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Chat Communication in a Command and Control Environment: How Does It Help?

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CHAT COMMUNICATION IN A COMMAND AND CONTROL ENVIRONMENT: HOW DOES IT HELP?

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I HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER MY SUPERVISON BY April M. Courtice ENTITLED Chat Communication In A Command And Control Environment: How Does It Help? BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Doctor of Philosophy.

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ABSTRACT

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Military command and control (C2) teams are often faced with difficult, complex, and distributed operations amidst the fog and friction of war. To deal with this uncertainty, teams rely on clear and effective communication to coordinate their actions; two current conduits for communication in distributed military teams include voice (i.e., radio) and chat. Chat communication is regarded by many in the C2 world as the premier method of communicating with the power to lessen some of the traffic and disturbances of current voice communication, and its usage continues to exponentially increase. Despite this operational view, countless laboratory studies have demonstrated detrimental effects of chat communication relative to voice communication. The current study investigates the gap between laboratory research results and usage in complex environments, and empirically tests the effects that chat communication has on tactical C2 performance through an air battle management synthetic task environment. Results demonstrate that participants performed better on time-critical, emergent events with voice communication and better on preplanned missions when they had access to archival information. Voice communication is a valuable, high bandwidth channel that is essential for coordination in highly complex situations, while chat communication is a nonintrusive form of communication that allows the operator flexibility in prioritizing the information flow

through the use of archival information. The challenge in operational settings with overcrowded radio channels, however, is to protect the voice channel to ensure it is available when the situation demands it. With careful implementation, voice and chat communication can be complementary technologies to facilitate complex work.

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While so many have helped me tremendously to shape this project and document, any opinions, conclusions, or mistakes found in this document are mine and mine alone.

CHAPTER I. Introduction

In World War I the standard communication rate was about 30 words per minute on a field phone. In World War II it was about 60 words per minute on a radio, but you had to talk clearly. In Vietnam it was probably 100 words per minute using satellite communications, etc. In the Gulf War it was roughly 192,000 words per minute using networked computers. I don't have any idea what it was in our recent conflict, but I bet it was far above 192,000. In 2010, if we should conduct a theater conflict, we are looking at 1.5 trillion words per minute transmitted to, from and across the theater. That is the equivalent of the content of the Library of Congress being transmitted every minute. Somewhere in those 1.5 trillion words is the precise information that a commander, planner, tactical squad leader, flight lead or ship's crew needs. <u>Where is their information</u>?
Brigadier General Marc E. Rogers (Anderson, 2003, p. 16).

Complexity in Military Operations

Every day thousands of military troops are scattered across the globe carrying out missions to protect our country and our freedom. These missions lie at the heart of America's safety and their outcomes rely on quick and accurate information being communicated across various domains. Teams of troops must work together to achieve common goals and act as a unified front. The challenge in these domains is that operators are working within communication-intense, distributed environments, where it is difficult to build and share a common operational picture. Rogers's quote illustrates the vast complexity of the current military information world. Information is flowing at a much faster speed than ever before, which renders information management a large problem. To maintain a cohesive organization or team, individual components need shared values, priorities, and understanding to help guide them into meaningful and coordinated action.

For teams to handle the complexity of war, they must learn to manage the complexity rather than reducing it. In most cases, it is simply not possible to lessen the complexities or the uncertainty of war. One way teams manage complexity is through team coordination (Brannick & Prince, 1997). Coordination has been defined as "the attempt by *multiple entities to act in concert* in order to achieve a *common goal* by carrying out a *script/plan* they all understand" (Klein, 2001, p. 70). In order to coordinate across people, there are two primary models of distributed control: centralized and decentralized. These are not separate entities, but rather can be thought of as a continuum. On one end of the spectrum is coordination with a high degree of centralization. This type of coordination is built around a specific plan that is distributed to the actors, and their role is to play out the script. Highly centralized coordination works well in situations when roles, scripts, actions, rules, and intentions are relatively stable, clear, and certain. A drawback to centralized command is that it requires more time to integrate information and relay additional instructions (plans) to the rest of the team if changes occur. This may lead to brittle systems that are slow or unable to adapt to dynamic changes.

On the other end of the continuum is decentralized control, where actors have localized authority to choose actions in service of a more general shared intention, rather than a specific plan. In this type of system, people have the freedom to react to local constraints, which allows adaptation to unexpected events or situations. Each of the interrelated actors is privy to a separate piece of the puzzle, but still dependent on each other, thus it is the responsibility of the different nodes to ensure information and plans are distributed and sufficient enough to produce coordinating action without stifling progress. Intentions and goals are pushed top down; however, degrees of freedom remain at the actor level of the organization, empowering people who are closest to the problem to adapt to local variability.

Suchman describes the importance of adaptability when describing a sailor who sets out on a predetermined course. She emphasizes that the sailor must set out with an objective rather than a plan. An objective is malleable; it can change with the weather or other external conditions (Suchman, 1987). With complexities at sea, the environment is bound to change, and places that once afforded safe travel may not be safe anymore. Perhaps a large storm has developed or a different less-desirable situation has arisen (e.g., a rebel strike on now-dangerous waters). If the sailor was constrained to follow one predetermined path without room for flexible action (or a "normative" plan), he/she could wind up in danger of a much larger problem than being a little off course. Suchman explains that individual actions are continuously constructed and reconstructed through the dynamic interactions people have with their environment. Instead of a rigid, pre-determined plan, Suchman recommends providing sailors (or operators) a rough outline with enough detail to inform the decisions of the sailor, but flexible enough to allow changes and adaptations based on local constraints they will face (Suchman, 1987). This view is consistent with the basic tenets of coordination with a low degree of centralization, and it works best during situations when the organization is faced with a dynamically changing environment. This type of system can be incredibly resilient in adapting to changing threats and opportunities.

The danger with a decentralized control method of coordination is the possibility that components will start acting completely independently or out of synch with one another. To be successful, there must be a rich information coupling to ensure actors are aware of their teammates' actions. In other words, different parts of the organization must be communicating with each other for joint collaboration and coordination to be successful. With rich information coupling, a flatter, less centralized configuration always outperforms a centralized model in terms of its resiliency and adaptability (Arquilla & Ronfeldt, 1997).

The United States Air Force promotes centralized control and decentralized execution to maximize strengths from both coordination methods.

> *Centralized control and decentralized execution provide commanders the ability to exploit the speed, flexibility, and versatility of global aerospace power. The unique vigilance, reach, and global power abilities of aerospace power to maneuver, to achieve strategic and theater effects, and to complement joint operations are inherently dependent on centralized control by an airman. (*United States Air Force, 2001, p.5)

Centralized control and decentralized execution is carried out through the use of various command and control (C2) elements, such as Air Operations Centers or Airborne

Warning and Control Systems. These elements are essentially large groups of people who are responsible for carrying out high level directives (centralized control) in various ways (decentralized execution). These teams work with a variety of other C2 elements to produce desired effects. Military command and control has been defined as:

> *The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission.* (Staff, 2001)

Communication as a Means of Performing Complex Work

The crux of making these complex situations and plans work successfully is the ability to convey useful information to those who need it when they need it. Communication is not an end in itself, but rather a means to do complex work. Historically, military leaders, command and control teams, and war fighters have been faced with performing difficult operations amidst the fog and friction of war. The situations these teams operate under are "rife with complexity and change," and the tempo of operations is steadily increasing (Gorman, Cooke, Winner, 2006; Bryant, Webb, & McCann, 2006). Complex chains of events often require frequent shifts between combat, peace-keeping, and humanitarian missions. These varying mission types often include the requirement of communicating and collaborating with other military coalitions and non-military groups with varying levels of sophistication (Essens, Spaans,

& Treurniet, 2007). In addition, over the past couple decades, enemy tactics have evolved into a much more elusive threat, with a distinct shift to non-traditional warfare techniques (Macloud, 2005). As stated in the Army Cyberspace Operations Plan:

> *The diverse and wide arrays of agents who use or exploit this technological revolution pose a grave threat to U.S. critical infrastructure and operational missions. These agents range from traditional nation-states to noncombatants, transnational corporations, criminal organizations, terrorists, hacker unions, mischievous hackers, and the unwitting individual who intends no malice. Collectively, they combine to create a condition of perpetual turbulence without traditional end states or resolution.* (United States Army, 2010, p. iii)

It is precisely this high degree of complexity and continuous change that renders war much more than an individual endeavor. Rather, it requires teams of people working from multiple perspectives to put the pieces of the puzzle together. In addition, military teams are often distributed across both space and time, which further increases the complexity. The combination of different geographical and temporal elements further render distributed, virtual teams highly complex (Duarte & Snyder, 1999). Distributed teams have higher degrees of freedom than face-to-face teams, but also additional challenges including the ability to maintain a shared understanding.

To maintain a shared understanding of team situations, actions, and goals, teams must rely heavily on voice and electronic communication. To maximize the effectiveness of these communication tools, it is important to understand the underlying communication mechanisms they are designed to support. The theoretical assumptions about how the communication process works have evolved, along with the overall image of communication, but researchers still have disparate opinions. Traditionally, communication has been viewed as a transmission of information from a speaker to a passive recipient, similar to sending a telegraph (Shannon, 1948; Clark, 1996; Reddy, 1979). One person develops a message, sends that message (via words or otherwise) to a recipient, who then encodes the message and ascribes meaning to it. The recipient then becomes the producer of a message in response. This view can be likened to a computer, sending and receiving messages in serial order, and thus the mental process of encoding and decoding are central to the theory.

A more recent view of communication uses the metaphor of two people dancing rather than the metaphor of a computer sending messages. The dance metaphor is used to demonstrate that the people communicating are not working in serial order, sending and receiving messages back and forth, but rather are constantly monitoring the other, through a constant negotiation of stance and understanding (Shanker & King, 2002; Clark & Brennon, 1991; Clark, 1996). This description of communication incorporates dynamic changes and adjustments that occur in real-time; partners must move in synchrony and to a shared rhythm. To achieve their goal, the dancers must monitor each other's movements and make necessary adjustments to stay in tune. In addition, the music itself and other dancers or obstacles located on the dance floor impose constraints on the dancers that must be taken into consideration to achieve successful coordination. In order to perform a "dance" of communication, both parties must attend to their partner, monitor his/her level of understanding, and maintain an awareness of the contextual landscape as well in order to make real-time adjustments to their messages and maintain a shared rhythm or cohesive conversation. For command and control, the music and other dancers or obstacles on the floor can be likened to the tempo of operations and number of participants, which further shape the landscape of the command and control context, and thus communication.

In the same vein, communication has also been likened to a game of charades, capturing the cooperative, on-going, synchronous nature of communication (Griffin, 2009). To be successful at the game, the actor needs to monitor his/her teammates for their understanding and to use clues that would be accessible to the group. The best clues are those that the actor and team can mutually understand, relate to, and reference. In other words, clues (or messages) are successful to the extent that the players share a common interpretation of the signs (i.e., gestures) that the actor uses. In the communication realm, the clues can be thought of as both explicit messages as well as non-verbal cues. A speaker's message is only effective if the recipient has a shared language and understanding of the words selected. The game of charades also illustrates the power of verbal and non-verbal methods of communication. Even without using words, the actor is able to convey his/her "message" to the team of guessers.

The dynamic adjustments used in charades are similar to the "surprise" version of twenty questions, where an individual is to guess an object based on no more than twenty yes or no questions. The surprise version is a little different than the usual game of twenty questions. Instead of the group selecting one word at the beginning of the game that an individual will try to guess, the surprise version requires the word be dynamically chosen as the game evolves. The answer changes and evolves as individuals answer yes or no questions, eliminating possibilities as they play. Each person has their own word selected, but this is not communicated to the group. The group members take turns answering each of the twenty questions, while keeping their own word in mind. If someone answers a question in such a way that it renders another participant's word invalid, the participant must then select another word that fits all previous responses. The game ends when the guesser accurately guesses the word that has "evolved" from the questions or when all twenty questions have been asked and the word has not been correctly guessed (Flach, Dekker, & Stappers, 2008). This game emphasizes the dynamic nature of teamwork and coordination, as actors and their environment (i.e., previous answers to the questions) influence each other. The problem itself continues to change as a result of the teamwork and communication, and vice versa. That is to say, the work situation (i.e., the constraints the new word must fit into) is in part created by the communication process (i.e., answering yes or no to the questions) and in turn impacts the communication process (i.e., future yes or no answers).

In addition to communicating the words themselves, understanding is also achieved through the context and manner in which messages are communicated. Clark and Brennan coined the term "common ground" to describe a type of mutual understanding, which is initially built into a conversation and from which future communication builds upon (1991). Common ground includes shared context, knowledge, expertise, beliefs, and assumptions that are mutually understood and negotiated over time and experience (Clark, 1996). Other terms commonly used to describe a mutual understanding include common knowledge (Lewis, 1969), mutual knowledge (Schiffer, 1972), and shared meaning or understanding (Griffin, 2009). The process of negotiation or coordination of common ground is the act of "grounding"

(Clark & Brennan, 1991). This includes negotiating both the content of the communication and also the communicative process itself (e.g., "if I don't call that means everything is okay"). Coordinating process variables can also be likened to the negotiation of pace, tempo, and loudness during a musical recital (Clark, 1996), all of which must be coordinated moment-to-moment to be effective and produce the desired effect.

Two particular models used to manage and coordinate the act of grounding include an optimistic and cautious strategy to gauge understanding. An optimistic strategy assumes the recipient understood the message unless they communicate otherwise (e.g., "Wait, I didn't catch that. Can you repeat?") (Larsson & Traum, 2000; Dillenbourg & Traum, 2006). This type of model would rely on negative evidence to confirm that one has been misheard or misunderstood (Clark & Brennan, 1991). In a cautious model, the recipient is assumed to not have understood the message until explicit confirmation is received (e.g., "Copy. Maverick needs fuel.") (Larsson & Traum, 2000; Dillenbourg & Traum, 2006). This model relies on positive evidence to confirm understanding. Examples of positive evidence include "copy," "uh huh," "yeah" (Clark & Brennan, 1991).

Communication Technology

As teams become more distributed over space and time, technology is the only way to connect these distributed players and allow them to develop common ground. Fortunately, technology has provided ample opportunity to create a rich information coupling between teams and their environment. Cairncross (2001) uses the phrase "the death of distance" to illustrate the vast connectivity of the world today and suggests how the "death of distance" might shape the future. He suggests that most people on earth will become connected to each other through interactive and broadband networks in the somewhat near future. Furthermore, these connections will become available on mobile devices and in remote locations. Essentially, the perceived distance between any two individuals is shrinking. He also cautions about the "deluge of information" that will result with the vast connectivity at our fingertips. To counter information overload, he promotes a need for filters to block, sort and analyze our information.

Rochlin (1997) suggests that technology itself is neutral, but the implementation and coordination structure architected into the system are what drives the outcome. That is to say technology can hinder or help, flatten or heighten hierarchical organizations, degrade or improve performance. As Klein (2001) explains, "a hammer can injure a thumb…antilock braking systems can promote speeding on treacherous roads. The fault is not in the technology, but in the application" (p. 68).

Chat communication is one type of collaborative technology that may have an impact on the ability of teams to coordinate and synchronize one another's actions. Chat communication is a text-based communication tool that allows users to type messages via a keyboard into an internet window and send the written message to someone else (or multiple others) in a distributed location. Real-time communication is conducted over a computer network in virtual spaces that are defined as chat "rooms." A chat room is an online network that users can connect to remotely in order to engage in real-time discussions with others. Chat rooms are often defined by common interests, topic areas, or user population, with different topics warranting different chat rooms. Users can connect to one chat room with a group of users focused on a particular topic or connect to multiple chat rooms simultaneously to gain access to different users and/or conversation topics. Each chat room generally requires the user to log into the room, and a list of all active members is visible.

Dissertation Roadmap

Chat communication is widely used in today's command and control assets; however, the human factors and communication literature on chat communication tends to describe chat technology in negative terms overall. Research on chat communication tends to report chat as being slow, inefficient, distracting to other visual tasks, and overly difficult (Dubrovsky, Kiesler & Sethna, 1991; Siegel, Dubrovsky, Kiesler, & McGuire, 1986; Munzer & Holmer, 2009; Cummings, 2004; Walther, Anderson, & Park, 1994; Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002; Cornelius & Boos, 2003). The research is often framed in terms of diametrically opposed sides: chat versus voice (e.g., radio), focusing on which provides a better capability for communication.

The disparity of the view on the value of chat communication is not limited to groups who do research and groups from the operational communities, but rather the perception of the utility of chat seems to be driven by the nature of the work context that is modeled or studied. The value of the technology is driven by the demands and complexity of the work that it is used to support. Previous research has demonstrated that the effects of the communication medium are mediated by the type of task the group is working on (McGrath & Hollingshead, 1993). This paper takes this idea a step further and suggests the structure of the overall work and complexity of the communication are two ways to functionally divide the research. It is not sufficient to characterize chat communication as good or bad, but rather the value of chat can only be determined relative to how well it fits and supports the specific work context. Thus, we need to carefully consider the representativeness of the experimental task when making generalizations about the value of chat.

