was not an automatic fix. The Command and Control section of the Congressional report (Davis et al., 2006) documents serious conflicts even among those entities that were supposed to be integrated. In the conflict between Louisiana state officials and FEMA, both entities felt they should be in authority. In the conflict between the National Guard and the New Orleans Police Department (at the Superdome in New Orleans), neither entity wanted authority and each insisted that it was there to support the other. In the conflict between FEMA and the Coast Guard (over rescue operations), FEMA, though supposedly in charge, was too overwhelmed to manage, yet viewed all efforts at circumventing its mismanagement as further impairing its ability to maintain unity of command.

On the one hand, NGOs with flexible, ad hoc structures failed to integrate with governmental organizations, and on the other hand, governmental organizations with rigid, but differing, structures failed to integrate with each other. Both situations resulted

from the failure of a group of entities (and the people representing them) to overcome these clashing internal cultures and learn to work as a team.

However, this does not capture the full picture of the Katrina response. The GAO and Congressional reports concentrated largely on the government side of the equation – the side that came up short. While these reports were intended to discuss both the successes and failures of the Katrina response, they missed many of the successes, because these took place in the private sector.

The Katrina Response – What Went Right?

In fact, within the private sector, resources were readily brought online for assistance, particularly ICT-enabled resources. For instance, Dan Chaney, a former UNIX administrator from California, set up one of the first Hurricane Katrina missing-persons databases on a Linux server in his house. The site got 25,000 visitors on the first day, and after the Red Cross put a link to it on their Web site, it was getting over 800,000 hits daily by the end of its first week (Vijayan, 2005). There was also a wealth of ideas available on ICT-type solutions, such as a suggestion by Tim Murphy of Autonomechs, an emergency systems company, that an eBay-type exchange could trade directly between people who had resources and people who needed them (MSNBC, 2005).

In particular, however, the role of socially-connected information networks was dramatically evident in the world's response to this crisis. Indiana University's Center on Philanthropy listed the amount of known private donations, including cash and in-kind gifts, at $3.13 billion as of January 9, 2006 (Davis et al., 2006). While anonymous connections, such as Craig's List and the American Red Cross Web site, certainly played

a major role, a search of Google's Katrina listings reveals that many of the unheralded players were connections with social context, such as blogs and listbots from neighborhood organizations, churches, unions, and professional associations (Newlon & Faiola, 2006). Such social networks exhibit the small-world phenomenon, where any two individuals in the network are likely to be connected through a short sequence of intermediate contacts. The effectiveness of small-world networks in moving information and resources to people in need is dependent on the amount of context they can provide. As Kleinberg (2000) pointed out, a correlation between local structure and long-range connections is essential; otherwise individuals cannot tell which contact is likely to lead to an efficient connection chain. It is much easier for individuals to orient to locally-connected long-range structures in deciding where and how to send aid.

Most effective of all were those long-range, ICT-enabled social networks with local connections at both ends, such as church to church, or union local to union local. For example, the International Association of Fire Fighters (IAFF) set up a command center in Baton Rouge on August 31, 2005 and spent a month and a half coordinating support for the area's emergency response workers. This support included assistance checks, medical care, clothing, equipment, and relief fire crews, who rotated in and out from as far away as New York City and Los Angeles. The IAFF was sometimes the first lifeline to arrive on the scene to assist the embattled local departments (IAFF, 2005). Clearly, this is the type of activity that should be encouraged in response to disasters.

Past Research in Related Areas

Significant research, conducted in a number of different areas, is potentially relevant to ICT-empowered improvements in disaster response. The capabilities of ICT hardware and software continue to expand, giving rise to greater speed and more potentially useful features. Developments in the areas of gaming and other types of contribution interfaces have increased the understanding of individual motivators, with implications for future user interfaces. Research in the areas of cultural negotiation and team dynamics has increased the understanding of cooperation, suggesting future tools for online collaboration. Research on task-oriented data structures has increased the understanding of content representation, with implications for information management. However, the results of this research have not heretofore been incorporated into an interface that will support the mega-collaboration model of empowerment.

1.3 Current Needs – What Has Not Been Addressed

Of the $854 million in donated aid that was offered to the government after Hurricane Katrina, only $40 million had been spent two years later. Most of the offered aid was never even collected (Solomon & Hsu, 2007). Clearly, the impact of this disaster could have been dramatically reduced if the energy, skills, and resources of governments, NGOs and individuals could have been effectively coordinated. But, rather than addressing this problem, US government policy for formal disaster response appears to be headed in the opposite direction. In choosing the NIMS model, the US government has mandated the use of its quasi-military approach for disaster response (Palen & Liu, 2007). This protocol, routes all activity through a single, unified command structure.

While this supposedly has the advantage of making each unit's responsibility clear, an analysis of the aftermath of Hurricane Katrina illustrates the hazard of organizing a response effort in this way; it is vulnerable to failure at a single point. Arguments over jurisdiction and responsibility undermined the effectiveness of the command structure, which had a severe effect on the response effort, especially on its ability to make use of volunteered resources (Davis et al., 2006; Walker, 2006).

As the general public becomes increasingly ICT-empowered, the conflict between these two approaches becomes more conspicuous (Newlon & Faiola, 2006; Palen & Liu, 2007; Newlon, MacDorman & Scerri, 2008). The problem has led Palen and Liu to call for designs to enhance the effect of citizen-generated information on the work practices of formal response organizations, thus extending HCI/CSCW research to the improvement of command-and-control capabilities in disaster situations. This research proposes such a design.

A new approach to mega-collaboration is needed as an over-arching framework to help disparate groups collaborate. Ideally, a mega-collaboration tool (MCT) should be a comprehensive, but general-purpose method of coordinating knowledge that allows data and personnel to be easily integrated if a project scales up and combines with adjacent projects that have been separately developed. It should also interface easily with existing command integration methods, such as the ICS; and it should facilitate small-world social networking, such as the church-to-church and union-to-union linkages that benefited victims of Hurricane Katrina.

However, aside from the functionality offered by basic office automation, project management, and Web development tools, nothing seems ready to fill such a role. A

significant amount of research has documented the various cognitive needs that would affect people in a mega-collaborative situation. But, none of it has actually been applied to support the large-scale, structured development of common ground, and to capture the results into an accessible knowledge-base.

The central concept of the MCT proposed by this research is that the human response effort can be divided into dynamically-populated sub-teams with the aid of web-based software agents, with each sub-team developing its own model to define its part of the problem. Sub-team representatives can iteratively consolidate these models in agent-facilitated compare-merge "playoffs," thus enabling large teams to agree on the nature and details of the problem and coordinate effective action. The information developed by this method can be captured, and dynamically organized into a knowledge-base, allowing linkage of the collaborative activities of the volunteer response to the command-and-control activities of the government response. The specification, design, prototyping, and testing of such an interface has not heretofore been addressed.

1.4 Significance of the Research for Emergency Response

The GAO and Congressional investigators did not appear to notice that the firefighter's union was first on the scene to provide Katrina relief, or that a former UNIX administrator conducted large-scale emergency coordination with the Linux server in his back room. But, while these achievements were laudable, they also highlighted the differential way in which ICT was empowering individuals via computer-mediated communication (CMC), while centralized authority continued to struggle with outdated approaches. A core reason for this discrepancy in ICT enablement was the existence of

incompatible organizational cultures, which limited the opportunity to use ICT between rigidly defined organizational units. Unless this differential implementation is corrected, the difference in functionality is likely to grow even more dramatic in the future.

It has long been understood that each organizational unit develops its own internal culture, hence the "multiple chains of command and myriad approaches" of the GAO report (Walker, 2006). It has also been understood that each organizational unit is embedded within layers of external culture, representing the values of such larger groupings as surrounding organizations, nations, genders, races, and professions. What is not clear is how the organizational unit's culture-building process can be "scaled up" when the unit's project grows to the size of a mega-collaboration.

1.5 Aims and Purpose of the Research

So, what sort of an interface would be best to support mega-collaboration? If a team has thousands, or even millions of members, how can it establish a team culture? Is it possible to make mega-collaboration more effective through expanded use of the small-world principle? If ICTs have created an imbalance between the availability of resources and the authority to use them, can an MCT offer any solution?

To answer these questions, this research surveyed a number of possible approaches that might help large team collaborations arrive at solutions on a massive scale. Based on this survey, a set of specifications has been proposed for a simple, yet robust tool to support this function. The proposed tool would incorporate advances in contribution interfaces and the concept of "serious games," as well as an increased understanding of the virtual team development process and the use of "third culture"

negotiation, through a generic interface. The interface would be intended to enable mega-collaborating teams to form a truly robust picture of their data, while automatically creating a data structure to manage it. The ability to explore this picture together, as a team-building exercise would be intended to encourage teams to move from competitive to cooperative behavior as they operate within their problem space, by developing their own unique cultural definitions and rules.

In addition to developing the vision for such a tool, this research documents the development of a prototype user interface for the tool, and the insights resulting from usability testing performed on it. While the prototype was necessarily crude, it has demonstrated the ability of team members to merge their ideas, and the ability of the tool to capture them. It has also provided clear indications of the features that will be important in such an interface if the MCT is to be successful.

CHAPTER TWO: LITERATURE REVIEW

2.1 Existing Approaches

Nothing similar to the envisioned MCT is currently in use for virtual teams. While the collaborative uses of CMC, and the social structures surrounding it, have been growing increasingly complex over the years, the technologies that support these collaborations are still fairly basic. Most small, virtual teams still collaborate through email and by telephone, although chat and Web portals are sometimes used, and project management software is also available. For instance, two applications potentially useful to disaster responders are Microsoft Office Groove and 37 Signals Basecamp. In fact, Groove was actually deployed in the field after Hurricane Katrina (Farnham, Kirkpatrick & Pedersen, 2006). Groove provides tools to help virtual team members synchronize their schedules and their document content ("Microsoft Office Breeze product overview," 2008). Basecamp includes tools for project and activity tracking, to do lists, file sharing, message boards, and scheduling ("37 Signals Basecamp Take a Tour," 2008). These tools are all potentially useful, but they represent only standard groupware functionality.

Mega-collaborating teams, by contrast, are using general-purpose database engines, but coordination problems have occurred between separately developed, ad hoc data structures. For instance, it was necessary to build a meta-search engine for all the survivor lists generated by Hurricane Katrina (Boyle, 2005).

However, a number of authors have conducted research that is potentially relevant to the requirements of an MCT. Crapo, Waisel, Wallace, and Willemain (2000) examined the visualization requirements of mental modeling. Brandt and Messeter (2004) and

Oliveira and Oliveira (2005) discussed the use of "serious games" in reducing barriers among participants. Leuf & Cunningham (2001) and Gulley (2004) described interfaces developed to encourage the contribution of knowledge by online users. Hewling (2005), Ess and Sudweeks (2005), Faiola and Matei (2005), and Lawley (1994) looked at the effect of culture on computer-mediated communication. Rauterberg (2003) made a study of spontaneous team formation in massively multiplayer online role playing games (MMORPGs), finding levels of interaction in the spontaneously-forming virtual teams that were similar to Tuckman's (1965) classic observations on team development in face-to-face teams. A number of studies have been done on various aspects of virtual teams (Powell, Piccoli & Ives, 2004; Farnham, Chesley, McGhee, Kawal, & Landau, 2000). Of particular importance is research that simulates the operation of very large teams in emergency situations (Scerri, Farinelli, Okamoto & Tambe, 2005; Scerri, Xu, Liao, Lai & Sycara, 2004; Scerri, Farinelli, Okamoto & Tambe, 2004; Turoff, 2002; Jain & McLean, 2004). In addition, Mawson (2005) and Fritz and Williams (1957) studied the behavior of humans in disaster situations. These papers, and others, all contributed ideas to the conceptualization of the MCT.

To design the user interface for an MCT, it will be important to understand the dynamics of collaboration and the cognitive processes involved in it. Much work has been done that is relevant to this topic, but none that addresses mega-collaboration directly (Newlon, Faiola and MacDorman, 2008). What is needed is an interface that takes into account the dynamics of mental modeling, motivation, team development, and data representation.

Mental Modeling

While mega-collaboration implies a massive set of players in the conversation space, the interface must support each player individually; it must support problem-solving at the individual level by facilitating mental modeling.

An individual encountering a problem attempts to understand it by forming a mental model of its salient aspects. The individual 1) builds a system of analogies—a description of subjective entities and the relations among them and 2) uses the model to imagine alternative courses of action, to assess the imagined outcomes of each, and to select the best one (Crapo et al., 2000). Expert modelers break large problems into smaller pieces, developing models of each. This allows them to move between the levels of the decomposed problem, developing each model based on experience with other parts of the problem. Breaking the information into chunks also reduces its load on working memory. Experts anchor aspects of their mental models as external visualizations, because comparing mental images and external figures lets them determine whether items are missing or have been mistakenly included (Crapo et al., 2000). To support mega-collaboration, the tool should first support the visualization of this mental modeling process.

Motivation

When examining the elements that an MCT must support, we must also consider the relationship of each individual participant to the problem space at large. What motivates the individual's activity within this problem space? In examining motivation in a virtual environment, Gulley (2004) asks why a potential team member would be

persuaded to share ideas with others, given that those ideas might then be used by them to compete. According to Rauterberg (2003), individuals must always make a trade-off between entering into collaboration with others, and competing against them. This problem is especially acute when a cultural barrier is perceived (Raybourn, 1997; Hewling, 2005). However, one very strong source of motivation is the creative ownership of ideas (Morris & Hartas, 2004). Therefore, to motivate each individual's contribution to the team, an MCT should be able to track the ideas contributed by individual team members, and provide some sort of recognition or reward for them. Several formats are available to draw from in designing such a feature.

The Use of "Serious" Games as a Motivational Tool

Raybourn (1997) recommends the use of computer games in bridging cultural gaps, because they offer a safer arena in which to confront cultural differences. Research is expanding on the "serious" use of games to help motivate participants on collaborative teams. Brandt and Messeter (2004) point out that framing collaborative activities in a game format improves idea generation and communication between stakeholders by shifting focus to the game, thus downplaying power relations and other factors that might inhibit new ideas. Oliveira and Oliveira (2005) summarized the advantages of using games by noting that, in addition to being enjoyable, games are intensely involving, motivating, and gratifying; they promote creativity by requiring problem solving, and promote learning through outcomes and feedback; and (most significantly in this context) the interactivity of games builds social groups.

However, volunteers may consider it frivolous to play computer games in the middle of a natural disaster. Therefore, employing linguistic slight-of-hand, it seems advisable to refer to the interactions as "matches," rather than games, because this more generic term can include such sober and respectable things as debate. Adding a match interface to the MCT will help supply the desired level of individual motivation and help overcome cultural barriers. In particular, one innovation of MMORPGs that might be especially useful is the expertise score. It carries the double advantage of providing a reward to the recipient, while informing the recipient's teammates of a parameter that is important to success. While access to information will act as an initial motivator to bring participants to the interface, the use of expertise scoring may be necessary to give the interface credibility.

Contribution Interfaces – Tweaking Contests and Wiki Web Sites

According to Powell, Piccoli, and Ives (2004), the defining features of a team over a group are its unity of purpose, its identity as a social structure, and its members' shared responsibility for outcomes. However, there is a continuum from interest group to virtual team, rather than a sharp demarcation. For example, one emergent phenomenon is a type of contribution interface represented by wikis and tweaking contests, both of which encourage people to spontaneously donate their expertise, and to correct each other's work. The major examples of these are the Wikipedia (Leuf & Cunningham, 2001), and the math programming contests conducted by MathWorks, Inc. (Gulley, 2004). These share characteristics of virtual teams in having some unity of purpose and sometimes even a social structure, but while the outcomes are a result of everyone's

input, the concept of “shared responsibility” is less well defined. In fact, the responsibility for outcomes in this type of collaboration might be called “emergent responsibility.” Wikis and tweaking contests also have the characteristic of mega-collaborating teams in that there is no limit on the number or location of the people involved in each project. There is also no limit on the number of people who might benefit from viewing the information developed by the project, even without participating. Therefore, in considering the form that a match-type feature should take, a contribution interface, like the interactional format of tweaking contests and wiki web sites, seems promising.

A tweaking contest is a competition to develop the best computer algorithm for a predetermined goal. (The word “tweak” describes the process of making a minor modification to someone else’s code.) As Gulley (2004) describes, once an idea has been put forward by one person, it can then be freely adopted and modified by anyone else as the contest is still running. This results in the winning entry being a combined effort by many contestants, who are simultaneously competing and collaborating. According to Gulley, the contests are addictive to the contestants and the “supercharged” back and forth tweaking duels also provide a good spectator sport. While these contests currently involve computer coding, they could certainly be used for other sorts of idea generation, in particular, the development of data models.

The tweaking interface offers an advantage in that the primary reward is social, and is therefore shared by both the winner and the losers. It has a disadvantage, however, in that the practice of equally rewarding the most minor tweak and the most inspired new idea results in a gradient of reward that applies only to the quantity of participation, not

its quality. A better method of scoring such a match might base reward on the number of reference links generated by each new idea (like Google).

Wiki Web sites, such as the Wikipedia, incorporate a couple of concepts that are relevant to an MCT. (The Hawaiian term, “wikiwiki” means to hurry or hasten. It also refers to something that is fast, or speedy.) The first relevant concept of the wiki method is that spontaneously linking one piece of information with another should be easy. The second is that, as in tweaking contests, anyone should be free to add to, or change, anything (Leuf and Cunningham, 2001). The idea is to encourage cross-linking to take advantage of the small-world principle, thus allowing the user to move logically from anywhere in the data to anywhere else with only a few clicks. This particular format seems to work very well in helping a collaborating team organize and examine data.

While even the simple accumulation of expertise points would provide an acquisition-type motivator, the content of the match itself could be a factor in providing even stronger forms of motivation. One characteristic of wiki Web sites is that they give individuals unprecedented power to initiate and shape discussions, thus establishing creative ownership, rather than merely allowing individuals to respond to topics with which they are presented. This principle could be used in a wiki-like tweaking contest. That is, the person who submitted the best idea would hold the top score until a better idea was submitted, but the group setting up the parameters of the contest would be the team of contestants itself, through adoption and use of the idea, thus increasing the number of other concepts linked to it.

The advantage of such an interface for an MCT is that the unlimited submission of ideas has already been demonstrated by the wiki sites and tweaking contests. The

ability to reach an extremely scalable consensus would seem to be the biggest issue. According to Scerri and Xu et al. (2004), chunking a problem into subtasks with smaller groups of participants is the solution to this scalability issue. They describe a network of autonomous software agents where each agent is involved with several sub-teams, and the small-world principle is used to pass information between the teams. (An autonomous software agent is an independent thread, or process, that does sensing of some environment, performs processing on the incoming data and then takes some action, Scerri, 2007.) By linking teams of human participants to teams of autonomous software agents, which are, themselves, linked through a small-world network, it should be possible to harness both the power of the agent teams to manage information, and the power of the human teams to evaluate it.

Team Development

The Third Culture

In considering the internal culture of a team, we must first ask ourselves what we mean by "culture." Definitions listed by Lawley (1997) include "collectively constructed meanings," "a unique pattern of beliefs that shapes personalities in each society," and "an unconscious structure that generates ideas and behavior."

However, Lawley argues that rather than culture shaping personalities and generating ideas and behavior, culture is shaped by personalities and generated through the exercise of ideas and behavior. Faiola and Matei (2005) express a reverse opinion, pointing out that, in the behaviorist tradition, culture is a product of behaviors; but from the cultural-psychological perspective, behavior is the product of culture. These models

do not necessarily clash, however. Not only are these two causal states not mutually exclusive, but if we assume both are true, they describe a feedback loop that keeps the individual in dynamic balance with the group. In fact, because each group is embedded within layers of larger groupings such as parent organizations, professions, nations, races, and genders, this same feedback loop must also operate on a larger scale, balancing the embedded group's culture with the embedding cultures.

The cultural barriers that hampered the Katrina recovery existed between people, and groups of people, rather than between nations. However, they were still related to Hofstede's classic dimensions of culture, such as differences in attitudes toward authority (power distance), uncertainty avoidance, and long-term orientation (Davis et al., 2006; Hewling, 2005). For example, in trying to rebuild from Katrina, one local school superintendant found that FEMA had sent numerous people to help, but it turned out their goal was to make sure she did not violate any regulations as she tried to clean up and reopen damaged schools (Chamlee-Wright, 2007). The FEMA team included people dedicated to the protection of historic buildings, and to the protection of endangered species, both long term orientations that might clash with the short-term goal of getting the schools open. But the difference in orientation was even more fundamental. It was the difference between the local superintendant who wanted to make something good happen, and the FEMA personnel, who wanted to make sure nothing bad happened. This indicated a difference in their orientation to uncertainty avoidance. Clearly, such differences must be resolved if people are to pull together and work as a team.

How might this happen in an online environment? Ess and Sudweeks (2005) and Hewling (2005) describe how virtual group participants from different cultures engage in

an ongoing process of negotiation to generate a new "third" culture through their unique interactions, where the "culture" is constructed out of the participants' online inter-cultural encounters. While this "third culture" principle must always involve the interaction of individuals, the groups they are representing at any moment can vary, thus creating a "third culture" that is an on-going iterative process, potentially acting upon many cultural layers. It is through this means that a team of thousands, even millions, of members might establish an internal culture. It would not be a homogeneous culture, but one consisting of an intricate "marble cake" of intertwined subcultures, with its most important characteristic being the on-going, iterative process of negotiation.

Culture versus Command

The ability to support iterative negotiation of diverse points of view could provide an alternative approach to the command and control problems that plague disaster response. The GAO report implied that "multiple chains of command and myriad approaches" to solving Katrina-induced problems were bad things (Walker, 2006). This follows the NIMS perspective on reducing chaos, which is to establish a single, hierarchical command structure that controls all recovery activity. However, the attempt to control private innovation and initiative draws resources and goodwill away from the recovery operation. It also produces a response structure with a single point of failure – the unitary command. The conflict between FEMA and the Coast Guard after Hurricane Katrina, over search and rescue, highlights the dangers of this approach. FEMA was clearly overwhelmed by the magnitude of the disaster, and was struggling to coordinate even its own activities. Yet it expected the Coast Guard to fuse their command in search

and rescue with FEMA's, claiming that the Coast Guard had no authority to direct the search and rescue operations. The Coast Guard refused to conduct joint search and rescue operations with FEMA, with the result that even though these operations had the positive outcome of saving lives, they had a negative impact on the unity of command (Davis et al., 2006). The Congressional report does not say whether FEMA wanted to add personnel for preserving historic buildings or for protecting endangered species to the rescue operations, but it certainly implies that the preservation of human lives might have to take a back seat to the preservation of FEMA's command structure under the NIMS approach.

A better solution would be to coordinate between the different command structures and approaches, by using an MCT to knit them together into a functional unit. This solution suggests that the MCT must support cultural pluralism, or the need for multiple cultures to develop and coexist simultaneously. It also suggests that the MCT must help each forming unit to engage in normative behavior, as independent teams with their own internal cultures combine into a larger team via the generation of a "third culture."

Anatomy of a Team

Johnson and Hyde (2003) define the participants' understanding of the team problem space as their "world model," their understanding of colleagues as their "people model," and their understanding of the strategies to attain team goals as their "team plan." From the discussion above, it seems clear (as Johnson and Hyde suggest) that each individual's models must be compatible with those of his teammates if the team members

are to work together. To successfully collaborate, the team needs a "shared world model," or a common understanding among team members of the team's objectives, structure, and process (Fan, Sun, McNeese & Yen, 2005). As discussed, each team needs to create its own shared internal culture, the "collectively constructed meanings" and "unique patterns of beliefs" that tell individual members how to operate. This is true whether the participants come to the team as individuals, or as part of an existing team that is attempting to work in partnership with another team. Each individual's models must still be compatible within every team of which he or she is a member, so "third culture" negotiations are very important.

Therefore, a specific goal for a collaboration tool is that it must support the development of a shared world model, or team culture, which provides the context in which each team member can make decisions and take actions. Research indicates that this support must begin at the earliest stages of team formation.

Levels of Cooperation

As the Katrina response revealed, it is one thing to be a group of individuals and another to be a team. According to Johnson and Hyde (2003), collaboration may be cooperative or adversarial, depending on whether the participants are attempting to maximize group or individual outcomes. To work cooperatively, the individuals must develop skill at working with each other as well as skill at harnessing each other's expertise to accomplish the task at hand.

So, how do individuals move from competition to cooperation – from being individuals to being a team? Rauterberg's (2003) study of the factors necessary to change

from competitive to cooperative behavior within a MMORPG distinguished five levels of interactions. These were 1) informing, where anonymous information is exchanged without the participants knowing each other, 2) coalition, where at least two participants decide to work together, 3) coordination, where communication leads to shared use of resources, but common goals are not necessary, though the participants must know each other a little, 4) collaborating, where participants are involved in the same task with different roles, and the assessment of each contribution is different, and 5) cooperating, where participants work together to reach a common goal in such a way that individual interests and goals are subordinate to the common goal, decisions are carried out together, and competition is minimal. Participants must generally know each other very well for cooperating behavior to occur.

In the case of getting the various government and private entities to work together as a team in a disaster scenario, cooperation is much better than competition, but at what cost in terms of implementation time? Is there any way to speed this process? Research on the use of ICT interfaces to overcome cultural barriers seems relevant here.

Stages of Team Development

Bruce Tuckman described a very similar set of categories for the sequential process of team development in his paper "Developmental Sequence in Small Groups," published in 1965. However, he was studying groups that met face-to-face, not online. The stages of team development he called "forming," "storming," "norming," and "performing" are still widely accepted today. One description of these stages is found in Barnum (2000). In the "forming" stage team members act as individuals and the purpose

of the team is still relatively undefined; in the “storming” stage the team members argue their way through the definition of rules and roles for the team; in the “norming” stage competition turns into cooperation, as rules, roles, and responsibilities are understood, and the team’s decision-making process is agreed upon; and in the “performing” stage the members are a fully functioning team, with the ability to constructively criticize each other and to work through conflicts productively.

Barnum (2000) suggests that a team-building activity in the forming stage can help to jump-start the team development process. This suggestion was corroborated in a controlled study documented by Farnham, Chesley, McGhee, Kawal, & Landau in 2000, describing the use of a communication-support tool, called “Lead-Line.” This tool created structured chat sessions by imposing a pre-written instruction script on a simple Internet chat format. The instruction script encouraged the development of a shared mental model by having the groups discuss the problem, fully explore the alternatives, and then evaluate and rank them.

Part of the reason the Lead Line Study was interesting was the fact that the authors were apparently surprised by the results. From the 2x2 within-groups design of the study, it was clear that they expected each group to be more likely to reach consensus and to make better quality decisions when they were in the structured chat session than when they were in the regular chat session.

What they found was something completely different. The group that started their work in the structured chat session excelled in their work from then on, no matter whether they were in a structured chat session or not. The group that started their work in the unstructured chat session never reached the level of function of the other group, even

when they moved on to the structured chat session. What seemed even stranger was that the group that started their work in the structured chat session did an overall better job in the unstructured chat session than they did in the structured chat session.

What happened? Significantly, what was missing from the authors' write-up was a discussion of group dynamics and the effect it might have had on the experimental results. In fact, the internal validity of this study suffered both from an order effect and from a maturation effect.

It seems likely that each group did its "storming," or self-definition, while completing the first task that it was assigned. The team that served as the initial test group apparently incorporated the external script into its internal working rules. However, the team that served as the initial control group apparently devised a less effective set of internal working rules through its ad hoc interactions. When the two groups then switched roles on the second task, the first group used its more effective working rules again, while the second group used its less effective rules, even though the script tried to impose the more effective rules on its working process.

The first group performed better on the second task than on the first task because it had passed through its "storming" stage and entered its "performing" stage. The second group also performed better on the second task than on the first task; but the amount of the improvement that was due to entering its "performing" stage, versus the amount that was due to the imposition of more effective rules, was never measured.

Aside from the cautionary tale about test design, these results have something very interesting to say about the design of collaboration support tools. Rather than letting group dynamics become a confounding factor in the experimental results, the tool itself

should have been designed with the goal of supporting team development. The unintended result of this experiment was to demonstrate how structured intervention at the formative stages of virtual team development can yield lasting results in terms of team effectiveness. This implies that an MCT should be designed with the goal of supporting the initial formative stages of teams.

The Dynamics of Mega-Collaboration

The discussion above covers the general process of team development. However, to understand how to support the bottom-up process of mega-collaboration, we need a clear picture of how bottom-up organization happens. Even though mega-collaboration refers to a massive set of players, decision-making teams must first form, and they must remain small enough to bring discussions to a close. The process of spontaneously forming bottom-up teams becomes increasingly difficult as the conversation space widens. Cultural barriers can make it especially hard (Hewling, 2005; Rauterberg, 2003). Denning (2006) predicts that such barriers will be a persistent problem for the HFNs tackling a disaster. Therefore, the MCT must support group problem-solving by facilitating the spontaneous formation of small teams and the negotiation of team culture.

The bottom-up emergence of teamwork across the Internet can be illustrated by the way people form spontaneous teams in MMORPGs. Rauterberg's (2003) study and Tuckman's (1965) team development stages provide a useful framework for this discussion.

When encountering a dangerous situation, an individual's course of action is usually motivated by survival and a desire to help others (Fritz and Williams, 1957;

Mawson, 2005). This causes the individual to reach out to others to obtain or give information, thus arriving at the first level of interaction, which Rauterberg (2003) calls *informing*. As the individuals exchange information, they must make a trade-off between entering into competition, and working together. While competition may be a common choice in a MMORPG, in a real emergency, working together is much more common, though competition does happen during mass panics (Fritz and Williams, 1957; Mawson, 2005). Once individuals choose to work together, they achieve the next level of interaction, *coalition* (Rauterberg, 2003), in which they agree to support each other. This stage is the "forming phase" of the team (Tuckman, 1965).

As the teammates get acquainted and begin to work out their relationships, they reach the next level of interaction, *coordination*, in which they share resources, but still lack common goals. At this stage the purpose of the team is relatively undefined, (Barnum, 2000; Rauterberg, 2003) and cultural differences can be an issue. If teammates have different expectations, they will have to negotiate common ground or the team will disintegrate (Beers, Kirschner, Gijselaers & Boshuizen, 2005). A support tool, however, can help at this stage, by facilitating "third culture" negotiation (Ess & Sudweeks, 2005; Hewling, 2005).

Based upon the forming of its internal culture, the team's agreement on both its purpose and common set of goals leads to the next level of interaction, called *collaborating*. At this level, the participants have collectively arrived at the same goals, but have different roles, which are individually assessed (Rauterberg, 2003). The team passes through two phases of development while collaborating, because, as mentioned,

collaboration may be adversarial or cooperative, depending on whether the participants are attempting to maximize individual or group outcomes (Johnson & Hyde, 2003).

The first phase of collaboration is Tuckman's (1965) turbulent "storming phase," in which the team members are in adversarial mode as they argue their way through defining team rules and roles (Barnum, 2000). As they seek to achieve efficiency by harnessing each other's expertise to accomplish the task at hand (Johnson & Hyde, 2003), the individuals need to gain *awareness* (Dourish & Bellotti, 1992)—an understanding of the activities of others, which provides a context for each individual's own activity. Continually updated awareness lets teammates move easily between close and loose collaboration as the situation demands (Dourish & Bellotti, 1992). A shared team plan must also be developed, translating the goals, roles, and awareness into a set of behavioral norms that governs the moment-by-moment operations of the team (Johnson & Hyde, 2003). As the team works out its issues, it enters the second phase of collaboration, the "norming phase" (Tuckman, 1965), in which competition turns into cooperation, as rules, roles, and responsibilities are understood, and the team's decision-making process is agreed upon (Barnum, 2000).

Once the team becomes proficient at its roles and processes, it moves to the final level of interaction, *cooperating*, in which participants subordinate their individual interests and goals, and work to reach a common goal, with decisions carried out together (Rauterberg, 2003). Here, at what Tuckman (1965) calls the "performing stage," the members are a fully functioning team. One indication that this stage has been reached is that the members no longer feel the need to protect their own turf and are willing to let

other teammates step into their roles, if it is necessary for the furtherance of the team's goals.

Scaling Up

The example of the MMORPGs indicates that Rauterberg's virtual teams form in the same way as Tuckman's face-to-face teams, giving us an understanding of small team formation across the Internet. However, to move to the next level of functionality in a mega-collaboration, virtual teams forming separately have to be able to find each other in cyberspace. Crisis situations make this harder. People may lack the time needed to search the Web for other forming teams. However, the tool itself could perform this function by using autonomous software agents to monitor the emerging conversation space on the Web for similarities. Each human team could spawn an agent that detected the formation of other human teams, analyzed their developing models, and formed agent teams with the agents of teams that had similar models (Scerri, 2007). Agents could then monitor for potential synergistic or detrimental interactions between sub-teams and alert their members of the need to coordinate.

Putting similar teams in touch with each other is just the beginning of the problems an agent network could handle. The network could take over many of the team management functions, such as mediating the division of teams that have grown too large for effective communication, and management of the communication function itself.

The agent network could go beyond mere team management and communication of information, however, to the facilitation of a mega-team-building process. The dynamics of individuals interacting with each other on a team would remain the same,

whether the individuals were representing themselves, or representing another team. Therefore, the team-building process, from coalition to cooperation, could happen iteratively whenever multiple teams worked together. A “team of teams” could be formed through the facilitation of an agent-managed interface.

However, to support this function, the MCT would need to create a searchable data structure in which to capture the mental models as they are being developed.