The following chapters will describe chat communication in terms of the nature of the work and the demands of the conversation. Through this discussion, the disparity between the two camps, those who claim chat degrades performance and those who claim they cannot successfully perform their jobs without it, will be explored. First, an overview of chat communication from an acontextual research perspective is outlined in Chapter 2. Chat communication from a command and control contextual perspective is then offered. A general overview of the operational command and control environment is first described in Chapter 3, with the widespread usage of chat communication in the operational community detailed in Chapter 4, including comprehensive results from an operational chat survey and subject matter expert interviews. Bridging the gap between the differing opinions on chat communication and the impetus for the experimental research to better align the camps is described in more detail in Chapter 5. Chapter 6 summarizes the design and analysis methods used in the course of this research, and the results of the current study are detailed in Chapter 7. A summary of conclusions and recommendations for further research are described in Chapter 8. References and appendices then follow.

CHAPTER II. Chat Communication

"Chat" is a text based communication tool with two or more people over a computer network. It is generally performed by typing messages via a keyboard that are displayed on a computer screen. Once sent the message will be transmitted and displayed to someone else (or multiple others) in another location. This is similar to email, but tends to be more synchronous, with shorter messages that allow a more informal, dialog-type approach to sending written messages. Benefits to this type of communication include its capability to send quick updates with minimal disruption, to receive synchronous feedback, and to be available asynchronously for future reference.

Chat is different than the face-to-face communication most people participate in daily. Face-to-face communication entails two or more people, in a shared physical space, communicating in real-time, using both verbal and non-verbal messages. Communicators are able to hear verbal messages and can see related gestures, movements, and facial expressions. They are also privy to the environmental context in which the communication is occurring (e.g., noisy conference room, peaceful outdoors, or dangerous military excursion). In some unique situations, chat communication is also privy to the same environmental context (e.g., NASA mission control, Air Operation Centers, etc.). Overall, face-to-face communication is the most widely used form of communication, dating back to the beginning of language (Clark, 1996).

Chat is an alternative form of communication that is becoming increasingly pervasive in our society today. Cairncross (2001) claims the vast connectivity through technology will impact many facets of our lives including changes to privacy, culture, convenience, general cost, and the shape of companies, blurring the lines between family and work life and increasing proliferation of the English language. The U.S. Army (2010) has noted that "technology is evolving at astonishing rates and the proliferation of information and communications technology has changed the context in which governments and militaries operate. From the 24-hour news cycle, to flash mobs, blogs, social networking, and text messaging, the rapid flow of information has changed the social fabric around the globe" (p. 15). The "death of distance" has implications in most facets of life, including the U.S. Armed Forces.

Chat technology has become an integral component in many military operations, both tactical and non-tactical. Chat has been widely used on C2 platforms to perform tactical operations in various branches of the Armed Forces. In fact, chat has become central to the C2 mission and drives most of the battle space management (Medina, Fugate, Duffy, Magsombol, Amezcua, Rogers, & Ceruti, 2007). In various situations, chat technology has superseded a more traditional radio communication approach. Chat is sometimes the only method of communicating situation updates between distributed nodes of control organizations (Medina et al., 2007), and thus is critical to the success of many missions.

Chat technology is viewed by command and control operators as a useful tool that is essential to mission success in the C2 domain. These individuals feel chat is a useful tool if employed and used properly, and they view chat as a tool that can augment performance and increase their efficacy. Jara and Lisowski (2003) claimed "the success of chat during Operation Iraqi Freedom has proved it to be an excellent tool to support various areas of mission planning, execution, and command and control" (p.54). The impression from human factors and communication experimental research literature is somewhat less clear however. In fact, a large number of studies raise significant concerns about the value of chat relative to other forms of communication. The results of these studies suggest chat is a communication tool that strips away many of the advantageous aspects of face-to-face communication, and replaces them with more effortful means to convey messages (Siegel, Dubrovsky, Kiesler, & McGuire, 1986; Clark & Krych, 2004; Hiltz, Johnson & Turoff, 1986). Chat is viewed as a degradation of voice communication, a slower method of communicating, and perhaps even an impedance to work (Cummings, 2004; Walther et al., 1994; Baltes et al., 2002; Dubrovsky et al., 1991; Munzer & Holmer, 2009; Cornelius & Boos, 2003). Conversely, other empirical studies and qualitative work have demonstrated that chat communication can have a valuable role in complex operational environments and increase efficacy in those domains (Medina, Fugate, Duffy, Magsombol, Amezcua, Rogers, & Ceruti, 2007; Jara & Lisowski, 2003; Patterson, Woods, Cook & Render, 2007; Knott, Bolia, Nelson, & Galster, 2006). To understand the mixed results that research has provided, it is critical to put each study into context. To frame these studies, a command and control model of current communications is first offered, and then different experimental perspectives will be explored in the context of the model.

ALCEC Model

Air Battle Managers (ABMs) are United States Air Force officers who perform command and control tasks as a team aboard various command and control platforms (for more extensive information see Chapter 3). ABMs must ensure the day-to-day tactical mission is executed seamlessly by working with various groups to direct, coordinate, and control forces. Communication between a variety of distributed players, decision makers, and controllers is critical to the success of tactical missions, and as such ABM training is a key element of this skill. The United States Air Force Weapons School trains ABMs to communicate using the ALCEC model. This model stands for Anticipate, Listen, Correlate, Evaluate, and Communicate (ALCEC) and was developed specifically for tactical command and control environments. The model is a way to provide focus to junior ABMs on the critical elements of their new job, namely: anticipating future events or states of players during a mission, confirming what is actually happening, and communicating the situation to the appropriate people.

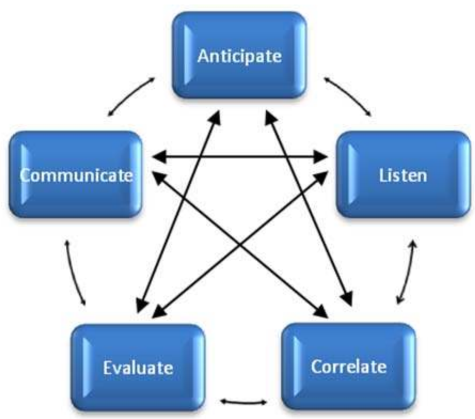

Figure 1. ALCEC Model of Tactical C2 Communication. (Image created by the author, not the operational community).

In the model, *Anticipate* refers to the ability to understand the current battle picture (including who is flying where, what others plan to do, who is changing course, etc.) and also predict what could happen based on the current picture. For example, ABMs may watch aircraft radar information in real time as the aircraft change altitude or perform maneuvers to ensure the aircraft are following the ABMs' guidelines to remain in the approved area that has been deemed safe. If unplanned events occur, ABMs must attempt to anticipate the possible effects and plan mitigations to any possible negative consequences. The *Anticipate* perspective provides a proactive stance to safety.

Listen refers to paying close attention to ongoing communication to understand what is already known, what is unknown, and what information might be relevant. Because the communication channels are already crowded (radio channels in particular), it is critical to be efficient while communicating. Sending redundant or useless information does not achieve that goal. The previous *Anticipate* phase is aimed at understanding and anticipating what is happening in the physical world, while the *Listen* phase is aimed at understanding and anticipating what task-specific information will be needed by other players (e.g., radar information, altitude changes, weather patterns, etc.). There are additional scan patterns taught in conjunction with the ALCEC model that teach an ABM to visually scan information sources to augment communication information with sensor and display information.

Correlate is the act of working to understand the individual actors' methods of communication, operation, and capabilities, and then considering how the ABMs communication might duplicate, correspond, augment, or conflict. For example, it is critical to understand the language and tools other actors have access to (e.g., radar information, range, direction, etc.) to avoid sending duplicative information and to leverage the language that individual actors might expect to hear in a message. This component includes activities like ensuring proper labels are used or correlating radar returns with ABMs message. ABMs may be communicating with various fighter pilots as well as remotely piloted aircraft pilots and the amount of information each has access to could be vastly different. Understanding their frame of reference will help the recipient more easily digest the information and lessen the burden on overcrowded communication channels. In addition, the timing of the message could be critical. An ABM would not want to overload a bomber pilot with information just as they were in a time-critical part of their mission. Overall, this ALCEC phase is described as choosing to "use the right words at the right time."

Evaluate is the act of checking and double checking the ABMs message against other known information, such as previous communication data, radar, air tasking orders, previous plans, and other data points, and ensuring any new information to be communicated corresponds with the entirety of the battle picture. ABMs are taught to consider the messages they will send in advance and ensure their messages make sense in the current context and are accurate. The *Evaluate* phase teaches ABMs to examine their message and determine how confident they are in their message.

Communicate is the final act of conveying the knowledge and understanding to those who need it when they need it, as determined by previous steps of anticipation and evaluation. The ALCEC model does not suggest these steps are independent, linear steps, but rather pieces of a puzzle that make up the overall success of an ABM. Each step builds upon the others, and in turn, impacts the others as well. These phases may happen concomitantly or in a more sequential order.

Communication State Space

Transitioning from the ALCEC model back to the research discussion, Figure 2 outlines a state space diagram with dimensions on the x- and y-axes that represent functional differences in the nature of work and communication. These dimensions are valuable in separating the disparate opinions and research results of chat communication and allow us to view each project in a two-dimensional context. On the x-axis are the demands of the conversation, with simpler conversational demands to the left and more complex conversational demands to the right. The complexity of conversational demands includes various elements that combine to create a complex environment, including things like the amount of detailed information that must be communicated, the temporal demands to convey said information, the temporal demands to act on the information, the spatial distribution of the team, and the size of the team who needs to receive the information. For example, conveying very detailed information about the status and location of enemy aircraft moving through airspace in real-time to a variety of pilots involved may be more complex than communicating the result of a simple arithmetic problem.

The complexity of the work is represented on the y-axis, with simple tasks represented on the bottom and more complex work towards the top. Perrow (1984) defines high complexity work environments as those who have tightly coupled components, with high levels of interaction, where failures of different components may interact in unexpected ways. In other words, these interactive components are closely related with very little slack, buffer, or redundancy, thus creating an environment where a chain of unexpected interactions have the potential to lead to catastrophic events (Perrow, 1984). These types of systems often have high levels of coordination demands, temporal constraints, and possibly spatial constraints. High reliability organizations (HRO's), such as an aircraft carrier, would fall into this highly complex category (Rochlin, LaPorte, &

Roberts, 1987). A simpler environment (e.g., less complexity) would be one whose individual components are more loosely coupled and actions are performed in a more linear manner. An example of this could be building a castle made from LEGO building bricks, which was a task used in a study to examine conversations between dyads (Clark & Krych, 2004).

The difference between the two dimensions can be summed up as the communication dimension describes the complexity of the team structure and information complexity, and the work complexity characterizes the world in which the teams are acting, solving problems, and sensemaking. Because of space limitations in the diagram, only the first author's last name is listed in the diagram. Each of the full citations can be found in the reference section. Not all of the authors listed have exclusively studied chat communication, but rather this represents a larger body of applicable research. Those who have explicitly reported positive views on chat communication or the affordances it offers are colored green, while those who have explicitly reported negative views on chat communication are colored red, neutral or mixed reviews are in black.

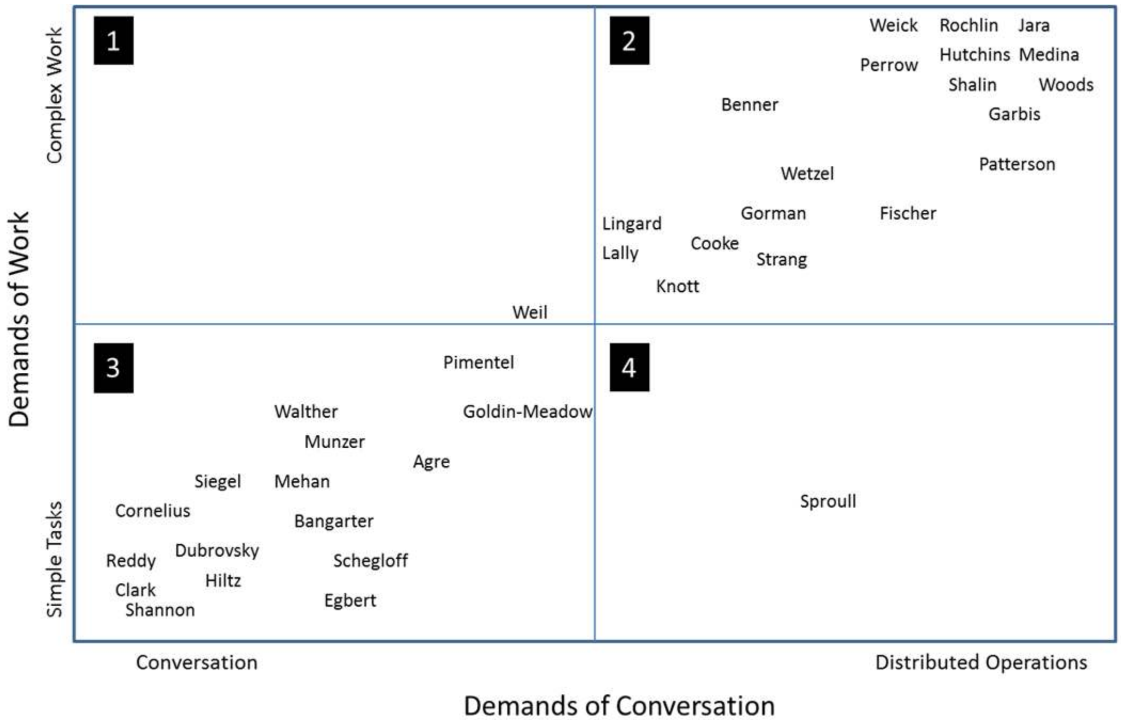

Figure 2. Functional differences in the nature of work and communication

Simple experimentally controlled environments, Quadrant III

The lower left quadrant (box 3) represents environments that have greater simplicity and allow more experimental control. These environments tend to have components with linear interactions and are often loosely coupled. Simple environments do not possess the same potential for catastrophic error with equivalent magnitude that complex environments do. The communication demands of this quadrant are characterized with fairly simple information that must be conveyed, fewer temporal demands, communicators in close physical proximity to each other, and information that remains constant unless impacted by a known agent.

An example of a study one might find in this quadrant is illustrated with a study done by Clark and Krych (2004). The premise was to develop an understanding of how speakers monitor the person they are speaking to for understanding, through both verbal and gestural cues, and how this information is used to tailor future messages. They had dyads of participants assemble LEGO models as a team. The pairs were split into director and builder positions. The director was given a physical LEGO model and their role was to direct the builder in creating an identical model. The builder was to follow the director's instructions and assemble the model. There were five different conditions that impacted the shared visibility of the participants and of their workspaces. These conditions were as follows: partners could see each other's workspaces, partners could not see each other's workspaces, partners could see each other's faces, partners could not see each other's faces, and a non-interactive condition where instructions were videotaped prior to the building phase. Except for the non-interactive condition, the communication between the teammates happened in real time.

To understand how teams monitored each other, Clark and Krych examined various performance measures and communication behaviors, including but not limited to: the total building time for each LEGO model, errors made, communicative turns taken, number of words spoken, amount of deictic expressions (e.g., this, that, here, etc), amount of speech delay, and gestures made. In addition, they reviewed video recordings of a sample of the sessions and broke the task into building and correcting components and calculated each of these segment times.

Clark and Krych found that people were substantially more efficient and less-error prone when they could monitor each other's workspaces. Monitoring each other's faces did not lead to any significant improvement in task efficiency. Without a shared space (or common ground), some teams developed compensation strategies to achieve the task successfully, but this typically came at a significant time cost. On average, the completion time for trials without a shared workspace was double that of trials with a shared workspace. Many were not able to overcome the challenge without any monitoring of the other participant and the error rates were significantly higher. These results led to the conclusion that speakers use different processes when speaking unilaterally (alone, an uninterrupted speech, etc.) versus speaking in a dialog and process models must reflect this. The most significant difference is that during a bilateral discussion, the recipient of the message can send instantaneous and continuous feedback of understanding, provide feedback at intervals, or remain ambiguous. Each of these inputs has a different impact on the speaker producing the message in real time, and thus bilateral speaking is opportunistic, capitalizing on information as it becomes available. The study results suggest recipient feedback is critical to efficient and accurate grounding of messages, and models of conversation must include this type of input and feedback to accurately reflect the bilateral conversation process (Clark & Krych, 2004).

This paradigm of research tends to be reductionist and attempts to discover generalizable truths that will work in any environment. An information processing or reductionist approach focuses on the underlying mental processes and generally operates on an assumption of an acontextual world. This particular perspective tends to have a very micro-approach to cognition, defining the focus and scope of study as the internal processes to cognition. Research is designed and executed in such a way to isolate specific processes of interest or cognitive limitations (Flach, Schwartz, Courtice, Behymer, and Shebilske, 2010). This reductionist paradigm explains complex phenomenon by breaking it into its simpler elements for scientific study and rigorous testing. There is a long history and tradition of decoupling processes and isolating process boxes into discreet objects of study. Oftentimes, entire research programs are developed around the individual steps.

In terms of the operational and training model of communication, the way this paradigm might represent the ALCEC model is through sequential information processing stages, much like many of the models of language treat communication as a transmission metaphor, moving sequentially along a series of steps. The primary focus of the ALCEC model from this viewpoint would be on the individual steps and less so on the interconnections. In this type of model, the process starts with a sensation/stimulus in the world and ends with a response or action in the world. It does not consider the idea that these might be interacting in different ways. This is essentially a type of open-loop approach, focusing on the input-output relations for individual stages (Jagacinski & Flach, 2003).

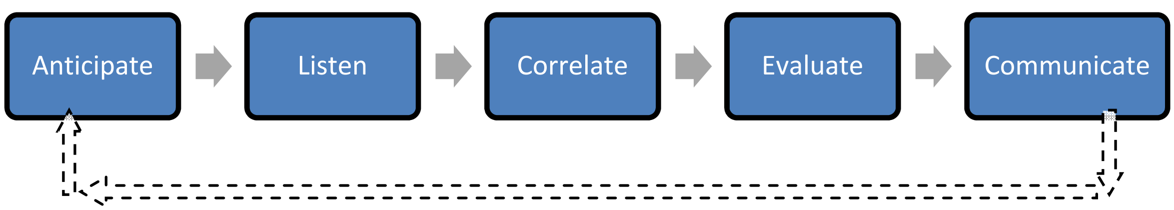

Figure 3. ALCEC Model from an Information Processing Paradigm

<u>Views of Chat Communication</u>

When chat communication is studied from this perspective, views of the technology tend to be very negative. Numerous research studies have pointed to vast amounts of negative attributes and unwanted effects of the implementation of chat technology relative to voice communication. The sections below outline some of the most common negative findings.

Lack of Verbal Cues

A primary concern with chat communication is the inherent lack of verbal and nonverbal cues it affords. Written communication is explicit and long-lasting, but on the other hand, strips away the verbal and non-verbal cues that people rely on daily to communicate ideas, intentions, and goals. People monitor each other for understanding during the communication process and chat messaging may impede this process or make it more difficult (Clark & Krych, 2004; Storper & Venables, 2004).

Verbal cues are those that can be pulled from the vocalization of sounds and the prosody of speech, including the words being spoken and also the way they are spoken. A person may convey a message by whispering or screaming. Each of those verbal cues conveys something about the message that the words themselves do not. With chat messaging, these cues are no longer present, but there are ways to insert them back into the message. One way to convey volume or urgency is to type in ALL CAPS (Schonfeldt & Golato, 2003). If the message is typed in all capital letters, the person can assume the message is either important or the sender is yelling for another reason (e.g., anger, frustration, excitement, etc). While not error proof, there are ways to infuse some of the lost context back into the messages. Another possible way of making verbal cues explicit is through the use of labeling. The words people choose can convey additional meaning beyond the word itself. Researchers have looked at labels and the politics of representation as a contextual or implicit cue (Mehan, 1993). Labels turn out to be a very powerful contextual cue. If shared, these types of labels can carry a lot of meaning, with very little collaborative effort (Mehan, 1993). Labels can be specified in a common culture, agreed upon words decided in a pre-planning type situation, or they can emerge in real-time out of a shared understanding of the work/context and the intention (Shalin, 2005). An example of an emergent label occurred with the crew working on the Mars-Rover exploration. They wanted to "test the waters" by sending the Rover just to the edge of the current area to verify the next route was safe and as expected. This was likened to a child testing the temperature of the pool with his/her toe before jumping straight in. Using this analogy, they came up with the term "toe dip" to convey the intention of "testing the waters" (Shalin, 2005). This type of terminology may continue to evolve to satisfy the problem of distributed communication.

Lack of Non-verbal Cues

Not only do people use verbal cues to infer meaning above and beyond the actual words being spoken, they also use non-verbal (paraverbal) cues to infer meaning of the message and also to determine if their message was received and understood. Non-verbal cues include things like eye contact, gestures, facial expressions, body movements, and posture that convey information about both the speaker and recipient. Chat communication threatens to eliminate non-verbal cues, both sending and receiving.

Clark and Krych found that as people communicate, they are constantly looking to the other for confirmation of understanding, which then allows them to make real-time corrections for misunderstandings. Confirmation is often not through any explicit verbal message, but rather speakers are picking up on non-verbal behaviors of the recipients, such as head nods or a confused affect. Speakers often stop mid-utterance to make corrections, and thus are not relying on a verbal response to indicate a misunderstanding (Clark & Krych, 2004;). People use non-verbal cues in part to further the development of common ground. Information is exchanged with non-verbal cues in a very low-cost, low-effort manner. Non-verbal cues have been shown to effectively communicate information about the disposition and/or stress levels of both the speaker and listener (Wetzel, Kneebone, Woloshynowych, Moorthy & Darzi, 2006). In addition to speech, non-verbal cues may serve to guide behavior and promote learning.

Chat communication currently does not capture the communicators' movements or affect (unless explicitly communicated via text or another technology), thus participants are unable to receive non-verbal cues of others. People tend to adapt their textual and linguistic behaviors to develop strategies for conveying and receiving the information they need (Walther, 1992; Schonfeldt & Golato, 2003), but again this will come at a cost. For example, a common non-verbal expression of smiling to show agreement, enjoyment, or happiness may turn into a "☺" in written text to convey the same emotions (Fineman, Maitlis & Panteli, 2007). That is to say, humans are opportunist and adaptable, and they will opt for the grounding methods that are the most efficient (Clark & Brennan, 1991).

Bangarter and Clark coined the term "activity marker" to describe words used to communicate changes in emotion, action, or purpose (Bangarter & Clark, 2003). In chat communication, there are fewer implicit markers of discourse to signal understanding or agreement (e.g., head nods, silence, pauses, confused expressions, smiles), thus markers of discourse or other methods of establishing common ground, signaling understanding or agreement, need to be made explicit, requiring more collaborative effort (Schonfeldt & Golato, 2003). If non-verbal cues are not somehow replaced with agreed upon messages (e.g., activity markers, labels, smiley faces, exclamation points, etc.), performance may be degraded.

Lack of Gestures

In addition to reducing the implicit markers of discourse, chat also threatens the use of gestures. Goldin-Meadow found that gesturing may help people solve problems and produce language (1998), thus a lack of gesturing might be detrimental. Gestures have been shown to increase third and fourth grade students' math ability and comprehension of verbal math instruction (Cook & Goldin-Meadow, 2006). Gestures are thought to convey or highlight different information than speech alone (e.g., visuospatial information). Other studies by Goldin-Meadow demonstrated that blind subjects use gestures in much the same way seeing people do, to augment what they are saying (Goldin-Meadow, 2006; Iverson & Goldin-Meadow, 1998). Interestingly, she noted that blind participants gestured despite the fact that they could not see the movements, and they also gestured to other blind participants who were also not able to see the movements. She claimed there is something fundamental about gestures and perhaps they actually help us to produce language (Goldin-Meadow, 2006; Goldin-Meadow, 1998; Iverson & Goldin-Meadow, 1998). This idea is consistent with Lakoff's theories of an embodied mind. He suggests that language evolves from our physical experiences, in much the same way Goldin-Meadow describes (Lakoff & Johnson, 1999). The physical act of typing messages reduces one's ability to gesture with his/her hands while communicating. As voice-to-text technology becomes more widely available, gestures may become more prevalent.

Speed

One of the problem users face with chat communication is that, stripped of verbal and non-verbal cues, the strategies for reducing uncertainty generally come at a significant speed cost. Chat communicators adapt their online behavior and add additional cues into the message that would already be present in traditional face-to-face communication. Numerous laboratory studies have shown that communicating with chat is much slower than communicating with voice (Dubrovsky et al., 1991; Siegel et al., 1986). Some have even shown speeds reduced on the magnitude of four to ten times slower than face-to-face communication (Dubrovsky et al., 1991; Siegel et al., 1986). Often these studies attribute the slower speed to the time it takes to physically type the message rather than speak and the time it takes to read a message rather than listen (Munzer & Holmer, 2009). This is often referred to as production and receiving costs. Perhaps for similar reasons, chat messaging has also been shown to produce fewer overall remarks (Hiltz et al., 1986, Kiesler, Zubrow, & Moses, 1985; McGuire, Kiesler, & Siegel, 1987; Siegel et al., 1986; Bordia, 1997).

The reported slower speeds of communicating and accomplishing tasks while using chat may not be simply a result of production and/or receiving costs. Clark and Krych found that particular joint activities took twice as long when participants were not able to see each other's work stations, even though they were communicating verbally (Clark & Krych, 2004). Segal found this shared knowledge of action is useful even if it is unrelated to the verbal communication (1995). For instance, watching a co-pilot put down the landing gear while discussing the weather provides two types of valuable information to the recipient: the state of the landing gear and the weather, for a lower coordination cost. The process of developing common ground may be more arduous in a distributed environment where a shared environment is not visible to each player. Studies that have shown a decline in speed may be illustrating the difficultly in establishing common ground in distributed environments, rather than a true effect of the communication modality.

Lack of Social Cues

Social discourse has been shown to shape a novice's development, including their values and attitudes towards the work and organization (Lingard, Reznick, Espin, Regehr, & DeVito, 2002; Lally, 1999). For example, during shift handover with other nurses, the traditional ritual not only passes along information, but helps to develop and enhance a shared value system amongst teams of nurses. Junior members are taught, shaped, evaluated, and socialized into the nursing world (Lingard, Reznick, Espin, Regehr, & DeVito, 2002; Benner, 1999; Lally, 1999). Research has also shown that for novice surgeons, paying attention to the communication interactions (both implicit and explicit) between other doctors and nurses aids in their career development. Learning how to handle tricky situations by monitoring others for understanding turns out to be a part of their success (or failure) (Lingard et al., 2002).

Researchers are concerned that communicating through a computerized media may impact this essential socialization and promote more impersonal interactions

(Walther, Anderson, & Park, 1994). Numerous theories have been developed describing the impact of a lack of social cues, including but not limited to: social presence theory (Short, Williams, & Christie, 1976), cues-filtered-out perspectives (Culnan & Markus, 1987), and lack of social cues theory (Sproull & Kiesler, 1986). These theories have different underlying tenets, but agree the social presence one feels depends on the cues available during the conversation (i.e., verbal and non-verbal), and that a lack of these cues will impact the social development as well as group behavior. In addition, researchers have reported higher incidences of uninhibited behavior happening with chat communication (Siegel et al., 1986; Kiesler et al., 1984; Bordia, 1997), but not all research has supported this finding (Hiltz, Turoff, & Johnson, 1989).

Flattening Organizations

Chat communication has been shown to "flatten" organizations by reducing the emphasis placed on seniority (Dubrovsky et al., 1991; Kiesler & Sproull, 1992; Weisband, 1992; Bordia, 1997; Mehan, 1993). Persistence of messages and a wider distribution range provides greater access to the information. This finding has been somewhat controversial; however, as other studies have demonstrated that chat technologies can both flatten organizations and also reinforce power relations (Spears & Lea, 1994). Mehan (1993) has studied how people make sense out of events, objects, and people in the world. He refers to this act as the "politics of representation" and has found the way in which these items are represented greatly impacts how they are perceived (1993). For instance, calling someone a "guest worker" has very different connotations than calling the same person an "undocumented worker" or an "illegal alien" (Mehan, 1993). He has found that the mode of presentation has similar effects as the labels. For instance, a psychologist who uses very technical terms to describe a child's disorder is assumed to be more competent or knowledgeable than the child's parents who ask simple, oftentimes interrupted, questions (Mehan, 1993). In the nursing field, doctors who "talk the talk" are assumed to be competent, regardless of their actual knowledge (Lingard et al., 2002). Extending these ideas to chat communication, it is possible that chat will impact the presentation of information by standardizing it more or less and thus will "level" out the playing field.

Multiple Conversational Threads and Confusion

Chat communication is at risk for multiple conversational threads happening simultaneously in each room and causing confusion. Simultaneous conversational threads would have different lines of text with topics that could be grouped into different conversations. For example, one person may ask a question about an aircraft, while another person may ask about dinner plans. If a third person responds with "yes," it may not be clear to whom the third person is responding. Thus, a response that may have been meant for one message may be interpreted as a response to a different message. This disconnect could render the statement nonsensical or worse, it may seem logical and thus provide inaccurate information (Cornelius & Boos, 2003; Holmer, 2008). This type of disconnect has also been called a "co-text loss" (Pimentel, Fuks, & de Lucena, 2003). Different conversation threads in a chat room may not be independent sequences of information. One conversation may have split into two sub-topics, or subthreads, which has been called schisming (Egbert, 1997). Egbert describes this as a single conversation becoming multiple conversations. Misunderstandings from these disconnects could cause tactical mistakes in the C2 world if left uncorrected.

Ambiguity

Another potential problem with chat communication is ambiguous or incoherent messages (Munzer & Holmer, 2009), even in the correct "thread," because each interpretation is context specific and requires understanding of the intent behind words and actions (Clark, 1979; Bransford & Johnson, 1972; Agre & Batali, 1990; Suchman, 1987). Agre and Batali performed a study that required subjects to work in teams to put together different pieces of furniture based on written instructions. They found the subjects' understanding of the instructions was situated in their current context and situation (1990). If distributed teams are "looking" at different pieces of the puzzle, messages may seem unclear or ambiguous. The participants' biggest struggle during this process was deciphering intent behind the instructions. The logic of what to do was not clear, and they were unable to interpret if they were performing the actions correctly or not. They did not understand how the commands fit into a larger plan, and thus were not able to sufficiently monitor their own performance (Agre & Batali, 1990).

Reciprocal interpretation depends on situated action, which may be disconnected by computerized communication. In addition, the context of the message does not persist with the message, and thus the message may become incoherent over time. Complications like delays may render the message unclear, dated, or even irrelevant. Through a meta-analysis, Bordia found support for the argument that people's perception of their partner(s) and task is less accurate during computer-mediated communication than during face-to-face communication (1997). In addition, communicators may be more tentative to act on messages, because the intent behind messages may not be clear. Part of the ambiguity with written messages may be a result of time delays and different environmental contexts of the communicators. Unclear messages may lead to gross misunderstandings.

Splitting Resources (Multiple Resource Theory)

One potential negative attribute of chat communication lies within the literature on split attention and resource theory. Single resource theory is predicated on the idea that there is a single pool of resources that can be used in mental tasks. There is a limited amount of resources overall, and these must be allocated across tasks. More demanding tasks (e.g., greater difficulty, higher temporal demands, greater number of tasks, etc.) will require more resources. As demands increase, additional resources will be allocated to the task(s) until the supply is depleted, at which point performance will begin to suffer (Kahneman, 1973).

Multiple resource theory is similar to single resource theory in the sense that there are limited-capacity channels in the brain to process incoming information. Single resource theory believes there is a single pool of resources, while multiple resource theory believes there are separate pools of resources. Navon and Gopher first expanded on Kahneman's single resource theory by suggesting there are multiple processors rather than one single processor to handle task demands (1979). Wickens took this theory a step further and suggested there are actually dichotomous dimensions of resources, including different perceptual modalities and processing codes. He named his theory Multiple

Resource Theory (1984) and this theory is depicted in Figure 4. He suggests there are different pools of resources for spatial and verbal information processing, sensory modalities, stages of information processing, and types of responses. These types of resources are all unique, thus they can be allocated in different ways, in different combinations. A task may demand only one type of processing or it may require multiple types of resources. The underlying concept is the same as Kahneman's – there is a capacity limit to any type of resource.

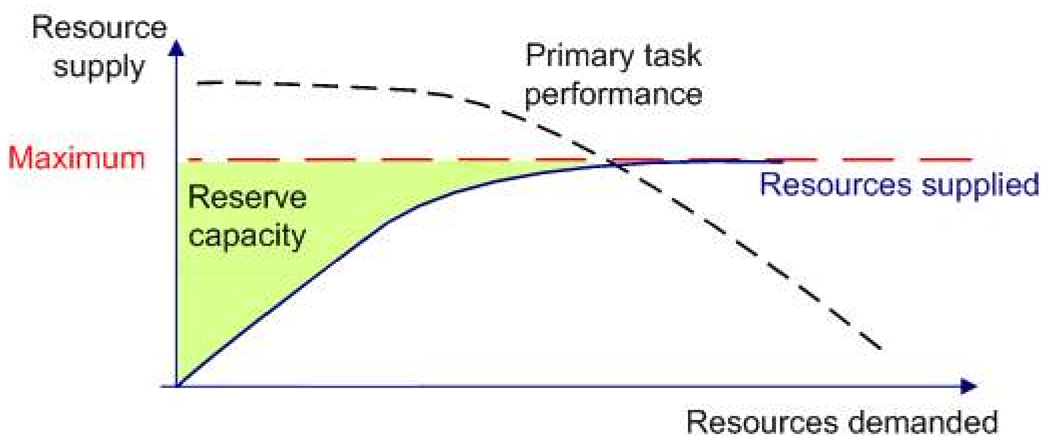

Figure 4. Multiple Resource Theory relationships. Reprinted from Wickens & Hollands, 2000.