Turning the World Model into a Data Model

Therefore, another body of research that applies to sharing these mental models of the problem space is found in the field of data structures. The concepts described below could be applied to a team development exercise. Integrating them could lead to significant improvements in the data and communication management capabilities of the team.

Information Needs

O’Neill and Johnson (2004) discuss the items of information that need to be defined for any given world model. They are 1) the domain in which the system exists, 2) the goal of the system, 3) a description of the tasks necessary to achieve that goal (which activities to perform in which order with which tools), 4) defined roles and their task assignments, and 5) the team players who will fill those roles. It is also necessary to follow the flow of work objects as they pass through the domain from role to role, and from task to task. Finally, relationships between subtasks must be represented, including decomposition level, sequence, selection, and iteration.

In addition to information needed to support task-work, participants also need information to support teamwork (Johnson & Hyde, 2003). This is where the participants' "people models" come into play. To know what they should be doing, and when, individual team participants need to know where their teammates are and what they are doing (Gutwin & Greenberg, 2000). However, this information only represents one moment in time. To truly understand the collaborative needs of that moment, they also need to predict what their teammates will be doing next. This requires them to know how their teammates collaborate, how they coordinate, and how they perform the tasks they have at hand (Johnson & Hyde, 2003). Zhang, Volz, Ioerger and Yen (2004) demonstrated that it is possible for one teammate to make reasonably accurate predictions about how another teammate will respond based on knowing how that teammate has behaved in the past, illustrating the importance of historical information.

Information Exchanges

Teamwork requires some method of communication. However, not only must the communication method provide desired information, it must filter out unwanted information to minimize the overhead. In an extremely chaotic situation, such as a disaster response, this can be difficult; but the amount and accuracy of the "pre-filtering" that teammates do for each other has a dramatic impact on the efficiency of the team (Scerri, Xu et al., 2004). Ideally, each individual should be able to calculate the trade-off between the expected cost of sending information and the expected value of sending it. Scerri and Xu et al. (2004) demonstrated that access to four items of information can significantly improve an individual team member's ability to judge this trade-off. These

are 1) who has asked for that type of information (either explicitly or implicitly) in the recent past, 2) who has recently sent information related to that type of information, 3) who has paid a big reward for that type of information (e.g. in money, praise, thanks), and 4) who has already sent the team member that particular piece of information. The first three items increase the expected value of sending information to an individual, while the last item reduces the expected value of sending it.

Most people carry a certain amount of this routing information in their memories, or in their email archives. If they do not have it, sometimes they will put out a request for it. Many times, they will not bother. However, it is certainly possible to build information such as this into the data structure that supports a mega-collaborating team. It might even be possible to establish accrued costs and rewards to the individual, based on the actual value of the information. Tim Murphy's suggestion of an eBay-style exchange for resources could easily lend itself to exchanges for both the information and the resources that a mega-collaborating team needs to function on such a large scale (MSNBC 2005).

Dimensions of the Data

Therefore, the information the mega-collaborating team needs to move from competition to cooperation, includes both a current and a historical perspective of both the task-work elements of the world model and the teamwork elements of the people model. In addition, a shared team plan is required, covering goals, roles, and behavioral norms (Johnson & Hyde, 2003), and the MCT must support efficient communication between the participants of each of these types of information.

While the data supporting this level of knowledge may be infinitely variable, it has enough elements in common to be stored in a database created from a generic data model. For instance, almost any entity with which a team works can be characterized either as a goal, a role, an object, a task, an event, or a player (Howes & Young, 1991; Johnson & Hyde, 2003; O'Neill & Johnson, 2004; van der Veer & van Welie, 2000). Any additional variability in the data beyond these generic categories can be handled as additional attributes, or even linkages.

An understanding of how mega-collaboration teams impose structure on a collaborative task aids system design. A review of several task-based conceptual frameworks (Howes & Young, 1991; Johnson & Hyde, 2003; O'Neill & Johnson, 2004; van der Veer & van Welie, 2000) reveals that at least two dimensions are necessary to capture the structural hierarchies. Each goal can be iteratively decomposed into sub-goals; each task can be decomposed into subtasks; each role can be decomposed into sub-roles; each object can be decomposed into sub-objects; and each triggering event can be decomposed into sub-events. The various entities can also be grouped into super-entities (for instance individual players could be grouped into squads, which could be grouped into teams, which could be grouped into leagues.) However, in addition to the decomposed and grouped hierarchies, on any given level the goal, task, role, objects, players, and events are all related to each other, in that the task "has" the goal, "uses" the object, "is triggered by" the event, and "is performed by" the role, which "is played by" the player. Therefore, to capture the process of collaboration, the data structure must show both dimensions of these structural hierarchies.

The data structure must also be able to handle provisional characterizations. For example, what one team sees as an "event" may be another team's "goal." In fact, negotiating the resolution of these differences is an important part of developing a common world model.

Whatever the underlying data structure, a working team will need to access its data via a number of different views. In addition to relational views, there are also several other types of views that must be represented.

Temporal: The first of these is the temporal dimension. Each subtask and sub-goal generally has time characteristics, such as start date and target date. It is often necessary to organize the task or goal information into a timeline, schedule, or calendar.

Social: The second dimension is social. The details of the participants in the collaboration must usually be tracked, especially the contact information. Information about participants' expertise and preferred methods of operation is also important.

Spatial: The third dimension is spatial. Team members must be able to monitor each other, tracking both location and activities to give assistance when it is needed (Johnson & Hyde, 2003). Also, with the proliferation of GIS systems, it is easier to track the location of such things as resources, participants, objects of interest, and triggering events. As a result, spatial information is coming into increasing usage.

Therefore, the research in these areas provides a number of concepts that are potentially useful in developing a data model that can capture the developing world model of a mega-collaborating team. Such a model must be very generic, with the ability to be customized, and yet must provide enough structure to support comparisons and multiple views.

As it develops, this data model will be available, not only to the active participants but also to those who just need information. It will ultimately serve as the primary recruitment tool that attracts new participants as they realize they have information to add.

A Vision of the MCT

So, where does all this lead? A mental exercise at this point might help to put things in context, following the bottom-up team development process to examine how an MCT might be used. As mentioned, there is already a source of information about this team development process. Every day, people who are playing in MMORPGs form spontaneous teams across the Internet. But the process of modeling problems and developing teams is the same, whether it is gamers trying to decide how to react to a monster, or office workers in the World Trade Center (WTC) trying to decide how to evacuate the burning building.

So, let us imagine a WTC office worker confronted by the sudden need to evacuate. The office worker would have formed a mental model of the evacuation routes, and would perhaps have even sketched a diagram of the situation if it was too complex to hold in memory. The office worker would then have evaluated alternative courses of action and chosen the one that seemed best. On the way to the stairwell, our office worker might have heard from someone in passing that there was a better stairwell, or might have told a stranger how to find the stairwell, thus operating at the informing level, where participants exchange information without knowing or supporting each other. Even at this stage, the HFN conversation space would have been developing. However the

information would have had a different interpretation in each context. For instance, survivors on a single floor would have rapidly worked out a set of descriptors for the hazards and escape routes; but survivors on a different floor might have been using the same descriptors for entirely different hazards or escape routes. Information is always "situated"– it can only be fully understood in the situation in which it occurs (Goguen, 1997).

While exchanging information with these individuals, our office worker would have had to decide whether to race them to the stairwell, or to help them to the stairwell. As mentioned above, competition can happen in mass panic situations (Mawson, 2005; Fritz and Williams, 1957), so the level of panic in the WTC might have affected our office worker's choice. If that choice was to form a coalition with a couple of other people, resulting in a tacit agreement to support each other, a new team would have begun to form. When these individuals began to work out the details of their relationship, they would have reached the coordination level of interaction, sharing resources, but having no common goals. For instance, our office worker might have teamed up with a couple of other people to share a flashlight on the way down the stairs, but aside from the general purpose of escaping the building, they would have initially had no agreement on how to navigate the crowded stairwell.

At this stage, cultural differences would have begun to be a problem. For instance, if the members of the team had had different expectations about how much to help the people around them, they would have had to negotiate a common goal that was more detailed than merely escaping the building; or the team would not have stayed together. Our hypothetical team of office workers would have had to develop a unique team culture

– one that identified a goal they could all accept, and a unique pattern of beliefs about the kinds of help they should give the people around them, and the amount of time they should be willing to spend helping others versus trying to save themselves. They would have been too busy to conduct any explicit team-building exercises, but if they had begun to capture some of their situational data on their cell phones (a common outgrowth of the mental modeling process) the software on their cell phones could have helped guide them through the process of negotiating a shared model.

The team's agreement on both its purpose and its common set of goals would have led to the next level of interaction, collaborating, where the teammates would have been working on the same tasks, but with different roles, and different assessments of each individual contribution (Rauterberg, 2003). In our hypothetical example, the office workers on our team would have known from the beginning that their common purpose was to escape the building, but they would now have come to an agreement that their common goal was to keep the crowd moving down the stairwell as efficiently as possible; and, based on their possession of the flashlight, they would have empowered themselves to facilitate this process. However, at this point in team-building, it is likely that the person who brought the flashlight would have been very possessive of it, and taken the role of providing light for the operations of the team. The other team members would have also established roles of their own, based in their individual interests and characteristics. For example, one who was very directive might have taken the role of demanding efficient movement, requiring that those who stopped move out of the traffic stream, and that those slowed by unsuitable footwear remove their shoes; another, who was very friendly might have taken the role of recruiting stronger people to physically

support weaker ones, who were struggling. At this point in their efforts, they would still have seen each other's failures as individual failures, and their own successes as individual successes. They would have been in Tuckman's "storming stage" (Tuckman, 1965), still arguing about how to do everything.

To work cooperatively, the teammates would have had to develop skill at working with each other and harnessing each other's expertise (Johnson and Hyde, 2003). For instance, to understand where to shine the flashlight, the office worker holding it would have needed to predict where the other teammates would be going next. This would have required understanding how the others performed their tasks (Johnson and Hyde, 2003), which could only have been learned through observation or communication. In the stairwell, this could have been accomplished by talking to each other. But if they had been using their cell phones for texting, something that is usually possible even when the voice network fails (Boyle, 2007), some of this shared knowledge could have been captured into their own primitive knowledge-base. For instance, a team member might have used his cell phone to send a text message listing criteria for when to help people and when to leave them behind. If the software on the cell phone was an MCT, this information would have been automatically added to the individual's world model and made available to everyone on the team.

As our hypothetical team tried to deal with the problems in the stairwell, the determination of whether it was better to work together or separately would have depended on the size and nature of the problem, so the answer would have been changing constantly as they moved from one problem to the next. This difficulty could have been resolved easily if everyone was within sight of each other, but it would have become

magnified as the team added members, and expanded up and down the stairwell. A cell phone-based support tool might have been especially handy in this situation. With such a tool, it would have been possible to develop an even larger stairwell team, with members on multiple floors who could not necessarily have seen or heard each other, but who could, nonetheless, have agreed on a common set of objectives, roles and processes to coordinate the flow of people down the stairs more effectively. The team's members could have alternated, as needed, between developing their own mental models as they worked individually, and negotiating the team's mental model and action plan, as they synchronized their data store and moved back into close collaboration.

As the team worked through its issues, it would have entered the norming stage of collaboration – with rules, roles, and responsibilities understood, and the team's decision-making process agreed upon (Barnum, 2000). At this stage, the members of our hypothetical team would still have been working in their separate roles, but they would now have fully understood how their failures affected their teammates, and how their teammates' successes benefited them. They could now have anticipated what their teammates would need next, and they would have been able to efficiently execute the team's processes. The development of the team culture would have helped them come to this understanding. On the stairwell, this process could have happened through verbal discussion, as the team members determined who could be supported down the stairs and who must be left behind, and as they worked out methods of dealing with people who were belligerent or panic-stricken. However, a common set of beliefs and meanings could also have emerged for the expanded stairwell team, using cell phones and text messaging.

Once the team became truly proficient at its roles and processes, it would have moved to the next level of interaction, cooperating, where the teammates would have subordinated their individual interests and goals, and worked together to reach a common goal, with decisions carried out together, and minimal competition. One sign of this would have been that, on our hypothetical team, the teammates would have begun to pass the flashlight back and forth if it was more efficient to do so, and each teammate would have felt free to implement any of the team's developed methods of dealing with people if a situation arose that called for it. They would have subordinated their individual survival goals to the team's survival goal, based on the mutual understanding and trust that had developed between them.

To this point, we have described the formation of an imaginary team in the chaos of the World Trade Center attack from its beginning with a single person to its achievement of full and efficient cooperation. As it formed, it could have propagated itself down the stairwell, driven by the need to keep everyone moving and resolve any bottlenecks. Even at this level, a tool supporting the team's operations would have allowed its members to develop team awareness, and cooperate on problems when they could not see or hear each other. But what if the team could also have coordinated with similar teams in the other stairwells? Would the evacuation have gone more smoothly if they could have balanced the load among staircases? What if they could have found out from people on the ground which exits led to danger and which to safety? What if they could have told the rescue teams in real-time whenever they had to leave someone behind? So far, we have been describing a situation where the team could have recruited new members by relaying the tool's contact information up and down the stairwell by

word of mouth. To recruit from the next stairwell, however, separately forming teams would have had to find each other in cyberspace.

This would have been a more difficult problem under these conditions than under non-crisis circumstances. People in this situation would have had all they could handle trying to climb down the stairs and help each other, while stealing an occasional glance at their cell phones. They would not have had the leisure to conduct web searches for other forming teams. However, the tool could have filled this function, itself, with its autonomous agents. In this case, the formation of each human team could have spawned an agent process to sense the formation of other human teams that were responding to the same emergency, and to form agent teams with the agents of human teams with similar stairwell and building evacuation concepts in their world models.

The Vision Expanded

In the future, it is anticipated that having a network of intelligent agents at the core of this system will open up a range of possibilities for significantly improving mega-collaboration. For example, autonomous agents could have searched for synergistic or detrimental interactions between teams and alerted their human members. They could also have managed the information exchange by tracking the information flow and calculating the relative value that their human team's information had to each of the other human teams. While agent technologies similar to this are already available, their use has been limited because of an inability to interface with real human organizations (Newlon, MacDorman, and Scerri, 2008). An MCT could address this technology gap.

2.2 Research Questions

Based upon the review of prior research on various aspects of this topic, and upon the existence of a number of free, or readily available, architectural platforms, it seems possible to develop a general-purpose tool for mega-collaboration. Therefore, the research questions this study attempts to address are as follows:

1. Can the use of a tool, which facilitates exploration of the team problem space, support online collaboration?
2. Can individuals be more effectively motivated to contribute to the forming team culture through the use of an interface that supports the building of a negotiated team model?
3. Can a tool be designed that dynamically builds team data structures as the team comes to an agreement on goals, roles, tasks, and strategies?

What follows in the next section is a discussion of how a prototype of an MCT interface was designed and developed, and how a series of usability studies were conducted to answer these research questions.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

The general methodology for this study was as follows:

1. Examine the needs of a mega-collaborating team, and develop specifications for an MCT.
2. Develop a paper prototype of the tool, and conduct a cognitive walk-through of it, to determine the feasibility of the design.
3. Develop a working prototype of the tool's user interface, and conduct a series of usability studies of the prototype to answer the research questions, and to see if the specifications and design of the tool meet the identified needs of the users.

3.2 Participants

Basically, the first and third research questions cover whether an interface can be developed to support online mental modeling and whether a database can be developed that captures the resulting models. Only the second research question involves participants, as it asks whether the users of the tool are more motivated to contribute to the team culture than they otherwise would have been. So, at first glance, this project would seem to be more about design than about participants. However, a participatory design process has been employed in the development of the prototype interface. So, participants have played a major role in the project.

The first stage of the development process was the creation, by this author, of an extensive set of use case scenarios (see Appendix A) that were based on documented occurrences during the Hurricane Katrina response, and on an early vision of how an MCT might work. Based on these use cases, a paper prototype was created and a series of cognitive walkthroughs were conducted, both on the MCT paper prototype and on the use cases. The participants at this stage consisted of two demographic groups. The first was a group of graduate students (and a professor) in the field of HCI. They were able to provide guidance from the perspective of experts on interface design. The second was a group of members from a local Quaker meeting. They were able to provide guidance from the perspective of everyday users.

The second stage of the development process was the design and development of a functional MCT interface prototype, based on results from the cognitive walkthroughs. While the design and development were primarily the work of this author, the group of HCI graduate students assisted with a number of debugging runs of the interface, providing additional input as to its usability.

The third stage of the development process was the conduct of a series of four usability tests on the completed prototype. These were not equivalent testing runs, because the interface was changed each time, based on the results of the previous test.

The participants in the first test were again members of the local Quaker meeting. They had widely varying levels of computer skill, and were therefore a good fit for the first test, which involved using the interface with minimal instructions in a computer laboratory setting. The demographics of this group are shown in Table 1.

Table 1. Demographic Data for Test 1

Participant [a]	T1	T2	C1
Age	51+	51+	51+
Gender	Female	Male	Male
Occupation	Clerical	Professional	Staff
Family Status	Married	Married	Single
Ethnic Group		White	White
Nationality	Europe	North America	North America
Computer Experience (years)	<1	21+	21+
Internet Usage (hours/day)	<1	9+	3-5
Computer Games (times/week)	<1	21+	1-2
Volunteer Experience (hours/quarter)	1-10	41+	11-20
Volunteer Groups (total)	1-5	1-5	6-10
Team Experience (total)	none	21+	1-5

[a] *n=3 for this test.*

The participants in the second and third tests were a class of nursing PhD students, using the interface across the Internet with a fully developed instruction set, but a non-disaster scenario. The demographics of this group are shown in Tables 2 and 3.

Table 2. Demographic Data for Test 2

Participant [a]	T1	T2	T3	C1	C2
Age	31-40	51+	51+	41-50	51+
Gender	Female	Female	Female	Female	Female
Occupation	Management	Faculty	Student	Student	Student
Family Status	Married	Married	Single	Married	Married
Ethnic Group	White	White	White	White	White
Nationality	North America	Other	North America	Europe	North America
Computer Experience (years)	11-20	11-20	21+	11-20	6-10

Internet Usage (hours/day)	6-8	6-8	1-2	3-5	3-5
Computer Games (times/week)	<1	<1	3-10	1-2	<1
Clinical Experience (% of time)	<1%	1-10%	41%+	21-40	41%+
Clinical Experience (years)	11-20	21+	21+	21+	21+
Team Experience (% of time)	41%+	21-40%	41%+	11-20%	11-20%

[a]*n=5 for this test.*

Table 3. Demographic Data for Test 3

Participant [a]	T1	T2	T3	T4	C1	C2	C3
Age	41-50	31-40	51+	31-40	41-50	31-40	41-50
Gender	Female	Female	Female	Female	Female	Female	Male
Occupation	Student	Student	Faculty	Student	Student	Student	Faculty
Family Status	Married	Single	Single	Married	Married	Married	Married
Ethnic Group	White	White	White	White	White	White	White
Nationality	North America	North America	North America	Europe	North America	North America	North America
Computer Experience (years)	21+	11-20	21+	11-20	11-20	21+	11-20
Internet Usage (hours/day)	3-5	3-5	3-5	1-2	6-8	3-5	3-5
Computer Games (times/week)	<1	<1	<1	<1	<1	<1	1-2
Clinical Experience (% of time)	21-40%	41%+	11-20%	41%+	11-20%	1-10%	11-20%
Clinical Experience (years)	21+	11-20	21+	11-20	21+	11-20	11-20

Team Experience (% of time)	none	21-40%	21-40%	41%+	41%+	41%+	41%+

[a]*n=7 for this test.*

The participants in the fourth test were again HCI masters students (and instructor), using the interface in a class setting with a full set of instructions and a disaster scenario. The demographics of this group are shown in Table 4.

Table 4. Demographic Data for Test 4

Participant [a]	T1	T2	T3	T4	C1	C2	C3	C4
Age	21-23	24-30	24-30	51+	31-40	41-50	41-50	31-40
Gender	Male	Male	Male	Male	Male	Male	Male	Male
Occupation	Student	Student	Student	Student	Staff	Other	Faculty	Student
Family Status	Single	Single	Married	Single	Single	Married	Single	Married
Ethnic Group	Asian	Asian	White	White	White	Asian	White	Asian
Nationality	North America	Asia	North America	North America	North America	North America	North America	Asia
Computer Experience (years)	6-10	1-5	11-20	21+	11-20	21+	21+	21+
Internet Usage (hours/day)	9+	9+	6-8	3-5	9+	9+	9+	9+
Computer Games (times/week)	11-20	<1	1-2	3-10	<1	<1	1-2	<1
Volunteer Experience (hours/quarter)	<1	1-10	1-10	<1	<1	1-10	<1	<1
Volunteer Groups (total)	1-5	1-5	1-5	1-5	1-5	6-10	1-5	1-5
Team Experience (total)	11-20	1-5	21+	11-20	none	6-10	1-5	11-20

[a]*n=8 for this test.*

Given that almost any adult is a potential user of the MCT, it was not necessary to target any particular population during the recruitment phase. Therefore, samples of convenience were used. However, the different tests covered a sample that varied widely in their background, age, gender, and computer experience. The total of 23 participants included three in Test 1, five in Test 2, seven in Test 3, and eight in Test 4.

3.3 Design of the MCT

Architectural Considerations

Any tool intended to coordinate data among large numbers of people across large distances must make effective use of available resources. The servers available to host data in a disaster situation could range from the spare computer in someone's back room to a huge mainframe run by the Defense Department. The devices used to access the data could range from someone's cell phone to a corporate call center. Therefore, it is important that the architecture of such a tool follow open-source standards and be as flexible as possible. Fortunately, a number of architectural technologies are available for use in these circumstances.

Because the data needed for a mega-collaboration will probably grow to massive size and be continually updated from many sources, the ability to manage it with relational database technology is important. The relational tables will probably need to be split between whatever servers are available, and cloned for load balancing to prevent server and network resources from becoming overloaded. It will also be necessary to redefine the data tables frequently, as separate databases are combined. Therefore, SQL is the preferred definition and query language, as an industry standard used for many types

of relational databases. (MySQL was chosen as the database engine for the interface prototype because it was both well-respected and free.)

Another requirement, to prevent overload of the servers and the network, is that as much of the processing as possible must be distributed to the individual workstations, or "clients." A growing number of platforms are available for this function, as well. JavaScript has been the primary tool of client-side processing for some time. It also has the advantage of being freely available, and supported by most browsers. However, Flash has been growing in popularity for client-side processing in recent years, due to its superior ability to handle graphics. The most recent release of the Flash browser plug-in incorporates a just-in-time compiler, which is resulting in dramatic speed improvements. However, download times can be a problem for Flash-driven interfaces, due to their large size. Conceptually, a client-side interface that combines both technologies, breaking the Flash interface into smaller pieces, and using JavaScript to deliver each piece as it is needed, could be the best solution of all.

In addition to these platforms, connecting the back-end database on one or more servers with the user interface on each individual workstation, will require server-side processing. A common platform for this task is PHP, another open standards-based package available for free over the internet. This makes it a good candidate for emergency access situations.

A final platform of interest is XML, another freely available open-source standard. Transmission of the data in an XML format is ideal for an MCT, because XML data can be used by so many applications, and because it allows both the data, and the data definition to be sent in the same file, which eases the storage space required by

unlimited scaling of a project. With a browser-based application, the interface for data input will not need to be permanently installed on each workstation, but will be downloaded from the server. In this way, the local storage space required for any given chunk of the data will depend primarily on the amount of data that is actively on the screen, because the screen will be updated from the remote server as needed. Once the XML data sent from the client arrives at whatever server it is assigned to, PHP can translate it into database tables. Also, when database information is requested by the client, PHP can retrieve it in XML format and send it to the client's browser to parse. This architecture makes the application suitable for cell phone access because it can be designed to have a very small client-side footprint.

Data stored with adequate relational information can be sorted and recalled in any of several formats, for example a schedule book, a task list, a map, an address book, or a decision tree. The ability to organize the data along any of these dimensions can make the team's goal much easier to define and achieve. This will require the data structure to store attributes of the data (that it is a time, or a location, for example) to facilitate formatting of the output. However, matching one concept's attributes to those of another will be very difficult unless there is a common set of data definitions to draw from while building and negotiating mental models. One possible solution to this would be to provide access to, or even build, Semantic Web ontologies for the MCT to use in adding pick-lists to the data entry forms ("Semantic Web," 2008). This would allow individuals to build their mental models more quickly, and would provide the autonomous software agents with a more standardized set of data from which to make comparisons in matching model to model.

The data structure must also accommodate the historical information needed to develop a base of expertise as work on the project progresses. The use of such expertise allows teams to solve ill-structured problems in a time-limited manner by recognizing the similarity between the current situation and previous experiences (Fan et al., 2005). One way to accomplish this is to dynamically link the individual elements of each conversation to the topic or entity under discussion as the conversation occurs. In this way, the conversations can be easily indexed, and stored as part of the entity to which they pertain. Database support for blogs (long-text) will help to accommodate this. Figure 1 illustrates the architecture of the MCT prototype.

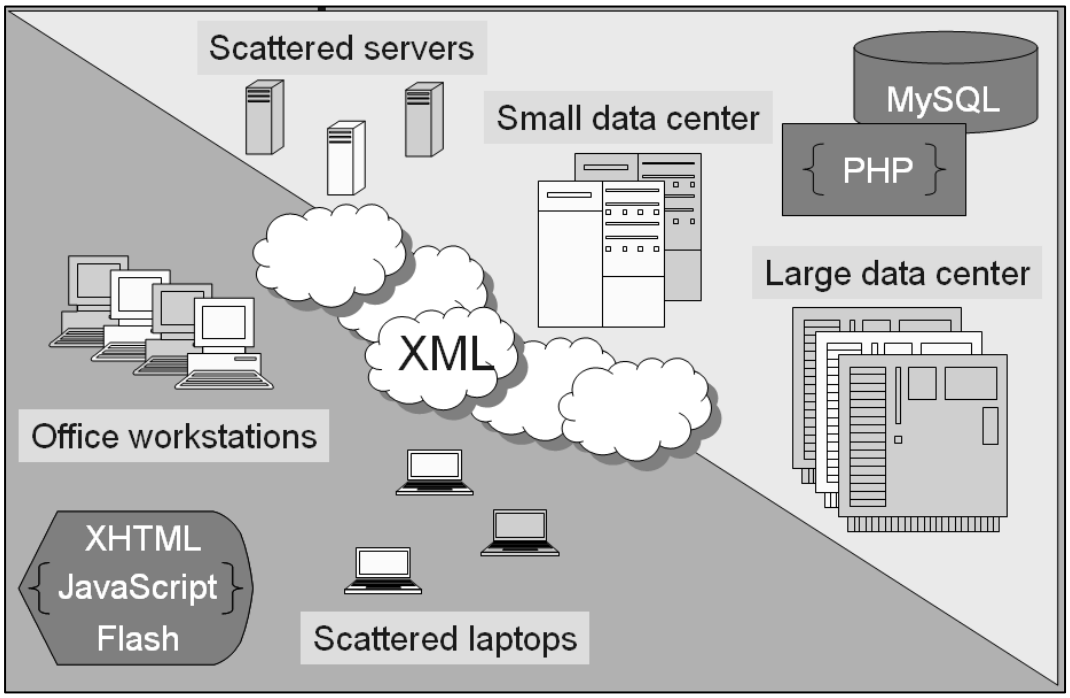


Figure 1. Architecture of the MCT Prototype

User Profiles and Use Case Scenarios

To develop a tool to be used in so many complex situations, it was necessary to consider in some detail what the target use cases were. Based on the various stories surrounding Hurricane Katrina, it was possible to create an extensive set of user profiles and usage scenarios to illustrate who might use this tool, and what its desired effects might be (Walker, 2006; Davis et al., 2006; Vijayan, 2005; MSNBC, 2005; Bloggers Blog, 2005; Craigslist 2005; IAFF, 2005). From the Katrina stories, it is clear that the proposed tool would be potentially useful to almost anyone. A catastrophe of such magnitude leaves few people untouched. The types of people who might use this tool, what it would do for them, and how, are described in Appendix A. These usage scenarios were based on an early concept of how the MCT might work, and are therefore somewhat dated. However, they still give the general context from which the MCT design began.

As can be seen from the extensive examples listed, a mega-collaboration project is potentially very complex. It must be driven by the individual initiative of each team member, or it will bog down. However, the same problem-definition function happens over and over again. It takes place in many different contexts, but each time it can be supported by the same tool. Based on the scenarios described in Appendix A, the following section describes the conceptual design of the proposed tool, as well as how this design was executed.

The Problem Space

As mentioned, the problem space addressed by this tool is at once infinitely complex, and fairly simple. It is as complex as the collective human imagination, but it

still consists of defining each aspect of each problem in terms that can be generically represented. The same sorts of decisions must be made over and over again. Ultimately, the tool must be able to handle the relationships among the various data items; it must manage the volume of the data and of the communications surrounding it; and it must present an interface, to the user, that is intelligible and easy to learn.

The Conceptual Model

Given everything considered to this point, the following specifications for the MCT were developed:

1. It should be comprehensive, but general-purpose in nature, and easy to coordinate if a project scales up and combines with adjacent projects that have been separately developed. Therefore, the design must be simple, robust, and extremely scalable.
2. The tool must support a team-building activity to aid the team development process. This should be in the form of a protocol that will encourage mega-collaborating team members to discuss their problem space, explore the alternative courses of action, then evaluate and rank those alternatives. The tool should provide a generic interface for this protocol. The protocol definitions and rules should be determined by the team participants as part of the protocol.
3. As an ongoing feature of this problem-space-definition/protocol-interface, the MCT must be able to track the contributions of individual team members, and provide recognition for them.

4. To facilitate the establishment of wiki-like tweaking interfaces, the MCT must provide a mechanism for reaching consensus on a large scale by coordinating sub-team formation and communication through use of autonomous software agents. These sub-team agents must be able to locate agents of similar sub-teams and share information via a small-world network.
5. The MCT must support the development of a shared world model. Not only must it provide a platform for the elucidation of team issues and norms using the data interface described above, but it must provide an easily referenced archive of what decisions the team has made in the past, including the reasoning behind them. To achieve this, the tool must support the dynamic linkage of each individual element of each conversation to the topic or entity under discussion as the conversation occurs. This will allow the conversations to be easily indexed, and stored as part of the task or entity to which they pertain.
6. The MCT must support both task-work and teamwork; therefore, it must support the structural data (both task-work and teamwork related) that the mega-collaborating team needs to gather about the problem at hand. Each element of this data can be characterized either as a goal, a role, an object, a task, an event, or a player, with more detailed information to be added as attributes.
7. The MCT must also support views of the data in several dimensions, the parent/child relations within each single entity hierarchy, and the relations between the different entities on any given level. These relations are as follows; the task “has” the goal, “uses” the resource, “is triggered by” the event, and “is performed by” the role, which “is played by” the player.

8. The MCT should have a front end that combines Flash ActionScript, JavaScript, and XHTML to give it as much local processing power as possible, to distribute the workload of large-scale collaborations. An XML structure is preferred for data transfer, because it is an open standard, and can facilitate the linkage of this tool to other types of software tools as the need arises. An open-source PHP back end on the server side should be able to receive the XML data and automatically convert it into a relational database using SQL.
9. The client-side data input interfaces of the MCT should be browser-based to minimize the client-side footprint and make the application suitable for cell phone access.
10. Once the data is stored with adequate relational information, the MCT should be able to sort and recall it in any common format in which it might be needed by the mega-collaborating team, including as schedule information, as task assignments, as spatial mappings, as an address book, or as a decision tree. It should be possible to create or use ontologies of common terms, and to create common display formats for these terms that will be available for reuse by others.

The Cognitive Model

The essential requirements for the client-side interface are the ability to establish a chat room containing a limited number of people, to relate it in a rigorous manner to other chat rooms, which are discussing the same or related topics, and to link it to various displays of the data items under discussion. The primary data display would be in a data-definition format, with other display formats available as needed. Other required

functions involve the ability of the system to track and acknowledge participant contributions, and to manage participant interactions.

Interactive Components

A more detailed discussion of the various interactive components required by this tool is as follows:

Function and rationale

The interface design for the tool is specifically intended to be fun and intuitive. This is because the situation for which the tool is intended requires spontaneous participation. Leadership in this sort of a project must be bottom-up, not top-down, as no single entity will ever have the resources to fully manage a project of this size.

Accordingly, a combination data entry and chat interface is proposed. Both of these interfaces have had good success in past web-based contexts, so it is reasonable to think they will succeed for this interface, as well.

Interface mechanisms

As currently developed, the MCT prototype consists of several viewing windows surrounded by navigation areas. This interface is shown in Figure 2. The windows hold a number of different data views to enable side-by-side comparison. They include a chat-room-style interface, and a data definition interface, as well as an area used for data visualization. Ultimately, users of the MCT should be able to choose from a number of different protocols, or make up their own, just as they can play many different card games with the same deck of cards. Also, each match should be played between

individuals either representing themselves, or representing teams of players, thus allowing the negotiation of "third culture" world view models at any level in the mega-collaborating team hierarchy.

Data structure

The current prototype's data structure is illustrated in Figure 3. What follows is a discussion of the considerations driving the data design.