Wickens believes that tasks that utilize multiple modalities, or multiple pools of resources, will produce better results. Wickens, Sandry, and Vidulich (1983), found that dual task performance was better when the tasks were cross-modal. In other words, if one task required auditory processing while the other required visual processing, or any other combination of modalities, the overall performance would be better. If tasks were intramodal, splitting the resources of one perceptual modality, performance would suffer (Wickens et al., 1983). Parkes and Coleman (1990) found similar results with a driving simulator. Performance was better when directions were presented auditorily rather than visually, as driving is primarily a visual task.

Multiple resource theory on attention and performance clearly predicts that chat communication would have a negative impact on performance if the primary task was a visual one. Chat is inherently visual and if paired with another visual task, such as monitoring a situation display, the competing resources would negatively impact performance. This theory suggests that voice communication would be better suited to pair with a primarily visual task.

Summary of Quadrant III

Overall, research from this perspective has been very negative about the value of chat communication. This quadrant typically views chat as a communication tool that strips away many of the advantageous aspects of face-to-face communication, and replaces them with a more effortful means to convey messages. Concerns highlight many of the differences between chat and voice communication, including verbal and non-verbal cues, the ability to gesture, and shared environments. The technology is usually cast in a one versus the other type argument with voice communication being far superior. Chat is considered to be a tool that is likely to reduce the efficacy of communication, and ultimately slow down and degrade performance.

Complex and/or operational environments, Quadrant II

Complex environments with complex communication demands reside in the second quadrant (upper right) in Figure 2. Research in this quadrant tends to focus on either directly observing real-world situations or environments or studying situations that closely resemble the complexity found in real-world domains, rather than focusing on simple laboratory tasks or conversations. This quadrant tends to emphasize the interrelationships between the processes and the implication for achieving broader functional goals, rather than on the elemental components of the ALEC model.

As an example of the types of concepts one might find in this quadrant, Weick (1995) coined the term sensemaking to describe how people in complex environments make sense of the world around them. Sensemaking is the act of placing items into frameworks, comprehending situations, redressing surprise, constructing meaning, interacting, pursuing mutual understanding, and discovering patterns (Weick, 1995). The concept of sensemaking emphasizes the dynamic relationship between actor and environment, rather than the environment being considered a static, independent entity that merely affects the actors. Weick argues that actors and their environment influence each other with a level of circular causality. He uses the term "enactment to preserve the fact that, in organizational life, people often produce part of the environment they face" (Weick, 1995).

This quadrant assumes that people are not passive observers, trying to figure out cues; rather, people actively seek information based on their expectations. The world never stops; life is constantly changing, moving, and evolving. Making sense of situations does not occur in discrete chunks of time. It is a constant, continual process of assessing, monitoring, adapting, acting, and refining situations. Thus, the awareness of the environment and communication space is constantly evolving and influencing the other steps.

An example of the dynamic relationship between actor and environment took place at Hartsfield Airport in Atlanta, GA. An air traffic controller decided to put five aircraft into a holding pattern on a clear and "normal" day. In a matter of six minutes, the five aircraft experienced ten near misses, each of which could have potentially been catastrophic. Since there was no weather or other environmental constraint that required this holding pattern, it was said the controller "enacted" an environment that suddenly became difficult to control (Weick, 1995). Weick argues that action is first and foremost in the process of enactment, rather than some analytical action where schemas or visions of the world are created.

Sensemaking is not limited to one individual actor and their environment however, as complex environments involve teams or organizations of people working together to achieve a goal. Chatman (1986) illustrates this point:

> *When we look at individual behavior in organizations, we are actually seeing two entities: the individual as himself and the individual as representative of his collectivity…Thus the individual not only acts on behalf of the organization in the usual agency sense, but he also acts, more subtly, "as the organization" when he embodies the values, beliefs, and goals of collectivity. As a result, individual behavior is more "macro" than we usually recognize.* (p. 211).

Individuals may appear to have focus on local, specific task goals, but they must work to achieve their own goals while working within the context of the larger, global organizational goals. Juarrero (2002) explicates, "when organized into a complex, integral whole, parts become correlated as a function of context-dependent constraints imposed on them by the newly organized system in which they are now embedded."

Collaborative agents must be mindful of their part, all the while striving to help accomplish the organizations purpose. A complex system can be described as a complex fabric of interwoven threads. Breaking one or more of those threads may lead to an unraveling of the entire system.

Woods and Patterson (2000) outline situations where entire systems do unravel and describe how sometimes system or cognitive support tools do not help or even make the job harder. They explain that the challenge is to understand the complex relationships between the problem space, individuals' cognitive abilities, and the artifacts themselves. They outline a concept of escalation which describes how the dynamic relationship between various coordinative and cognitive elements of complex work tend to increase or escalate as the work situations move to more complex or non-standard situations (Woods & Patterson, 2000).

In a similar vein, Shannon and Weaver (1949) pointed out in their information theory that to understand the importance of any piece of information (or event, action, thought, choice), one must understand the field of possibilities. Gibson and Crooks (1982) further described the field of possibilities in their research on locomotion. They coined the term "field of safe travel" to describe all the possible paths a vehicle can take without hindrance in a certain environment. The boundaries include physical objects in the situation and their associated valence. This field of safe travel is not fixed in position, but rather is a spatial field relative to the object and location at a particular time. Thus, the field moves and adjusts as the vehicle moves and adjusts (Gibson & Crooks, 1982). This can be likened to a command and control group monitoring other entities, while also impacting the movements of those entities. The field of safe travel is tightly coupled to the location and position of the object in time.

Bennett and Flach (2011) emphasize the significance of the coupling with their triadic semiotic model of meaning processing that includes the ecological context as an intrinsic component of the cognitive system (see Figure 5). Their model includes the environment, individuals who interact with the environment, and the interface between the two. These interactions are the focus of study, as critical pieces for understanding human behavior.

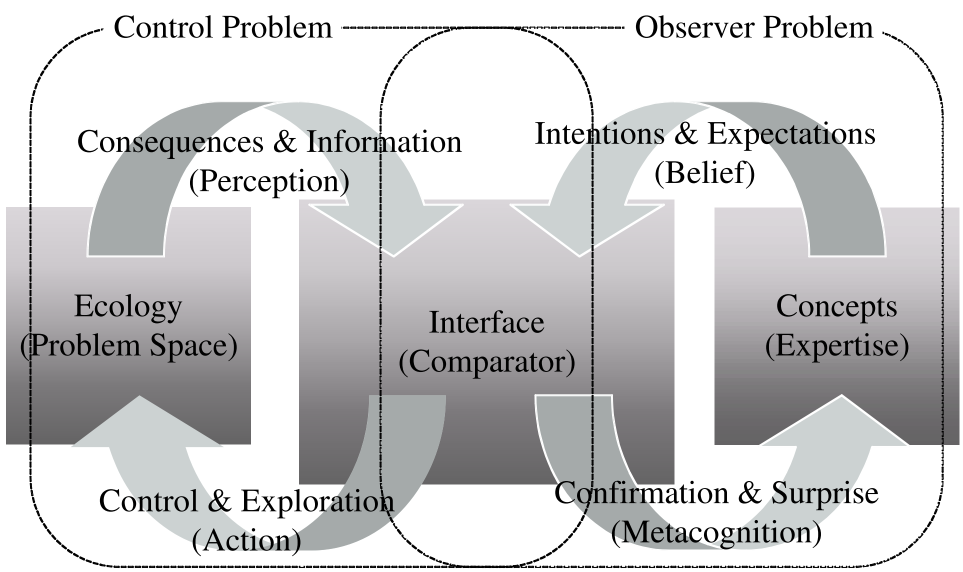

Figure 5. Triadic semiotic model of meaning. Reprinted from Bennett & Flach 2011.

In terms of the ALCEC model, the way this paradigm might represent each of the steps is through strong interconnections between the components rather than through sequential linear stages. It is in this spirit that a broader image of the ALCEC is offered in Figure 6, which is more representative of the C2 operational world. In this complexity perspective, the individual components become less salient and the interconnections become the dominant focus as shown with the cloud outline and solid lines between them. This perspective emphasizes that a reductionist approach that attempts to characterize behavior by segmenting experience into discreet processing stages can fail to appreciate the organization level dynamics and the associated emergent properties. This view is analogous to the dance communication metaphor, with the success being a function of the interaction between the two rather than one transmitting information to the other in sequence. The point is not to ignore the components, but rather to view the components in terms of their functions within the larger organizational dynamic. As with analysis of variance, main effects can only be appreciated in relation to the interactions that they are involved within. The converse is not possible; one cannot discover interactions from only examining main effects.

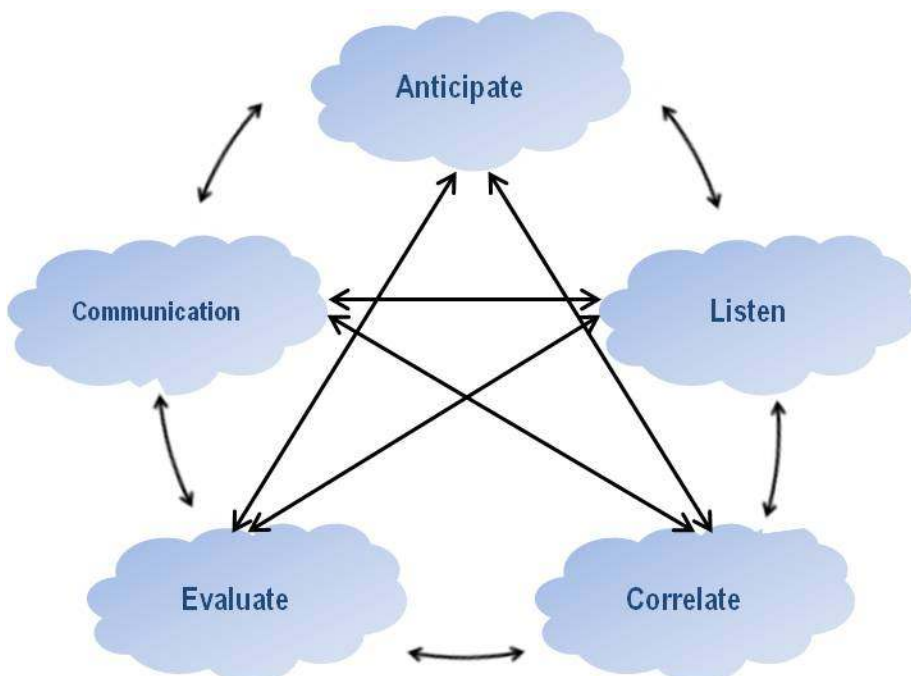

Figure 6. Complexity quadrant view of the ALCEC model.

View of Chat Communication

As a whole, this quadrant tends to have a very different perspective on chat communication than the previously discussed quadrant. There are a host of benefits to this modality of communication that operationally relevant situations might be able to capitalize on. In this context, chat is often found to be a valuable form of communication that may be able to augment voice communication, rather than replace it. The following section outlines some of these benefits.

Archival Information

Archival information promotes the ability to multi-task by supporting both synchronous and asynchronous communication. Synchronous communication refers to communication that happens between two or more individuals instantaneously. For example, face-to-face communication is a synchronous method of communication. Voice communication is driven by the voice messages themselves because it is a transient medium. A person must attend at the moment the messages are sent or the words will disappear and the message will be gone. Clark (1996) states "synchrony is required in [verbal] conversation because speech is evanescent. If addressees are ever to recover an utterance, they must attend to the speech while it is being produced, and that requires speakers and addressees to synchronize their processes" (Clark, 1996, p. 90). If the message was sent verbally, the recipient may either miss the message, be forced to stop his/her current task to attend, or request the message be resent. Asynchronous communication, on the other hand, refers to messages that can be sent at one time period and responded to at another. Email is an example of an asynchronous method of communication where the recipients do not need to be present or available to communicate and can respond at their leisure.

For messages sent via chat, the recipients can choose to communicate either synchronously or asynchronously, depending on their current task load. They could attend to the message immediately or finish their task and respond when the time was more convenient. Chat rooms store data and allow users to subscribe to various rooms, thus an individual does not necessarily even need to be in the room at the time of the message, but theoretically can still retrieve that message at a later date (Medina, 2008).

In addition, the persistence of chat data could reduce the amount of information a person is required to remember. This memory aid capability would be most compelling during situations where the user has a heavy load of information to remember (e.g., a situation where a controller is required to remember multiple pieces of information like aircraft altitudes while doing a simultaneous task). These memory aids may be similar to the idea of "speed bugs" that Hutchins describes (1995).

Archival information may also serve as a "linguistic artifact" which complements activity by serving as a memory augmentation. Clark (1998) explains this concept with an example of leaving a post-it note on a mirror to prompt recall. A linguistic artifact can be likened to physical item or external manipulation, such as leaving a briefcase by the door to ensure one remembers to grab it (Clark, 1998). An operator may see text that jogs his/her memory in the same way that a post-it might. With a transient voice message, there is no lasting linguistic artifact to prompt action at a later time.

A distinction should be drawn here between archiving information and information being visible. The capability of archiving messages may greatly enhance distributed communication, as long as they are visible. Oftentimes, screen real-estate to display chat communication is limited (e.g., on an aircraft with limited physical space), thus most messages will only be "visible" for a short time. With archival data, these transient messages may be retrieved after they disappear; however, this may prove to be quite difficult in some situations (e.g., a situation where an operator is monitoring eighteen simultaneous chat rooms). That is to say archival information can be useful if the technology is designed in such a way to make it easily accessible after it is no longer visible.

Archival information may also benefit a user by allowing them to reflect on the time history of messages and detect patterns that occur over time. This may be particularly informative during situations that require history of events to be understood (e.g., during shift handovers). As Hutchins says "verbal descriptions typically fail not because they don't provide enough structure but because they provide the wrong kind of structure. The difference between the right and the wrong kinds of structure is determined by both the nature of the task and the other structural resources that are available … Pointing isn't more information than a detailed verbal description: it is a different kind of information than can be put to work in a different way" (Hutchins, 1995, p. 230). There needs to be a match between the type of task requirements and the communicative tools that support a user.

Collaborative Cross-checking

Collaborative cross-checking has been defined as a system where at least two or more individuals or groups from different perspectives review the other's actions and/or assumptions to ensure accurate information and a plausible plan (Patterson et al., 2007). The benefits of collaborative cross-checking include the ability to detect things such as: erroneous beliefs, misguided actions, possible collateral damage of actions, problems with current plans, information gaps, or unidentified key players (Patterson et. al., 2007). Collaborative cross-checking is related to the idea of the "necessary friction" of a system to increase resiliency. Rochlin (1993) describes necessary friction as "an antidote to the inertia of error," meaning it provides the possibility for checks and balances to review courses of action in advance. An example of friction could be the positive verification sometimes required in military communications (e.g., repeat coordinates to ensure correct input).

The cross-checking is possible because chat communication allows multiple players to monitor each chat room. Keeping multiple people in the loop about future action allows proper safety checks and precautions to be put in place. Even if someone joins the chat room after much of the action or decision making has taken place, there is a historical record of happenings, and thus the archival record may still allow for these checks and balances. Redundancy has been considered by many as a source of safety in complex systems (Rochlin, 1993; Patterson, Watts-Perotti, & Woods, 1999). Necessary friction may slow down the communication process, but in a way that helps ensure accuracy and safety. Both of these components (collaborative cross-checking and necessary friction) may increase reliability (accuracy or stability), although this can be at the cost of efficiency (speed).

Anticipation

Chat communication allows operators to monitor multiple chat conversations, thereby increasing their awareness of the overall battle space and other missions, allowing them to anticipate future assignments, problems, or changes to their own plan. Operators might not closely monitor each channel for detailed specifications of other missions, but "overhearing" the conversation may allow them to pick up on relevant information to their own missions. This is analogous to the "voice loops" idea that was introduced at NASA, where scientists were able to overhear other groups' planning and troubleshooting discussions, leading to greater anticipatory behavior (Patterson et al., 1999). That is to say they are passively monitoring conversations in order to anticipate future changes or demands for information and prepare in advance. In addition, they can anticipate potential hazards, synchronize planned events, and understand the rationale for non-routine requests, as well as pick up on non-routine behavior that may alert them to changing situations (Patterson, Watts-Perotti, & Woods, 2008). The idea of overhearing was also an important aspect of successful performance with difficult aircraft carrier landings (Rochlin, LaPorte, & Roberts, 1987). Overhearing may help foster common ground with less effort by providing a shared context.

Reducing Social Pressure

Researchers have found there is less normative social pressure in chat communication, and people are less likely to conform to a group decision (Bordia, 1997). This further supports the idea of necessary checks and balances. With less normative social pressure, people may be more likely to speak up when he/she detects a problem.

Research has also shown that people perform idea generation tasks better while communicating via chat rather than face-to-face communication because of the reduction in social pressure (Bordia, 1997).

Summary of Quadrant II

Overall, research and observations from this perspective recognize the potential value of chat communication in complex operational environments. Performance in this quadrant often benefits from the added value chat can add to existing communication modalities, namely in the areas of archiving information, reviewing time history data, collaborative cross-checking, anticipating future states and needs, and reducing social pressure.

Overall Summary

The differences in researchers' opinions of chat communication seem to be well explained by the structure of the work and the demands of the communication. Face-to-face communication is great for local situations with smaller groups of individuals. For those doing simpler tasks, chat becomes more of a degradation of a system that already works well (e.g., face-to-face communication), rather than a value-added tool. For those dealing with complex domains and problems, the value of chat communication grows. It allows asynchronicity and archival capabilities that voice communication does not. In addition, in complex situations, face-to-face communication is often not physically possible, so other modalities must be considered.

Neither of the perspectives is more right than the other. The value of the technology is mitigated by the situation or environment that it will be used for. In order to effectively implement the technology or decide against it, one must consider the demands and goals that it will support or limit. For simple environments, chat may be a more arduous method of communicating and other tools such as voice communication may be better suited. For more complex environments, the benefits of chat may outweigh the costs, which is perhaps one of the reasons we higher values of chat for tactical command and control. Each focus of study has vastly different underlying tenets, focuses, and conclusions. One potential danger of these differences lies in generalizing the results and information learned from one quadrant of study to another without careful consideration of the differences of communication and work situation and demands. Thus, to understand the potential value of chat for C2, it is necessary to consider the demands of specific C2 environments. The following chapter outlines the C2 environment with particular attention to Airborne Warning and Control Systems (AWACS) and Control and Reporting Centers (CRC).

CHAPTER III. Operational Environment

Overview

Command and control (C2) has been said to be the glue that holds the entire Air Force theater information architecture together (Ackerman, 2009). Alberts and Hayes (2006) suggest C2 is about "focusing the efforts of a number of entities (individuals and organizations) and resources, including information, toward the achievement of some task, objective, or goal." They further suggest that C2 functions establish the boundaries in which sensemaking and execution can take place (Alberts & Hayes, 2006).

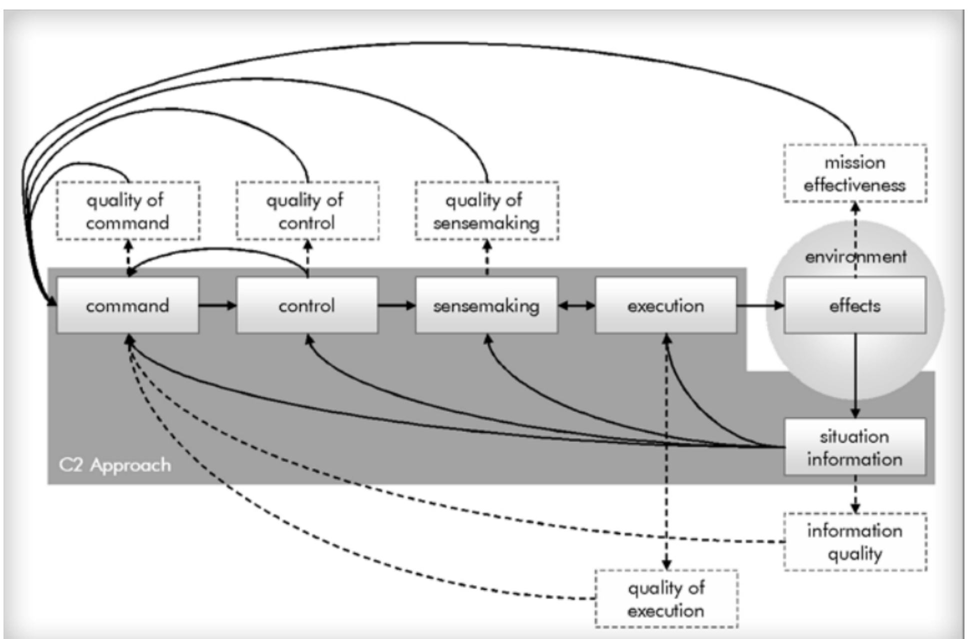

Figure 7. C2 Conceptual Model. Reprinted from Alberts & Hayes, 2006.

The elements, impact, and feedback of C2 functions are illustrated in Figure 7. The boxes in the gray shaded area represent different functions or actions of the C2 approach, rather than separate entities. Each box may involve many different organizations or individuals. The command box represents the act of establishing and communicating initial plans and conditions, continuing assessment of the situation, and making changes to the overall intent. The control box represents the act of monitoring the current situation and actions to ensure everything is operating within the command boundaries and making adjustments if necessary. The sensemaking box represents interactions between entities aimed at making sense of the situation, problem solving and developing responses to create desired effects. The execution box is the act of performing the response plan developed in the sensemaking section (Alberts & Hayes, 2006). It is important to note that these functions are not mutually exclusive, and each depends on the feedback from the other functions.

As an entity, C2 is crucial to the success of the armed forces. In the U.S. Air Force, there are multiple platforms that perform C2 functions, including E-3 Sentry Airborne Warning and Control Systems (AWACS), Control and Reporting Centers (CRC), Air Operation Centers (AOC), E-8 Joint Surveillance Target Attack Radar Systems (JSTARS), as well as many others.

Current Platforms

The E-3 Sentry is an Airborne Warning and Control System (AWACS) that provides all-weather surveillance, command, control and communications needed by commanders of U.S. military forces, North Atlantic Treaty Organization (NATO), and other allied air defense forces. The E-3 is a modified Boeing 707 commercial airframe with a rotating radar dome as depicted in Figure 8. The rotating dome contains a million-watt doppler radar system. The radar and the computer systems can gather and present a variety of detailed battle field information, including position, tracking, and status information for friendly and enemy aircraft.

Figure 8. United States E-3 Sentry, AWACS.

A Control and Reporting Center (CRC) is a similar C2 platform that is housed in a ground-based environment and is illustrated in Figure 9. The CRC uses multiple data links from sensors that are air, sea, and land-based to produce a similar air picture as that on an AWACS. CRCs perform “decentralized command and control of joint operations by conducting threat warning, battle management, theater missile defense, weapons control, combat identification, and strategic communications” (United States Air Force, 2009). CRC’s are a key component of the U.S. Air Force Theater Air Control System (TACS).

Figure 9. United States Control and Reporting Center. Reprinted from USAF, 2009.

Functional Groups

The AWACS and CRC's overall missions are to provide air surveillance, warning and control capabilities in support of alliance objectives. Numerous personnel are aboard the aircraft and in the ground station, all grouped into small teams performing unique job functions. Functional teams include pilot and navigation team (exclusively AWACS), weapons team, surveillance team, and various technicians and maintenance teams. Figure 10 illustrates the locations of each function aboard the jet. The weapons and surveillance teams are listed as "data display and control" in the diagram. Figure 11 depicts a team working inside of the jet. The CRC has similar functions but substantially more people. A full CRC unit is approximately 350 personnel, but not all of those individuals are involved in direct C2 roles.

Figure 10. Standard configuration for AWACS. Reprinted from NATO, 2007.

Air Battle Managers

Air battle managers (ABMs) are individuals who perform command and control tasks as a team on various C2 platforms. An ABM's primary duty is to ensure the day-to-day air mission is executed. They are responsible for holding the plans together and ensuring communication occurs between various groups. They primarily accomplish this task by using radar and communication systems to provide an overall battle picture to the troops involved who are not privy to all of the information systems that an ABM has access to. ABMs keep track of all aircraft in a particular region, ensure deconfliction and safety of friendly assets, and provide information about dynamically changing air threats. Essentially, ABMs are responsible for an incredibly complex system of a variety of people and technology, including manned military aircraft, unmanned aircraft, helicopters (both military and civilian), commercial airliners, Army troops on the ground, ammunition or weapons that may impact or compromise the airspace safety, as well as enemy activity or other unrelated threats like weather balloons or large flocks of birds. They ensure everyone is playing on the same sheet of music, because even one rogue player could have catastrophic results.

Figure 11. Air Battle Managers at work aboard an AWACS (NATO, 2007).

The crux of organizing and ensuring the safety of everyone involved is through communication channels. ABMs must have a clear understanding of what is happening in each block of airspace they are responsible for and must ensure the safety of those in the area through appropriate separation. They must understand the plan each player is to follow, ensure he/she follows the plan, and update the plan as the mission requires. They must react quickly to unexpected events that may endanger their airmen and ground troops and provide timely communication to do so. ABMs have neither direct control over any aircraft or ground troop nor are they collocated with any of these players, thus they must rely on effective and efficient means of distributed communication. If they are unable or inefficient at communicating critical information, they are rendered useless.

ABMs have been referred to as the "keepers of the comm.," meaning they are the gateway of information to a vast number of individual actors.

Effective communication is one of the most critical pieces of an ABMs job, and thus training ABMs to accomplish this feat is also critical. As previously mentioned, the United States Air Force Weapons School trains ABMs to communicate using the ALCEC model. With successful communication, ABMs are critical to the effective coordination of all the tactical players. *"In the past ten years, the U.S. Air Force has realized the benefits of what ABMs provide to the fight and has grown our utilization…you can find ABMs at pretty much every level and in most C2 related communities"*(Operational interview). None of the ABM duties are mutually exclusive; each is important to the primary goals of the others, and thus teamwork is also central to their success.

An ABM position on an AWACS is an exclusively officer-only position. In a CRC, it is possible to have a mix of officer and enlisted controller positions. The ABM position is still officer-only, but there are also enlisted controllers performing very similar work. The enlisted individuals fall under the title C2 Battle Management Operators. For the sake of simplicity, the current document references only the ABM position, but the findings and suggestions could be generalized to the C2 Battle Management Operator as well. Those on an AWACS and in a CRC have similar duties, must work together, and are housed under the same Air Control Wing, thus controllers from both platforms were used in the current study.

Training Events & Locations

In order to capture the demands of an actual command and control environment in the laboratory, it was necessary to first explore the types of events, scenarios, and demands ABMs are faced with every day. The specific set-up and implementation in the lab is described in more detail in later chapters, but the current chapter describes the ways in which we became knowledgeable about the domain. Over the span of two years, a team of researchers journeyed to multiple locations, training exercises, and military conferences to learn about the operational environment. Below are a list of the major events we were able to attend and the locations where operators were interviewed.

Weapons and Tactics Conferences, Nellis AFB

The Combat Air Force's (CAF) Weapons and Tactics Conference is an annual two week event that brings together hundreds of warfighters to discuss current issues, prepare for future needs, and provide solutions for joint employment of forces. Our research team was able to attend the group sessions, as well as meet with individual warfighters to discuss their operations.

Weapons School exercise, AWACS flight, Nellis AFB

The U.S. Air Force Weapons School teaches graduate level courses to provide advanced training in weapons and tactics employment to officers of the Combat Air Forces. Within the graduate program, ABMs must take periodic exams to exercise and prove the skills they have learned. The mission exercise we attended was a large scale, live-fly exercise, with multiple aircraft involved. Our team of researchers was able to fly aboard the AWACS jet during the exercise to witness tactical command and control in action. We also attended all the pre- and de-brief sessions.

Operator Interviews & Training Simulation, Tinker AFB

Our research team had the opportunity to sit down with a group of ABMs and technicians who had recently returned from a theater deployment as an AWACS crew. The operators described their C2 missions and communication in great detail, including common events they faced in the current conflict. They also provided extensive detail about the communications that occurred during these events. After the interviews, our research team was able to observe a deployment training exercise, which included various C2 tasks, as well as the usage of voice and chat communication.

Interviews w/ the AWACS Joint Test Force, Seattle, WA

Our research team met with various members of the Joint Test Force (JTF), chartered to manage and perform all testing for future AWACS jet upgrades. The JTF team has diverse deployment experiences and backgrounds. During the sessions, the JTF team described their C2 missions in great detail. They provided information about the types of events that are common in the current conflict.

AWACS Technology Systems Working Group – Hanscom AFB

The Technology Systems Working Group is a semi-annual event that brings together decision makers from various military groups to discuss operational issues and future needs, and to develop financial plans to meet objectives. Our research team was able to attend the sessions, as well as meet with individual warfighters to discuss the details of their operations and current needs.

CRC spin-up training, Mountain Home AFB

The CRC units have a mobile training center that is used to train troops prior to deployment. CRCs have been using chat communication in a more comprehensive way than the AWACS currently can because of bandwidth limitations, and the CRC training centers reflected this. Our research team was able to witness an entire week of training exercises, as well as discuss chat usage with operators. We interviewed several ABMs with varying levels of experience.

Discussion

The operational interviews, observation periods, and discussions demonstrated the complexity of the operational environment in an AWACS and a CRC, with dynamically changing requirements and situations demanding quick decision making. The more common elements that ABMs must deal with on a daily basis are outlined in greater detail in the methods section, as they were incorporated into the current study. In addition to an overview of the environment, these interviews and training events provided insight into the communication of tactical C2. Through interviews and observations, it became clear that chat communication was a critical component of ABMs daily work. In fact, ABMs were very outspoken about the value of chat and described the value of the technology with a surprising level of criticality. For example, quotes such as "95% of all Command and Control information comes across mIRC [chat]," "without mIRC [chat], we would get sent home [from theater] because we'd be slowing down the decision making process," and "when mIRC [chat] goes down, we're taken out of the fight" highlight just how instrumental chat communication is to the ABM community. Because the majority of tactical command and control information is currently sent via chat communication, many ABMs expressed the concern that without access to chat, they are rendered ineffective at their job, both as an individual ABM and as a broader AWACS unit.

To illustrate the vast amount of communication currently passed through chat communication, one ABM shared an example of what could happen when chat is not available. Internet connectivity to an aircraft is not perfect, and if the chat system goes down for any amount of time, ABMs must transmit necessary information via radio channels. If this occurs, operators have explained that it can overload the radio channels and may upset many users who are not directly involved or interested in the information they temporarily have to pass this way. One anecdote was shared where a Senior Director was using a satellite communications (SATCOM) radio so heavily to transmit crucial information in a particularly challenging mission that his individual hand piece almost broke down from overheating. Another individual stated, "I used chat extensively for five months in OEF/OIF [Operation Enduring Freedom/Operation Iraqi Freedom], and even partial chat is better than no chat at all." From the operators' perspective the benefits seem to outweigh possible technical issues, which is perhaps because "connectivity to a chat window provides command and control opportunities never seen before for the E-3."

The most compelling evidence of the value of chat communication to the operational community however was the lengths that AWACS crews and their leadership went to in order to ensure this technology was onboard their aircraft. Instead of waiting for requirements to make their way through the procurement and acquisition processes, the operational AWACS units created organic ways to implement the technology into their aircraft in substantially accelerated timeframes. If they had waited for the technology to go through a traditional acquisition cycle before implementing this technology, they feel their ability to contribute in theater may have been compromised.

Armed with operational insights and observations about C2 communication, I wanted to know more specific details about how chat communication is used and the situations for which it is preferred. I developed a chat specific questionnaire for the AWACS and CRC battle management communities to ascertain more specific chat details. The following chapter details the survey, outlines communication findings, and continues to illustrate the complexity of the C2 domain. Additional lessons learned from the operational interviews will be addressed in the subsequent chapters.

CHAPTER IV. Chat usage in the Operational Environment

Participants

A total of ninety-three participants from U.S. active and guard duty military, command and control operational units voluntarily participated to complete a chat communication survey. Specifically, participants from the 552nd Air Control Wing were sought through the use of email notifications, and those notifications suggested the email could be forwarded as the recipient saw fit. The email contained a link which allowed volunteers to go to a website location to fill out the online survey. The survey was completely anonymous and remained open for three months. There were neither extrinsic incentives for participation, nor any penalty for not volunteering.

Seventy-eight men and fifteen women completed the survey. The first section of the survey asked demographic and background information about age, gender, military experience, rank, position, career field. These responses can be found in Figure 12. Respondents were all over the age of 18 years, with the majority of respondents being in the age range of 26-35 yrs old (37.9%). The majority of respondents were in the U.S. Air Force (92.9%). The other groups represented were the U.S. Marines (1.2%) and U.S. National Guard (5.9%). All participants were either in AWACS or CRC units. Participants in AWACS units were mostly ABMs (officers), while participants from CRC's were mostly C2 Battle Management Operators (enlisted). The combination of these two very similar job positions accounted for 54% of the respondants, but this number was likely significantly higher because 24% of respondents did not respond to the question.

All respondents claimed to have intermediate or advanced experience with computers (57% and 43% respectively). The greatest number of respondents also claimed to have advanced experience with text messaging (49.5%).

Instrument

The "Chat Communication Survey" was constructed to ask respondents about their current chat usage and their opinions about chat communication tools (see Appendix B). They were told to consider aspects of current communication technology they like and aspects they would like to see changed. The first section contained biographical information questions. Following this section, respondents were asked questions about their chat usage in their current job position. They were asked if they use chat for their job, the frequency at which they do, the number of chat rooms they regularly monitor and if they feel comfortable monitoring that number. Other questions in this section include queries about respondents' opinions about the importance, safety, efficiency, and utility of chat communication. The next section contained open-ended questions asking about their overall usage of chat.