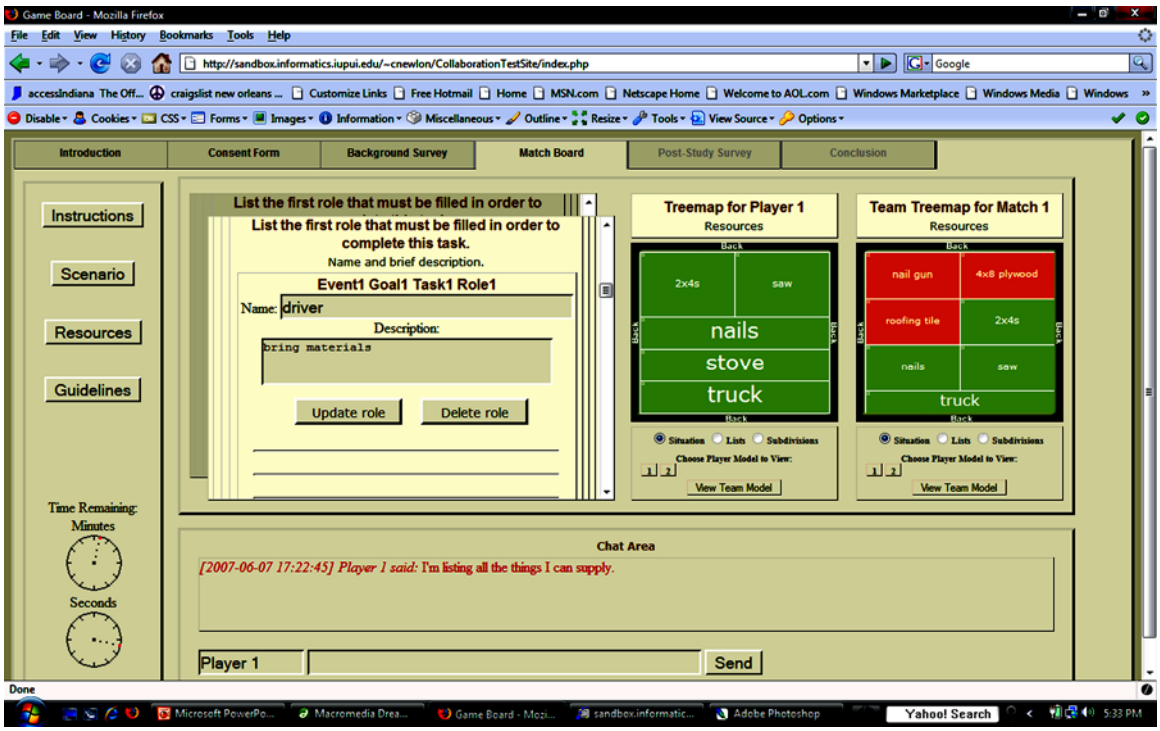


Figure 2. Prototype Interface for Virtual Collaboration

The initial problem to be solved in developing this structure is the potential for redundancies in the data that arise from the fact that people view it from different perspectives. For example, as previously mentioned, one person's event may be another person's goal. Therefore, it is important that every data item be defined first as an entity.

It should be possible to associate a few parameters with this entity in its raw state. However, most of the description variables associated with any entity will depend on its context, or the situation in which it is being viewed. This linkage is accomplished via the situation table, which identifies the various situations (or contexts) in which the entity has been defined.

But how is the entity described as an event, goal, task, role, or resource? It is possible to define these entity types (and also any types that may be developed in the future), and to connect each entity to its context-based type in the situation table.

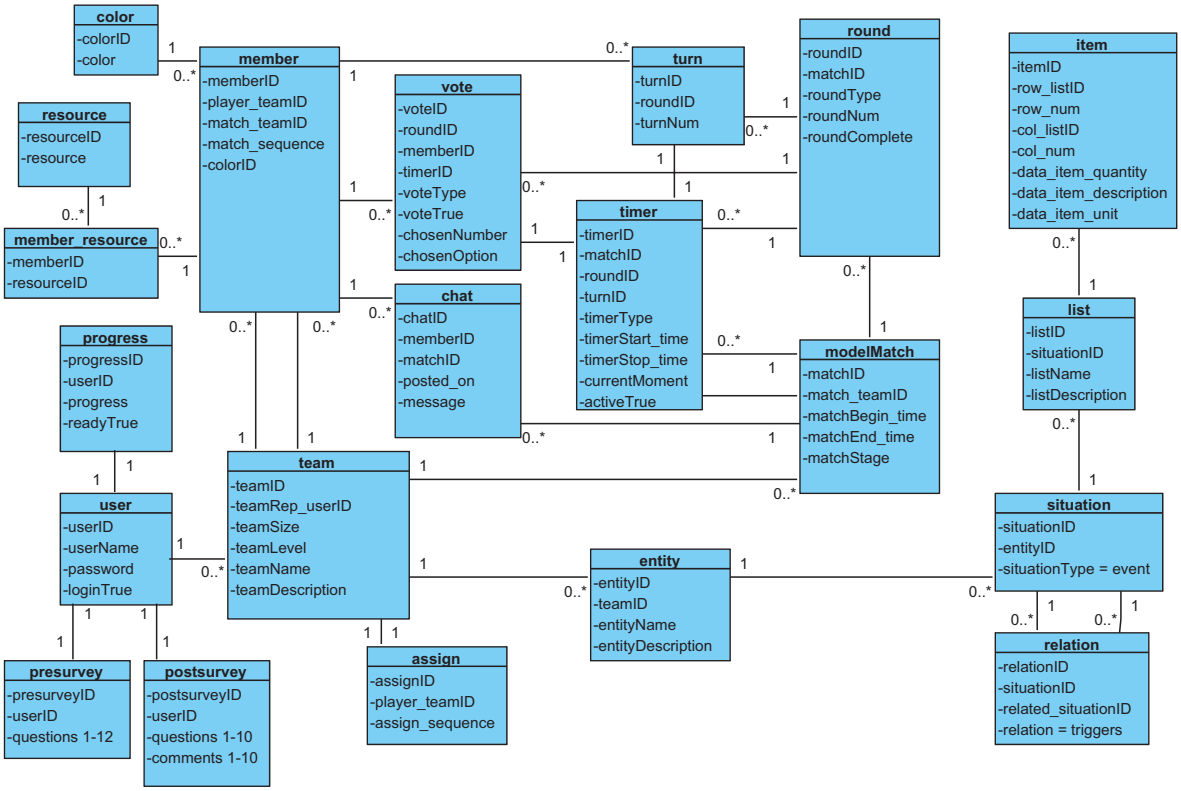


Figure 3. Diagram of Data Structure

The next problem that must be solved is how to represent the relationships between each entity and other entities. As previously discussed, this is a three dimensional set of relationships. Each entity can have parent and child entities. In fact, the entity's parent and child entities may differ depending on the situation in which the entity is being discussed. Each entity may also relate to other entities at the same level, as in a task entity having a goal entity, or a goal entity being triggered by an event entity. Fortunately, the same method can be used for each of these linkages. The situation and relation tables can be used to link each entity to any related entities, with the relationship type being defined for each linkage. Note, however, that this table links different entities within the situation table, rather than linking directly to the entity table. This allows the entity to link differently in different situations.

A final problem to be solved is how to design a data structure that will iterate, allowing teams of teams of teams, and yet also allowing the members of the bottom level team to be individuals. This problem has been solved by creating an even lower level of teams, where each individual forms a team of one. In this way, it is possible to link the individuals to each team as a team representative, which allows the iteration to take place entirely within the team table.

As has been shown, each of the specific problems the application must address can be resolved by appropriate design of the data structure. The result is a set of generic relationships that can be used to describe any problem.

3.4 Procedures for Testing

What follows, is a description of the tests that were performed during various stages of development of the MCT interface prototype, as well as the testing scenarios by which it was evaluated.

The Cognitive Walk-Throughs

As part of the development process, preliminary testing was run on a paper prototype of the MCT, and the test scenario created to drive the usability studies. For this trial, several cognitive walk-through sessions were performed. The intent of these preliminary studies was to identify potential usability problems before any coding took place, and also to identify any conceptual problems with the test scenario that might have compromised the usability studies. The only data gathered was a list of the problems encountered.

The Usability Studies

Once the prototype was working, a series of usability studies was run on the tool, using one of two test scenarios. These tests used a total of 23 participants, who were divided across eight teams in four separate trials. In each trial, one team tested the prototype MCT interface, while a second team tested a control interface that had a simple chat window substituted for the model-building portion of the MCT interface, but that was otherwise identical to the MCT interface.

The roles in these scenarios were deliberately chosen because they are roles that any of the participants might play in their lives, which minimized the participants' uncertainty about them.

The protocol of each test was that individuals completed a pre-trial survey that gathered the demographic information shown in Tables 1 through 4, and were then randomly assigned to either the test or the control team. The test team started with a period of individual model development, during which they were supposed to familiarize themselves with the relevant instructions, with the interface, with any personal ownerships that had been assigned to them, and with the general scenario of the simulation. After this initial period, the protocol of the test then moved into a phase where the team members were supposed to compare their own models with those developed by their teammates. This was followed by a period where each team member took a turn at entering definitions into the team model. After every team member had taken a turn, the team members then voted on whether they wanted another round, or were ready to move to the creation of the team action plan. The control team, by contrast, had only an extended chat period instead of these three model-building phases, after which they voted on whether they wanted another chat period.

Once the teams finished taking model-building or chat rounds and voted to move on, they were presented with a second vote to elect a team representative. This was the only person who could add action items to the action plan. After they elected the team representative, the team then spent a period of time during which they were supposed to be helping their team representative create the team action plan through their suggestions and encouragement in the chat window. After the action-plan-building period was over, the trial was finished, and the participants were directed to the post-trial survey.

As mentioned, these were not equivalent trials, because adjustments were made between each trial in response to the results obtained. The specific variations were:

1) The pre-trial surveys were modified slightly because the difference in scenarios caused different demographics to be of interest.

2) The instructions were modified from one trial to the next, based on what aspects the participants had struggled with in the previous trial.

3) The timing of the various periods was altered to examine the sensitivity of the results. It was not possible to give the test and control groups equivalent timing, given the extent to which the teams controlled their own timing. However, adjustments were sought that made the sessions more similar.

The intent of this study was to identify and correct usability problems in the working prototype, to gather information for future development of the MCT interface, and to answer the research questions as to whether the MCT interface and data structure would work at all, and whether it would encourage participation if it did work.

Information for the individual test sessions is as follows:

Test 1 – A copy of the instructions for this test can be found in Appendix B. Because this was the first actual usability test, the instructions were deliberately kept to a minimum to see what questions the participants needed to have answered as they worked.

The time settings for this trial are shown in Table 5. “BuildModels” represents the individual model building period, “compareModels” represents the period for comparing the models among teammates, and “turn” represents the length of time each member of the team got during each round to edit the team model. “Control” represents the length of each control team chat period. “RoundVote,” “repVote,” “repRunoff,” and “actionPlan” represent the voting period to decide on a new round, the voting periods for original and

runoff elections for the team representative, and the length of time to create the action plan.

Table 5. Trial Segment Intervals (minutes) – Test 1

Segment Type	Test	Control
buildModels	20	
compareModels	10	
turn	5	
control		20
roundVote	1	1
repVote	1	1
repRunoff	1	1
actionPlan	15	15

The scenario and ownerships for Test 1 are shown in Tables 6 and 7. The ownerships were presented as a list of resources, and were automatically divided among the participants by the test application, so each of them would have unique concepts, or resources, to bring to the discussion.

Table 6. Scenario for Tests 1 and 4

The test scenario involves a community-based recovery effort following a disaster. A local neighborhood association in the city's historic district has organized to help rebuild a sister historic neighborhood in the next state that has been devastated by a tornado.
Your group has volunteered to help rebuild three houses. There are some resources available for this from a communal stockpile near the damaged neighborhood, and each of you has some resources that you can offer. The list of communal resources is as follows:
500 board feet of lumber 50 4x8 sheets of plywood 15 squares of asphalt roofing tiles (100 sq ft ea) 800 sq ft of siding 400 feet of electrical wire 10 feet of plumbing pipe 2 hammers 1 circular saw 1 nail gun with nails an expert advisor 2 single beds with mattresses An assortment of clothes covering most sizes
The resources each of you has to offer will be randomly determined by a computer-

generated drawing. These resources include building materials, tools, and a truck. Also, one of you (as determined by the drawing) lives in the damaged neighborhood, rather than in the sister city. Your house is undamaged, but in addition to whatever resources you have drawn, you will have been chosen by your neighbors to act as their spokesperson.

In addition to construction supplies, you may also pledge whatever time you are willing to volunteer.

Try to imagine that this situation has happened in real life. Any of you might own these resources, or have neighbors with tornado-damaged houses. How would you handle the situation?

The following is an assessment of the damage to your three houses, and the needs of the families who live in them:

The Smith House

Building Damage

The Smith house lost its roof, which will need to be entirely rebuilt. The rest of the structure suffered little damage, but the upstairs bedrooms for their three children lost all three beds; and virtually all of the children's clothing and possessions were damaged or destroyed. The building itself is of some historic value to the neighborhood, so the neighbors are anxious to see it repaired quickly, before the rest of the structure suffers serious water damage from the lack of a roof.

Needed for Repair

100 board feet of lumber
50 sheets of plywood
16 squares of roofing
50 feet of electrical wire
40 person-hours of labor
3 beds
Children’s clothing

Family Needs

The Smiths are a young, working-poor family with no insurance. They inherited the house from Mrs. Smiths mother, but now they have no place to stay and no money for rent. Fortunately, everyone was downstairs watching TV when the roof blew off, so no one was physically hurt. However, their youngest daughter is currently being treated for emotional trauma. They really need to move her out of the homeless shelter and back into a familiar environment.

The Jones House

Building Damage

The Jones house had a tree fall through the kitchen wall. The tree has been removed, but that entire side of the house will need to be repaired, and the stove and refrigerator were destroyed. The house is only a few years old, so its historic value is low.

Needed for Repair

1000 board feet of lumber
20 sheets of plywood

9 squares of roofing
1000 sq ft of siding
500 feet of electrical wire
50 feet of plumbing pipe
40 person-hours of labor
1 refrigerator
1 stove

Family Needs

Mr. and Mrs. Jones are currently staying in a motel. However, Mr. Jones suffers from a metabolic problem, and needs a special diet that cannot be found in restaurants. The Joneses really need to be able to cook for themselves. Unfortunately, their homeowners policy only covers the mortgage company's share of the house, so there is no provision for temporary housing for the couple. They are really struggling to get by.

The Robinson House

Building Damage

The Robinson house had a hole punched in the roof by a piece of debris. Mr. Robinson also lost most of his clothing which was hanging on a clothesline in the backyard when the storm hit. The biggest concern, however, is the potential for water damage to the historic ceiling medallions in this beautiful old Victorian home. Naturally, the neighbors hope the hole will be repaired as soon as possible.

Needed for Repair

20 board feet of lumber
3 sheets of plywood
2 squares of roofing
15 person-hours of labor
Man's size medium clothing

Family Needs

Mr. Robinson does have insurance. However, the particular company he bought the insurance from is not noted for its quick response. A heavy rainstorm is due in the area in three days, and there is little hope the insurance company will respond before then. Mr. Robinson is elderly, and this has been quite a shock to him. He really needs to have the situation resolved and get back to normal.

Your challenge will be to create a schedule by which the homes will be repaired, including which tools and materials will be sent to which house at which time, what schedule the expert advisor will follow, and who will be working when on which house.

Table 7. Individual Resources for Tests 1 and 4

You have the following materials left from a playhouse you never built: 112 board feet of lumber 5 4x8 sheets of plywood 1 square of black asphalt roofing tiles (100 sq ft) 25 sq ft of siding 75 feet of electrical wire 1 hammer 1 circular saw
You have a spare refrigerator in your garage. It's old, but it still works OK.
You got the construction company down the street to donate: 250 board feet of lumber 10 4x8 sheets of plywood 3 square of black asphalt roofing tiles (300 sq ft) 100 sq ft of siding 10 feet of electrical wire 20 feet of plumbing pipe 1 hammer 1 circular saw 1 nail gun with nails
You just bought a new stove. You were planning to donate your old one to Goodwill.
When you got a new roof last year, the contractors left you 1 square (100 sq ft) of black asphalt roofing tiles in case you needed them for repairs.
You've been collecting leftover building material from all your neighbors. You have: 100 board feet of lumber 2 4x8 sheets of plywood 2 squares of black asphalt roofing tiles (200 sq ft) 50 sq ft of siding 50 feet of electrical wire 10 feet of plumbing pipe 1 hammer 1 circular saw
You have a double bed and mattress in the spare bedroom. But you are converting the room to a study.
When you remodeled your bathroom and added the skylight, you had the following materials left over: 75 board feet of lumber 1 4x8 sheet of plywood 2 squares of black asphalt roofing tiles (200 sq ft) 7 feet of plumbing pipe
You have a metal army cot and mattress stored in your attic.
You have the following in the basement, left over from various projects and home repairs: 10 board feet of lumber 5 4x8 sheets of plywood

1 square of black asphalt roofing tile (10 sq ft)
You have assorted clothing for a size medium male that you were planning to take to Goodwill.
You went to a local construction salvage store that was established to help low income people with repair projects, and bought the following: 98 board feet of lumber 4 4x8 sheets of plywood 1 square of black asphalt roofing tile 40 sq ft of siding 15 feet of plumbing pipe 1 nail gun with nails
You have boxes of children's clothing in the attic, for both genders, and every size, left over from when the kids were little.
You have 2 squares of black asphalt roofing tile (200 sq ft) left from the last time you re-roofed your house because the contractor overestimated.
You own a half-ton pickup that is good for hauling moderate loads. It gets 12 miles per gallon when it is fully loaded, and 18 miles per gallon then it is running without a load.
You live in the damaged neighborhood, but fortunately your house escaped unharmed. However, due to your position on the neighborhood association board, you have been chosen to represent the neighborhood association's interests during the repair drive.

Test 2 – The instructions for both Tests 2 and 3 were identical, and can be found in Appendix B. They were much more extensive than the first set of instructions, and were somewhat customized for the nursing scenario that was used for these two tests. The time settings for Test 2 are shown in Table 8.

Table 8. Trial Segment Intervals (minutes) – Test 2

Segment Type	Test	Control
buildModels	30	
compareModels	10	
turn	5	
control		15
roundVote	1	1
repVote	1	1
repRunoff	1	1
actionPlan	15	15

Test 3 – The time settings for Test 3 can be found in Table 9.

Table 9. Trial Segment Intervals (minutes) – Test 3

Segment Type	Test	Control
buildModels	15	
compareModels	5	
turn	5	
control		35
roundVote	1	1
repVote	1	1
repRunoff	1	1
actionPlan	15	15

Tests 2 and 3 were conducted entirely on the Internet, with participants in several states. While the participants, being members of the same distance learning class, had conversed online before, they were assigned pseudonyms while they took part in the exercise, so they did not necessarily know who their teammates were. However, due to the online nature of these tests, it was necessary to use Indiana University's existing groupware interface, Oncourse, to provided management. Oncourse offers a fairly standard chat window, but there is one unusual feature about it. The system automatically enters each student's full legal name on all the chat messages. As a result, there was no anonymity possible during the time the participants used Oncourse Chat, even though they were given pseudonyms during the time they were participating in the trial. Uses of Oncourse Chat included gathering the participants before starting the exercise, troubleshooting during the exercise, and conducting a focus session after the exercise ended.

The scenario and ownerships for Tests 2 and 3 were identical. They are shown in Tables 10 and 11. The ownerships were presented as a list of concerns, and were again

divided among the participants by the test application, to provide them with unique concepts to bring to the discussion.

Table 10. Scenario for Tests 2 and 3

You are a faculty member at a nursing school. Today you are meeting online with other nursing faculty to discuss modifying the current undergraduate curriculum. Your school has decided to integrate nursing informatics content and experiences into the curriculum to ensure future nursing graduates leave with informatics competencies that are necessary for current practice with applications they will encounter in the real world.
Specific questions your group must address are:
What informatics competencies do future nurses need?
How do we as a faculty figure that out?
What resources do we have as a school?
There are hidden issues involved in answering these questions. Each of you will be assigned issues that you must raise and have the group discuss. Try to take ownership of this issue, just as you would in real life if there was an area of interest about which you were passionate.
Your challenge will be to create a schedule by which the group will develop the changes to the curriculum, including which resources will be used by whom at what time, and who will be working when on which issue.

Table 11. Individual Concerns for Tests 2 and 3

Faculty often doesn't have informatics competencies themselves, so faculty development needs are great.
How do we provide competencies? How do we encourage (mandate?) participation?
Resources - HIT, HIS, and CIS for learning labs will be costly to integrate and maintain.
Students have experiences in different hospitals that have different clinical information systems.
Information literacy and computer skills are uneven among both faculty and students.
External pressures are great. Accrediting bodies include informatics competencies in their expectations.
Future employers want to hire graduates that have informatics skills.
The curriculum is already packed and no one wants to give up content to make room for informatics.
Competencies haven't been clearly defined; they are a moving target.

Test 4 – The instructions for Test 4 can be found in Appendix B. These were the most complete of all, and represented what was learned from the previous usability tests. The time settings for Test 4 are shown in Table 12.

Table 12. Trial Segment Intervals (minutes) – Test 4

Segment Type	Test	Control
buildModels	20	
compareModels	10	
turn	5	
control		35
roundVote	1	1
repVote	1	1
repRunoff	1	1
actionPlan	20	20

The scenario and ownerships for Test 4 were identical to those for Test 1.

Quantitative and Qualitative Data Collected

Quantitative data was gathered on the number of contributions from each of the participants, in the form of chat postings and entries into their individual models, and also from each of the teams, in the form of total chat postings, entries into the team model, and entries into the team action plan. Quantitative data was also gathered on participant experience in the form of Likert-scale scores on a number of experience questions.

Qualitative data was gathered on the effectiveness of the resulting action plans, on the experiences of the participants during online negotiations, and on the capability of the resulting data structure.

Sample Size

The total sample size was 23 individuals and eight teams, with a total of 13 participants on test teams and 10 participants on control teams. This sample was divided across four test sessions in the following manner:

Test 1 had two participants on the test team and one on the control team.[1] Test 2 had three participants on the test team and two on the control team. Test 3 had four participants on the test team and three on the control team. Test 4 had four participants on the test team and four on the control team.

This was a sample of convenience, drawn with the goal of testing at least five teams. Due to the fact that the ultimate measure of success was collaboration, some of the usability results could only be measured at the team level. As a result, to achieve the n=5 recommended by Nielson (2000), it was necessary to view the entire team as the subject in some cases.

3.5 Data Analysis Techniques

The design of the current study was influenced by the findings of the Farnham Study (2000). This study demonstrated that the decision-making method a team encounters during its forming stage tends to become incorporated into its culture, thus changing the subsequent behavior of the team (a carry-over effect). Because of this, the current design used a simple test-control comparison, avoiding the Farnham study's 2x2

[1] A stand-in was used as a second member of the control team, since at least two people were required on each team in order to run the application.

crossover design, because any within-group results would be invalidated by the carry-over effect.

Participant narratives were used to shed light on individual and group experiences. However, observed behavior, such as total contributions was also used. Heuristic analysis was performed on some of the project databases and action plans created by the tool to determine whether they were adequate to the simulated task. The system's automatic communication tracking was also examined to determine if it met expectations.

Statistical methods for analysis are of somewhat less importance in a usability study. Because there is debate over whether ANOVA yields meaningful results when used on the ordinal rating data of Likert scales (Shah & Madden, 2004), a nonparametric equivalent to ANOVA was used – the Wilcoxon/Mann-Whitney *U* Test, was chosen because there were only two groups in each test.

CHAPTER FOUR: RESULTS

4.1 Introduction

This research yielded a number of results in regard to its research questions. The first question, whether using a tool to facilitate exploration of the team problem space will support online collaboration, requires two specific results to find in the affirmative. First, it must be possible to develop such a tool, and second, the tool must support online collaboration. The research yielded positive findings for both results. The second question, whether individuals will be more effectively motivated to contribute through use of this interface, yielded mixed results. The third question, whether it is possible to dynamically build the team data structure through use of this interface, yielded positive results. The following covers these findings in more detail.

4.2 Results of Usability Tests

Question 1: Can the use of a tool, which facilitates exploration of the team problem space, support online collaboration?

This was a two-part question. In order to answer it in the affirmative, it was first necessary to demonstrate that a tool could be developed that facilitates the exploration of the team problem space. As discussed in Section 3.3, the prototype MCT design and development was accomplished, thus demonstrating that such a tool *could* be developed. It remained to demonstrate that the participants could use it to successfully explore their problem space.

The success of problem space exploration was demonstrated in a couple of different ways by the test results. The first was through an examination of the individual mental models that were developed using the tool, and of the team world models that were developed based on the collective knowledge thus gained.

Figures 4 and 5 illustrate this mental model negotiation process. Figure 4 shows the entries made in the individual and team models during Test 2. Figure 5 shows the entries made in the individual and team models during Test 3. What is evident upon examination of these entries is that the team model is a step ahead of the individual models in both cases.

In Figure 4, the team model has more layers, and shows evidence that specific ideas from the individual models have been combined into a more universal form. For instance, Player 1's concern with faculty competencies, Player 2's concern with student competencies, and Player 3's concern with situated knowledge at the different clinical facilities, have all been distilled in the team model into a goal to determine the needs of faculty, students, and clinical facilities. This goal has been elaborated with some of the tasks and roles required to achieve it.

In Figure 5, the individual models are both prolific and detailed, showing evidence of brainstorming, while the team model again distills the ideas down into a couple of succinct requirements, and the steps necessary to meet them.

It is interesting to note that even though these were different people working on different nights, both teams decided that a survey was necessary. In a full mega-collaboration, their team agents could have arranged a playoff session to allow them to coordinate their survey plans.

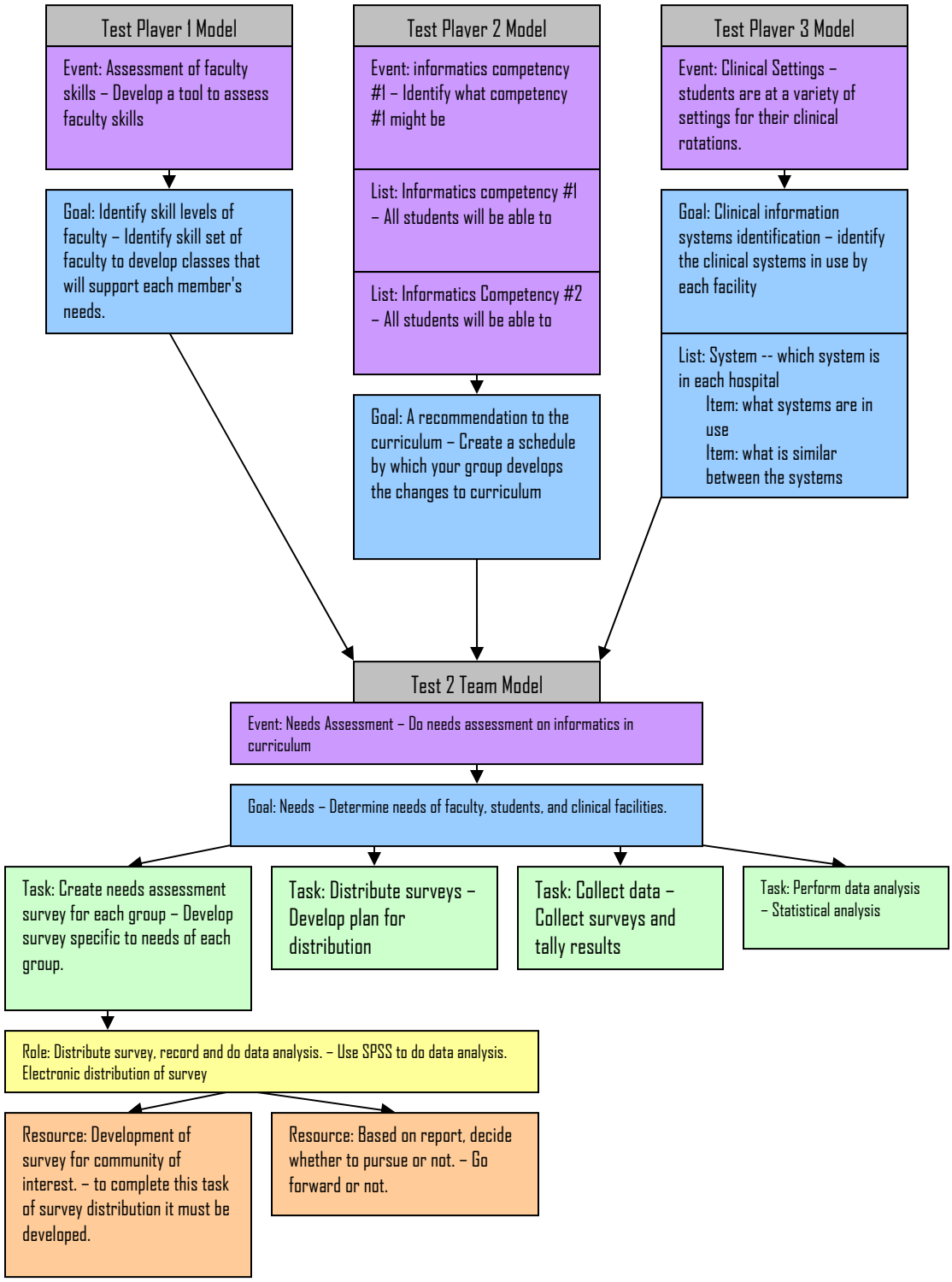
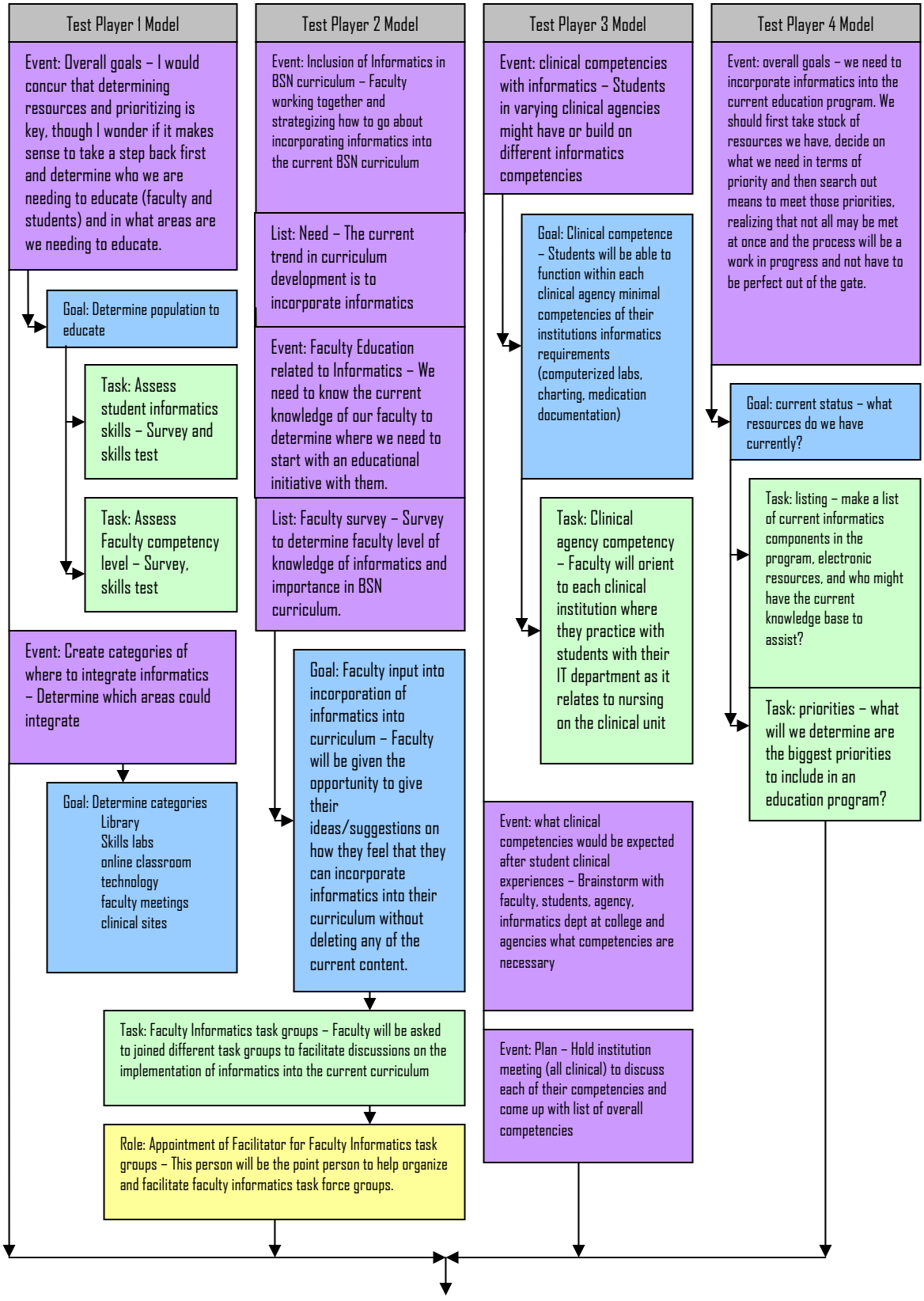


Figure 4. Mental Model Negotiation – Test 2


Test Player 1 Model
Event: Overall goals – I would concur that determining resources and prioritizing is key, though I wonder if it makes sense to take a step back first and determine who we are needing to educate (faculty and students) and in what areas are we needing to educate.
Goal: Determine population to educate
Task: Assess student informatics skills – Survey and skills test
Task: Assess Faculty competency level – Survey, skills test
Event: Create categories of where to integrate informatics – Determine which areas could integrate
Goal: Determine categories
Library
Skills labs
online classroom technology
faculty meetings
clinical sites
Test Player 2 Model
Event: Inclusion of Informatics in BSN curriculum – Faculty working together and strategizing how to go about incorporating informatics into the current BSN curriculum
List: Need – The current trend in curriculum development is to incorporate informatics
Event: Faculty Education related to Informatics – We need to know the current knowledge of our faculty to determine where we need to start with an educational initiative with them.
List: Faculty survey – Survey to determine faculty level of knowledge of informatics and importance in BSN curriculum.
Goal: Faculty input into incorporation of informatics into curriculum – Faculty will be given the opportunity to give their ideas/suggestions on how they feel that they can incorporate informatics into their curriculum without deleting any of the current content.
Task: Faculty Informatics task groups – Faculty will be asked to joined different task groups to facilitate discussions on the implementation of informatics into the current curriculum
Role: Appointment of Facilitator for Faculty Informatics task groups – This person will be the point person to help organize and facilitate faculty informatics task force groups.
Test Player 3 Model
Event: clinical competencies with informatics – Students in varying clinical agencies might have or build on different informatics competencies
Goal: Clinical competence – Students will be able to function within each clinical agency minimal competencies of their institutions informatics requirements (computerized labs, charting, medication documentation)
Task: Clinical agency competency – Faculty will orient to each clinical institution where they practice with students with their IT department as it relates to nursing on the clinical unit
Event: what clinical competencies would be expected after student clinical experiences – Brainstorm with faculty, students, agency, informatics dept at college and agencies what competencies are necessary
Event: Plan – Hold institution meeting (all clinical) to discuss each of their competencies and come up with list of overall competencies
Test Player 4 Model
Event: overall goals – we need to incorporate informatics into the current education program. We should first take stock of resources we have, decide on what we need in terms of priority and then search out means to meet those priorities, realizing that not all may be met at once and the process will be a work in progress and not have to be perfect out of the gate.
Goal: current status – what resources do we have currently?
Task: listing – make a list of current informatics components in the program, electronic resources, and who might have the current knowledge base to assist?
Task: priorities – what will we determine are the biggest priorities to include in an education program?