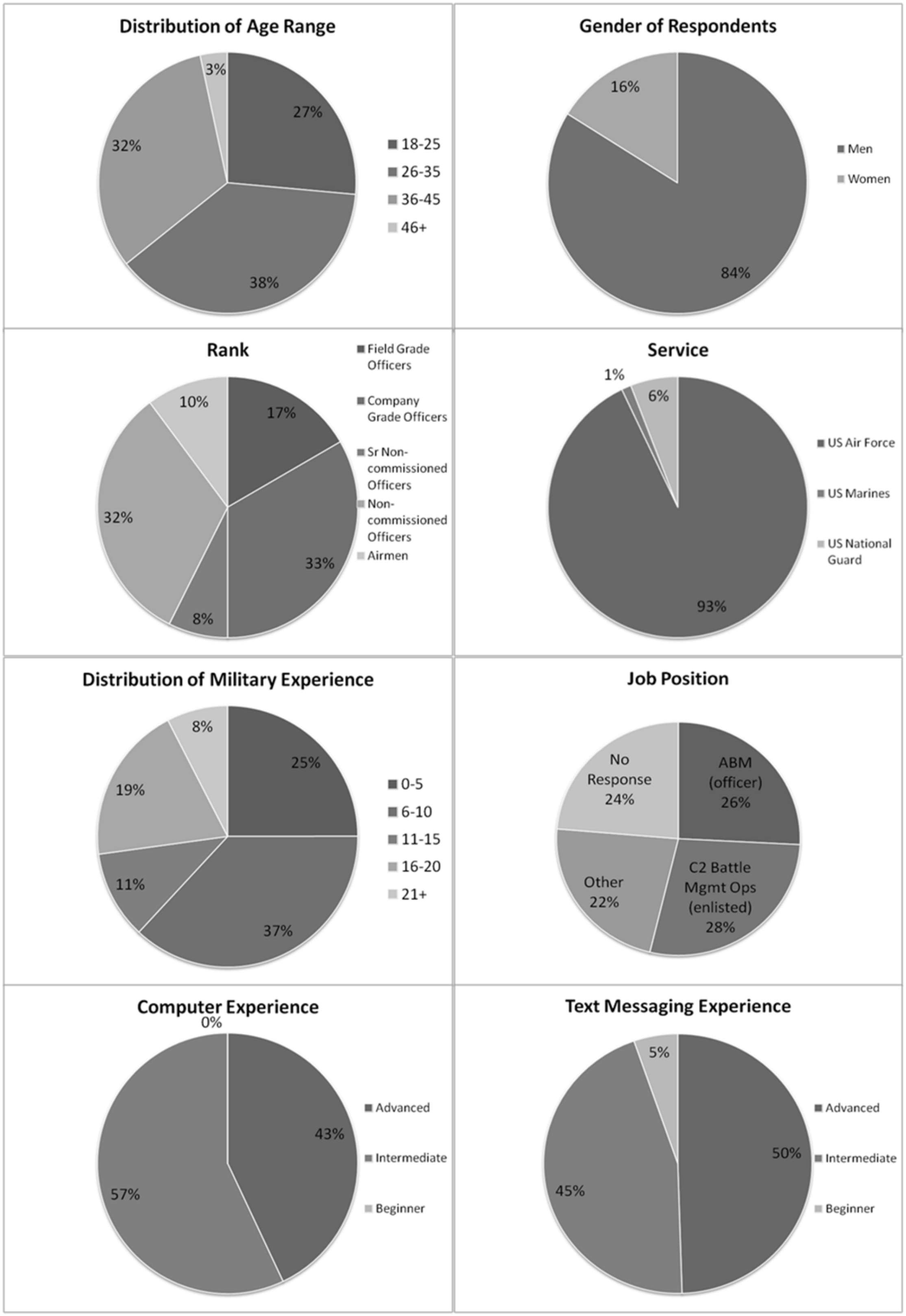

Figure 12 . Biographical information for survey respondents.

Results

Training. Respondents were asked what training (if any) they received for chat communication, and most responded with none or only on-the-job informal training. Only 4.3% of responses listed any sort of formalized training, and these responses included deployment specific training and/or security briefings about general computer threats but not chat necessarily (see Figure 13).

Current Usage. The majority of respondents use chat to communicate in their current job. Of those respondents, most of these individuals have used chat in theater, and over half claimed to use it frequently (used throughout mission or for long durations), as shown in Figure 13.

Respondents were asked the types of communication messages they would send with chat communication, and the types of messages they would avoid using chat communication to send. A summarized table of the responses is listed in Table 1. Note that not all ABMs' preferences were in agreement. In general, operators prefer to use chat for coordination messages of any type, situation updates, dynamic task assignments, and communication with outside agencies, while they avoid using chat for personal interactions, time-critical or safety-critical messages, and overly complex messages that might be too difficult or time consuming to convey with text. For time critical messages sent over the radio, operators reported that they often publish the information into the chat room after the discussion to help enhance the awareness of others who may be monitoring that room, but not privy to radio conversations, and also to leverage the historical record that chat affords. Operators reported that they prefer radio communication for highly time-sensitive messages, but others claimed to use chat for these as well. Some suggested the chat medium is much more responsive than radio. One in particular claimed the difference to be on the order of a 95% response rate for chat messages and a 50% response rate for voice radio, provided the recipients are following established procedures and contracts for communication.

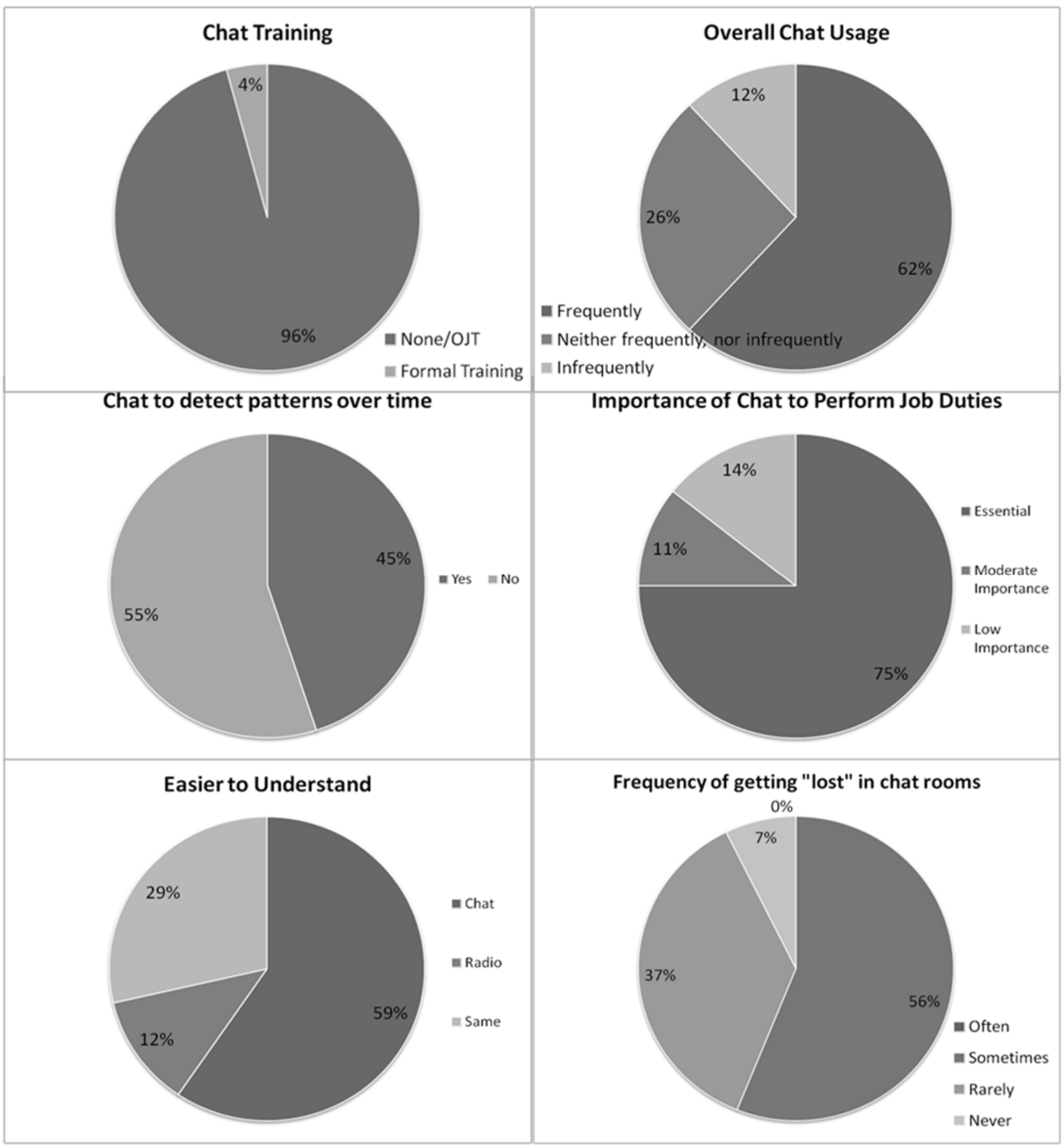

Figure 13. Chat survey responses.

Prefer chat for:	Dislike chat for:
Real-time coordination	Complex coordination messages
Dynamic situation updates	Immediate safety messages
Time-sensitive taskings	Time-sensitive messages
Dynamic change requests	Engagement orders
Mission/situation updates	Great amount of detail
Ground troop support & coordination	Control directions to manned aircraft
Mission information	Highly sensitive - e.g., hostile declarations, engagement authorities
Detailed messages (e.g., location, alt, speed, etc)	Lengthy/complex messages
Brief Messages	Non-mission critical errors
Planned schedule, events	Personal messages/information
Dynamic situation updates	Complex coordination messages
All messages – from mundane to emergencies	Immediate safety messages
Any communication w/ outside agencies	

Table 1. A summarized chart of ABMs' message preferences

Nearly half of respondents claimed to use chat logs to detect patterns over time. Of those who have, many reported the value in using the historical record for training purposes, as well as for accident reconstruction (specifically Hazardous Air Traffic Reports). The historical record provides information about what happened and when, which radio is currently unequipped to provide. The fact that operators record high level decisions or plans from voice communications in the chat logs after the fact further emphasizes the value of the archival information. Operators also reported historical records being used to investigate inefficiencies with the goal of increasing overall performance.

The survey asked the number of chat rooms an operator monitors regularly (for those who use chat), and the responses are shown in Figure 14. One thing to note is that over 63% of operators monitor six or more chat rooms at a time in addition to their primary display(s) and radio channels. Despite the heavy load, 95.7% claimed to be comfortable monitoring this number of chat rooms, and everyone claimed that chat helps them perform their duties. Operators were asked an open-ended question about why they are comfortable with this number of chat rooms and aggregated responses are listed in Table 2.

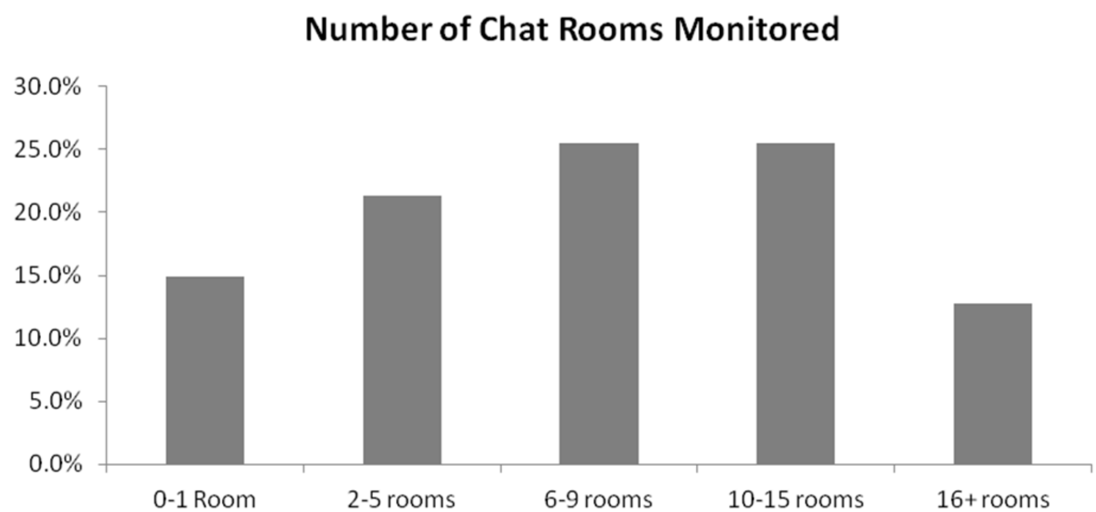

Figure 14. Total number of chat rooms monitored by operators at any given time.

Of those who use chat in their current chat duties, the majority felt that chat is essential for performing their job duties (76.7%). On average, operators were also satisfied with chat communication, with a mean score of 5.58 on a 7 point likert scale, with 1 being not at all satisfied and 7 being very satisfied. The majority of individuals who are not currently using chat in their positions feel having access to chat would help them perform their job duties (76.5%).

Comfortable because:	Reservations because:
Rooms split by function/topic are easier to manage and minimizes unnecessary communication	Depends on the volume of chat traffic, with high volumes of messages, additional support may be necessary
Alerting mechanisms are sufficient	Fatigue may increase missed messages
Not difficult to do	Can be overwhelming
Quick, fast, secure	Depends on subjects being discussed
Experience – over time develop a scan pattern and learn what to look for	Things could get missed
No different than listening to multiple radios for critical communications	
Not all are "primary" rooms	
Standard of practice in the C2 community	
Effective use of screen real estate	
Allows monitoring of activity on minimized rooms	
Skill learned over time	
Some rooms are only monitored, not actively used	
Current standards and procedures are sufficient	

Table 2. Why operators are comfortable (or not) with their current number of chat rooms.

As far as safety is concerned, operators who use chat rated the perceived safety of chat an average of 5.05 on a 7 point likert scale, with a score of 1 meaning they have serious safety concerns and 7 meaning they feel extremely safe. Overall, operators feel relatively safe with their current chat tools. In addition, the majority (81%) of operators feel comfortable giving or receiving official orders over chat communication, and feel confident that others in each chat room are who they claim to be (92.5%). Reliability was rated higher than safety, an average of 5.40 on the same scale with unreliable (lowest) and extremely reliable (highest) on opposing ends. Voice communication (radio) was rated with a lower reliability, an average of 4.42 on the same scale. When asked to explain any concerns about reliability, the participants made comments aggregated in Table 3. Operators felt chat was an efficient method of communication, with nearly unanimous agreement. When asked about the ease of understanding, 59.5% of operators felt chat communication was easier to understand than voice communication, as shown in Figure 13.

Chat	Voice
Need standardized rules and procedures	Too much interference
Need an internally developed product	Voice inflection is helpful
Bandwidth concerns	Analog radio concerns
Computer security concerns	

Table 3. Comments explaining view on reliability of both voice and chat.

Despite being considered mostly safe, reliable and efficient, chat communication has been reported to have negative attributes as well. Multiple conversation threads often occur in the same chat room, and sometimes people have difficulty keeping a coherent set of thoughts or messages tied together. That is to say it is possible to become "lost" in the rhythm of the conversation, which renders the messages unclear or indiscernible (Cornelius & Boos, 2003; Holmer, 2008). Operators were asked how often they feel they or others "get lost" in chat rooms. No one felt this disconnect happened often, while the majority claimed it does sometimes happen (see Figure 13).

The majority of respondents reported that chat communication has never put themselves or their team into a negative and/or preventable situation, but 38.1% of the operators claimed it has. Respondents explain this can be a result of too much information coming across a chat room too quickly, inappropriate or insufficient visual scan patterns, time delays, or even focusing on personal discussions rather than work information (see Table 4).

Responses to "Why" regarding negative/preventable situations	
Information not accurate or timely	Exclusively using chat
Non-adherence to chat standards/procedures	Multiple requests concurrently
Connectivity loss	Recipients distributed among chat and radio
Task saturation	Lack of standardization
Not quick enough/Time Constraints	Too much information passed too quickly
No confirmation of message read	Not enough time for read back

Table 4. Open-ended responses answering why their team was put into negative or preventable situations while using chat to communicate.

Coupled with interviews and training exercises, this survey provided information to better understand how operators in a tactical command and control environment are currently employing chat capabilities. The survey responses highlighted the ways in which chat communication is considered beneficial to the command and control population, and potential problems it may create with its usage. The operational interviews and training observations further highlight the positives and negatives of using chat communication in a C2 environment. The following sections detail these additional findings.

Positive Attributes

Archival Information

Operators identified many advantageous aspects of chat communication, one of which includes a lasting, archival record of communication. As opposed to verbal messages, which are transient, chat communication affords the ability to archive previous messages, while maintaining current real-time (or near-real time) connectivity. It captures the stream of information providing a historical record of much of the C2 picture. If the environmental situation changes, users are able to search through the communication threads to look for information that may not have been relevant at the time, but has become more important now based off ever-changing context. It also affords a user the ability to scroll up through conversations to see what may have been missed. In addition, the historical record of chat can serve as a training tool to capture training events and facilitate after action reviews at a later time.