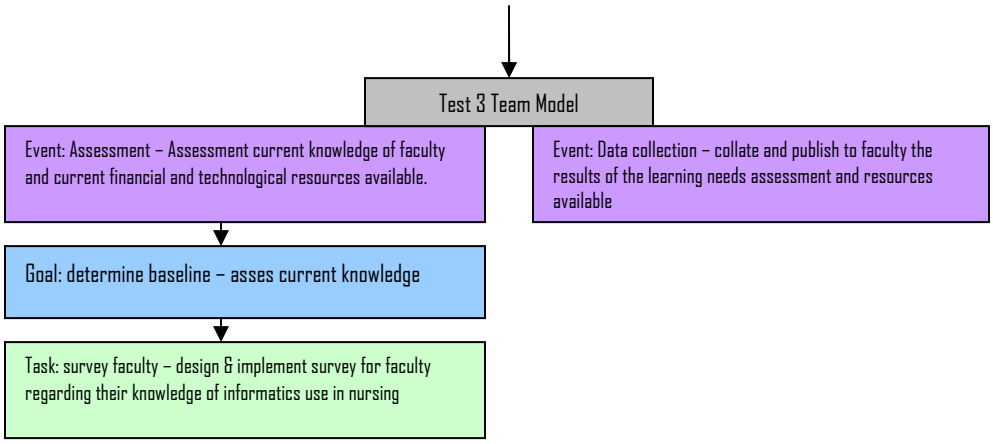


Figure 5. Mental Model Negotiation – Test 3

In order to gain confirmation that the problem space had been successfully explored, the action plans resulting from these two tests were evaluated by an expert panel composed of three Indiana University faculty members with expertise in both nursing and informatics (Dixon and Newlon, 2008). The panel reviewed the action plans of both test and control teams from both tests, blinded so that the panel did not know who contributed to each plan or whether the plan was from a control team or a test team. Panel members were asked to rank each plan, indicate whether they felt the plan addressed issues implied by the test scenario, and assess how feasible each plan would be to execute. The scenario's issues were inferred from a formal nursing informatics implementation strategy, known as the TIGER Initiative. The full action plans are shown in Tables 13 through 16.

Table 13. Action Plan – Test 2 Test Team

Sequence	Action Description
1	Perform an informatics needs assessment of students, faculty, and clinical facilities.
2	Present results to faculty.
3	Outline recommendations based on what the assessment shows.
4	Organize a faculty meeting to discuss the issue.

5	Discuss individual issues as they are brought up.
6	Form sub groups for issues that need more discussion.
7	Have each sub group present its suggestions at the next faculty meeting.
8	Set a deadline for each issue to be resolved.
9	At a full faculty meeting discuss the suggestions and come to a consensus on how to proceed.
10	Assign responsibilities for each task, with deadlines.
11	Faculty to present to administration for budget approval.
12	Negotiate as needed with administration.
13	Once approved, decide how to implement the plan and educate everyone.

Table 14. Action Plan – Test 2 Control Team

Sequence	Action Description
1	Phase 1 – literature search, site visit and other aspects of information gathering
1	Also for Phase 1 – current clinical site informatics and what are college resources
2	Phase 2 – Pilot program as part of a course already in the curriculum
3	Phase 3 – Evaluation of what works and what doesn't, what changes might want to be made
4	Phase 4 – Proposal for expanded curriculum with the result of the pilot study

Table 15. Action Plan – Test 3 Test Team

Sequence	Action Description
1	assessment
2	survey knowledge
3	survey available resources
4	survey current technologies present in known clinical sites
5	share findings with all faculty members
6	determine current or needed pre-requisites for nursing informatics

Table 16. Action Plan – Test 3 Control Team

Sequence	Action Description
1	Identify/locate faculty with informatics knowledge
1	Set up a date and time for a brainstorming session to determine goals, future events, tasks
1	Define competency levels for each semester/level

1	Incorporate competencies into curriculum
1	Determine where informatics can be placed in each didactic and clinical course
1	Develop operationalizing statements on competency objectives
1	Faculty development on nursing informatics
1	Education and research of current technology by staff
1	Define nursing informatics four curriculum: i.e. NLN the specialty that integrates nursing science, computer science and information science in identifying, collecting, processing and managing data and information to support nursing practice, administration, education, research and the expansion of nursing knowledge
1	Investigation of not only different utility of informatics, but also the wide variety of systems available
1	We want faculty to be champions they have to be part of the process of planning the integration into the curriculum
1	Focus on tooling up faculty first and/or plan for students simultaneously
1	Integrate the information into the courses
1	Develop the end in mind: students will be asked to demonstrate an activity (i.e. evidence-based project) using nursing informatics
1	Talk to the teachers of those courses and find out what they are currently doing to meet those objectives
1	Keep the ball rolling/moving forward for the students and faculty through bi-weekly celebration work sessions
1	Identify what we currently have then we can plan where there are deficits and areas to focus new informatics content and experiences
1	Consider not only systems informatics but personal informatics related tools too. Introducing the hand-held PDRs for instance when students are learning to look up medications
1	Locate informatics competencies that have been published
1	Locate recent curriculum review or one of our colleagues is on the curriculum committee and they can provide us with a topical outline of the courses
1	Create a rubric or graphic of the courses in the curriculum and use that to fill in what is happening currently in courses then we can have a visual picture to share with faculty and compare against those informatics competencies
1	Informatics could easily be integrated into clinical, as we all know. However virtual learning would also be very simple

1	I think that if it's a common thread throughout the program students will not only see the importance but the different tools in different specialties
1	Create/develop super users

The action plans ranked from best to worst by the panelists belonged to 1) the Test 3 Control Team, 2) the Test 2 Test Team, 3) the Test 3 Test Team, and 4) the Test 2 Control Team. The characteristics of the highest ranking plans included rich detail, strong faculty involvement, and information-gathering tasks to identify existing curricula, competencies, and informatics education resources.

Two panelists indicated that they would endorse the plans outlined by the Test 3 Control Team and the Test 2 Test Team within their School of Nursing.[2] Furthermore, the panel felt that these two plans best aligned with the TIGER initiative (Dixon & Newlon, 2008), indicating the teams that created them had successfully explored their problem spaces.

The burden of proof for this research question requires only that at least one test team create a successful model and action plan, not necessarily that its action plan be preferred over the action plans of all control teams. It is interesting to note, however, that the action plan of the Test 2 Test Team gained the approval of the panel despite being less than half as long as the winning action plan – that of the Test 3 Control Team. Closer examination of the Test 3 Control Team's action plan reveals that it is similar to the individual models of the Test 3 Test Team in that it appears to capture a brainstorming session, rather than consisting of the ordered and distilled concepts that are evident in the

[2] The third panelist did not complete this question for any of the plans.

Test 2 Test Team's action plan. Therefore, even though the longer action plan was preferred by the panelists, it shows signs of being less well thought out than the action plan resulting from model negotiation. This offers additional validation for the prototype MCT. However, given the success of the Test 2 Test Team's action plan, it is unclear why the Test 3 Test Team progressed from its very detailed individual brainstorming models to an action plan so cryptic that it appeared to be incomplete.

In addition to successful exploration of the problem space, the second part of this research question required demonstrating that the tool could support online collaboration. It was for this reason that the models and action plans for Tests 2 and 3 were analyzed, rather than those for Tests 1 or 4. As mentioned in the previous chapter, Tests 2 and 3 were conducted entirely over the Internet, with the participants scattered across several states. This provides definitive evidence that the prototype MCT can support online collaboration, thus answering in the affirmative to Research Question 1.

Question 2: Can individuals be more effectively motivated to contribute to the forming team culture through the use of an interface that supports the building of a negotiated team model?

The second research question asks whether the users of the tool are more motivated to contribute to the team culture than they otherwise would have been. To determine whether the participants were more effectively motivated through the use of the MCT interface, two versions of the tool were developed, both with and without the model-building mechanism. The participants' qualitative experiences, behavioral observations of

the participants, and ordinal rating data from participant-completed Likert-type scales were compared.

Some representative comments made in the post-test survey and in the follow-up focus group give a picture of the participants' qualitative experiences with this tool:

What was good about the tool?

- "Collaboration was what it was all about for me. Without that aspect, I would have preferred an assignment on my own to be turned in on a specific date and time. Interactions with unknown individuals in an attempt to collaborate to achieve success was the motivating factor!"
- "We made something that I think we could work from."
- "I think our discussion was most helpful. The model did make us think through the detail"
- "I really liked the chat box. That was helpful and I felt I could follow and contribute."

What was bad about the tool?

- "It was so frustrating with the technology issues, plus we really did not understand the exercise, so that, too, added frustration."
- "I felt frustrated about not being able to contribute more, because I could not figure out how work the boxes and get my information where I wanted to put it."

- “I didn't find inserting in the boxes hard, but I felt it was a cumbersome way to do it. Being able to just have the tree develop as you do it would be better. You need to see the whole thing. More like an outline.”
- “I think that if we were to work like a team the individual side work was distracting from the cohesive vision of where we needed to go.”
- “I came in much later than others and couldn't read fast and perform. I personally would have needed much more time as my style is slow and deliberate and writing notes is helpful. I would type things in and find no way to enter it into the box. Button language was unfamiliar.”
- “I would have liked some pictures... visual person... of what the screen looked like that I was supposed to be on as I learned... I'd read but then wasn't sure what I had put in or what I could or couldn't edit when it was my turn”
- “It would have been really helpful to have been able to play around in the site before the exercise began, so we understood how to work within it and focus on the intended purpose of collaborative decision making.”

These observations indicate that there were problems with the user-interface of the tool, but also indicate that there was significant motivation for the participants to use it. It is not clear how these two factors balance out.

Behavioral observation of the participants sheds additional light on the level of interface difficulty with the test version of the prototype MCT versus the control version without the model-building mechanism. These observations were made through conversational analysis of the captured chat postings from each test. Table 17 shows the

total number of chat postings discussing the tool interface versus chat postings discussing the topic.

Table 17. Chat Items Discussing Interface versus Chat Items Discussing Topic

	Test 2 (N=5)		Test 3 (N=7)	
	Interface	Topic	Interface	Topic
Test Team	60	64	126	36
Control Team	34	70	37	96

It is evident that there was much more discussion of the interface by the test teams compared to the control teams, and less discussion of the topic. This indicates that ease-of-use was probably not a positive factor in motivating participants to contribute to the forming team culture of the test interface.

An examination of the ordinal rating data from the post-test survey is the final step in determining whether the test interface provides more motivation to contribute than the control interface. While there were differences in the way each of the four test runs was conducted, each had its own control group to limit the confounding effects. Therefore, it is reasonable to combine the data on user satisfaction to achieve better significance. Table 18 and Figure 6 describe the quantitative results of the post-test survey.

Table 18. Wilcoxon/Mann-Whitney *U* Test
(non-directional a = 0.05)
n1=test/n2=control

Survey Question	Observed *U*	Critical *U*
Was the site easy to navigate?	60.5	26
Was the exercise easy to complete?	64.0	26
Was it fun?	58.0	26
Was it easy to figure out what to do next?	68.5	26
Was it helpful in understanding the problem?	60.5	23
Was it helpful in getting the team to come to an agreement?	50.5	23

Was the resulting data structure useful?	58.5	23
Would the exercise have been more rewarding if it was scored?	69.5	23
Does the concept of scoring seem fair in this situation?	60.0	23
Did the collaboration aspect increase your motivation to contribute?	56.5	23

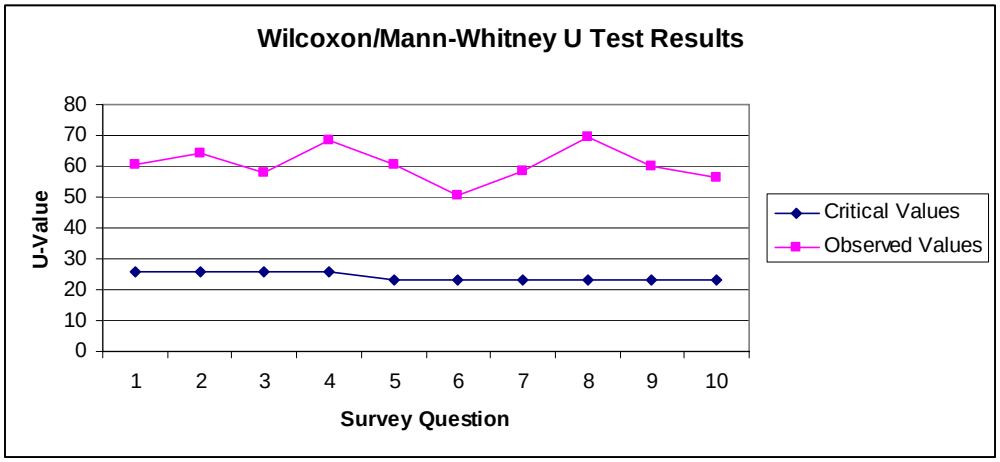


Figure 6. Wilcoxon/Mann-Whitney U Test Results

Unfortunately, these results demonstrate with significance just how dissatisfied the users were with the interface. An examination of the actual contribution levels, however, yields a slightly different picture. Tables 19 and 20 and Figure 7 describe the contribution results. As can be seen, the test and control groups are much more similar in contribution level than in satisfaction level, indicating that frustration with the raw interface did not necessarily de-motivate the users.

Table 19. Total Contributions for Test Teams

	Participant	Elements in model	Contrib. to chat	Elements in team model	Items in action plan	Total	Avg./Person
Test 1	T1	1	5				
	T2	14	8				
	Total	15	13	6	3	37	18.50
Test 2	T1	2	49				

	T2	4	38				
	T3	10	37				
	Total	16	124	9	13	162	54.00
	T1	10	27				
	T2	7	32				
	T3	7	34				
Test	T4	5	68				
3	Total	29	161	4	6	200	50.00
	T1	9	17				
	T2	9	31				
	T3	17	23				
Test	T4	20	13				
4	Total	55	84	32	9	180	45.00
Grand Total						579	44.54

Table 20. Total Contributions for Control Teams

	Participant	Elements in model	Contrib. to chat	Elements in team model	Items in action plan	Total	Avg./Person
Test	C1	0	10				
1	Total	0	10	0	0	10	10.00
Test	C1	0	60				
2	C2	0	44				
	Total	0	104	0	5	109	54.50
	C1	0	41				
Test	C2	0	48				
3	C3	0	44				
	Total	0	133	0	24	157	52.33
	C1	0	68				
Test	C2	0	52				
4	C3	0	62				
	C4	0	6				
	Total	0	188	0	36	224	56.00
Grand Total						500	50.00

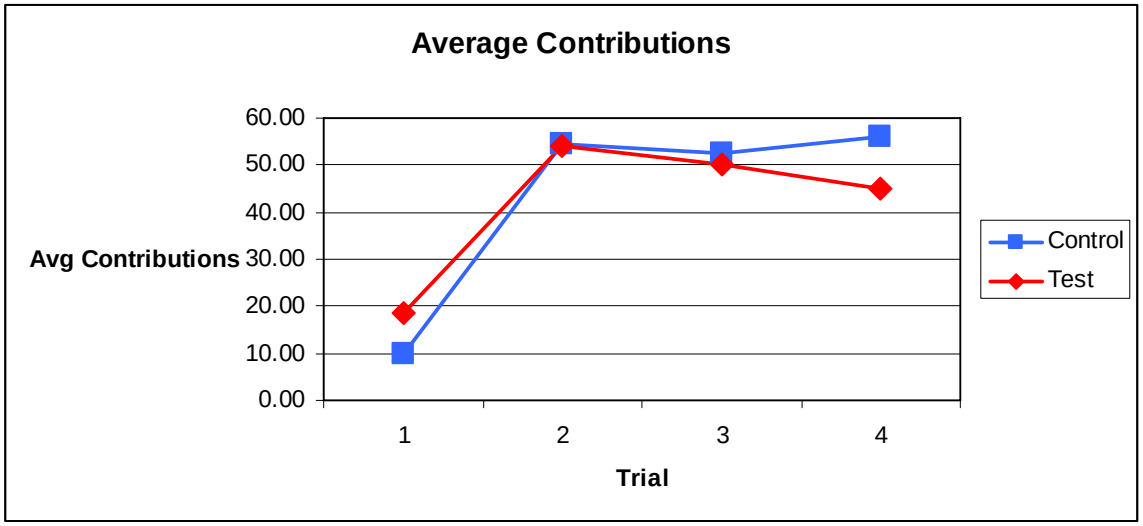


Figure 7. Average Number of Contributions to the Knowledge-Base

These usability issues with the prototype MCT interface will presumably fade as work continues on it. As mentioned under Research Question 1, examination of the models and action plans resulting from use of the tool indicates that there is already some advantage to using the model-building interface rather than a simple chat interface. Therefore, it is not yet clear whether the interface will ultimately prove to be motivating or de-motivating. The only thing that can be said with certainty is that the test interface does not currently provide motivation over and above the motivation provided by the control interface.

Question 3: Can a tool be designed that dynamically builds team data structures as the team comes to an agreement on goals, roles, tasks, and strategies?

The third research question asks whether a database can be developed that captures the resulting models. To determine whether the tool dynamically builds the necessary team data structures as the team comes to an agreement on goals, roles, tasks, and

strategies, the data structures built during testing of the prototype were evaluated in terms of errors, design suitability, and whether it was possible to capture all necessary facets of the problem. Heuristic analysis was performed on some of the project databases created by the tool to determine whether they were adequate to the simulated task. The system's automatic communication tracking was also examined to determine if it met expectations.

The ultimate test of the database, of course, was whether or not it successfully drove the application. It would not have been possible to design the tool to do the things described under the previous two research questions unless the database had adequately captured the participant-generated data. The very generic data structure described in Section 3.3 was still able to capture the participant-defined structural details shown in Figures 4 and 5. The communication tracking was able to separate and display the conversations of the test teams and the conversations of the control teams in every test without any errors or cross-contamination. It was also able to capture each conversation in its entirety for later study.

In examining the participant-generated data structures, there is some evidence that additional relation-types will need to be added. For instance, in Figure 4, the "Resources" shown in the team model are not resources at all, but constraints. While constraints could be viewed as negative resources, they could also be defined separately. In addition, there are many situations that would be better described by simple "parent-child" relations, rather than event-goal-task-role-resource relations. However, none of these considerations will require any significant changes in the overall data structure shown in Figure 3. These new relations will merely create more line items in the relation table. Therefore, the answer to Research Question 3 is affirmative.

4.3 Summary of Findings

In summary, it was definitely possible to use this prototype MCT interface over the Internet to collaborate with team members in remote locations, as required by Research Question 1. The MCT definitely captured the users' mental models, conversations, and action plans into a database in a way that would lend itself to the uses envisioned, as required by Research Question 3. However, the test interface does not yet have the ease of use that is required to motivate to its users over and above what they could achieve with a simple chat interface, as required by Research Question 2. The experience of the users, however, and their captured suggestions, has provided a valuable source of guidance for future MCT development.

CHAPTER FIVE: DISCUSSION

5.1 Explanation of the Outcomes

So why are these research questions important? Why do we care whether the use of the prototype MCT facilitates exploration of the team problem space, and supports online collaboration? Remember, the goal is to create an interface that supports the bottom-up development of mega-collaborating teams by supporting activity that aids the team development process. A protocol that encourages team members to discuss their problem space, and explore the alternative courses of action, will help the team build its shared world model from the mental models of its members and establish its internal culture. By demonstrating that the prototype MCT meets this criterion, this research project has achieved the basic building block of a system that can develop consensus on a large scale. With this basic building block, it will be possible to divide even the most massive problem into tiny pieces by coordinating the spontaneous formation and communication of small sub-teams. It is this basic building block that will serve as the underlying method by which attached autonomous software agents can locate agents of similar sub-teams and build small-world networks to share information. It is also this basic building block that can be spontaneously formed at any level of a playoff hierarchy to build and rebuild shared world models from the world models of the sub-teams represented by its members. This research has not achieved a fully-functional MCT, but it has achieved the basic unit from which to build one.

Why do we care if individuals are more effectively motivated to contribute to the forming team culture through an interface that supports the building of a negotiated team

model? Remember that the interface design for the tool must be fun and intuitive, because bottom-up organization requires spontaneous participation. No single entity will ever have the resources to fully manage a true mega-collaboration project. So, the success of the interface will depend on the willingness of people to voluntarily use it. If it is easier for the team members to merely chat rather than build a team model, if the MCT does not provide them with clear and immediate gratification for their efforts, there will be no way to achieve a spontaneously-forming structure. Therefore, the fact that testing of the prototype MCT yielded mixed results on Research Question 2 represents a clear challenge for future development of the concept. The MCT must demonstrate an advantage over other available interaction alternatives, or it will not be used.

Finally, why should we care whether the prototype MCT dynamically builds team data structures as the team comes to an agreement on goals, roles, tasks, and strategies? Remember, if it is to be successful in supporting the scale-up of online collaboration to larger team sizes, the MCT must provide a way for autonomous software agents to efficiently compare the developing models of different sub-teams. It must also demonstrate the ability to track individual interests and activities, and to provide views of the data in several dimensions, including the ability to sort and recall it in any common format in which it might be needed by the mega-collaborating team, such as schedule information or task assignments. All of these functionalities depend on the MCT's underlying database architecture to be flexible, yet robust. By demonstrating that the prototype MCT's database architecture meets this criterion, the research project has achieved a proof-of-concept for this architectural approach, giving a clear indication that further development along this line will yield good results.

5.2 Implications of the Results

Revisiting the Big Picture

In considering the implications of the research results, we must again consider the problem discussed in Chapter 1, the emergence of conflicting empowerment models, and the need to coordinate between them. By posing and answering the three research questions, this project has also addressed the larger questions that arise from this conflict.

What sort of an interface can support mega-collaboration? The affirmative answer to Research Question 1 indicates that the mental model building and negotiation interface of the prototype MCT has the potential to meet this need.

If a team has thousands, or even millions of members, how can it establish a team culture? The research results from the model and action plan building processes indicate that the MCT will support the development of an internal team culture; and the successful testing of the MCT database architecture indicates that the MCT will support the autonomous agent functionality required for large-scale operations.

Is it possible to make mega-collaboration more effective through expanded use of the small-world principle? While this research project does not directly address this question, it has achieved the basic building block necessary to put the small-world network idea to the test in a human-based system. It should be possible to design a research project to discover whether the concept simulated by Scerri and Xu et al. (2004) will actually work in real life.

If ICTs have created an imbalance between the availability of resources and the authority to use them, can an MCT offer any solution? This research has demonstrated

that the MCT can potentially offer a solution to this problem through the building of a knowledge-base that can be used to coordinate resource needs and chain-of-command conflicts. However, because the solution would depend on spontaneous usage of the MCT by volunteers, the usability issues raised by Research Question 2 will need to be resolved before any such solution can be achieved. In order to address these issues, the improvements discussed in the following section must be made.

Future Development of the MCT

Several problems must be solved to move from the small test bed currently in use to a useful tool for a real emergency. These are discussed below.

The Architecture

Now that the MCT application is leaving its conceptual stage, the time has come to think seriously about its formal architecture. There are a number of factors that make it a clear candidate for object-oriented development. In addition to its more permanent software algorithms, even the participant-developed structures could benefit from an object-oriented approach. The information in a developing mental model must be viewed in a number of different contexts, each a type of hierarchy. Together, these individual hierarchies form a complex network. The object-oriented paradigm (Booch et al., 2007) offers a couple of clear advantages as a method to support visualization of this network. First, the paradigm was designed to support such visualization. Second, it will be easier to interface the resulting mental models with other software tools if the underlying paradigm of both is the same.

Therefore, we can assume that the model visualization interface will need to describe 1) the parts of a decomposed entity (its class structure), 2) specific instances of the entity's general categories (its object structure), 3) the relations among the physical components of the entity (its module structure), and 4) the relations among the dynamic components of the entity (its process structure). Logical descriptions will constitute the structure of each entity, while physical descriptions will constitute the control boundaries and documentation needs. Processes will describe the behaviors and interactions among the various elements within the entity.

The initial steps of the formal architectural design have already been started, with the current structure shown in Appendix D as a series of UML diagrams. This structure will be extensively elaborated before the next round of coding on the MCT project.

The Teaming Interface

The first challenge facing mega-collaboration in the context of disaster response is the team formation procedure. One model already in use is the spontaneous teaming of MMORPGs (Rauterberg, 2003). Typically, someone will pick a quest or other goal and then issue a call to the general chat room. Others who want to participate will answer. The nascent team then establishes its own private conversation. Another possibility is to have the MCT itself form teams through the use of random assignment, the use of friends' lists, or the use of temporal proximity. Alternatively, participants could scan the topics and teams already established and join a team according to their preference. The final interface should probably be a synthesis of all of these. In addition to these unrestricted teaming strategies, allowances must also be made for the formation of

restricted participation teams, with assigned participants, as would be required by a formal chain-of-command structure.

The next experimental interface will use the MMORPG model, providing a general chat room where prospective teammates can meet and create team chat rooms. A name and description of each active team will be shown in a data tree in the general chat room, serving as a link to each team chat room for latecomers. In this way, the experimental MCT interface can support formation of the initial coalition in addition to the later team phases.

Input Interfaces

Usability testing of the current test bed has helped to determine the interfaces needed for model development. Despite the general frustration with the current interface, it was clear that the users were able to grasp what was required in a short period of time with little or no training. Even the most computer illiterate of the participants, working with virtually no instructions, was able to make a rudimentary mental model entry into this program.

The participatory development process has highlighted some pitfalls, however. The cognitive walkthrough results steered development away from a game board pattern and into an expanding form pattern. The usability testing results are now steering development away from the expanding form and toward data tree and data grid patterns.

The current expanding-list entry form is extremely simplistic when compared to the specifications listed in Chapter 3. Not surprisingly, the test participants struggled with it, and expressed a preference for data tree and data grid methods of entry. In particular, a

data tree (Figure 8) would allow more flexibility in describing the hierarchy, because icons could be used to denote different types of entities. Most coordination requires cross comparison, so the data grid's support of matrix views will also be important.

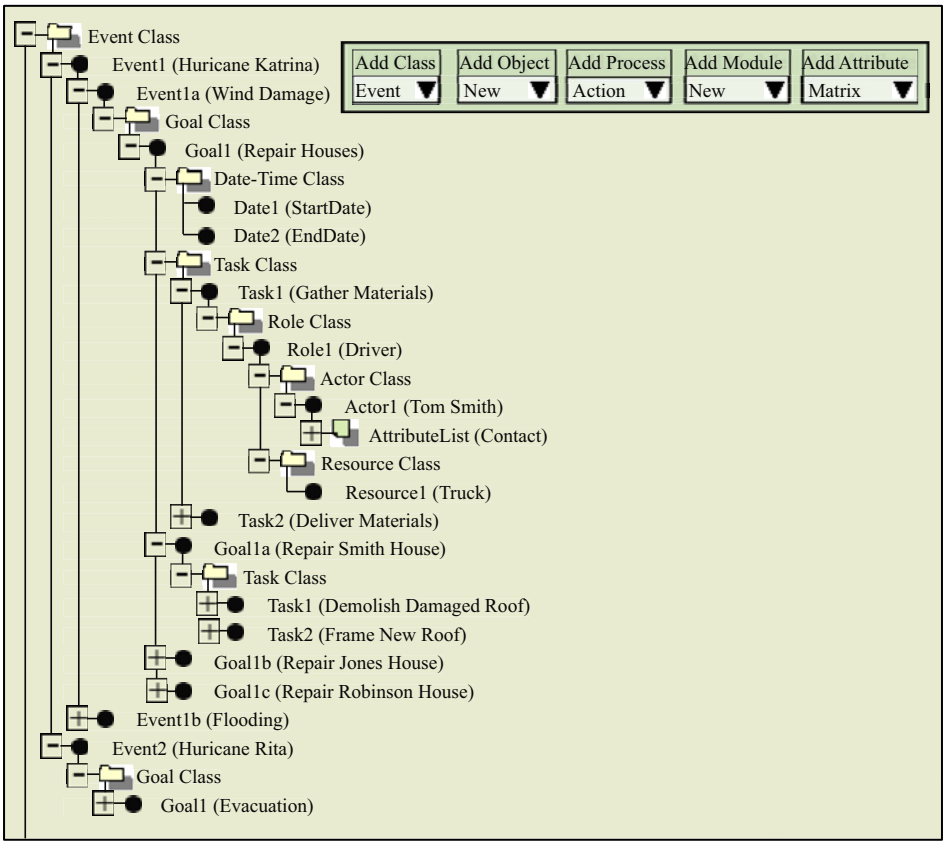


Figure 8. Data Tree – Under Development

It was evident from the beginning that several formats would be needed for input. As of this writing, the clear winners, data-entry tree, data grid, and list entry, all have standard widgets available in various development environments.

Another envisioned interface would enable participants to "felt-board" their hierarchies by moving disconnected tree structures around as the situation's structure becomes clearer. This is similar to the white-board pattern. The data structure generated by the MCT will be a network, not a simple tree. The assumption is that viewing

"chunks" of the network as hierarchies can improve both development and display. People tend to think in this way. A method for navigating between chunks would need to be determined.

Other input forms for scheduling, contact information, and location information would also be useful. Types of variables that might need to be recorded include function, structure, dimensionality, degree of certainty, temporal reference, and degree of generality, degree of closure, and degree of quantification (Crapo et al., 2000). In particular, action plan items should be part of the model, rather than a separate interface, as they are in the current test bed.

In addition to these general data entry formats, enabling participants to customize formats would help structure their thinking while boosting their creativity. A longer-term goal will be giving the team the ability to define its own data input and data output widgets. It would be a leap in functionality to allow participants to develop their own specific input formats that could be adapted to the problem at hand and made available to others.

Output Interfaces

Despite the obvious need for multiple display interfaces, the current test bed has only a treemap, which is not at all intuitive, at least in its present implementation. Although the treemap was not well received in its prototype form, it is nevertheless a very space-efficient form of display (Johnson & Schneiderman, 1991). The current plan is to enhance its visualization, displaying each cell's contents instead of just listing the

number of items in each cell, though it may be dropped altogether if it cannot be made more usable.

Participants specifically requested additional interfaces, such as a flowchart of the model. Flowcharts (Figures 4 and 5) have been the only effective way to illustrate the models that resulted from runs of the current test bed. At the moment, these are created by hand from the database. Hence, it is important to generate these flowcharts automatically. A disadvantage of flowcharts is that they are space inefficient, so scrolling is often required.

In addition to the general display formats, specific display formats for specific types of data will be needed. These will probably mirror the specific entry formats, namely, action plans, schedules, address books, maps, and so on. The greatest leap in functionality will come from the participants' ability to sort and search the available data to create the specific output in the specific format they want and then to make this information available to whomever they choose. This is true whether the participant is a member of a spontaneous team or a formal chain-of-command team.

Model-Building Process

The current prototype interface supports the negotiation process with script windows, a chat window, and a timed negotiation protocol. The script encourages each teammate to develop an individual model of the problem, to compare this model with those of other teammates, and to negotiate consolidation of the models into a team model. The team then develops an action plan based on this consolidated model.