Unambiguous

With a written record of communication, there is less ambiguity in the content of each message. Furthermore, voice channels are susceptible to various types of interference, including interference by other electronic agents, static, malicious interference, and difficulties in hearing and understanding various foreign accents. Chat communication has the power of lessening some of these disturbances to current voice communication. Chat messages do not override each other like verbal messages, and they eliminate the possibility of voice or language distortion. Chat has even been shown to mediate communication across communities that speak different languages (Patterson et al., 2008). There are no misunderstandings of accents or pronunciations, no question of whether the individual wanted “S7” or “F7.” Coordinates or directions are clear and documented. ABMs prefer to send restricted operating zone (ROZ) and complicated battle space updates via chat because of this lack of ambiguity. The coordinates and other complicated details are in plain black and white and stored for future reference. Chat messages are susceptible to other potential problems of their own, however, including mistyping, loss of connectivity, ambiguous acronyms, and cyber attacks. In general, chat communication is believed to be far more unambiguous than typical radio communication.

Wide range of participants

Other benefits of chat communication include the benefits of redundancy and simultaneity with multiple people communicating in the same “room” at the same time. Chat allows individuals to speak to a wider, more geographically separated group of people than traditional radios. With traditional radio communication, there are vast limitations with bandwidth and range. In addition, people are unable to monitor and discern conversations on upwards of twenty channels on a radio at a time, but with chat those numbers are entirely possible and quite realistic (also demonstrated in Medina et al., 2007). In fast-paced tactical operations, chat rooms allow multiple people to be in the loop of planned action, thus providing the potential of less coordination overhead, and even the possibility for recovery before incidents occur.

With chat, people can synchronously or asynchronously monitor various channels, depending on their interests and needs, even without ever being an active participant. They can communicate on select channels, while only monitoring others. In fact, operators have claimed that chat “instantly provides situation awareness” to a broad spectrum of players. While this is likely exaggerated, there is considerable value in being able to monitor various conversations to understand the state of the world. An outsider could replay what happened through the communication without actually being there or taking part in the conversation. In addition, with chat communication, different groups of people are now privy to information that was never accessible to them before because of radio limitations.

Chat does not always entail large groups of participants; it is possible to communicate to a smaller group of participants for particularly sensitive matters. A chat participant can initiate a private chat room, called a “whisper,” to communicate directly and privately with another individual. Chat provides the benefit of talking to multiple people at once, with the flexibility of one-to-one communication as well.

Anticipation

Chat communication allows operators to monitor multiple chat conversations, thereby increasing their awareness of the overall battle space and other missions, allowing them to anticipate future assignments (“taskings”), problems, or changes to their own plan. Operators might not closely monitor each channel for detailed specifications of other missions, but “overhearing” the conversation may allow them to pick up on relevant information to their own missions. This is analogous to the “voice loops” idea that was introduced at NASA (Patterson et al., 1999), where scientists were able to overhear other groups’ planning and troubleshooting discussions, which lead to greater anticipatory behavior. That is to say they are passively monitoring conversations in order to anticipate future changes or demands for information and prepare in advance. In addition, they can anticipate potential hazards, synchronize planned events, and understand the rationale for non-routine requests (Patterson et al., 2008). Overhearing may help foster common ground with less effort by providing a shared context. Operators describe this type of anticipation strategy of monitoring chat rooms for upcoming needs or changes as being pervasive throughout the various C2 groups. Anticipation allows preemptive action to be taken, and the overall timeline may be reduced.

Speed

The simultaneity of organizing action with multiple players may foster faster decision-making and planning endeavors because the cost of coordination may be reduced. Operators claim chat substantially accelerates their time to act, even claiming as high as a 75-80% decrease in time to respond to certain emergent events. For ABMs, their work is structured by carrying out "contracts," which includes expectations for communication. The contracts for transmitting information differ depending on the technology used to communicate. For ABMs on an AWACS, they strive to make sure any critical information is passed within five minutes when using only radios to communicate. This timeline is greatly accelerated when using chat to communicate. Critical information is expected to be passed in one minute or less, which is an 80% reduction in the time to respond to chat versus radio information.

For especially time critical events (e.g., Troops in Contact), ABMs are expected to acknowledge the request within five seconds of the request for assistance being sent. In addition to the accelerated response times, they believe the time to get assets on time-sensitive targets (e.g., Troops in Contact air support) is cut in fourth (75% reduction) when using chat communication versus voice. When lives are at stake, every second an ABM can reduce in the process could be another life saved.

Operators believe one of the reasons chat decreases the time to react is because chat speeds up the chain of events they describe as the Observe, Orient, Decide, and Act (OODA) loop. USAF Colonel John Boyd coined the term to describe decision making in strategic military operations, highlighting that those who are most agile and can swiftly move through the overlapping stages can gain an advantage over their adversaries. The loop's simplest form is represented in Figure 15, but Boyd's vision was more complex than this figure suggests. His concept pulled rich ideas from various sources such as information theory, cognitive science, physics, and cybernetics. In fact, the OODA loop has tremendous widespread use in military doctrine, and the concept has expanded to other realms of military and commercial processes as well.

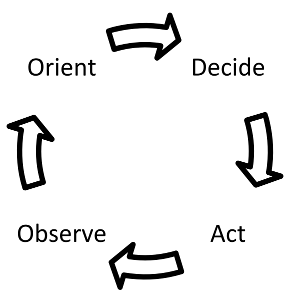

Figure 15. Reproduction of Boyd's basic OODA loop.

The OODA loop is not to be thought of as discreet stages, but rather continuously interacting cycles that are inextricably linked to each other. Boyd's more fleshed out version of the OODA loop is pictured in Figure 16. Operators feel chat speeds up the first three portions of the chain: Observe, Orient, and Decide, which leads to faster action.

They feel multiple conversations occurring in tandem allow action to be completed in more of a parallel manner rather than serial order. In addition, the ability to anticipate future states of the world, as described above, is likely a large factor in speeding up the OODA loop.

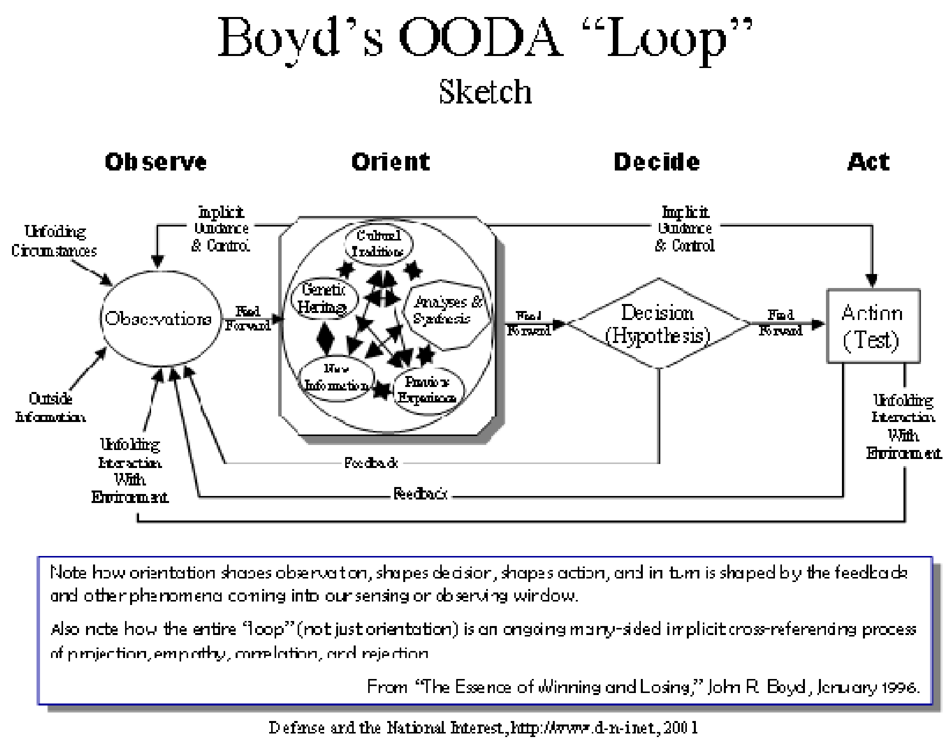

Figure 16. The modified OODA-loop. Reproduced from Boyd, 2001.

Flattening Organizations

Another way chat has been shown to decrease time to act is through its ability to flatten the organization for information dissemination. Chat affords a direct line to higher level authority to authorize certain requests or missions, rather than going through an arduous process of relaying information through a series of radio channels until the information had reached the appropriate higher level authorities. Instead of trying to reach particular individuals or to find the individuals currently in charge of a particular region or mission, there are dedicated chat rooms for high priority topics where all the "right" players are already located. These high priority chat rooms are protected from everyday banal topics and as such may be rarely used, but when issues arise, these chat rooms are instrumental to mission success. Chat allows easier access to leaders at the top of the decision hierarchy, thus shortening the time it takes to complete the OODA loop overall. Chat also provides information about who is monitoring each room and provides a level of authority to the messages.

Customization and Alerting Capabilities

The current chat systems allow users to fully customize their view based on their preferences to alleviate some of the struggle with data overload. Operators are able to select key words to appear as different colors to alert the user to potential critical messages, as well as select auditory alerting (e.g., tones, beeps, etc. when a particular word appears). For example, words like Troops In Contact (TIC) or Restricted Operating Zone (ROZ) may signify critical events or changing environments and might warrant color and/or sound alerting. In addition, selected individuals or groups can be set to a different color as well. It may be critical to see all messages from a director of operations or a particular forward air controller. These choices are context specific and allow the user a greater chance to detect critical messages.

Reduces radio traffic, not limited by typical radio traffic problems

Currently, most U.S. military tactical command and control platforms are plagued with crowded, noisy, overloaded verbal communication channels. Each message sent over the radio runs the risk of "stepping" on another message (i.e., two messages sent at same time may distort one or both of the messages). When two messages are sent across a radio channel simultaneously, neither may be perceptible. For clear communication, there must be accepted turn-taking behaviors. Every message sent over the radio further taxes the heavily used medium, thus voice messages sent are brief and concise. The need for brevity typically precludes a more in-depth conversation on radio channels. On the other hand, chat communication enables the opportunity for more in-depth conversations with fewer restrictions, and more bandwidth and flexibility. For instance, chat is the preferred method to send consistent weather and unit report information because of its low-overhead (Medina, 2008). Chat is certainly not limited to only weather, as the majority of general C2 information is conveyed in this manner. For particularly extensive conversations, communicators can open up a separate chat room to avoid bombarding others with information.

Negative Attributes

Not all of the information reported for chat communication was positive. In addition to the benefits, the following negative information was shared as well.

Too Much Information

One reported issue with chat communication is the plethora of information that is transmitted across the chat communication rooms. On the AWACS, operators typically monitor at least six chat rooms with an additional four or more individual whisper rooms set up. Airborne platforms are heavily limited by bandwidth issues, while ground platforms are much less limited. For that reason, operations on the ground typically monitor more chat rooms because they have the ability to do so. Operators are often monitoring upwards of twenty chat rooms (also demonstrated in Medina, 2008).

The tempo of individual chat rooms varies widely according to the operational tempo, time of day, and many other factors. When critical events happen, the chat room often increases its tempo with more messages being transmitted. Likewise, when fewer missions are ongoing, overall messages in chat rooms slow down. As a general guideline, it is not unusual to see a rough average of a message a minute per chat room. While this may not seem like a lot of information, the cumulative effects can be quite striking. If an operator is monitoring six chat rooms, they will see roughly a message every ten seconds. If they are monitoring six chat rooms and four whispers, that number may be closer to every six seconds. If they are monitoring twenty chat rooms, a new message will appear every three seconds. It is important to note that chat messages are in addition to radio traffic and situational display information. Messages every three seconds can add up to a lot of information, and these rates can increase dramatically during high tempo missions. After one particular AWACS eight-hour mission, the chat logs were copied and pasted into a Microsoft Word document, single spaced. For an eight hour mission, including six chat rooms and a few whispers, the document contained 95 pages of chat. The number of pages could likely double with additional rooms. Not every message is critical to an ABMs job, but the vast majority are.

Missing Critical Information

One of the issues with the magnitude and tempo of messages sent is the rate at which the messages move off the screen. Operators have anywhere from six to twenty or more chat rooms opened on a single computer screen, and because of screen real-estate limitations, each of those chat rooms is fairly small. Only a few messages can be displayed at a time, and the room may be moving at such a speed that the operator does not see a message before it scrolls out of sight. Operators may not always take the time to scroll back up each room to see if they missed anything unless they see a discussion about an issue they are unfamiliar with. Once they realize they missed something, they go in search of that missing information. Problems may result if that discovery is never made.

Abbreviations/Language

To further compound the issue of an utter deluge of information, there are also concerns with the content of the messages. Chat communication relies heavily on abbreviations and acronyms to reduce the amount of time required to type out lengthy messages. The new abbreviates essentially equates to new operators having to learn a new language while in the middle of high pressure mission critical situations. Abbreviations render the text more difficult to interpret, and this is especially difficult between organizations and/or nations, where many acronyms may be identical, but mean different things between the groups (Medina, 2008). Once these abbreviations are learned, the interpretation becomes much easier and faster.

Personnel/Training issues

ABMs do not have any formalized training course on how to communicate with chat technology. This may further exacerbate the issues with overwhelming information and an abundance of acronyms. Without any formal training, there tends to be a steep learning curve for a new chat user. They are often initially overwhelmed at how much information actually comes across the chat rooms. Operators appreciate it will be busy and fast paced, but are often surprised by the utter deluge of information. The vast majority of all C2 information is flowing through the chat system (estimated to be up to 95% of all C2 information), and yet there is little if any training to prepare. Most training reported from operators is in the form of on-the-job training. They essentially are thrown in the deep-end and must either sink or swim. The learning curve is steep, but by necessity, operators become sufficient rather quickly.

Lack of Common Standards

The issue of training is further compounded or perhaps results from the fact that there is not currently an overarching standard for chat communications across all services (Medina, 2008). Official chat shorthand is approved in Air Force Doctrine, but operators report that not everyone they communicate with is necessarily using this shorthand, especially groups in separate agencies or nations. In addition, not all events have agreed upon ways of reporting. For example, when referring to restricted operating zones, operators may post the information in at least five different ways. Deciphering various ways of communicating the same information may render communication more difficult, slow, or confusing. Current usage is somewhat of an emergent behavior, with people using the technology to support their current mission in the best way they see fit. This may work on a small scale, but becomes more difficult as the complexity and scale increases.

Persistence of Inaccurate Data

Archival information can be both a blessing and a curse. While extremely useful for identifying trends, memory aiding, and post hoc analysis, chat communication can propagate false information incredibly quickly. The persistence of the communication means that errors cannot be fully erased. With voice communication, false information disappears and the corrected data can be shared with others, but with chat communication, that false record is lasting. Operators often use copy and paste features to quickly disseminate information, and thus it is easy for information to propagate from one room to another. Clear guidelines need to be in place to ensure there are methods for stopping the dissemination of false or inaccurate information.

Conclusion

Through both interviews and survey responses, the ABM community was able to share extensive detail about how they use chat communication and their opinions on the technology. In particular, respondents use chat communication for various types of messages, including coordination messages, situation updates, and anything that might be useful to refer back to at a later time. It affords the ability to communicate with a large number of individuals or groups, allows operators to passively monitor chat rooms to gain an awareness of the battle space, and provides an archival record of the events. Most feel chat is essential to performing their duties and would prefer it in terms of reliability and understandability relative to radio communication. However, they prefer radio communication for situations where messages are time-critical or safety-critical, as it provides a faster mechanism for transmitting information. In addition, there are risks associated with chat communication, including missed messages, an abundance of information, and a steep learning curve.

One of the most surprising findings from this research was the extent to which operators use and prefer chat in a variety of situations. Chat communication is the premier and primary method of communicating in the C2 world, and its usage continues to increase. It is clear to me that there are positive attributes of chat communication that have not been fully captured in previous academic studies. Almost 80% of respondents claim chat is essential to performing their job, and for C2 tasks, up to 95% of all information is transmitted through chat communication. If chat was simply inferior, a burden, or disruption, its usage would be far less. Additional research into this lacuna between research results and operational value is warranted.

CHAPTER V. Bridging the Gap

Computerization certainly impacts the way we communicate, and it may also impact what we communicate. That is to say changing the nature of communication may qualitatively change the perceived space of possibilities. Language is an external artifact, and may shape the space of possible thought; it may actually influence the solutions that are developed. Clark (1999) supports this view and explains it with an example of writing a paper. Many researchers view written words as artifacts of our thoughts or the products of thought, but Clark takes a more radical approach, suggesting people “think” on paper as they write. As the paper begins to form, it will continue to shape the way the writer thinks about the problem. Coming back to the document the next day, the writer’s thoughts will be somewhat shaped by the context already on the page (Clark, 1999). In effect, the written words provide a context that changes the problem space. This idea is consistent with the surprise version of twenty questions, as the “word” is created by the process of interacting, rather than it being a static external stimulus (e.g., a predetermined word). This idea is also a key component of Weick’s description of sensemaking, in the sense that an organization discovers and develops its values by watching its own actions (Weick, 1995). Garbis and Artman (1998) have demonstrated through their field studies on rescue and emergency management control that meaning is co-constructed through both discourse and artifacts. They suggest any new artifacts or technologies (e.g., communication modality changes) added to any type of work necessitates examining the set of trade-offs that is inherent (Garbis & Artman, 1998).