However, the usability testing has identified shortcomings in this protocol. Experience from testing indicates that beginners need a period of training on the interface, but that formation of individual and team models tends to happen concurrently, along with chat room discussion of the problem. Therefore, individual and team model development should be concurrent, and participants should get training time on the interface before starting. Teams also need the flexibility of repeating segments as necessary and setting their own time intervals. Some standardization will be necessary to interconnect the different teams, but it should be possible for each team to set up its own timers and to call its own votes. The next protocol will need to accommodate these findings.

Data Structure: The Big Picture

Although the current database structure (Figure 3) will need to be elaborated as features are added, it has tested very well and appears to be adequate in concept to support the MCT. The current test bed makes use of a prewritten scenario for an initial crisis. However, a working version of the MCT will need to draw from the developing data structure to provide scenario information to the participants. One way to do this would be to let the participants browse the data structure on their own to form a mental picture of the problem. Another way would be to develop a "scenario-building" process, which could be agent-driven, that abstracts from the data structure and provides drill-down links.

The developing structure will be at varying levels of maturity, depending on how many playoffs each of its parts have completed. This maturity information must be

maintained for each data item, because it is a measure of confidence concerning the accuracy of the data. The ability to count the number of edits and links to other models could provide a general picture of each data item's maturity.

Another feature of the data structure is access control. The test bed already controls who can edit and view items at any given time. If the MCT is to interface with chain-of-command organizations, it must also enable restricted participation teams to control access to their models. This control should extend to the data-item level, so that such teams can selectively release information. One issue is how much access the autonomous software agents will have. Although the restricted participation team's agent will be able to identify potential conflicts in the models of unrestricted teams, what about conflicts with restricted teams? Security clearance levels may be required, even for the agents. In a global situation, with multinational restricted teams interacting with unrestricted teams, some warning system may need to be developed. Another challenge is conducting a playoff when one or more of the teams is restricted. Presumably, each restricted team could alter its model based on any unrestricted information available, but the playoff model could only use information a restricted team had specifically released.

The Scaling Interface

The next step in MCT development is to add the autonomous software agents that will assist small teams to coalesce into mega-teams. Agents spawned by the formation of each team can continually scan the developing team models as they are added to the shared database. The agents can then form teams of their own with the agents of other human teams that have similar team models, and coordinate the human teams.

This is necessary because the mega-collaboration concept hinges on the scalability of teams. While someone should be able to visually inspect the MCT's output and determine that several teams need to get together and compare their models, with all users concentrating on their own piece of the problem, this comparison may be difficult. Therefore, the process should be assisted by the software agents. The power of having all the activity take place in one data structure is that each forming team can automatically generate its own agent that searches for other teams developing similar models and coordinates compare-merge playoffs with the agents of those teams. Given the network structure of the data, these playoffs could take place in any direction, though an operational hierarchy will probably develop that mirrors the hierarchy of the relief effort.

While the autonomous agents will work in the background, communicating through messages, their improvement on people's ability to visualize the big picture is expected to be dramatic. By managing the synchronization and efficient communication of information, the agents will expand people's ability to visualize by telling them where to look.

Similar agent technologies are already available, but their use has been limited because of an inability to interface with real human organizations (Scerri, 2007). The MCT should address this gap. The plan is to extend prior research by Paul Scerri on Carnegie Mellon University's small-world networking architecture. This has already been used successfully to test the goal coordination of large agent teams facing an emergency response scenario, and to allocate roles and tasks to these teams (Scerri, Farinelli, Okamoto, & Tambe, 2004, Scerri, Farinelli, Okamoto, & Tambe, 2005, Scerri, Xu, Liao,

Lai, & Sycara, 2004). However, by adding human teams that essentially serve as methods of the agent teams, it is believed that significant functionality can be achieved.

The agent network will facilitate the mega-team-building process because, as discussed in Chapter 2, the relationship of independently forming teams to each other is similar to the relationship of individuals to each other. A meta-team can be formed with the support of an agent-managed interface. As the collaboration progresses, the agent teams can use programmed rules to determine the conditions under which the continually dividing and merging streams of activity will be synchronized, allowing humans on the meta-teams to renegotiate common views of the data. The agent network can also mediate the division of teams that have grown too large and manage communications.

Although the playoff concept has always been integral to the conceptual framework of the prototype, the current test bed focuses on the interfaces that connect a single team and that team's ability to choose a team representative. The agents, the search procedure, and the playoff process all remain for the next phase of development.

Interface with the Chain-of-Command

The MCT provides a place where individuals and groups make explicit, step-by-step plans and store information generated about the unfolding disaster and response. Autonomous software agents use this formalized information environment to integrate and streamline activities not only within a particular coordination paradigm but, ultimately, across paradigms.

Information on volunteer activities and resources available constitutes the greatest benefit of the MCT to chain-of-command agencies. As mentioned, the ability to construct

output reports and determine the maturity of each data item would be important for all users, not just formal organizations. However, the MCT would provide an interface for negotiation between the two different organizational cultures in addition to a knowledge-base that both could use.

The MCT will match the teams according to similarities in the objects they are modeling and the agents will manage the negotiation process. However, the agents can also track the authority structures of the teams based on how they are formed. Therefore, in theory, top-down formulated rules can be added to the negotiation process for restricted-access teams.

Another possible interface for chain-of-command organizations would be an output report resembling a request for proposal. Once the government formed a top-down plan, the generation of a formal list of requests would allow agents to connect their teams to relevant problems selectively. This process could be followed by any organization seeking to coordinate through a mega-collaboration framework.

Notice that the interface supports both bottom-up and top-down information flows. Bottom-up organizations can be alerted to opportunities or holes in a top-down plan, showing where their efforts might be most effective. The MCT can give them rapid access to all the information available in the entire response and ensure that local efforts work synergistically with the larger response. This access should encourage volunteers to use the MCT.

5.3 Summary of the Discussion

This research project determined that using a tool to facilitate exploration of the team problem space will support online collaboration. In doing so, it successfully demonstrated that the basic building block necessary to construction of an MCT could be achieved. The project failed to determine whether individuals will be more effectively motivated to contribute through use of this interface, though there were indications that future improvements in the user interface may eventually demonstrate this. It will be important to answer this question before the full MCT vision can become a reality, since the tool's success will depend on participants' willingness to use it. The project also demonstrated that it is possible to dynamically build the team data structure through use of this interface. This finding was critically important in validating the database design planned for use at the core of the MCT. In addressing these research questions, this project has also addressed the wider issues facing modern disaster recovery activities, which increasingly have to deal with conflicts between top-down and bottom-up empowerment structures. The research indicates that the MCT interface can assist in mediating this conflict through the development of shared world models and a shared knowledge-base.

This project has moved through its inception stage following a user-centered development regimen, completing the first stage of a usability study using paper prototypes of the system, and the second stage using an interactive prototype of the team negotiation interface. The successes and failures of the prototype MCT have provided insights that will drive the future development of the concept, including the planned expansions and improvements described above. Current plans are to complete an

experimental Web site that will feature another generation of the interactive prototype, which will be elaborated with an agent-driven mega-collaboration interface. This fully functioning system will then undergo another round of user-centered heuristic inspections, task studies, and questionnaires to further examine its usability.

CHAPTER SIX: CONCLUSION

To recap, this research project was inspired by the nationwide crisis following Hurricane Katrina. It initially identified an emergent phenomenon termed *mega-collaboration* that resulted from the ICT-driven empowerment of the general population. The project focused on the observation that this bottom-up form of empowerment was increasingly in conflict with the traditional top-down empowerment structures of the formal disaster response organizations, and proposed a mega-collaboration tool (MCT) to help mediate this conflict, developing the following research questions as a means of determining whether such a tool would work:

1. Can the use of a tool, which facilitates exploration of the team problem space, support online collaboration?
2. Can individuals be more effectively motivated to contribute to the forming team culture through the use of an interface that supports the building of a negotiated team model?
3. Can a tool be designed that dynamically builds team data structures as the team comes to an agreement on goals, roles, tasks, and strategies?

This research project successfully demonstrated the basic building block necessary to the construction of an MCT, by determining that using a tool to facilitate exploration of the team problem space will support online collaboration. However, the project failed to determine whether individuals will be more effectively motivated to contribute through use of this interface. Future improvements in the user interface will be required before this can be determined. Since the tool's success will depend on

participants' willingness to use it, an answer this question must be found before the full MCT vision can become a reality. The project did demonstrate, however, that it is possible to dynamically build the team data structure through use of this interface, a finding that is critically important in validating the database design planned for use at the core of the MCT. The research indicates that the MCT interface can assist in mediating conflicts between top-down and bottom-up empowerment structures through the development of shared world models and a shared knowledge-base.

6.1 Limitations

There are obvious limitations to what can be discerned from a usability study conducted this early in the development process. With so few users, such a primitive interface, and changes made between every test, one cannot expect much in the way of statistical rigor. Once the interface has "fleshed out" a bit, it will be necessary to conduct a much larger study to determine what effect it has on the team formation and coordination process. However, the results of this usability study have been generally encouraging. They have provided solid information on what problems the interface currently faces, and what will need to be done to correct them.

6.2 Future Research – Beyond the MCT

In addition to the future development necessary to move the MCT from its prototype phase to future operational phases, described in Chapter 5, it is envisioned that the MCT will serve as a platform for future studies on various other topics. Some of these are discussed below.

Leadership

One avenue of research is to further examine how the MCT affects, and is affected by, group dynamics and leadership. Conversation analysis of the chat dialogues turned up some intriguing indications. To determine the effect of leadership within the test and control groups, chat messages were flagged where participants focused a question or comment on the task to keep the group moving forward (e.g., “What is the next step?”), provided encouragement to other members of the group (e.g., “Great thinking Player 2!”), and assigned or suggested assignments for individual group members (e.g., “Player 3 should be the spokesperson because he can type quickly.”) It was noted that the groups displaying significant leadership were the same groups that produced good action plans. This clearly has implications as a confounding factor, and may need to be controlled for in subsequent studies. However, it also indicates that the MCT may provide a platform for studying the spontaneous development of leadership in a small team context.

Mental Modeling

This project has already reached a stage at which design ideas can be drawn from current ICT theory and tested using the prototype MCT. For instance, Crapo et al. (2000), in his cognitive-theoretic survey of visualization and modeling, recognizes the problem identification stage of model development as separate from the problem definition and structuring stage. The prototype design instructed the teammates to begin by working individually on problem definitions. This was difficult for the users, however. Not only did they want a separate problem identification stage before the definition stage, they

wanted it to be a group activity conducted in chat. Apparently, teammates need to become familiar with their group context in a social setting even before developing their individual definitions of the problem. With its ability to explicitly capture developing mental models, and also the conversations surrounding them, the MCT interface will undoubtedly provide more insights of this nature in the future, resulting in a better understanding of the mental modeling process.

Terror Management

Another theory that has major implications for the success of such an interface is terror management theory. It has been demonstrated that individuals who have been reminded of their own mortality (as will be the case in most disaster situations) tend to cling to their cultural worldviews, look for strong leaders, and display more hostility toward out-groups or perceived external threats (Solomon, Greenberg, & Pyszczynski, 1998). However, a structure that enfolds many different organizational entities can potentially convert them from external threats to internal resources in the minds of those involved in disaster response. By providing a flexible, but structured interface for negotiation and dialogue, such a tool could facilitate development of the culture and leadership needed to respond to the crisis. Therefore, the MCT represents a potential platform for studying the effect of terror management on group dynamics.

6.3 Summary – Implications of the Theory

While this research draws from much other research in many different areas, it has made a unique contribution in pulling these theories together into a new operational vision of how disaster response, and potentially many other problems, should be managed

in the future. In addition to proposing the mechanism by which this approach might work, this project was able to form and examine three research questions designed to determine its viability. While it was not possible to definitively answer all three questions, two of them were answered in the affirmative, while the third remains with indications that it may be answered affirmatively in the future. In sum, the MCT appears to be a promising approach for the support of mega-collaborative processes, and the results of this project have provided valuable guidance for its future development.

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APPENDICES

Appendix A: User Analysis

Table A-1. User Profiles

District Fire Superintendent (DFS) – In his early sixties, DFS is proud of his organization. He has always run a very tight ship, and his equipment and facilities have mirrored this fact. Now that the hurricane has passed, he is feeling completely overwhelmed. The communications are so spotty that he has no way of knowing who needs help, or how dangerous things might be for his men. How can he set priorities? Perhaps he could have the boys tidy up the mess at the stations while things settle down a bit…
IAFF Coordinator (IC) – In his late forties, IC has handled crises before, but this is so much bigger than 9/11. He can draw on firefighting and paramedic reserves from across the country, but he cannot seem to find a place locally to set up shop. On top of that, one local superintendent keeps refusing help because he does not like unions…
Red Cross Coordinator (RCC) – In her mid thirties, RCC already has the perfect base of operations set up in a vacant former Kmart building. But for some reason, the National Guard keeps bugging her because she is not running things from their emergency operations center. She really depends on all this warehouse space. Supplies of clothing are arriving by the truckload, but what she needs is food for the many emergency shelters. Who told people to send clothing? The Red Cross does not normally even accept clothing. On top of that, she cannot seem to convince FEMA that feeding people will not wait…
National Guard Coordinator (NGC) – In his late thirties, NGC has a huge headache. The local police department keeps claiming that his organization is in charge of providing security for all the refugees in the sports arena. But it is a local facility, so the local police are really the ones responsible, right? Besides, he cannot do more than provide a little support for the local police because his men are stretched thin providing security throughout the region. All of a sudden, every Tom, Dick, and Harry is showing up as a "rescue volunteer." The situation could spiral into chaos. He has given his men orders to set up roadblocks and deny access to everyone unless they have authorization to be there. On top of everything else, he cannot figure out why no one has come to repair the emergency communications system…
FEMA Coordinator (FC) – In his late forties, FC has handled lots of hurricanes, but he has never seen anything like this before. FEMA does not have enough of the right emergency supplies on hand. People are just going to have to wait on food until he can get some emergency contracts in place. There is plenty of ice, however. Maybe he could roll a few truckloads in, if he could figure out where to send them…
Remote Citizen on Neighborhood Listbot (RCNL) – In her mid fifties, RCNL has been following the crisis on the news and on the web. Her heart goes out to all those suffering people. She feels powerless, and wishes there was something she could do to help. But she has just read on her neighborhood listbot that one of her neighbors has a friend with a truck, and they are calling for donated supplies to

take down to the people who need them. She has several bags of perfectly good clothing items that no longer fit…
Remote Social Worker (RSW) – In her late sixties, RSW thought she would be less busy once she retired, but it seems that everyone wants a volunteer with a background in social work. She has been following the crisis on the news and it is clear that a large number of refugees will soon be arriving in town suffering from post-traumatic stress syndrome. She knows her expertise will be sorely needed, but she does not know where and how to connect up with the people in need…
Remote Computer Expert (RCE) – In his mid twenties, RCE quit his corporate system administration job six months ago so he could start his own small web-hosting business. Things have not worked out so well, and the old UNIX box in the back room that he thought he could use as his web server has been sitting idle. But this crisis is the worst thing he can even imagine. He can easily set up a database to help track the missing people, but he does not know who needs the information, or how to push it out to them. He'll just have to hope they can find their way to it on his site…
Remote Relative (RR) – In her early forties, RR moved away from the hurricane area when she got married. Now she is worried sick about her parents, who have not been in touch since the evening before the hurricane hit. She can see from the satellite images on the web that her parent's home is under water. She has entered information on her parents into a missing-persons database she found on the web, including the exact street and number for their house. But she does not know of any way to get someone there to check on them…

Table A-2. Use Case Scenarios

District Fire Superintendent, DFS, knows that the emergency communications system is down, but the land-line phone system in his part of town is still working, so he has internet access from his home. When he does a Google search for hurricane information, he discovers a site where resources are being coordinated. The people in the chat room seem to be playing some sort of board game, but from the conversation about rescue operations, he discovers that he can click on some of the buttons and pull up a satellite map of the houses in his district showing which houses are underwater, and listing the people in each house who are currently unaccounted for. Many of the other houses have labels saying, "Found, click here for location." When he clicks on one of the labels, a window opens listing the residents of that house, and showing the name, address, and phone number of the shelter at which they are staying. Clicking another label opens a window listing only an email address at which that house's residents can be reached. Apparently, they want more privacy. Where did all this information come from? When he asks this question in the chat room, someone explains how he can click tiles on the game board to open windows showing the source of each data item. Amazingly, the satellite map came from someone in New York, who used Google-Earth to create it; and most of the missing and found persons information is being supplied by someone in California, who has set up a database. He sends a chat message that

he is in charge of the local fire department, but he does not have enough crews to search all the houses of people who are missing. Almost immediately, he sees a reply from the IAFF offering to supply as many firefighters as he needs from around the country. He then sees another message explaining how his staff can enter information on rescued people, so shelter space can be found for them…IAFF coordinator, IC, gets onto the internet using his laptop and a connection in his motel room. After sending an email to his home office detailing the problems he is having, he does a Google search of available hurricane information, and discovers a website where resources are being coordinated. He joins a chat room on rescue activities and asks if anyone knows of a place where he can set up a base of operations. Someone chats him through the process of defining his needs and functions on a sort of game board. He notices that he earns quite a few points in this "game" when he lists the firefighting and paramedic resources that he can supply, based on volunteers from fire departments around the country. He enters his email address as the person to be notified if someone has the resources he needs, or if someone needs the resources he has. When he checks his email half an hour later, he finds a message of sympathy from his home office, and five offers of space and supplies from local churches and businesses. He also finds three messages from local fire departments requesting help. When he goes back to the chat room to look at more detailed descriptions of the space resources he has been offered, he sees a chat message from one of the local fire superintendents about needing more crews to search houses for missing people. He replies, offering to supply as many as are needed. Then he sets about defining the requests for crews that he has received onto the game board, and also the volunteers that he knows are available. He discovers this information is going into a database, and he can view lists, maps, schedules, and contact information for the operation. He notices the list of available firefighters has been growing on its own. The information is being input directly by fire departments all over the country…
Red Cross Coordinator, RCC, plugs her laptop into the phone line at her base of operations, and sends an emergency email to national Red Cross Headquarters, asking them to issue a press release about not needing clothing. Then she checks Google to see what information is available about the hurricane situation. She finds a chat room where they seem to be playing a board game. Then she realizes that the "game" is actually a list of needs and available resources. She sees from the conversation in the chat window that a map is already available, based on satellite images, showing house-by-house who is still unaccounted for. It also lists contact information, sometimes even shelter location, for the ones who have been found. She wonders if it would be possible to track the location and needs of each shelter with this "game," as it is already tracking the people staying at the shelters. When she asks, someone explains how to list the shelter details. To her surprise, she discovers that most of the information she needs has already been entered onto the game board by the volunteers at each shelter. Encouraged by this, she calls her FEMA contact to ask about food supplies for the shelters. He tells her that nothing will be available until an emergency contract has been signed in three days' time. Horrified, she takes her FEMA contact through the process of accessing the

"game" on the resource coordination website so she can show him what resource requirements the shelters have. He still cannot supply what she needs, but at least he agrees to work from the needs list on the website to write the specifications for the contract. As she hangs up, she receives a call from the State National Guard Commander asking why no Red Cross representative has arrived for the emergency operations center (EOC). Up until now, she has resisted sending anyone, because she feels it is a waste of their time to sit around talking while they could be out organizing, so she explains that she cannot spare anyone because of the food crisis in the shelters. The National Guard Commander mentions that he might have some "meals-ready-to-eat" (MREs) that he can spare. Delighted, she talks him through the process of accessing the coordination website to get the shelter locations and the amount of food needed at each. He agrees to supply the food, but requests that she coordinate delivery from the EOC. She agrees to send someone who can update the website database with information received from other organizations at the EOC. Obviously, this will not be a waste of time after all, because the information will be immediately available to her. When she checks the website again, she notices that a house-to-house rescue operation is being organized. She sends a message explaining how information on any rescued people can be input to the database so shelter space can be found for them…
National Guard Coordinator, NGC, hangs up the phone after talking to the Red Cross Coordinator. Thankfully, she has finally agreed to send someone to the EOC. It is sure hard to coordinate with volunteer organizations that are not represented there. He takes a closer look at the game board on the website, surprised at how much information it has. He would love to use a tool like this in tracking the deployment of his men. It could also be used to track who is in charge of every different venue. He wishes this website could do role-based security. On a whim, he checks the help menu, and discovers that he can set up role-based private chat rooms and game boards that draw from the overall database, but control access to internally-defined data elements. Just then NGC receives a call from the local Police Chief, who wants to continue that silly argument over who is in charge at the sports arena. To distract his attention, NGC gives the Chief the URL for the "game" site so they can both look at it. They discover that the local fire departments are coordinating a house-to-house search for missing people. Should the police and National Guard be involved? Is the Coast Guard already doing something like this? He and the Police Chief agree to set up a controlled-access chat room and game board, invite the fire departments and the Coast Guard to participate, and use it to track deployment of all emergency personnel during the rescue effort. As he and the Police Chief talk each other through the simple steps required to set this up, it occurs to NGC to ask the Chief why he has been so reluctant to assume command at the sports arena. The Chief explains that he has no experience running shelters, and does not want to take physical responsibility for that many people. NGC has to admit to himself that he feels the same way. But surly the Red Cross should be running the shelter part of it? He suggests to the Chief that they set up a similar chat room to coordinate who is doing what at the arena, so they can segment the command responsibility. But when NGC starts

defining the data items they will need for this, the system notifies him that someone from the Red Cross already has a similar set of data items defined. He remembers an entry in the "help" section about how to combine two similar projects, so he looks it up and uses something called "inheritance" to expand on the Red Cross data definitions, instead of making new ones. NGC has barely ended his phone call with the Chief of Police when his phone rings again. It is the emergency communications people, who are still waiting for someone to repair their generator, so they can get the communications system running again. This gives him an idea, so he returns to the resource coordination chat room and sends a plea for someone who can repair the generator. There is an immediate response to this, but it is not what he expects. Instead of a "can do" from some technician, he gets an angry flame from the company that supplied the generator. They apparently sent a repair crew hours ago, but it was turned back at a National Guard roadblock because it did not have "authorization" to be in the disaster area. This response is followed by a cascade of angry flames from many other people who have important work to do but cannot get "authorization" to enter the area. NGC decides that he really needs a game board where people can define the location, nature, and personnel requirements of activities they want to conduct within the disaster area, so his people at the EOC can email them the required authorization papers…

FEMA Coordinator, FC, has been looking at this new website ever since the Red Cross Coordinator pointed it out to him. It is amazing to see a map of houses with the names of the missing residents, especially as more and more of them are marked "found." A new label is starting to appear on the houses giving the date and time of when they were searched, as well as which team went in. And the shelter tracking is also amazing, but he's not sure how he can use it when he specs the supply contract. Almost as soon as some supply need is listed for a shelter, someone responds with arrangements to provide it. He sends a request to the chat room asking that the shelters keep a cumulative list of unmet needs, and one of the responses explains how he can pull that list directly from the database whenever he wants it. Then FC's phone rings again. It is his FEMA representative at the EOC calling to tell him that the National Guard has set up a restricted chat room and game board to track who is in charge of what. What nonsense! FEMA is in charge of everything! He demands access to this chat room, and his EOC contact talks him through the login process. As soon as he enters the chat room, he begins a heated debate with the other agencies over who is in charge. Someone adds a role-piece to the current game board, names it "command," and chooses "create a sub-role game board" in the field for role definition. A goal window opens for the new game-board object, and the board's creator enters "specify in detail what the term 'in charge' means to everyone." A hat icon appears, with the instructions that initial players on this board click for the initial turn order. FC clicks on the icon and his login name appears over the hat. A number of other login names also appear. After a minute, the hat makes shaking motions, and the list of names appears in a new order. FC's name is on top, so he apparently gets the first turn. He looks at the pieces available. Surely he needs to define a "role." He follows the instructions to drag and drop a role-piece onto the board, and then double-clicks it to open its

definition window. In the role name field, he types, “agency in charge.” In the description field, he types, “coordinates emergency food and water, and search and rescue operations.” But how should he specify that FEMA has this role? He pulls up the game instructions again, then drags an actor-piece onto the board, enters “FEMA” into the actor name field, and clicks “agency in charge” on the drop-down role-list in the actor’s “roles played” field. On the board, a “plays/is played by” link appears between the two pieces. FC notices that a silhouette with his logon name at one side of the board shows that 20 points has been awarded to him. A pop-up window asks him if he is done with his turn, and he clicks on “yes.” The next player immediately reopens his “agency in charge” role-piece, changes the name to “agency in charge of FEMA resources” and changes the definition to “supplies and coordinates emergency food, water, and financial support; and provides logistics support to rescue and recovery operations,” then defines a new role, “agency in charge of coordinating rescue operations” and assigns it to the National Guard. There is much debate in the chat window over whether FEMA can coordinate resources it does not provide, whether FEMA has the expertise and manpower to coordinate rescue operations on the ground, and who is really coordinating the local fire departments and police – the ones who are currently rescuing people. Within a few rounds of the game, the general command roles have been spelled out on the game board to everyone’s satisfaction. It turns out that to be “in charge” means something different in every context. So, they all agree to define each context on the game board as it arises, and detail the command structure for each, rather than continuing to argue over who is “in charge.” Then FC remembers all the ice he has. Surely it should be put to good use at this point, but where? He puts out a general request in the main resource coordination chat room. Someone immediately creates a map to track the location, and priority, of everyone needing ice. It should be easy to create some route maps for the delivery trucks…

Remote Citizen on Neighborhood Listbot, RCNL, has been going through her closet for unwanted clothing, but she stops periodically to check the Net for news about what is happening with the hurricane victims. During a search on the topic she discovers a message from the Red Cross warning that they are not accepting clothing. Disappointed, she continues to look at the search results and discovers a very strange-looking site. People appear to be playing a sort of board game, but the topics being discussed in the chat window all involve coordinating hurricane aid. RCNL tries to send an entry to the chat room to ask what is going on, but a pop-up window appears telling her that the initial board at this level has reached its limit of ten players. A drop-down menu appears, attached to a button labeled “participate.” She is given the choice of either 1) looking for a sub-game or super-game spawned from this board that is not yet full, 2) joining an auxiliary game board for this board, 3) starting an entirely new game on a different topic, or 4) simply becoming an observer of any non-private game boards attached to this game. RCNL chooses to merely observe for now, and begins to explore the site. The map of the rescue operations is wonderful, but she is more interested in the boards coordinating shelter needs. Is it true that these people do not need clothing? RCNL finds an

auxiliary board for the shelter needs board that is not full, and presses the "participate" button. Because she is already at an open site, a login screen comes up immediately. She creates a login id and password for herself, enters the chat room, and asks her question. Someone explains how she can add another sub-board under the "needs" object to track the personal needs of the shelter residents. Once this new game board is established, several players from the other board join it, and a turn-taking order is created by the program. Then a menu opens giving the players a vote on how game-entries will be scored. They decide to accept or reject player entries by consensus, but use a fixed-point scoring system for entries once they have been accepted. The group spends a few minutes defining the various things that must be identified to meet evacuees' personal needs. RCNL creates some clothing objects and begins to enter the type, color, and size of each. Suddenly an announcement appears on the screen. The main board one level up and the auxiliary board that their current board spawned from have both gone over 20 new entities, and have entered into a playoff. As a result, the board they are playing has been accepted as a sub-board of the main board, as well as continuing to be a sub-board of the original auxiliary board. A couple of players from the main board join their board. As the players continue to define and add data items, several more of the boards, one level up, have playoffs with the main board. Each time, the current sub-board is added to another auxiliary board, and each auxiliary board contributes a few more players to the sub-board. The sub-board grows large enough to split off a couple of auxiliary boards of its own. These boards stay synchronized very well, however. Whenever an auxiliary board has more than 20 new entities, it plays off against the original board to resolve any differences in definition. As a result, the same data items are discussed by as many groups of people as there are auxiliary boards. Whenever an auxiliary board appears to be drifting away from the main board in its decisions, someone can earn a lot of points by defining how it differs in approach from the main board. It then becomes a new main board, connected by the reference definition to the original game board. RCNL is so excited by this new game that she sends an email to everyone on the neighborhood listbot. A database of personal needs by individual and shelter is starting to accumulate, and there is a map of the shelter locations. If her neighbors can come up with some of the items needed, the friend with the truck can deliver them directly to some of the shelters. On the other hand the shelters are scattered all over the country. Maybe it would be better to decide which shelters should be on the truck's route and concentrate on the needs of the people in them. RCNL enters the truck as an object, along with a question about routing. Someone immediately creates a number of possible shelter routes that a single truck could drive over a two-day period. Someone else explains to RCNL how to pull a list of needed items for each possible route. This process passes through several iterations, as more neighborhoods and businesses volunteer trucks and items. However, within a day the available trucks, along with the routes for each truck, and the items to be sent in each truck, have all been worked out. In most cases, the trucks will be making several loading stops, in addition to several delivery stops. Then someone asks what people will need once they leave the shelters…

Remote Social Worker, RSW, has been searching the web looking for local opportunities to help hurricane victims. Instead, she finds an odd sort of game. From the various linked chat windows, she comes to understand that she must join an unfilled game board on her topic of interest to ask her question in the attached chat room. The closest RSW can find is an auxiliary board on the personal needs of evacuees. She joins and asks how she can find out if any of the evacuees sent to her city could benefit from her grief counseling experience. Someone explains how she can add a "mental health needs" object to the list of need types, and then create a new sub-board to coordinate it. Once the details of the new board set-up are completed, RSW adds herself as a resource, along with a list of her qualifications. However, she also lists the requirement that evacuees she counsels be located within 50 miles of where she lives. She notices that a number of others immediately start adding themselves, and their qualifications. Someone else opens her object type definition and changes it to split "type of counseling," "years of experience," "contact information," and "radius of physical availability" into separate parameter fields. When RSW's next turn comes, she opens the window for her personal information and moves things to the new fields. Almost immediately, her phone rings. It is someone local who has taken in his sister's family. One of his sister's little girls has been having nightmares. RSW asks how he found out about her so quickly, as he was not at a shelter. Was he looking at the computer game board? He was not looking at it at all. In fact, he did not know it existed. He had sent an email to his church listbot. Someone on the listbot had searched some website for the words "mental health," "counseling," and the name of their city, and called to give him RSW's phone number. After making arrangements to counsel the man's little niece, RSW goes back to the game board and asks if there is any way to enter her schedule into the game. Clearly, it could be filling up fast. After much discussion, someone figures out how to create timeslot objects for each counseling resource. This will allow the counselors to specify their times of availability, and to mark whether each slot is full or not. Then someone else shows her how the timeslots can be displayed in schedule book format for easy updates, and as a calendar to give her the big picture…

Remote Computer Expert, RCE, has been on his computer for the last twelve hours. This game would be addictive, even if it was not accomplishing something important. So far, he has the top score, and that guy in New York is second. It is a good thing they initially decided to score themselves on the number of data items defined, and not on the total number of hits each item got. Otherwise, that map of the hurricane rescue operations would have beat him flat. His missing people are getting a lot of hits overall, but only a few for each person. It was easy to set up an automatic link, so each new entry into his missing-persons website automatically created a new entity on that particular game board. After all, the game talks in XML. But that is not what keeps RCE glued to the computer. He moved on to game management hours ago. It's cool to play a game of managing a game – very self-referential. Right now, he's working with people at three universities to find hosting space for the growing databases. Not only do they need space for each original data item, but they need to clone each site several times and set up load

balancing to spread the web traffic across as many regions as possible. This game is generating so much traffic it almost looks like a virus. Thank goodness for the traffic map that gal in Seattle added. Right now, RCE is busy splitting up a new part of the database. Someone created a board to track the personal needs of people in shelters, and it's growing like a mushroom. He decides, based on growth rate, to put the medical needs on a different server from the clothing needs. He checks the server-resources game board and discovers that the University of Texas has just offered the use of a sizeable server. So when his next turn comes on the space-management board, he opens the descriptor for evacuee-needs-medical, and changes the host-server name to send the data to Texas. Then he jumps to the traffic-management game board and sets up clones of the Texas site on servers in Chicago and Boston. That should do for now. Anyway, it earned him a few hundred more points. Just then, RCE's pager goes off. He has his notification information on the security board set to page him with any new messages. When he jumps to the security chat room, he finds that one of the other game administrators needs to go off shift (leave for his day job), and has suggested that a replacement be added. This might take a few minutes. Due to the serious nature of this particular game, they are requiring references and some type of security clearance for administrators. Fortunately, the guy from the Denver police department is friends with an FBI sys-admin. The advantage of using people like her is that they can do administration work on this particular game as part of their day job. RCE checks the security clearance and reference information, and casts his vote for approval. They have already set the roles so the new person has access to the boards she needs, so they each take a few minutes explaining the parts of the game they have been monitoring, and showing her how to work the various boards. She seems to be catching on fast, so RCE leaves her with the suggestion that she shadow her friend for awhile before trying to play on her own…

Remote Relative, RR, has been checking the computer every few minutes all day. She got an email this morning from the missing-persons site where she entered her parents' names. It suggested that she look at a web-based map of the rescue operations to see if her parents' house had been searched yet. She has watched the houses on her parents' street show search information, one-by-one. Now they must be at her parents' house. RR is watching, and praying, for the search information. To her joy, a "found" label suddenly appears for her parents. But it shows their contact information to be a hospital. She immediately calls the hospital. All she gets is a recording, due to the hospital lines being busy, but at least she manages to leave her name and phone number, and the fact that she is next-of-kin for her parents. Half an hour later, RR's phone rings. It is a nurse at the hospital. She puts RR's mother on the line. Her mother sounds weak, but very relieved. She tells RR that she and RR's father have been stuck in their sweltering attic for the last day and a half. They are both in the hospital with heat stroke and dehydration, but she already feels much better, and they have assured her that Dad will be all right, too. After RR hangs up the phone, she goes back to her computer. While she was waiting for her parents' house to be searched, she explored the game site, so she knows there is a section on the personal needs of the refugees. She wants to find out how to get her parents' house and belongings put right again…

Appendix B: Test Instruments

Table B-1. Pre-Test Questionnaire for Tests 1 and 4

Demographic Data							
1.	Age	18-20	21-23	24-30	31-40	41-50	51+
2.	Gender	Female		Male			
3.	Occupation	Student		Staff	Faculty	Management	Other
4.	Family	Single		Married			
5.	Ethnic Group	Asian	Black	Hispanic	White	Other	
6.	Nationality	Africa	Asia	Europe	South America	North America	Other
Computer Experience							
7.	How many years have you been using computers?						
	<1	1-5	6-10	11-20	21+		
8.	How many hours a day do you spend using the Internet?						
	<1	1-2	3-5	6-8	9+		
9.	How many times a week do you play computer games?						
	<1	1-2	3-10	11-20	21+		
Volunteer Experience							
10.	How many hours of volunteer work have you performed in the past three months?						
	<1	1-10	11-20	21-40	41+		
11	How many different volunteer groups have you worked for, or contributed to, in the past?						
	none	1-5	6-10	11-20	21+		
Team Experience							
12.	How many teams have you served on in the past?						
	none	1-5	6-10	11-20	21+		

Table B-2. Pre-Test Questionnaire for Tests 2 and 3

Demographic Data							
1.	Age	18-20	21-23	24-30	31-40	41-50	51+
2.	Gender	Female	Male				
3.	Occupation	Student		Clerical	Staff	Faculty	Management
4.	Family	Single	Married				
5.	Ethnic Group	Asian	Black	Hispanic	White	Other	
6.	Nationality	Africa	Asia	Europe	South America	North America	Other
Computer Experience							
7.	How many years have you been using computers?						
	<1	1-5	6-10	11-20	21+		
8.	How many hours a day do you spend using the Internet?						
	<1	1-2	3-5	6-8	9+		

9. How many times a week do you play computer games?
<1 1-2 3-10 11-20 21+
Clinical Experience
10. What percentage of your work time has been spent doing clinical work in the past three months?'
<1% 1-10% 11-20% 21-40% 41%+
11. How many years of clinical experience do you have?
none 1-5 6-10 11-20 21+
Team Experience
12. What percentage of your work time is spent working on a team?
none 1-10% 11-20% 21-40% 41%+

Table B-3. Post-Test Questionnaire

1.	Was the site easy to navigate?
2.	Was the exercise easy to complete?
3.	Was it fun?
4.	Was it easy to figure out what to do next?
5.	Was it helpful in understanding the problem?
6.	Was it helpful in getting the team to come to an agreement?
7.	Was the resulting data structure useful?
8.	Would the exercise have been more rewarding if it was scored?
9.	Does the concept of scoring seem fair in this situation?
10.	Did the collaboration aspect increase your motivation to contribute?

Table B-4. Test Instructions for Test 1

This is a team-based problem definition exercise. The goal of the exercise is to identify a detailed course of action that is mutually agreeable to the team. To accomplish this, you must first explore your problem space and define as many aspects of it as possible. You should begin by defining each aspect of your problem in terms of events, goals, tasks, roles, and resources.
During the initial phase, each player will spend ten minutes creating an individual picture of the situation based on the information that is generally available, as well as the player's unique knowledge, perspective, and personal resources. In the second phase, the players will have five minutes to compare their individual models. During the third phase, the players will take turns working on a team model that combines the best of the individual models. After each round of turn-taking, the players will vote on whether or not they want another round to continue working on the team model. When they are ready to move on, the players will choose a spokesperson for the team. In the final phase, the team spokesperson, with encouragement and suggestions from the rest of the team, will spend five minutes filling out a plan of action to accomplish the team goal. Once the exercise is finished, the team members will rate how well they think their plan of action will work, and what opinions they have of the exercise in general.
Press the 'resources' button on the left side of the screen to look over your personal

resources. The timer on the left side of the screen will show how much time you have for the current phase. You can communicate with your fellow team members via the chat window. You can reopen the match information with the buttons on the left.

Table B-5. Test Instructions for Tests 2 and 3

This is a team-based problem definition exercise. The goal of the exercise is to identify a detailed course of action that is mutually agreeable to the team. In order to accomplish this, you must first explore your problem space and define as many aspects of it as possible. You should begin by defining each aspect of your problem in terms of events, goals, tasks, roles, and resources.
Phase 1 Instructions: During the initial phase, each team member will spend a few minutes exploring the interface, getting acquainted with teammates, and creating an individual picture of the situation based on the information that is generally available, as well as the team member\'s unique knowledge, perspective, and personal resources.
Please do the following:
Press the scenario button on the left to remind yourself of the problem you will be working on. You can move this window by dragging the blue top bar, and resize it by dragging the side or bottom bars. View hidden parts of the window by moving the slider up and down if there is a slider bar on the right, or moving the slider left and right if there is a slider bar at the bottom. (To close a window, either press OK or click on the X in the upper right corner of the window you want to close.)
Move and resize both the Instruction window and the Scenario window so that you can see the rest of the screen.
Press the 'ownership' button on the left side of the screen to look over any personal ownership items or issues that you have been assigned.
Press the Guidelines button and read through the guidelines.
Notice that the countdown timer on the left side of the screen will show how much time you have for the current phase.
Familiarize yourself with the expanding form by entering nonsense items into it. (Due to an unresolved bug, the cursor does not always show in the entry box, but it is there.)
Notice that adding an event will cause both a goal form, and a second event form to be added. Adding a goal will cause both a task form and a second goal form to be added. Adding a task creates a role form and a second task form, and adding a role creates a resource form and a second role form, but adding a resource only creates a second resource form. Play with these forms until you feel comfortable. Once you have mastered the main items, try creating a list under one of them. This feature can be used to enter any descriptive information about the main item that you want to list. Notice that once you give your list a name and description, both an item box and a second list form are added. Each time you add an item, another item box is created.
Once you have made one or more entries at every level and added at least one list, explore the treemap on the right. Notice that if you roll over the name of one of

your entries a box will open showing its description. Also notice that if you click on the entry name you move down one level in the treemap. (This feature occasionally goes to an error screen, due to an unresolved bug in the program. If you see this, just press the browser's back button to move back to the regular screen and wait a few seconds for the treemap to update before trying again.) If you click on one of the treemap edges when it says "Back" you move up one level.
Try moving back and forth between the Situation and List radio buttons below the treemap and get familiar with how to examine the lists and items under each of the main entries. Play with this feature until you are comfortable with it.
Now it is time to communicate with your fellow team members via the chat window at the bottom. Introduce yourselves and spend a few minutes discussing approaches to the next, and final, Phase 1 task.
Delete any nonsense entries you made in the expanding form and use it to construct your own, personal model of the problem at hand. If you can not think of events to list, use the entire exercise as an event, and start with goals. If you cannot separate something into goals, tasks, roles, or resources, create one or more lists and just list its characteristics. If you cannot even think of lists for something, just add information to its description box. (If you don\'t want to hand enter items into the form, you can cut and paste from any other window. However, you must do it one entry-box at a time.)
Stop at this point in the instructions until you are directed to move to the next phase.
Phase 2 Instructions: In the second phase, the team members will have several minutes to compare their individual models.
Please do the following:
Notice that a second treemap area has appeared next to the first one.
Click through all of the numbered buttons in each treemap area and notice that the area displays the treemap of the team member whose number you clicked. You can use the buttons to compare any two levels of any two treemaps side-by-side.
Also notice that the entry form that matches each of the treemaps opens in one of two overlapping form windows on the left, the one that corresponds to that particular treemap area.
Practice clicking on the edge of the overlapped form window to bring it to the front.
Notice that the only entry form that can be edited is your own. You can view, but not edit, the forms of other team members.
Explore the forms and the treemaps to examine the models created by each of your teammates. (Don\'t forget to look for lists.)
Discuss the differences in the models with your teammates.
Make any changes to your model that seem appropriate. Your models do not have to agree at this point. Just complete your model to your own satisfaction.
Stop at this point in the instructions until you are directed to move to the next phase.
Phase 3 Instructions: During the third phase, the team members will take turns working

on a team model that combines the best of the individual models. After each round of turn-taking, the team members will vote on whether or not they want another round to continue working on the team model. When they are ready to move on, the team members will choose a spokesperson for the team.
Please do the following:
Click on the "View Team Model" button in one of the treemap areas. A treemap and entry form will appear that represents the team model.
If it is your turn to edit the team model, the editing buttons will be visible on the entry form. Otherwise, you will be able to view, but not edit.
If it is your turn, begin to add your ideas to the team model. (You will have to cut and paste to move existing items over to it, but you can cut and paste from anyone's model, from the chat window, or from any other window.) If it is not your turn, you can continue working on your own model or make suggestions via the chat window to the person who is currently working on the team model.
When every team member has had a turn, the team will vote on whether to go around again. Each team member only gets one ballot, but that ballot is updated whenever the vote button is pressed. An abstain vote is recorded if the vote button is pressed with no vote choice selected. The vote window can be moved or resized to get it out of the way, but it will remain open for a full minute during the vote, enabling team members to negotiate and change their vote. A tie vote here means that the team will take another round. You should decide whether to move on or not based on whether the team has reached a consensus, and has a clear picture of the problem.
If the team chooses to move on, another vote window will open listing the team members. This will also remain open for one minute. A tie vote here will lead to a runoff vote. You should choose the team member you feel is best able to edit the Action Plan.
Stop at this point in the instructions until you are directed to move to the next phase.
Phase 4 Instructions: In the final phase, the team spokesperson, with encouragement and suggestions from the rest of the team, will spend a few minutes filling out a plan of action to accomplish the team goal. Once the exercise is finished, the team members will rate how well they think their plan of action will work, and what opinions they have of the exercise in general.
Please do the following:
Click on the Action Plan button that has appeared on the bottom of the button column at the left. This will open the Action Plan form.
If you are the chosen representative, begin editing the form. If not, watch what changes are being made to the form, and use the chat window to make suggestions.
Create a list of action items in either temporal or priority order, based on the team model you developed. The items can be resorted by changing their numbering.
You have only this single time period in which to complete your Action Plan. Do the best job you can in the time you have.

Once the exercise completion message has appeared, clicking OK in the message window will close the entire exercise window, and move you to the final survey.

Table B-6. Test Instructions for Test 4

This is a team-based problem definition exercise. The goal of the exercise is to identify a detailed course of action that is mutually agreeable to the team. In order to accomplish this, you must first explore your problem space and define as many aspects of it as possible. You should begin by defining each aspect of your problem in terms of events, goals, tasks, roles, and resources.
Phase 1 Instructions: During the initial phase, each team member will spend a few minutes exploring the interface, getting acquainted with teammates, and creating an individual picture of the situation based on the information that is generally available, as well as the team member\'s unique knowledge, perspective, and personal resources.
Please do the following:
Press the scenario button on the left to remind yourself of the problem you will be working on. You can move this window by dragging the blue top bar, and resize it by dragging the side or bottom bars. View hidden parts of the window by moving the slider up and down if there is a slider bar on the right, or moving the slider left and right if there is a slider bar at the bottom. (To close a window, either press OK or click on the X in the upper right corner of the window you want to close.)
Move and resize both the Instruction window and the Scenario window so that you can see the rest of the screen.
Press the 'ownership' button on the left side of the screen to look over any personal ownership items or issues that you have been assigned.
Press the Guidelines button and read through the guidelines.
Notice that the countdown timer on the left side of the screen will show how much time you have for the current phase.
Familiarize yourself with the expanding form in the center of your screen by entering the following items into it:
Enter 'tornado' as an event name, and 'damaged houses' as an event description; press the 'add event' button.
Enter 'fix houses' as a goal name, and 'three' as a goal description; press the 'add goal' button.
Enter 'plan repairs' as a task name, and 'match resources to needs' as a task description; press the 'add task' button.
Enter 'truck driver' as a role name, and 'pick up materials and deliver to sites' as a role description; press the 'add role' button;
Enter 'truck' as a resource name, and '1/2-ton pick-up' as a resource description; press the 'add resource' button.
(Due to an unresolved bug, the cursor does not always show in the entry box, but it is there.)
Notice that adding an event will cause both a goal form, and a second event form to be added. Adding a goal will cause both a task form and a second goal form to

be added. Adding a task creates a role form and a second task form, and adding a role creates a resource form and a second role form, but adding a resource only creates a second resource form. Play with these forms until you feel comfortable.
Once you have mastered the main items, create a list.
Press the 'create a list' button under the 'fix houses' goal; enter 'fix' as the list name, and 'houses to fix' as the list description; press the 'add list' button.
Enter the name of the first house to fix under 'item description'; press the 'add item' button. Repeat this process for the other two houses.
This feature can be used to enter any descriptive information about the main item that you want to list. Notice that once you give your list a name and description, both an item box and a second list form are added. Each time you add an item, another item box is created.
Once you have made one or more entries at every level and added at least one list, explore the treemap on the right. Notice that if you roll over the name of one of your entries a box will open showing its description.
Also notice that if you click on the entry name you move down one level in the treemap. (This feature occasionally goes to an error screen, due to an unresolved bug in the program. If you see this, just press the browser's back button to move back to the regular screen and wait a few seconds for the treemap to update before trying again.)
If you click on one of the treemap edges when it says "Back" you move up one level.
Go to the goal level and try moving back and forth between the Situation and List radio buttons below the treemap to get familiar with how to examine the lists and items under each of the main entries. Play with this feature until you are comfortable with it.
Now it is time to communicate with your fellow team members via the chat window at the bottom. Introduce yourselves and spend a few minutes discussing approaches to the next, and final, Phase 1 task.
Delete or update any entries you do not like in the expanding form and use it to construct your own, personal model of the problem at hand. If you cannot think of events to list, use the entire exercise an event, and start with goals. If you cannot separate something into goals, tasks, roles, or resources, create one or more lists and just list its characteristics. If you can\'t even think of lists for something, just add information to its description box. (If you don\'t want to hand enter items into the form, you can cut and paste from any other window. However, you must do it one entry-box at a time.)
Stop at this point in the instructions until you are directed to move to the next phase.
Phase 2 Instructions: In the second phase, the team members will have several minutes to compare their individual models.
Please do the following:
Notice that a second treemap area has appeared next to the first one.
Click through all of the numbered buttons in each treemap area and notice that the

area displays the treemap of the team member whose number you clicked. You can use the buttons to compare any two levels of any two treemaps side-by-side.
Also notice that the entry form that matches each of the treemaps opens in one of two overlapping form windows on the left, the one that corresponds to that particular treemap area.
Practice clicking on the edge of the overlapped form window to bring it to the front.
Notice that the only entry form that can be edited is your own. You can view, but not edit, the forms of other team members.
Explore the forms and the treemaps to examine the models created by each of your teammates. (Don\'t forget to look for lists.)
Discuss the differences in the models with your teammates.
Make any changes to your model that seem appropriate. Your models do not have to agree at this point. Just complete your model to your own satisfaction.
Stop at this point in the instructions until you are directed to move to the next phase.
Phase 3 Instructions: During the third phase, the team members will take turns working on a team model that combines the best of the individual models. After each round of turn-taking, the team members will vote on whether or not they want another round to continue working on the team model. When they are ready to move on, the team members will choose a spokesperson for the team.
Please do the following:
Click on the "View Team Model" button in one of the treemap areas. A treemap and entry form will appear that represents the team model. Until the first entries are made in it, this model will be empty.
If it is your turn to edit the team model, the editing buttons will be visible on the entry form. Otherwise, you will be able to view, but not edit.
If it is your turn, begin to add your ideas to the team model. (You will have to cut and paste to move existing items over to it, but you can cut and paste from anyone\'s model, from the chat window, or from any other window.) If it is not your turn, you can continue working on your own model or make suggestions via the chat window to the person who is currently working on the team model.
When every team member has had a turn, the team will vote on whether to go around again. Each team member only gets one ballot, but that ballot is updated whenever the vote button is pressed. An 'abstain' vote is recorded if the vote button is pressed with no vote choice selected. The vote window can be moved or resized to get it out of the way, but it will remain open for a full minute during the vote, enabling team members to negotiate and change their vote. A tie vote here means that the team will take another round. You should decide whether to move on or not based on whether the team has reached a consensus, and has a clear picture of the problem.
If the team chooses to move on, another vote window will open listing the team members. This will also remain open for one minute. A tie vote here will lead to a runoff vote. You should choose the team member you feel is best able to edit the Action Plan.

Stop at this point in the instructions until you are directed to move to the next phase.
Phase 4 Instructions: In the final phase, the team spokesperson, with encouragement and suggestions from the rest of the team, will spend a few minutes filling out a plan of action to accomplish the team goal. Once the exercise is finished, the team members will rate how well they think their plan of action will work, and what opinions they have of the exercise in general.
Please do the following:
Click on the Action Plan button that has appeared on the bottom of the button column at the left. This will open the Action Plan form.
If you are the chosen representative, begin editing the form. If not, watch what changes are being made to the form, and use the chat window to make suggestions.
Create a list of action items in either temporal or priority order, based on the team model you developed. The items can be resorted by changing their numbering.
You have only this single time period in which to complete your Action Plan. Do the best job you can in the time you have.
Once the exercise completion message has appeared, clicking OK in the message window will close the entire exercise window, and move you to the final survey.

Appendix C: Test Result Details

1. Test 1

The participant demographics were as follows:

Table C-1. Demographic Data for Test 1

Participant	T1	T2	C1
Age	51+	51+	51+
Gender	Female	Male	Male
Occupation	Clerical	Professional	Staff
Family Status	Married	Married	Single
Ethnic Group		White	White
Nationality	Europe	North America	North America
Computer Experience (years)	<1	21+	21+
Internet Usage (hours/day)	<1	9+	3-5
Computer Games (times/week)	<1	21+	1-2
Volunteer Experience (hours/quarter)	1-10	41+	11-20
Volunteer Groups (total)	1-5	1-5	6-10
Team Experience (total)	none	21+	1-5

The individual ratings of the tool were as follows:

Table C-2. Individual User Satisfaction for Test 1

	Participant	T1	T2	C1
1	Was the site easy to navigate?	2	3	4
2	Was the exercise easy to complete?	2	1	4
3	Was it fun?	3	1	4
4	Was it easy to figure out what to do next?	3	1	3
5	Was it helpful in understanding the problem?	3	0	4
6	Was it helpful in getting the team to come to an agreement?	3	0	4
7	Was the resulting data structure useful?	4	0	4
8	Would the exercise have been more rewarding if it was scored?	1	0	2

9	Does the concept of scoring seem fair in this situation?	2	0	1
10	Did the collaboration aspect increase your motivation to contribute?	2	0	4

Table C-3. Individual Comments for Test 1

Participant		T1	T2	C1
1	Was the site easy to navigate?		But only after one-on-one instruction	
2	Was the exercise easy to complete?		Need better instructions	
3	Was it fun?		Too frustrating	
4	Was it easy to figure out what to do next?		I didn't know the overall task or structure	After I caught on to the buttons on the left for resources, etc.
5	Was it helpful in understanding the problem?		Was what helpful?	
6	Was it helpful in getting the team to come to an agreement?		We never started to discuss	
7	Was the resulting data structure useful?		no	
8	Would the exercise have been more rewarding if it was scored?		no	
9	Does the concept of scoring seem fair in this situation?		It seems irrelevant	
10	Did the collaboration aspect increase your motivation to contribute?		no	

The individual usage results were as follows:

Table C-4. Individual Usage Results for Test 1

Participant		T1	T2	C1
1	Number of elements in model	1	14	0
2	Contributions to chat	5	8	10
3	Team leader?	no	yes	N/A

The team ratings of the tool were as follows:

Table C-5. Mean User Satisfaction for Test 1

		Test	**Control**	**Overall**
1	Was the site easy to navigate?	3.5	4	3.00
2	Was the exercise easy to complete?	2.5	4	2.33
3	Was it fun?	3.5	4	2.67
4	Was it easy to figure out what to do next?	3.5	3	2.33
5	Was it helpful in understanding the problem?	3	4	2.33
6	Was it helpful in getting the team to come to an agreement?	3	4	2.33
7	Was the resulting data structure useful?	4	4	2.67
8	Would the exercise have been more rewarding if it was scored?	1	2	1.00
9	Does the concept of scoring seem fair in this situation?	2	1	1.00
10	Did the collaboration aspect increase your motivation to contribute?	2	4	2.00

The team usage results were as follows:

Table C-6. Team Usage Results for Test 1

		Test	Control	Overall
1	Number of elements in model	6	0	6
2	Contributions to chat	13	16	29
3	Number of items in action plan	3	N/A	3

2. Test 2

The participant demographics were as follows:

Table C-7. Demographic Data for Test 2

Participant	T1	T2	T3	C1	C2
Age	31-40	51+	51+	41-50	51+
Gender	Female	Female	Female	Female	Female
Occupation	Management	Faculty	Student	Student	Student
Family Status	Married	Married	Single	Married	Married
Ethnic Group	White	White	White	White	White
Nationality	North America	Other	North America	Europe	North America
Computer Experience (years)	11-20	11-20	21+	11-20	6-10
Internet Usage (hours/day)	6-8	6-8	1-2	3-5	3-5
Computer Games (times/week)	<1	<1	3-10	1-2	<1
Clinical Experience (% of time)	<1%	1-10%	41%+	21-40	41%+
Clinical Experience (years)	11-20	21+	21+	21+	21+
Team Experience (% of time)	41%+	21-40	41%+	11-20	11-20

The individual ratings of the tool were as follows:

Table C-8. Individual User Satisfaction for Test 2

	Participant	T1	T2	T3	C1	C2
1	Was the site easy to navigate?	1	4	5	2	3
2	Was the exercise easy to complete?	2	2	2	5	4
3	Was it fun?	1	1	3	4	4
4	Was it easy to figure out what to do next?	4	4	3	4	5

5	Was it helpful in understanding the problem?	2	1	3	5	4
6	Was it helpful in getting the team to come to an agreement?	3	1	5	5	5
7	Was the resulting data structure useful?	3	4	2	5	5
8	Would the exercise have been more rewarding if it was scored?	4	1	0	3	4
9	Does the concept of scoring seem fair in this situation?	1	1	1	2	1
10	Did the collaboration aspect increase your motivation to contribute?	2	1	1	4	1

Table C-9. Individual Comments for Test 2

Participant		T1	T2	T3	C1	C2
1	Was the site easy to navigate?	Directions were not always clear and it was difficult to see what the others were working on.	I had difficulty navigating the site. I expected to see an algorithm created in the tree map.	It took to much time to figure out where to put each thing. It would require education before use to make it more effective.		It seems the layout was wider than the page limit, so I did a lot of scooting around
2	Was the exercise easy to complete?	It was hard to communicate effectively through the format and get it done within the time frame.	No directions were complicated and difficult to follow	Too much time to figure out the system before we could get into discussion. I think if it was already known, it would go much smoother.		It was fine, except it would be nice to have more people in the group
3	Was it fun?	I always like a challenge!	yes, this was fun to do.	I liked working with others, but the program made it difficult for me to communicate easily without having to go between the chat and the mode.		yes

4	Was it easy to figure out what to do next?	We often said, what are we supposed to do now?	Not really. The prompts came up but were difficult to interpret.	It takes a bit to get going. Keeping the instruction box open gets in the way, I know it\'s needed, but I had to keep moving it depending on where I was working. I did make is smaller, but that didn't solve the whole problem.	I was just worried about forgetting my ownership s	yes, except I don\'t know much about informatics planning
5	Was it helpful in understanding the problem?	In the end		Yes, I think it\'s essential to know what you\'re going to work on. This gives people time to think about what issues they want to bring up.		I loved having the set issues and viewpoints
6	Was it helpful in getting the team to come to an agreement?	In the end we had to. :)	The chat box was helpful to assist in agreement.	Not necessarily, I think just a chat with maybe one area to develop the model as we go would be easier.		we had no problems agreeing
7	Was the resulting data structure useful?	We made something that I think we could work from.		If you\'re referring to the tree, I didn't find it helpful at all. Make if it actually listed what everyone had written instead of just saying what is there and you have to hover or look at the box we typed in.		it was fine, but some technical problems writing the action plan
8	Would the exercise have been more rewarding if it was scored?	That would add a lot of stress as we struggled.		For me scoring wouldn't be helpful. As a new program and knowing I was getting scored would probably be worse. You spend more time trying to understand the program then doing the work, so a score, I think, would be detrimental.		no, it would have been more pressure, I liked the freedom the exercise offered

9	Does the concept of scoring seem fair in this situation?	Not especially. I think our skills and abilities were not well demonstrated. Maybe flexibility and stress management. :)		It would only be fair if everyone already had a working knowledge of the program. It\'s to hard to try to learn on the fly.		nope
10	Did the collaboration aspect increase your motivation to contribute?	It was a good team.	Absolutely, I felt it was extremely important to contribute.	I\'m so used to collaborating that it\'s the normal for me. The program has nothing to do with that, for me. My job is collaborating and contributing.		yes, especially when the group is very small

The individual usage results were as follows:

Table C-10. Individual Usage Results for Test 2

Participant		T1	T2	T3	C1	C2
1	Number of elements in model	2	4	10	0	0
2	Contributions to chat	49	38	37	60	44
3	Team leader?	no	yes	no	yes	no

3. Test 3:

The participant demographics were as follows:

Table C-11. Demographic Data for Test 3

Participant	T1	T2	T3	T4	C1	C2	C3
Age	41-50	31-40	51+	31-40	41-50	31-40	41-50
Gender	Female	Female	Female	Female	Female	Female	Male
Occupation	Student	Student	Faculty	Student	Student	Student	Faculty
Family Status	Married	Single	Single	Married	Married	Married	Married
Ethnic Group	White	White	White	White	White	White	White
Nationality	North America	North America	North America	Europe	North America	North America	North America

Computer Experience (years)	21+	11-20	21+	11-20	11-20	21+	11-20
Internet Usage (hours/day)	3-5	3-5	3-5	1-2	6-8	3-5	3-5
Computer Games (times/week)	<1	<1	<1	<1	<1	<1	1-2
Clinical Experience (% of time)	21-40	41%+	11-20	41%+	11-20	1-10%	11-20
Clinical Experience (years)	21+	11-20	21+	11-20	21+	11-20	11-20
Team Experience (% of time)	none	21-40	21-40	41%+	41%+	41%+	41%+

The individual ratings of the tool were as follows:

Table C-12. Individual User Satisfaction for Test 3

	Participant	T1	T2	T3	T4	C1	C2	C3
1	Was the site easy to navigate?		1	2	2	2		4
2	Was the exercise easy to complete?		1	2	2	1		3
3	Was it fun?		4	3	3	1		3
4	Was it easy to figure out what to do next?		2	2	1	1		3
5	Was it helpful in understanding the problem?		1	3	2	1		3
6	Was it helpful in getting the team to come to an agreement?		5	3	2	1		3
7	Was the resulting data structure useful?		1	1	1	1		3
8	Would the exercise have been more rewarding if it was scored?		1	2	1	1		4
9	Does the concept of scoring seem fair in this situation?		1	1	3	1		3
10	Did the collaboration aspect increase your motivation to contribute?		5	3	5	2		5

Comments:

Table C-13. Individual Comments for Test 3

Participant		T1	T2	T3	T4	C1	C2	C3
1	Was the site easy to navigate?		It would have been really helpful to have been able to played around in the site before the exercise began, so we understood how to work within it and focus on the intended purpose of collaborative decision making.	directions didn't match screen would have been more helpful to have them ahead with pictures of the exercise itself screens	easy to navigate but you don\'t really know where you\'re navigating to	It seemed easy to use--like other discussion boards in format and use		Only did a chat and posted items in the action plan - it seemed to be an incomplete navigation process.
2	Was the exercise easy to complete?				it would have helped to have had instructions and a preview before tonight	I had many technical problems. Huge delays in seeing the chat, the dialog window not working, getting kicked out of the room, losing contact with my fellow chat mates.		Technologically, yes. Operationally with the other \"players,\" yes and no. Several technological issues appeared to interfere with the other participants in my group making it difficult to complete with everyone\'s input.

3	Was it fun?				only because we were ALL frustrated with using it!	It was so frustrating with the technology issues plus we really did not understand the exercise so that too added frustration.		Not too fun, but not painful either (fun~painful). I was disheartened when I was unable to look at my final listing of actions to be taken and I was unable to rank them in order due to the time running out. The wind was taken out of my sails a bit because I was on a roll with all of the tasks I was listing as a result of our meaningful chat/dialog.

4	Was it easy to figure out what to do next?		Good prompt messages, but just couldn't figure out what to do.	when it was my turn to edit ... no buttons so could do nothing but click around	nope. It was not intuitive, you would think a button would do a certain command but then it wouldn't and you were lost	when things went bad--it was hard to know if the system was working or not. Problem solving was not intuitive and help was not quickly available on the Oncourse chat site.		Not sure if it was the technology glitches or the process - action steps were not really clear. The clock was difficult to read in relation to timing accuracy. It looked like the clock had four dots instead of five in between the big lines making it unclear if they were actually minutes or "pseudo" minutes.
5	Was it helpful in understanding the problem?			the chat went well to determine areas of the problem	eventually we just used the chat to discuss issues instead of the modeling and that prompted good discussion	Not really		Versus not knowing what the problem we were going to work on? Not certain what this question is asking about.

6	Was it helpful in getting the team to come to an agreement?		We all seemed to be just as lost as the next player, but still were able to come to a consensus with ease.	chat was	we were all pretty much on the same page from the word go, so that made it easy, I don\'t know that the program per se helped that much	No--we really did not understand the outcome or what we were trying to do		What is \"it?\" It was great to come to an agreement based on our chat/dialog.
7	Was the resulting data structure useful?			too difficult to type – not able to cut and paste a summary ..the box only allowed 2-4 words and I tried it several times	no, I have no idea what we ended up with	Never saw it		Structure for the action steps? The action steps might have been useful, however, time ran out so I was unable to complete the process.
8	Would the exercise have been more rewarding if it was scored?				absolutely not, that would have put more pressure on everyone and probably made everyone grumpy.	not really since the technology was so unreliable		Sure, I was not really certain where we were in the plan (i.e. behind, ahead, just right). If the goal was a schedule, we failed miserably. If the goal was about interacting in a community of practice, it was wonderful and we scored very highly!

9	Does the concept of scoring seem fair in this situation?				ONLY IF you have education about the program first and a trial run before the scoring	not unless there is a better understanding of the assignment, more reliable technology and a scoring rubric published before the activity starts		It would depend on what scoring system was used. Based on the process, scoring could be directed toward interactions and agreement OR timeliness of completing the assignment OR a combination of both.
10	Did the collaboration aspect increase your motivation to contribute?		I felt frustrated about not being able to contribute more, because I could not figure out how work the boxes and get my information where I wanted to put it.	The chat and yest to do my area	yes, because we were all struggling together so we all kept trying to figure it out together	perhaps but when there were such delays in seeing others responses, unsure if the system was working or not and then the technology issues--the motivation to even try with no understanding of the outcome was pretty low in general		Collaboration was what it was all about for me. Without that aspect, I would have preferred an assignment on my own to be turned in on a specific date and time. Interactions with unknown individuals in an attempt to collaborate to achieve success was the motivating factor!

The individual usage results were as follows:

Table C-14. Individual Usage Results for Test 3

	Participant	T1	T2	T3	T4	C1	C2	C3
1	Number of elements in model	10	7	7	5	0	0	0
2	Contributions to chat	27	32	34	68	41	48	44
3	Team leader?	no	no	no	yes	no	no	yes

The team ratings of the tool were as follows:

Table C-15. User Satisfaction for Tests 2 and 3

		Test 2		Test 3		Overall Test	Overall Control	Overall
		Test	Control	Test	Control			
1	Was the site easy to navigate?	2.00	4.50	1.67	3.00	1.83	3.75	2.60
2	Was the exercise easy to complete?	1.67	4.00	1.67	2.00	1.67	3.00	2.20
3	Was it fun?	3.67	4.50	3.33	2.00	3.50	3.25	3.40
4	Was it easy to figure out what to do next?	2.00	4.50	1.67	2.00	1.83	3.25	2.40
5	Was it helpful in understanding the problem?	3.00	5.00	2.00	2.00	2.50	3.50	2.90
6	Was it helpful in getting the team to come to an agreement?	3.00	5.00	3.33	2.00	3.17	3.50	3.30
7	Was the resulting data structure useful?	1.67	3.50	1.00	2.00	1.33	2.75	1.90
8	Would the exercise have been more rewarding if it was scored?	1.00	1.50	1.33	2.50	1.17	2.00	1.50
9	Does the concept of scoring seem fair in this situation?	1.33	2.50	1.67	2.00	1.50	2.25	1.80
10	Did the collaboration aspect increase your motivation to contribute?	4.33	5.00	4.33	3.50	4.33	4.25	4.30

The team usage results were as follows:

Table C-16. Team Usage Results for Tests 2 and 3

		Test 2		Test 3		Over all	Over all	Over all
		Test	Contr	Test	Contr	Test	Contr	
1	Number of elements in model	9	0	4	0	13	0	13
2	Contributions to chat	124	104	161	133	285	237	522
3	Number of items in action plan	13	5	6	24	19	29	48

4. Test 4

The participant demographics were as follows:

Table C-17. Demographic Data for Test 4

Participant	T1	T2	T3	T4	C1	C2	C3	C4
Age	21-23	24-30	24-30	51+	31-40	41-50	41-50	31-40
Gender	Male	Male	Male	Male	Male	Male	Male	Male
Occupation	Student	Student	Student	Student	Staff	Other	Faculty	Student
Family Status	Single	Single	Married	Single	Single	Married	Single	Married
Ethnic Group	Asian	Asian	White	White	White	Asian	White	Asian
Nationality	North America	Asia	North America	North America	North America	North America	North America	Asia
Computer Experience (years)	6-10	1-5	11-20	21+	11-20	21+	21+	21+
Internet Usage (hours/day)	9+	9+	6-8	3-5	9+	9+	9+	9+
Computer Games (times /week)	11-20	<1	1-2	3-10	<1	<1	1-2	<1
Volunteer Experience (hours /quarter)	<1	1-10	1-10	<1	<1	1-10	<1	<1

Volunteer Groups (total)	1-5	1-5	1-5	1-5	1-5	6-10	1-5	1-5
Team Experience (total)	11-20	1-5	21+	11-20	none	6-10	1-5	11-20

The individual ratings of the tool were as follows:

Table C-18. Individual User Satisfaction for Test 4

Participant		T1	T2	T3	T4	C1	C2	C3	C4
1	Was the site easy to navigate?	3	1	4	2	3	2	3	1
2	Was the exercise easy to complete?	4	1	3	1	1	1	3	1
3	Was it fun?	4	1	4	4	2	3	3	2
4	Was it easy to figure out what to do next?	3	1	3	2	4	2	3	2
5	Was it helpful in understanding the problem?	4	2	4	4	3	3	3	2
6	Was it helpful in getting the team to come to an agreement?	3	1	4	2	2	2	3	2
7	Was the resulting data structure useful?	3	1	2	4	3	1	1	3
8	Would the exercise have been more rewarding if it was scored?	2	1	4	2	2	1	5	2
9	Does the concept of scoring seem fair in this situation?	2	1	3	1	2	1	3	3
10	Did the collaboration aspect increase your motivation to contribute?	5	1	4	4	4	3	5	3

Comments:

Table C-19. Individual Comments for Test 4

Participant		T1	T2	T3	T4	C1	C2	C3	C4
1	Was the site easy to navigate?	Mental model of 2D desktop works for the most part; grab handles for pop-up windows and back button target for maps are hard to track down; grouping of items (goal, task, lists) uncomfortably linear		overall, it was easy to see what was going on in the UI	If the windows could all be moved around &/or tiled it would help		No - it would be nice to be able to see the scenario & resources without popping up windows. I opened notepad and copied things in		there is no clear resource list for collections and needs

2	Was the exercise easy to complete?			it wasn't always clear what should be an event vs. a goal vs. a task in a given scenario	It was hard to get the team to work in an organized fashion	The scenario and the owned resources could not be seen at the same time. The timer was difficult to keep track of. A notice of time remaining at say, 10 minutes would be nice.	We didn't complete. The interval times were unknown (or at least we didn't know it). It would be nice to call for an end of discussion from the chat.	Smith plan: P4 buys 15 wire deficit. Collect 3 beds (from P1 and 3). Collect Lumber 100, Plywood 50, Roofing 16, and 35 wire. Jones plan: use Player 3 truck, and group materials and all players materials (100 lumber, 50 plywood, 16 roofing, 50 wire, and Kids clothing from P1). Use P2s labor. Use P1s hammer and saw, and P4s nail gun. Get stove from P4. Make them buy a refrigerator, since they can afford a hotel, and were saving them that money. Robinson plan: use Player 3 truck, and group materials (20 lumber, 3 plywood, and 2 roofing). Use Player 1 labor (15 hours). Use Player 3 hammer, nail gun, and saw. Bring Player 3s men’s clothing. Done.	In the chat, it spends time to check the needs and goals back and forward

3	Was it fun?			it was fun to be able to collaborate with a problem and its given constraints			was it supposed to be?		It takes too much time for understanding the situation

4	Was it easy to figure out what to do next?			not always...it wasn't clear where the treemap fit in to the problem and solution and eventually the action plan. People who are available to volunteer in such a situation may not be familiar with it either.	The timed popups helped		We were just chatting away and stuff would happen		

5	Was it helpful in understanding the problem?			yes, collaboratin g did shed light on the shortest path to solutions to a given event					
6	Was it helpful in getting the team to come to an agreement ?			yes	not about any one issue - but we never agreed on a project organization		we didn't really come to a conclusio n		It is better to know the role of all players first. It is better to know who is the expert.
7	Was the resulting data structure useful?	hierarchy was useful, but arbitrary naming was confusing		I\'m not sure what the resulting data structure was...			Didn't see much data structure		It takes much time to review all contents

8	Would the exercise have been more rewarding if it was scored?			feedback may be appropriate so a user knows that they are on the right path					It is not the game
9	Does the concept of scoring seem fair in this situation?			possibly scoring on the allocation of resources and prioritizing amongst the team					No, solving the problem as quick as possible is the first priority, not winning high score.

10	Did the collaboration aspect increase your motivation to contribute?			it did...seeing what every one had available to contribute and seeing that they were contributing as much as they could is a motivator					

The individual usage results were as follows:

Table C-20. Individual Usage Results for Test 4

	Participant	T1	T2	T3	T4	C1	C2	C3	C4
1	Number of elements in model	9	9	17	20	0	0	0	0
2	Contributions to chat	17	31	23	13	68	52	62	6
3	Team leader?	no	no	no	yes	no	no	yes	no

The team ratings of the tool were as follows:

Table C-21. Mean User Satisfaction for Test 4

		Test	**Control**	**Overall**
1	Was the site easy to navigate?	2.5	2.25	2.38
2	Was the exercise easy to complete?	2.25	1.5	1.88
3	Was it fun?	3.25	2.5	2.88
4	Was it easy to figure out what to do next?	2.25	2.75	2.50
5	Was it helpful in understanding the problem?	3.5	2.75	3.13
6	Was it helpful in getting the team to come to an agreement?	2.5	2.25	2.38
7	Was the resulting data structure useful?	2.5	2	2.25

8	Would the exercise have been more rewarding if it was scored?	2.25	2.5	2.38
9	Does the concept of scoring seem fair in this situation?	1.75	2.25	2.00
10	Did the collaboration aspect increase your motivation to contribute?	3.5	3.75	3.63

The team usage results were as follows:

Table C-22. Team Usage Results for Test 4

		Test	Control	Overall
1	Number of elements in model	32	0	32
2	Contributions to chat	84	188	272
3	Number of items in action plan	9	36	9

Overall Summaries are as follows:

Table C-23. Total Contributions from Test Teams

	Participant	Number of elements in individual model	Contributions to chat	Number of elements in team model	Number of items in action plan	Total
Trial 1						
	T1	1	5			
	T2	14	8			
	Total	15	13	6	3	37
Trial 2						
	T1	2	49			
	T2	4	38			
	T3	10	37			
	Total	16	124	9	13	162
Trial 3						
	T1	10	27			
	T2	7	32			
	T3	7	34			
	T4	5	68			
	Total	29	161	4	6	200
Trial 4						
	T1	9	17			
	T2	9	31			
	T3	17	23			

	T4	20	13			
	Total	55	84	32	9	180

Table C-24. Total Contributions from Control Teams

	Participant	Number of elements in individual model	Contributions to chat	Number of elements in team model	Number of items in action plan	Total
Trial 1						
	C1	0	10			
	Total	0	10	0	0	10
Trial 2						
	C1	0	60			
	C2	0	44			
	Total	0	104	0	5	109
Trial 3						
	C1	0	41			
	C2	0	48			
	C3	0	44			
	Total	0	133	0	24	157
Trial 4						
	C1	0	68			
	C2	0	52			
	C3	0	62			
	C4	0	6			
	Total	0	188	0	36	224

Appendix D: Architectural Analysis

Figure D-1 is a high-level context diagram that illustrates the basic MCT dependencies.

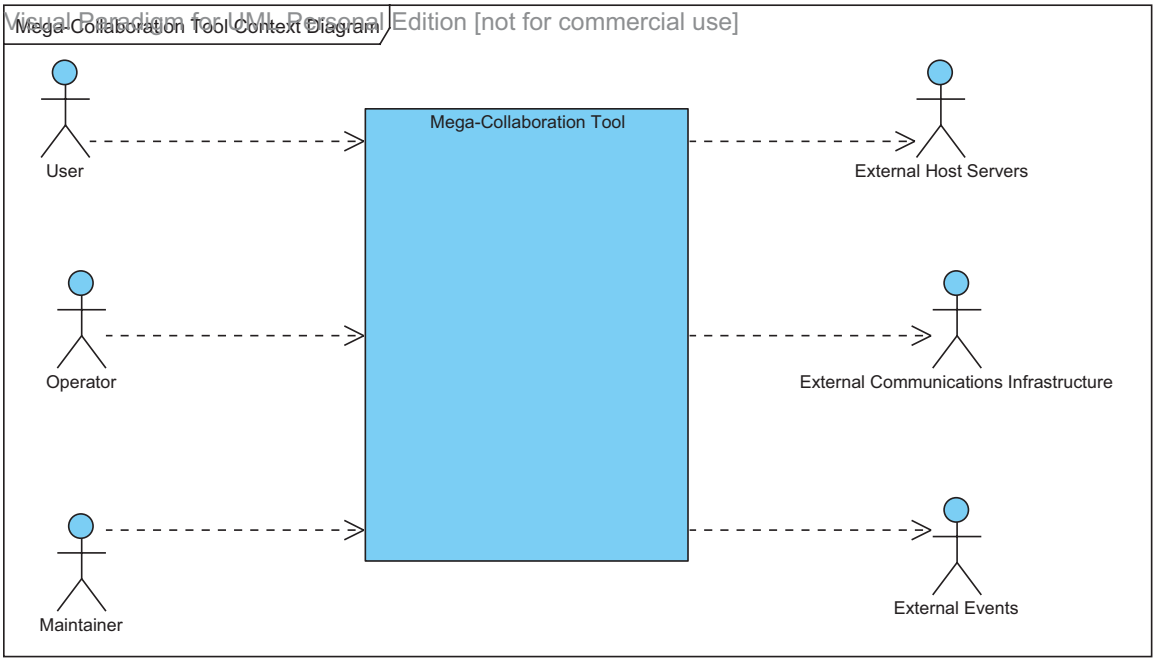

Figure D-1. MCT Context Diagram

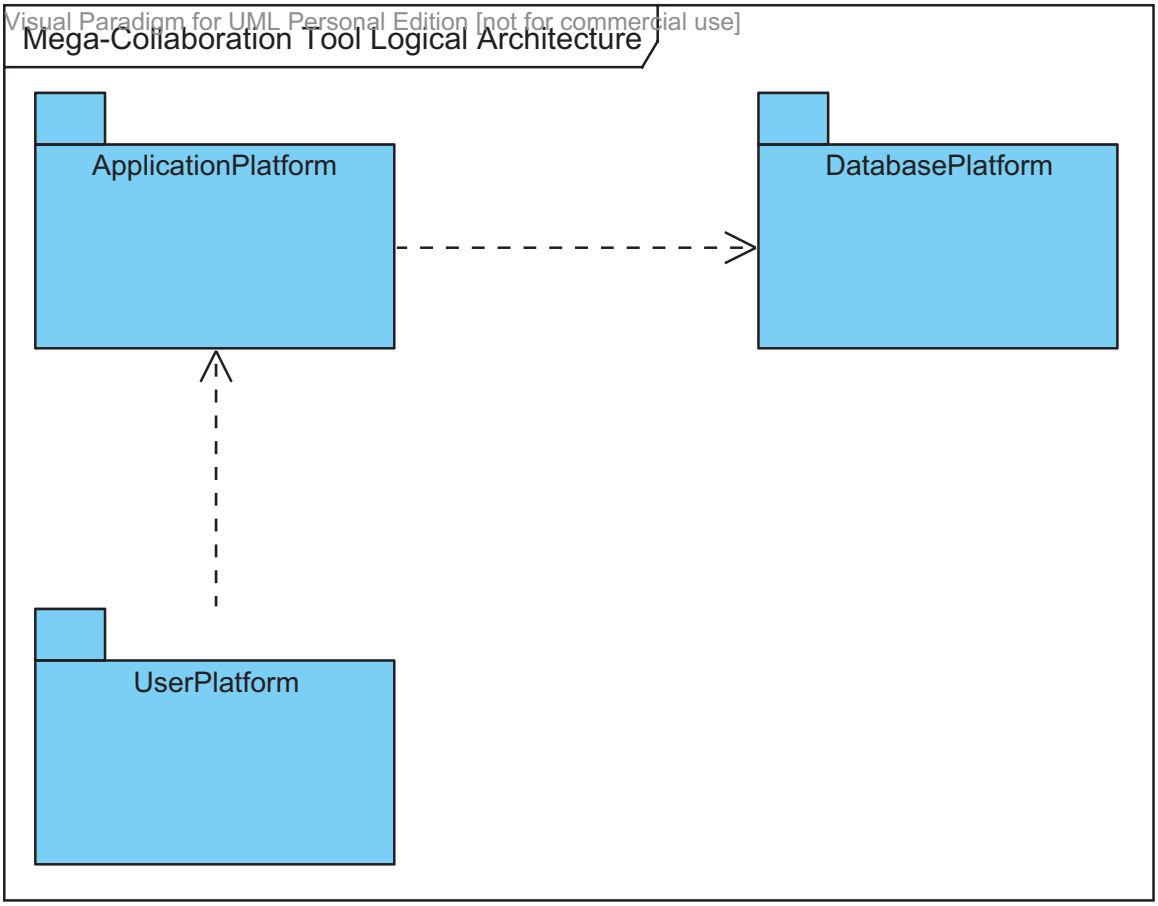

Figure D-2. MCT Logical Architecture

Figure D-2 illustrates the logical architecture of the MCT, which is a fairly simple 3-tier structure.

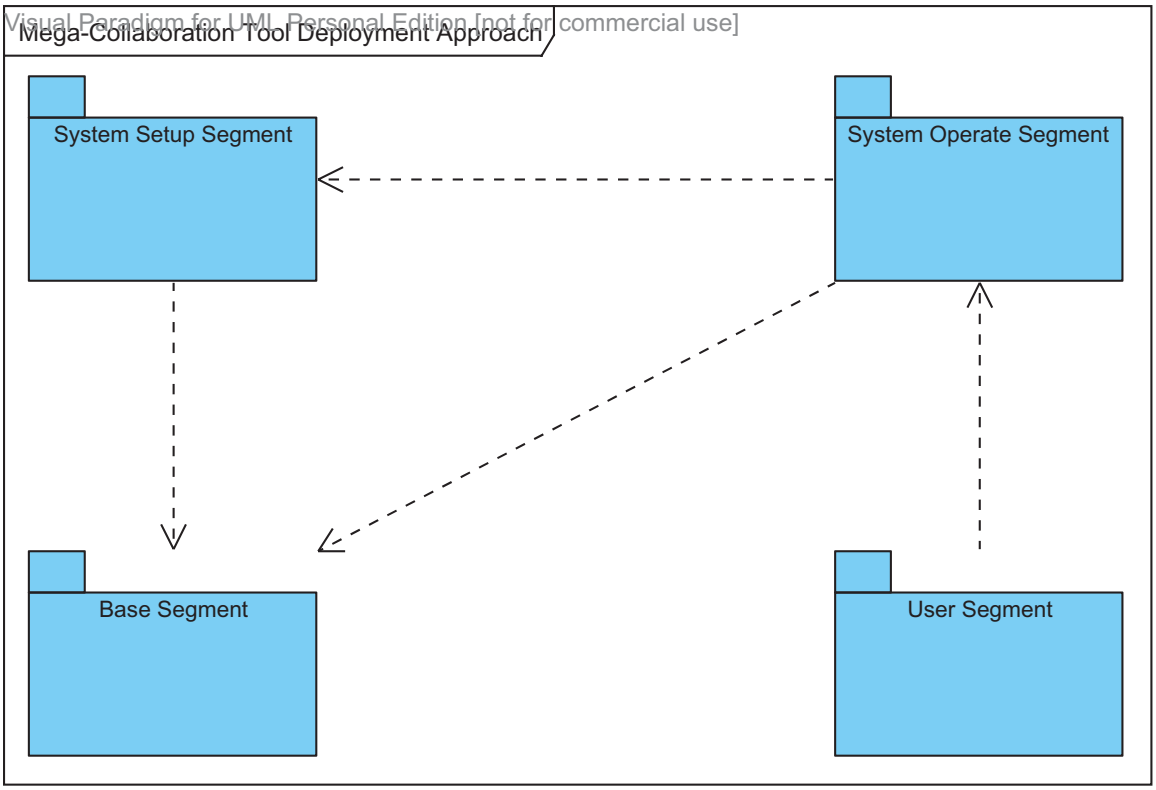

Figure D-3. MCT Deployment Diagram

Figure D-3 illustrates the deployment of the MCT. It assumes that a basic implementation exists under normal circumstances in the form of the base segment. However, during a crisis, the system setup segment would be responsible for expanding the implementation to meet growing demand, while the system operation segment would be responsible for working with the users to make sure their needs were being met.

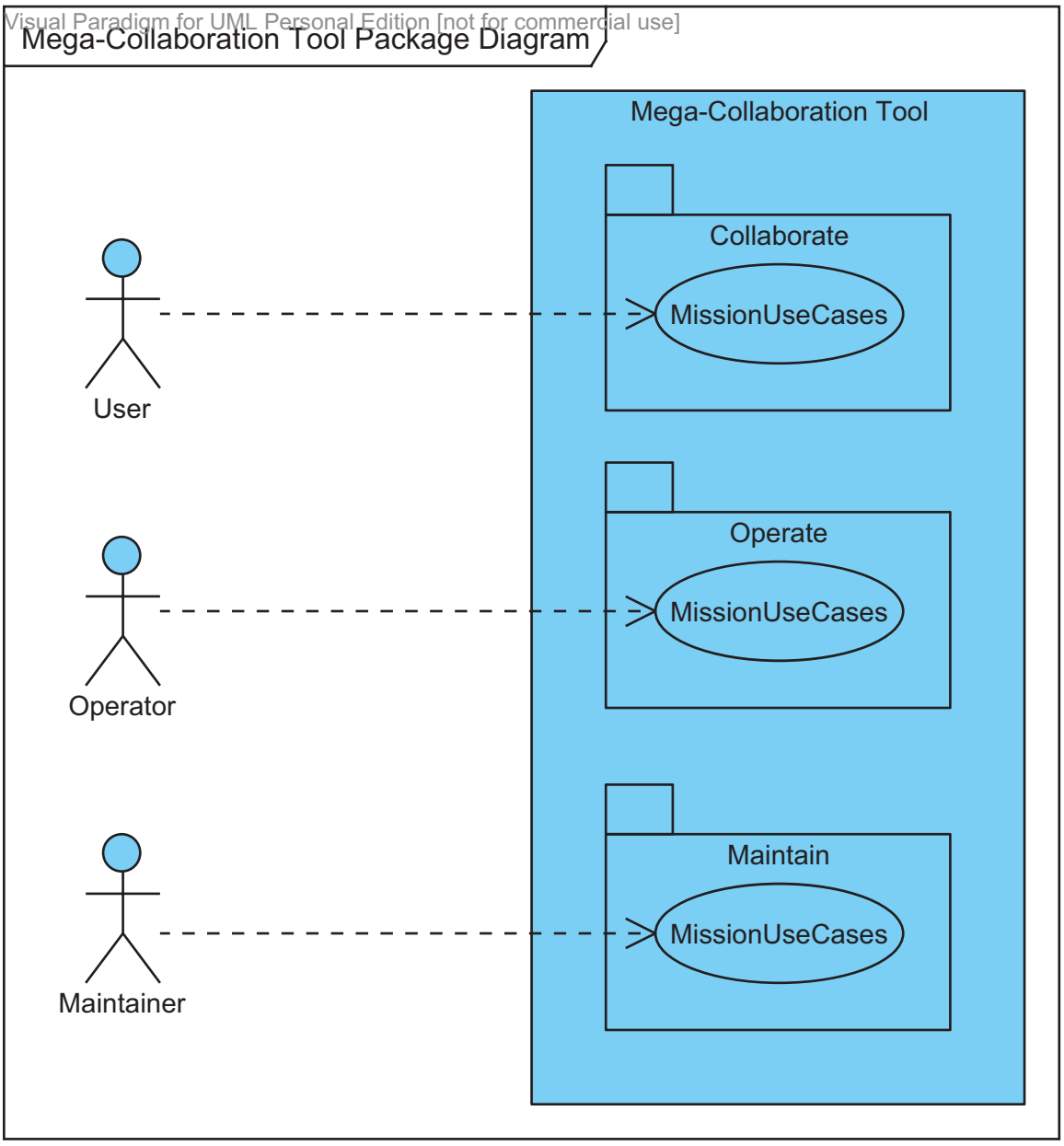

Figure D-4. MCT Package Diagram

Figure D-4 illustrates the three packages into which the mission use cases are divided.

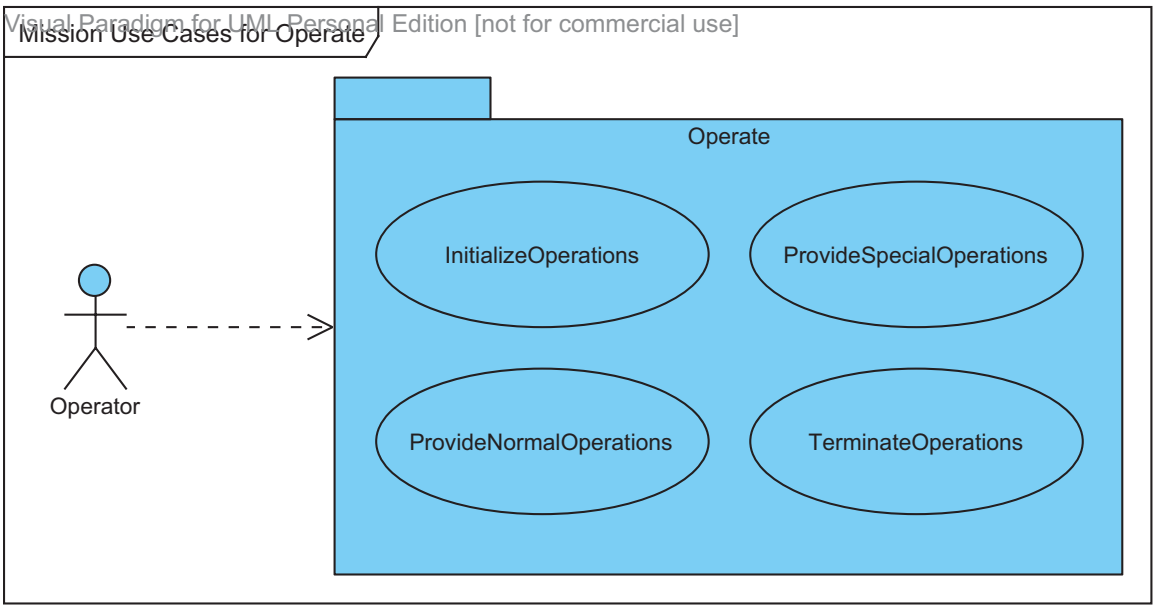

Figure D-5. Mission Use Cases for MCT Operation

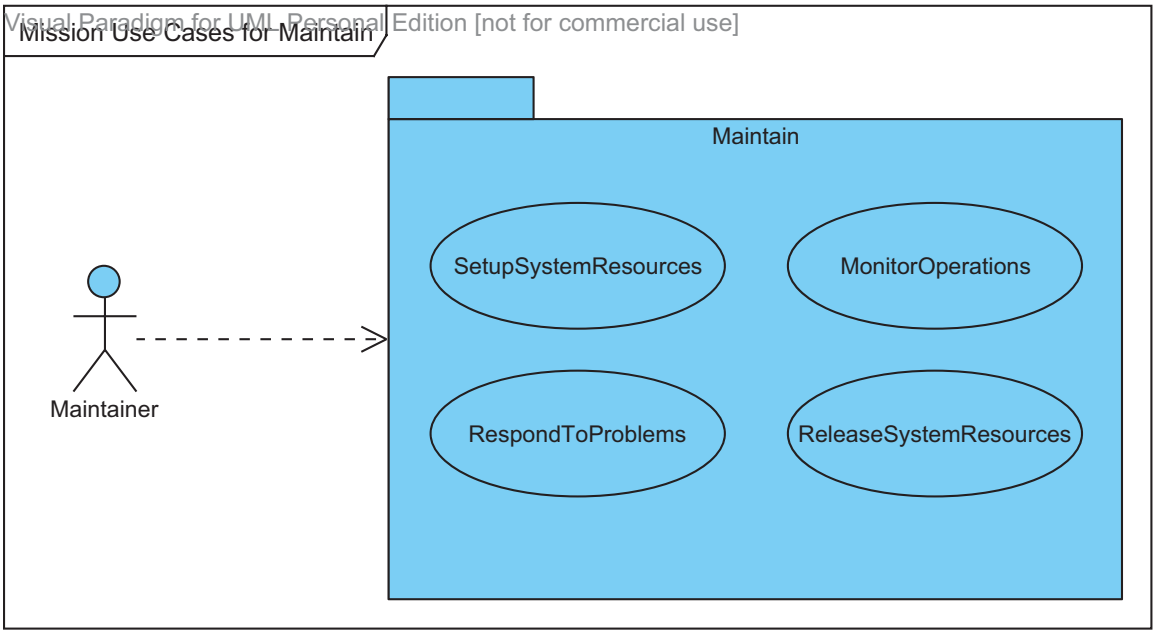

Figure D-6. Mission Use Cases for MCT Maintenance

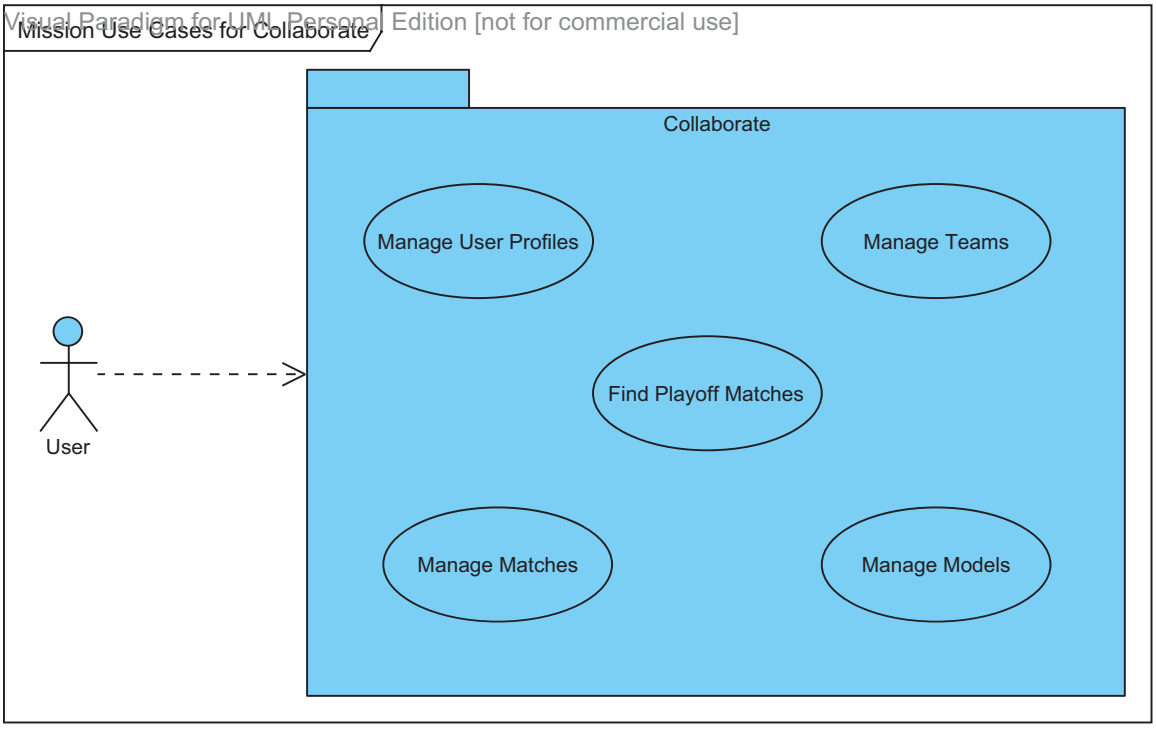

Figure D-7. Mission Use Cases for MCT Collaboration

Figures D-5, D-6, and D-7 illustrate the mission use cases within each of the three packages.

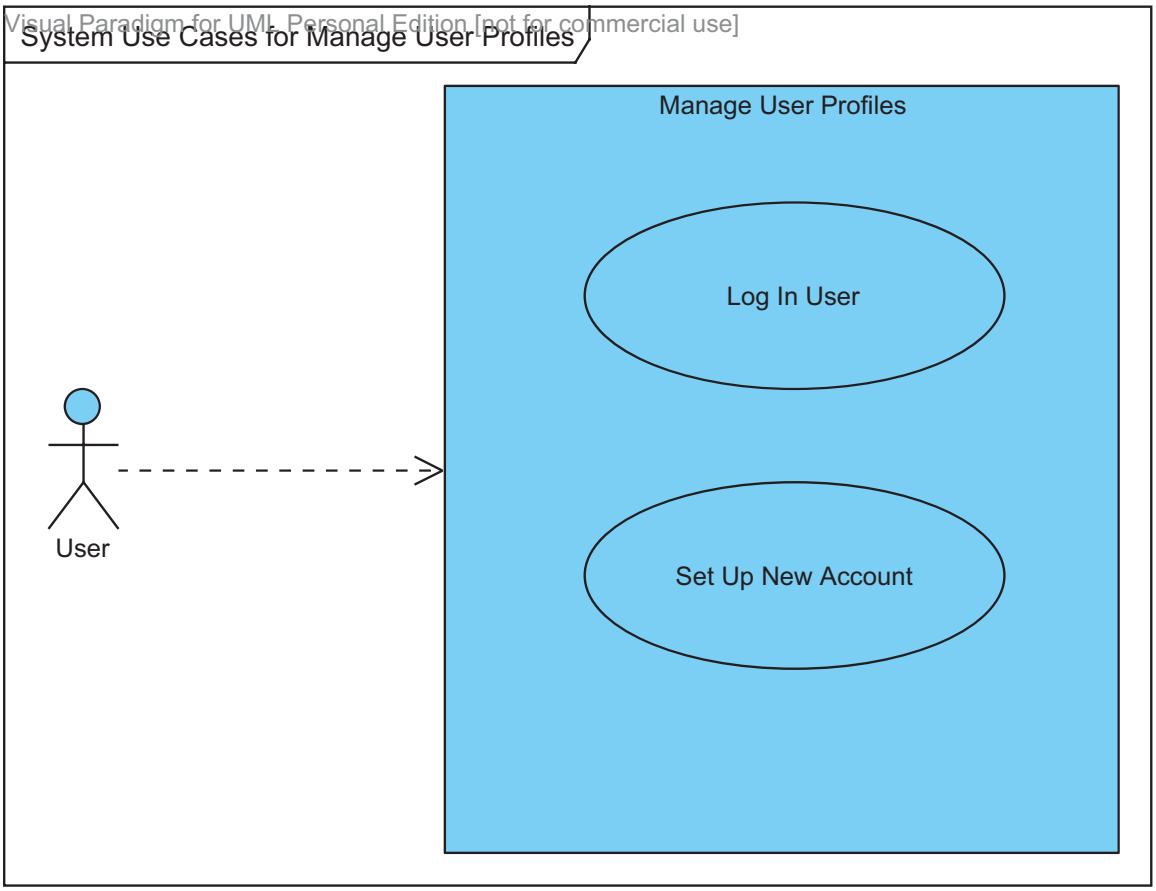

Figure D-8. System Use Cases for Manage User Profiles

Figure D-8 shows the system use cases for managing the MCT user profiles.

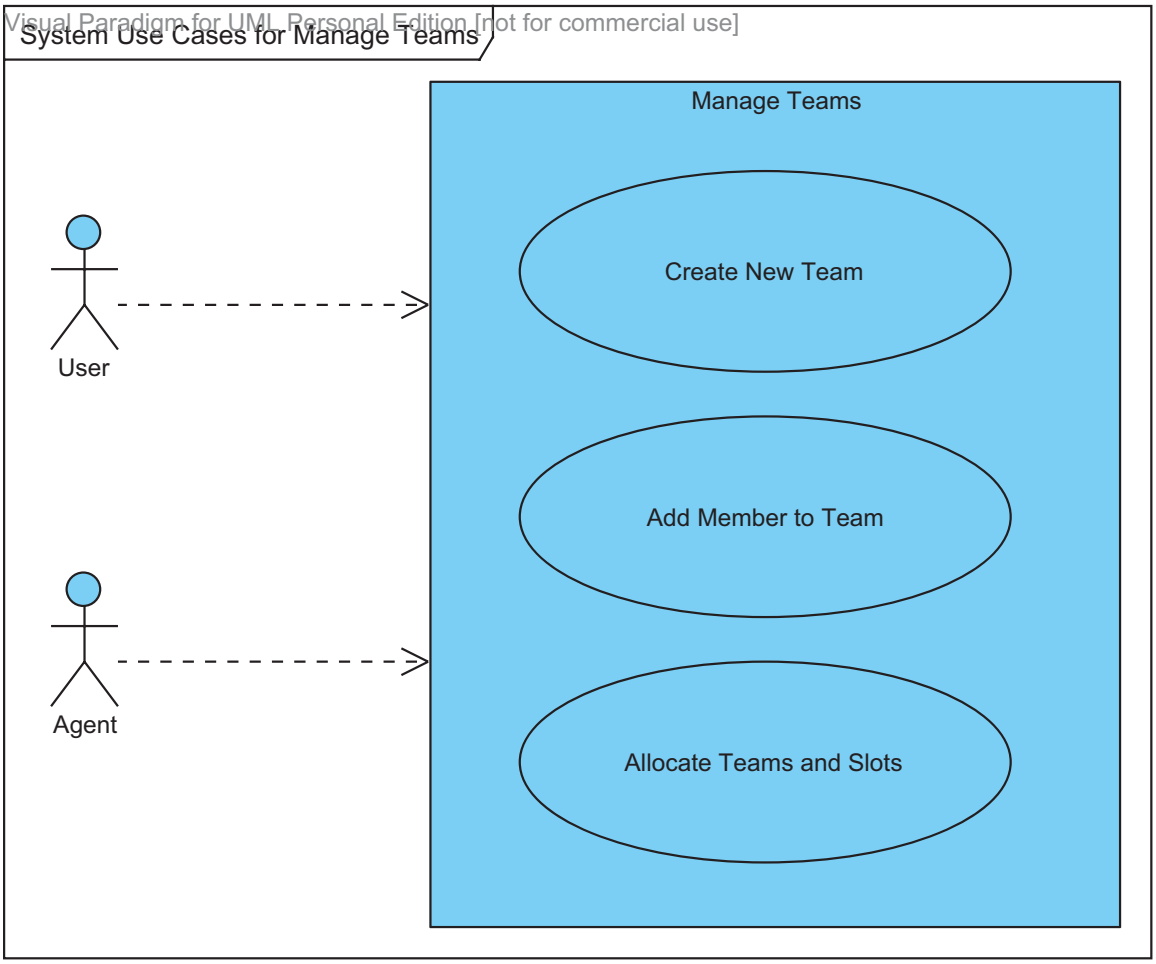

Figure D-9. System Use Cases for Manage Teams

Figure D-9 shows the system use cases for managing the MCT's teams. The final use case, allocate teams and slots, assumes that there are enough matching concepts to form more than one playoff team.

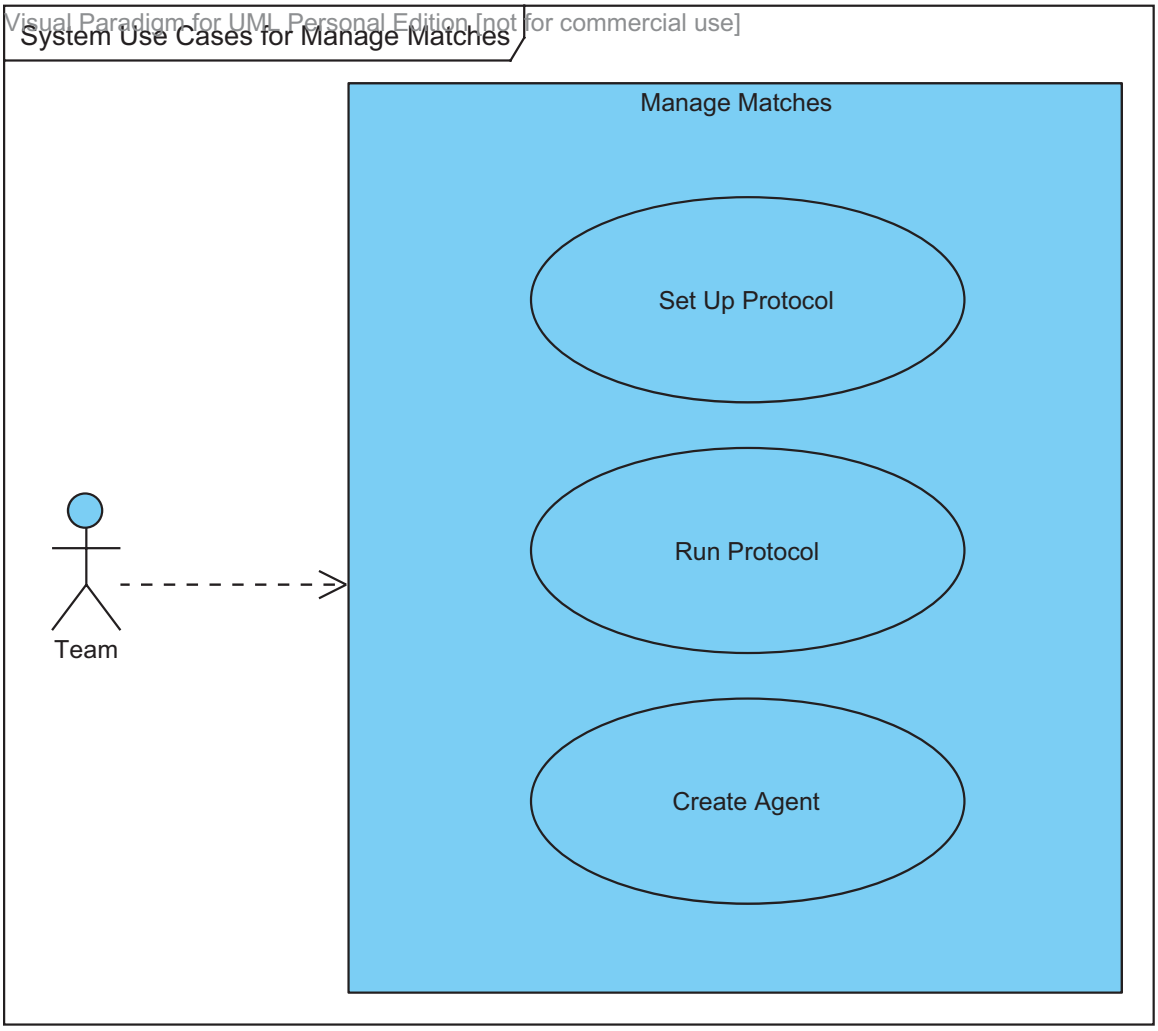

Figure D-10. System Use Cases for Manage Matches

Figure D-10 shows the system use cases for the management of MCT matches. Notice that the team agent is created as part of the match.

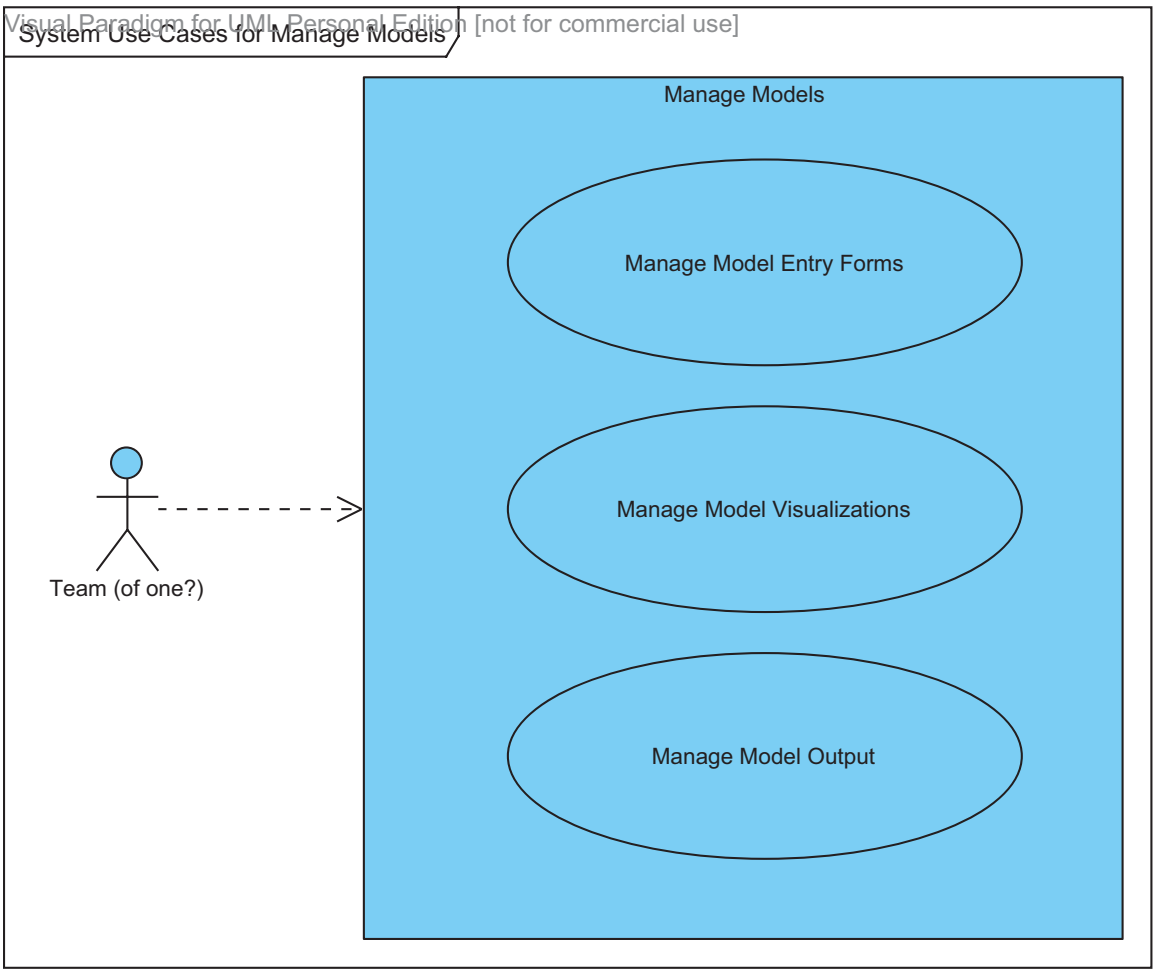

Figure D-11. System Use Cases for Manage Models

Figure D-11 shows the system use cases for managing MCT models. At the moment, the three major categories are input, output, and visualization. More may be added in the future as the data structure is elaborated.

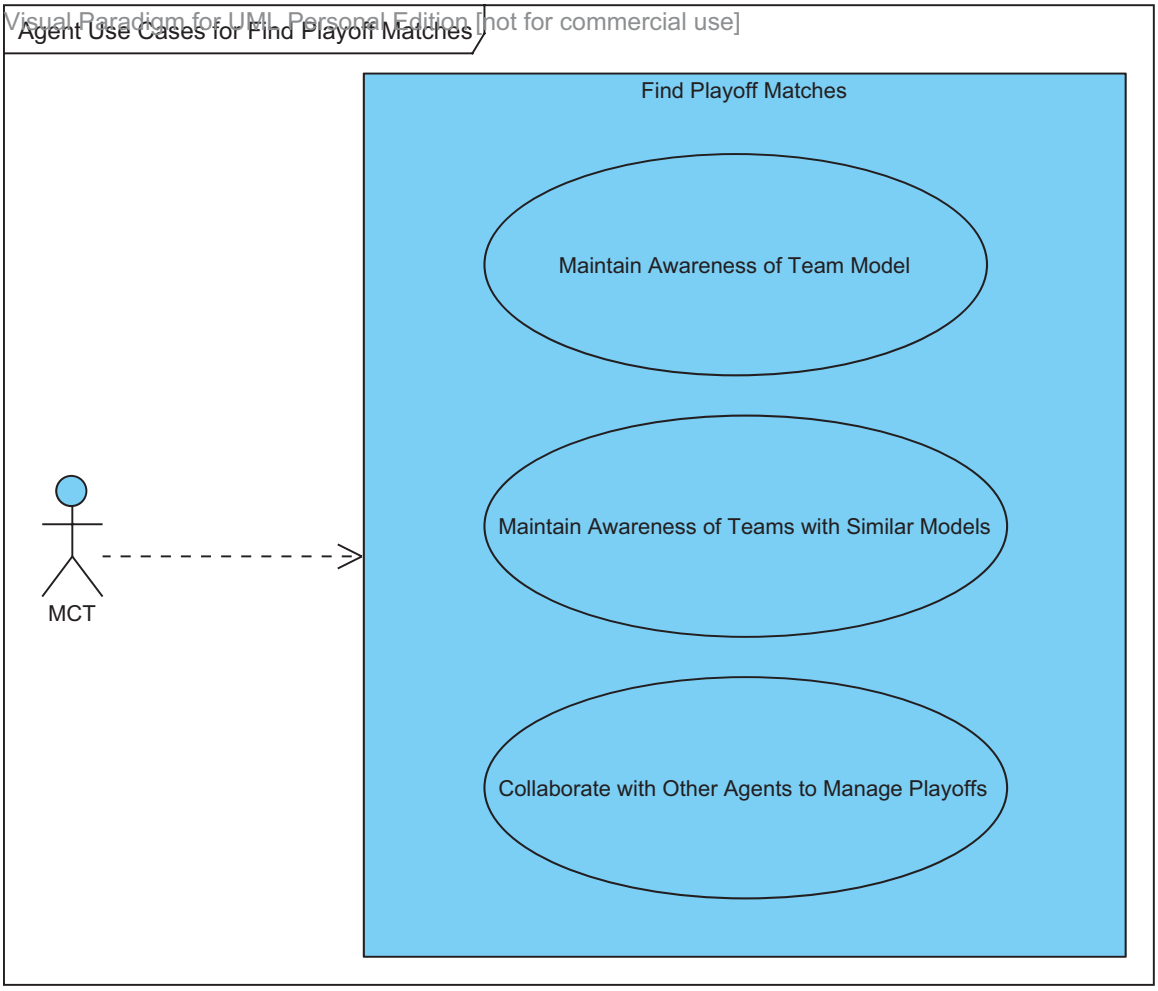

Figure D-12. Agent Use Cases for Find Playoff Matches

Figure D-12 shows the agent use cases from the point of view of the MCT system.

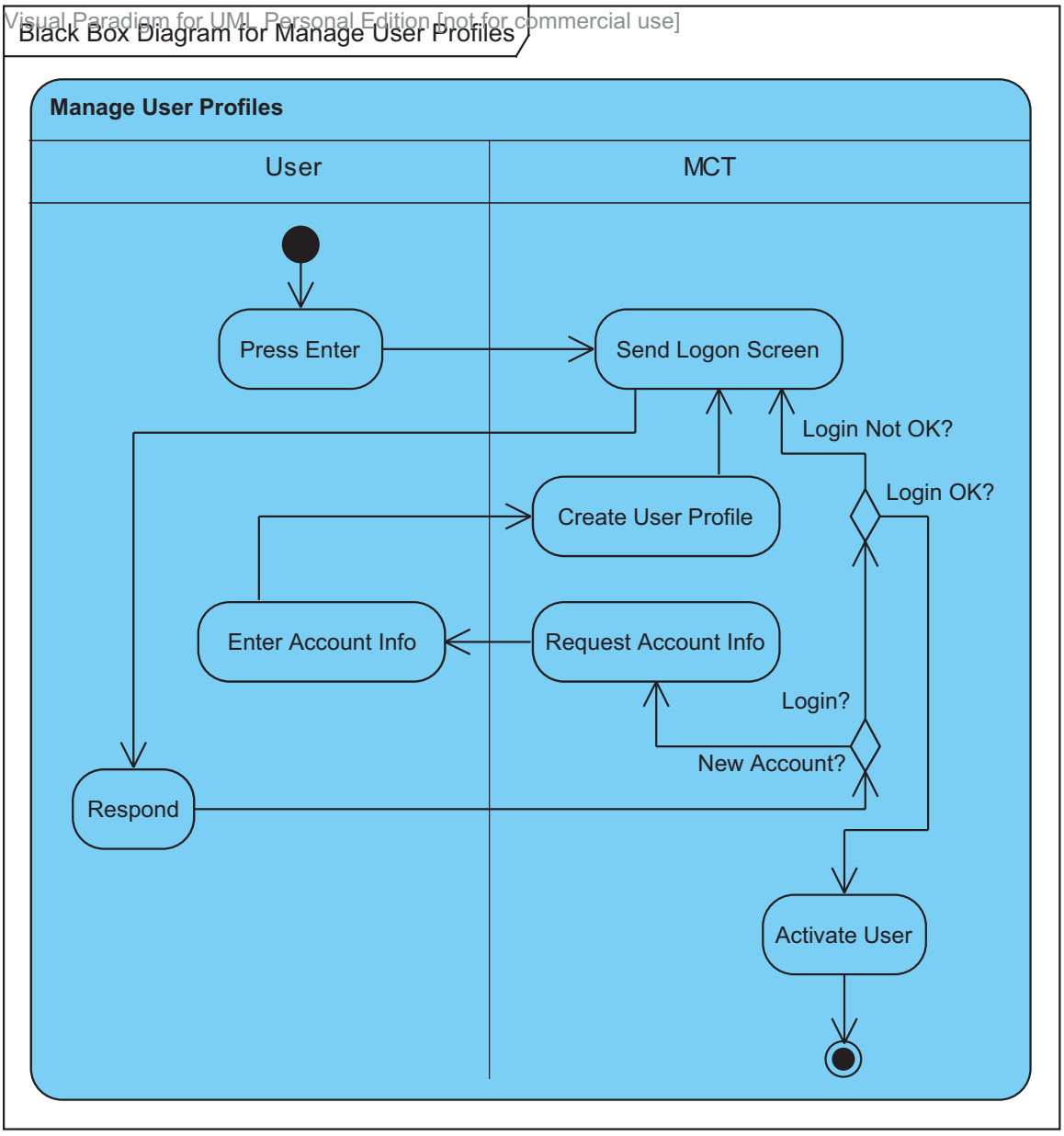

Figure D-13. Manage User Profiles Black Box Diagram

Figure D-13 illustrates the components of the manage user profiles use case.

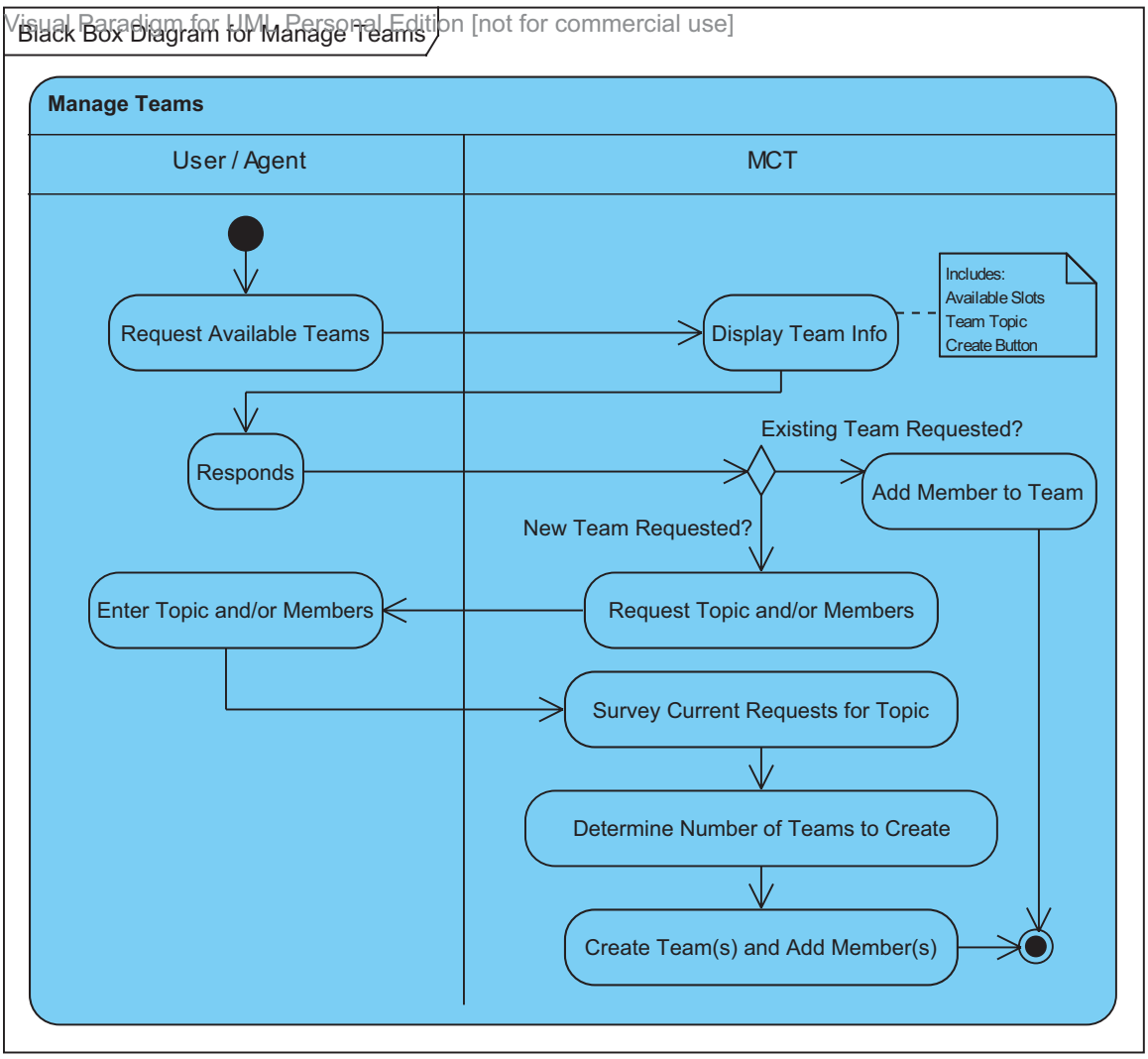

Figure D-14. Black Box Diagram for Manage Teams

Figure D-14 illustrates the process of managing MCT teams.

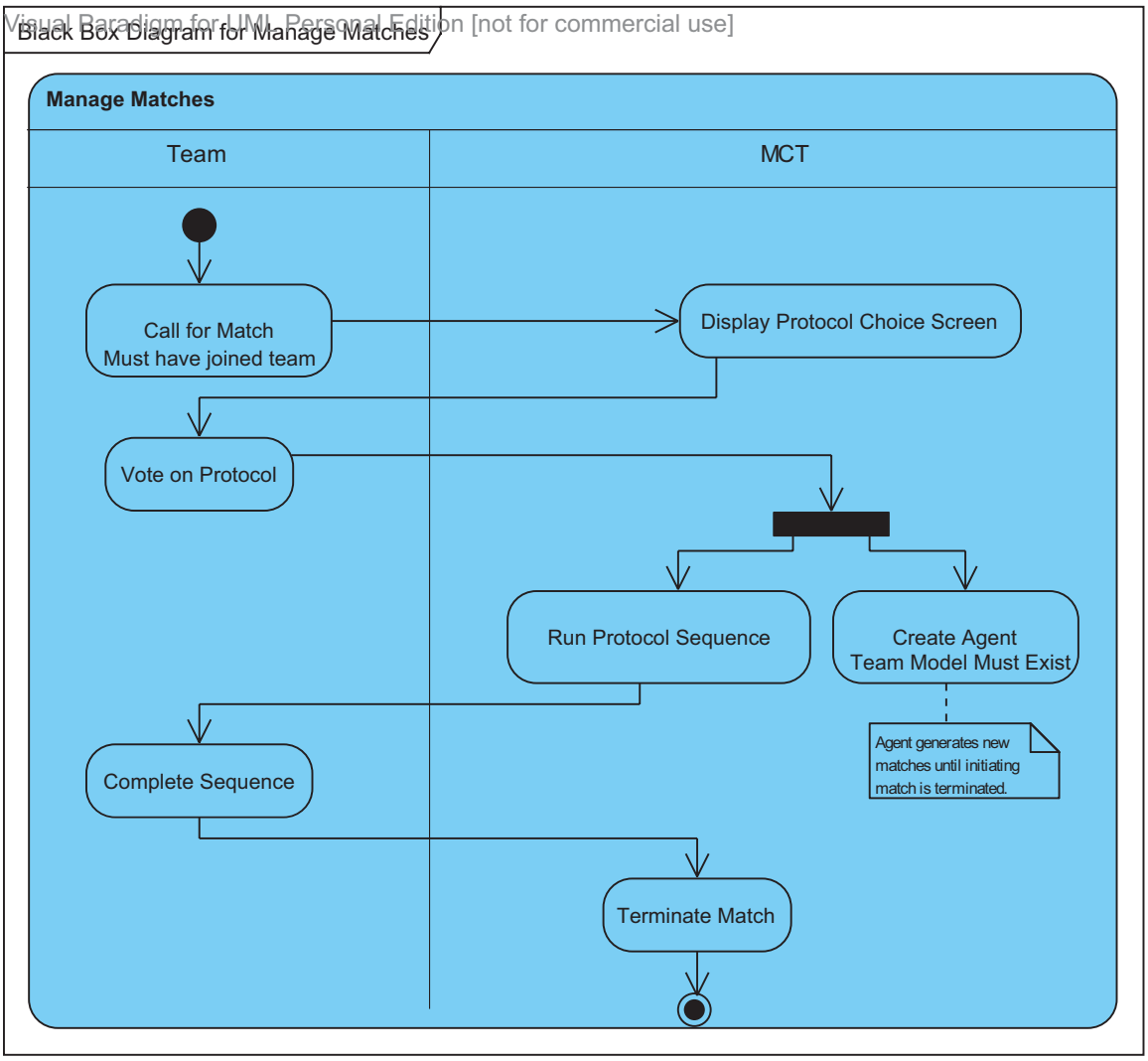

Figure D-15. Black Box Diagram for Manage Matches

Figure D-15 illustrates the process of managing MCT matches.

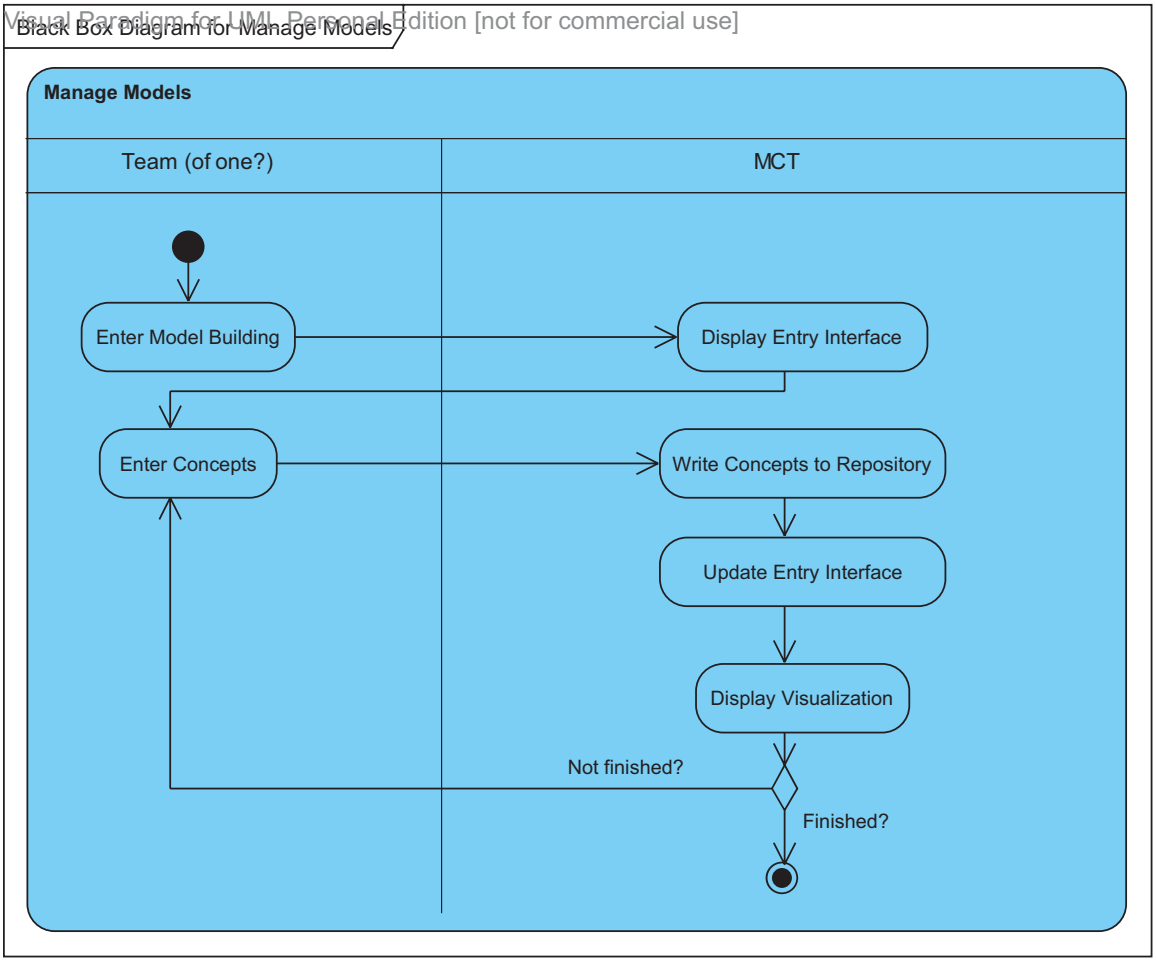

Figure D-16. Black Box Diagram for Manage Models

Figure D-16 illustrates the process of managing MCT models.

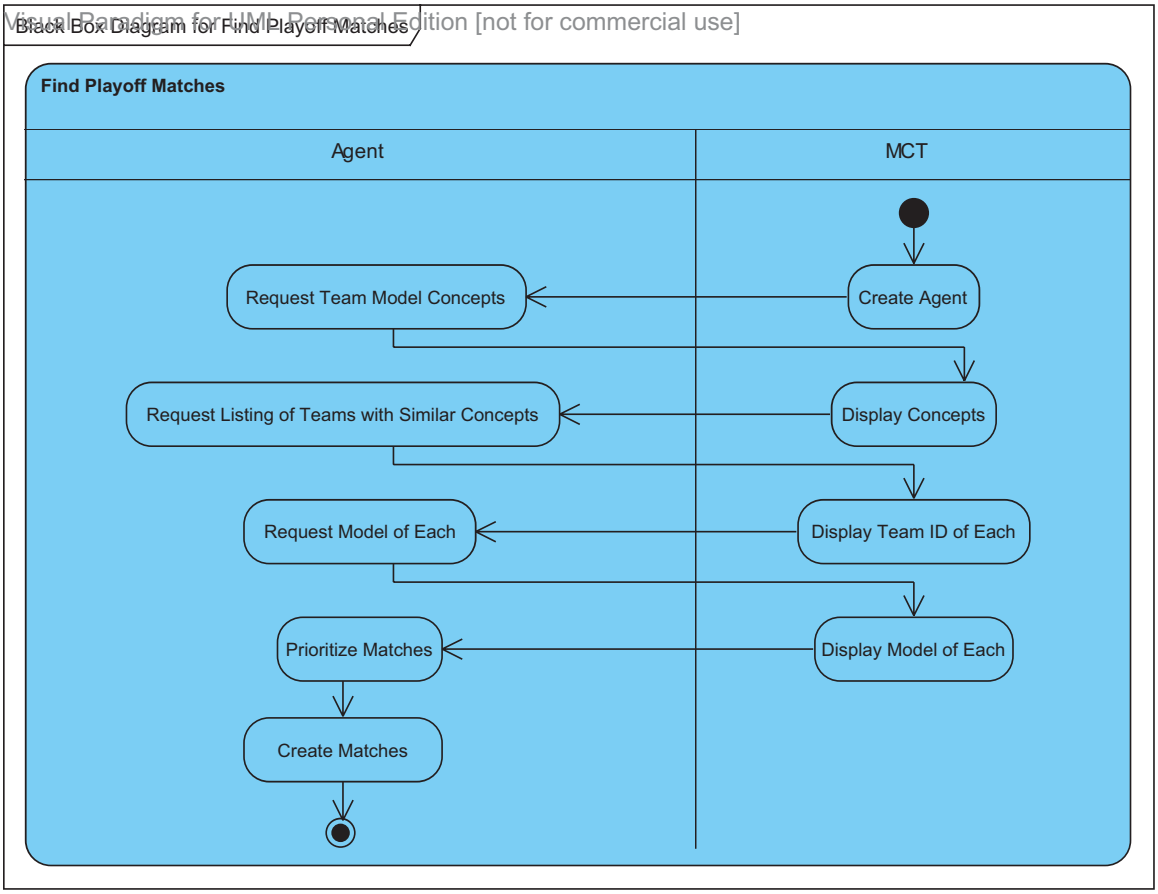

Figure D-17. Black Box Diagram for Find Playoff Matches

Figure D-17 illustrates the agent's process for finding playoff matches.

VITA

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Publications and Papers

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Newlon C. (2007) Developing a Tool for Mega-Collaboration. Paper presented at Five Minutes of Fame, New Media Consortium Summer Conference. Indianapolis, Indiana. http://archive.nmc.org/events/2007summerconf/materials/Mega-Collaboration.pdf.

Newlon, C, MacDorman, K. and Scerri, P. (2008) A New Model for Mega-Collaboration. Paper presented at First International Workshop on HCI for Emergencies, CHI 2008, Florence, Italy.

Newlon, C, Faiola, A, MacDorman, K. (2008) Building the Mega-Collaboration Interface: Behavioral, Cultural, and Cognitive Factors in Visualization Support. Paper to be presented at International Symposium of Human-Computer Interaction, HCI, 12th International Conference on Information Visualization, London, England.

Dixon, B, Newlon, C. (2008) Advancing the Nursing Informatics Agenda: Results of a Multi-Method Online Simulation in Nursing Education. Paper submitted to CIN: Computers, Informatics, Nursing.