Studies have shown that speech may function to guide behavior (Wetzel, Kneebone, Woloshynowych, Moorthy & Darzi, 2006; Clark, 1998; Vygotsky, 1986). A common example is a small child learning to tie his/her shoe while a parent helps by reciting a mnemonic story (e.g., “the bunny runs around the tree…”). When a child is talked through a task, they can accomplish things they were unable to before. As the child learns, he/she may be able to conduct similar dialog for themselves (Clark, 1998). Even surgeons report “self-talk” as a method to reduce stress and gain control in the operating room. If they use positive self-talk and reaffirm their self-efficacy, surgeons have reported lessened cognitive and emotional stressors (Wetzel, Kneebone, Woloshynowych, Moorthy & Darzi, 2006).

Vygotsky stressed the importance of experience with external structures (e.g., words and sentences) on shaping and informing individuals’ overall understanding (Clark, 1998; Vygotsky, 1986). Environmental structures form a backdrop relative to some problem solving/action. A further extreme to this idea of speech guiding behavior is Benjamin Whorf’s theory of linguistic relativity (1956). He claimed people’s thoughts were influenced by the language available to them to express ideas, and demonstrated the differences between people who speak different languages. Whorf stated “*users of markedly different grammars are pointed by their grammars towards different types of observations and different evaluations of externally similar acts of observation, and hence are not equivalent as observers, but must arrive at somewhat different views of the world”* (1956; p. 221). This is similar to the idea of Linguistic Determinism, essentially the idea that language shapes thought (Wittgenstein, 1922/1974).

The purpose of this document is not to dispute or confirm linguistic relativity, rather the purpose is instead to explore a potentially related construct of "modality relativity." This is a hypothesis that if researchers believe our language affects the way we think, it is possible that the medium in which we use language may also affect the way in which we think. An archival record provides a backdrop from which future messages are interpreted, much like the beginning of a written document provides a backdrop for the rest of the paper. Edwin Hutchins claims that "the properties of the language itself interact with the properties of the communications technology in ways that affect the computational properties of the larger cognitive system" (Hutchins, 1995, p. 232). That is to say the form of the representation will impact or shape the problem solving and thoughts of those using it. This idea dates back to gestalt psychologists, such as Dunker and Wertheimer. Scholars have long suggested that technology and language may interact, impacting the problem solving and computational properties of the system (e.g., Clark, 1999; Hutchins, 1995; Cech & Condon, 1998). As such, it is critical to evaluate the impact new technology has on the properties of any system in context of the environmental demands, in this case - the command and control system.

Despite research cautioning about the negative impacts of chat communication on performance, chat is proliferating at incredible rates in complex environments. Higher usage does not necessarily imply the technology is "good;" however, high percentages of operators claim they would be unable to successfully perform their current jobs without this technology. There must be something about this technology that complex environments are finding incredibly valuable. Various command and control groups in particular have been large proponents in supporting the widespread usage of this new technology (Medina, 2008; Jara & Lisowski, 2003). Perhaps there are advantages to chat in complex environments that are overpowering negative attributes found in simpler environments. These advantages may only emerge when the task difficulty is great enough to warrant them, thus they may not be captured in current literature with simple environmental demands, but are being experienced in the operational community.

Based on the literature I reviewed and the operational experiences I had, Table 5 outlines differences in perspective between simple and complex environments concerning the advantages and disadvantages of chat communication. I found many more advantages for chat communication in complex situations than those represented by more simple environments. The differences are consistent with previous studies that have shown that the type of task can mediate the effect of different communication mediums (Funke, Galster, Nelson, Dukes, 2006; McGrath & Hollingshead 1993). Despite the noted differences, a question remains - what is it about chat communication that is being leveraged in complex environments but not in simple ones?

	Simple	Complex
Advantages		
Anticipatory		X
Archival Capability	X	X
Asynchronous		X
Collaborative Cross-checking		X
Customizable		X
Flattens Organization	X	X
Increases Awareness		X
Increases Clarity/Unambiguous		X
Reduces Social Pressure		X
Reduces Radio Traffic		X
Simultaneity		X
Increases Speed of Action		X
Wide Range of Participants		X
Disadvantages		
Ambiguous/Confusing	X	
Attention Sharing	X	
Lack Common Standards/Language		X
Lack of Gestures	X	
Lack of Non-verbal Cues	X	
Lack of Social Cues	X	
Lack of Verbal Cues	X	
Missing Information		X
Personnel/Training		X
Speed Changes (Slower)	X	
Too Much Information		X

Table 5. Advantages and disadvantages of chat communication broken out by the environment in which the tool is used.

The power of chat in complex environments may lie in the ability to archive information. Archival information promotes the ability to multi-task by supporting both synchronous and asynchronous communication. Messages can be sent and viewed at the sender and receiver's convenience, which is vastly different than verbal communication. A person must react to speech by shifting their attention to the message when it is sent;

hence it is strictly a reactive medium. On the other hand, chat communication affords greater control over the interaction as it is not strictly reactionary. Chat messages have a greater level of control than voice because of its ability to archive the information. A recipient can check the archival record for relevant information as needed, rather than at the exact time a message is sent. In essence, communicators choose the sampling rate of information based on their situational demands.

Further examining the list of chat communication advantages, the benefits that are directly connected to or a result of the ability to archive information are marked with bold text in Table 6. More than half of the advantages are connected to the ability to archive information.

	Simple	**Complex**
Advantages		
Anticipatory		X
Archival Capability	X	X
Asynchronous		X
Collaborative Cross-checking		X
Customizable		X
Flattens Organization	X	X
Increases Awareness		X
Increases Clarity/Unambiguous		X
Reduces Social Pressure		X
Reduces Radio Traffic		X
Simultaneity		X
Increases Speed of Action		X
Wide Range of Participants		X

Table 6. Advantages of chat communication connected to the ability to archive information.

After exploring the command and control domain, which heavily relies on chat communication, I discovered that the either/or question of chat versus voice was missing the point. This was not an issue of “either/or,” but rather an issue of “both/and.” C2 operators use both extensively and want access to both for very different reasons. Voice communication is a valuable, high bandwidth channel that is essential for rapid communication (Dubrovsky et al, 1991). Chat communication is valuable because it is nonintrusive and allows archiving of messages, which enables the user to control the time and rate at which to sample the information (Medina, 2008).

Multiple resource theory would predict that voice communication when coupled with a visual task would result in better performance, because information is split across two different modalities (i.e., radar information is visual and communication is auditory). The cross-modal input allows a greater number of resources to be allocated to performing the dual tasks. An alternative explanation is suggested here that would account for chat communication when coupled with a visual task resulting in better performance. *It may be the case that the ability to distribute messages across time is more important in temporally demanding situations than the ability to distribute across modalities.* Thus the interaction between the communication capability and the demands of the environmental demands is a critical factor in the value of the communication technology. There is certainly a limit in humans’ abilities to process visual information, but I hypothesize the benefits of archival information to control the sampling rate and time of information will prove more beneficial in the C2 temporal-demanding context. If chat communication does enable better performance, the ability to distribute attention resources across time may be another important way to cope with the demands of complex, distributed operations.

Instead of a chat versus voice dichotomy, it may be more valuable to consider the strengths and weaknesses of each to better implement this technology in the operational world. Typically when chat is studied, it is compared to other communication modalities in an “either or” kind of way, and elements inherent in the technology are often confounded. For instance, the archival information it provides is confounded with the method with which messages are input (e.g., talking versus typing). In order to understand the strengths and weaknesses of each, it is important to parse out these differences. Instead of pitting technologies head to head, the current study aims to isolate the strengths and weaknesses of the communication technology by teasing out the often confounded mode of input and the ability to archive.

Synthetic Task Environment

To test these hypotheses, it is necessary to have experimental control, while maintaining critical elements of the operational environment in which chat is found to be essential. Simple environments allow a high level of experimental control and causal assessments, while complex environments provide insight into the interaction between various system components and a greater degree of realism. A key limitation of studies using simple tasks is the possibility of reducing the complexity to such a point that key interactions are broken, thus limiting the generalizability of the results to behavior or cognition as experienced in the operational context. On the other hand, a concern for highly complex situations is the inability to render any control over the environment and interactions amongst variables, limiting the ability to draw causal conclusions.

Cooke, Salas, Cannon-Bowers, and Stout (2000) describe two ways to measure team performance. The first is to measure the global outcome variables (e.g., Did they win the war? Did they save the patient's life?). These tend to be objective types of measurements and may provide valuable information regarding a system's performance. Describing performance only in terms of the global outcome is not always sufficient, especially in situations with high complexity or many dimensions. A problem with this type of measurement is the possibility that good decisions or performance may lead to undesirable outcomes because of the complexity of the environment. Judging performance solely from the outcome may not accurately reflect the quality of the operator(s)'s actions (Flach et al., 2010).

Another method to assess team performance is to measure process variables (Cooke et al., 2000). Process variables examine the parts of performance that are tied to the actual method of achieving an outcome, rather than focusing solely on the end product. For instance, effective teams have been shown to do the following processes: anticipate each other needs and volunteer information, share task-critical information, respond immediately to other's initiations or have "tight" communication, and avoid indirect or ambiguous references. None of these metrics describe the outcome per se; rather they describe actions that lead up to an outcome. A problem within this realm of measurement is the possibility that the variables are not practically significant. A statistically significant pattern of behavior could be essentially meaningless when put into the context of the domain (Flach et al., 2010). In other words, if the patterns are not related to the outcome in any real way, then pragmatically, they may not hold much weight.

Each of these two methods alone may not be satisfactory for measuring the success of a team. Another possibility is to measure team performance at different levels of abstraction (outcome, process, individual) and to examine patterns across levels that might help link the micro-structure (e.g., communication patterns), with the macro-structure (e.g., mission success) (Flach et al., 2010). Synthetic task environments are one way to bridge the gap between micro-structure (reductionist research) and cognition in the real world (high complexity). Synthetic task environments are defined as "experimental situations where there is an explicit effort to represent the constraints of a natural work domain" (Flach et al., 2010, p. 279). The tasks used must represent the nature of the tasks in the natural environment, rather than simply offering face validity to the study (Flach et al., 2010). With a synthetic task environment built around a domain, researchers are able to measure team performance at varying levels of abstraction that will map back onto the original domain of interest, thus providing information to answer research and pragmatic questions about both micro and macro-structure. For example, clients may want to know if a particular surgical tool allows greater precision in a suture. A pragmatic or micro-structure question may be: does a more precise suture result in better patient outcomes? With a synthetic task environment, the combination of micro and macro-structures allows a deeper level of analysis and measurement.

In the current study, I created a synthetic task environment to represent communication and task constraints of the C2 world that ABMs face daily, which are outlined in greater detail in the following chapter. Through this synthetic task environment, I was able to test the value that chat communication brings to C2 performance relative to the costs and attempt to explain the gap between the different perspectives from the simple and complex quadrants shown in Figure 2. The following chapter defines the outlines the methodology used for creating a synthetic task environment and describes the task in detail.

CHAPTER VI. Experimental Study Methods

Participants

A total of fourteen groups of two from active duty military, command and control operational units voluntarily participated in this study (twenty-eight participants total). In addition, eight active-duty military, command and control operators acted as confederates in this study. Three confederates were present for each data collection session. The total of all active duty participants was thirty-six volunteers. Air Battle Managers from AWACS and CRC operational groups were sought through the use of email notifications. All participants received their regular compensation for their time and were compensated for their travel if necessary.

ABMs are trained through a series of qualification training courses. They first attend initial qualification training (IQT) and then achieve more advanced mission qualification training (MQT). Individuals who complete MQT are highly trained, ready to deploy, and designated “Combat Mission Ready.” In addition to completing the qualification training, there are continuation training (CT) requirements to maintain a Combat Mission Ready (CMR) status. If an individual is not currently CMR, it could mean either they have not completed the required training or one or more continuous training requirements have lapsed. A highly experienced ABM may be in a situation where their CMR status has lapsed, not because they are not experienced enough for combat, but because their mission or circumstances may have interfered with their ability to complete continuation training. Thus, CMR designation is not necessarily a perfect measure of experience or expertise level. The current study did not control for CMR status, but did ask about it in the initial demographic questionnaire.

In addition to the above participants, a small pilot study was conducted with local collaborators prior to testing the domain experts. Two groups of two participated in the pilot study, which was performed to ensure validity of the manipulations and evaluate the performance metrics listed below.

Design

A 2 x 2 (Message Input x Archival Log) within-subjects design was used to identify and isolate the unique value of chat and voice communication. The first factor (message input) dictated whether the participant input their message using voice (e.g., speaking into a headset) or manual entry (e.g., typing into a keyboard). The second factor concerned the archival log of the message. For some conditions, the messages were transient and disappeared after 15 seconds, similar to the transient nature of voice communication. Other conditions had a permanent chat log of all messages that were communicated for the trial. An automated transcription capability (see *Apparatus* section for technical details regarding this capability) enabled voice-to-text input during the trials. The ability to create voice conditions that would populate archival logs in real time enabled the ability to explore the value of archival logs independent of the type of input of information. These factors were combined as shown in Table 7.

	Voice	Chat
No Log	Voice Only	Chat Only (messages disappear)
Log	Voice + Archival Log	Chat + Archival Log

Table 7. Experimental conditions

Apparatus

The simulated command and control environment was developed using Aptima, Inc.'s software package, Distributed Dynamic Decision-making (DDD) (Ver 4.1). The team-in-the-loop simulated scenario was used to design and operate the command and control simulation. Individual elements that appear in the simulation were created using Aptima, Inc.'s Visual Simulator Generator (VSG).

The simulation and communication required thirteen networked personal computers, connected through TCP/IP protocol. Each workstation was equipped with a keyboard, mouse, two monitors, webcam, and a radio headset (Sennheiser HMD 280-13). The DDD display and chat environment was projected on two separate 19-inch Dell LCD Monitors (Model 1908FPb), as shown in Figure 17. A Synergy KM switch (version 1.3.1) will allow confederates to interact with desktop objects on both monitors with a single mouse. Study participants only interacted with the monitor on the right, which housed the communication suite.

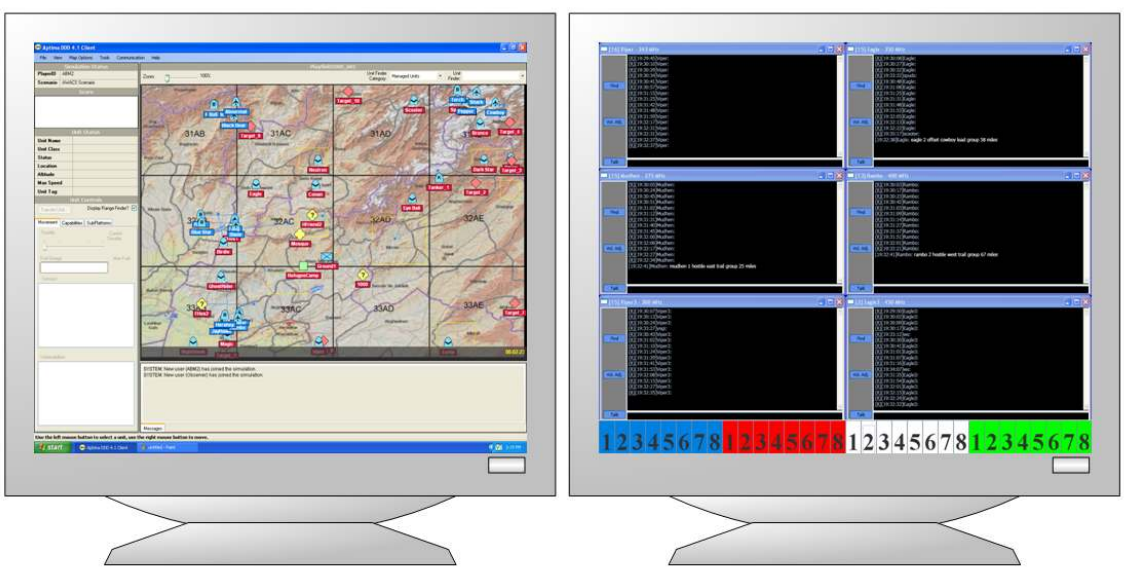

Figure 17. Participant's dual monitor display.

The chat communication was performed with a modified version of the Air Force Research Laboratory's Multi-Modal Communication (MMC) tool (version 3). The MMC is a network-centric communication management suite designed to transform military communications. It aims to increase mission effectiveness by combining voice-to-text, chat, 3-D Audio, and real-time playback. The MMC is a somewhat radical departure from current operations with its vast capabilities. For this reason, much of the functionality was reduced for the current study. It was primarily used to allow participants to communicate through both chat and radio, send pre-scripted radio and chat messages, and transcribe voice communication in near real time. The MMC tool, set up with six chat rooms is shown in Figure 18.

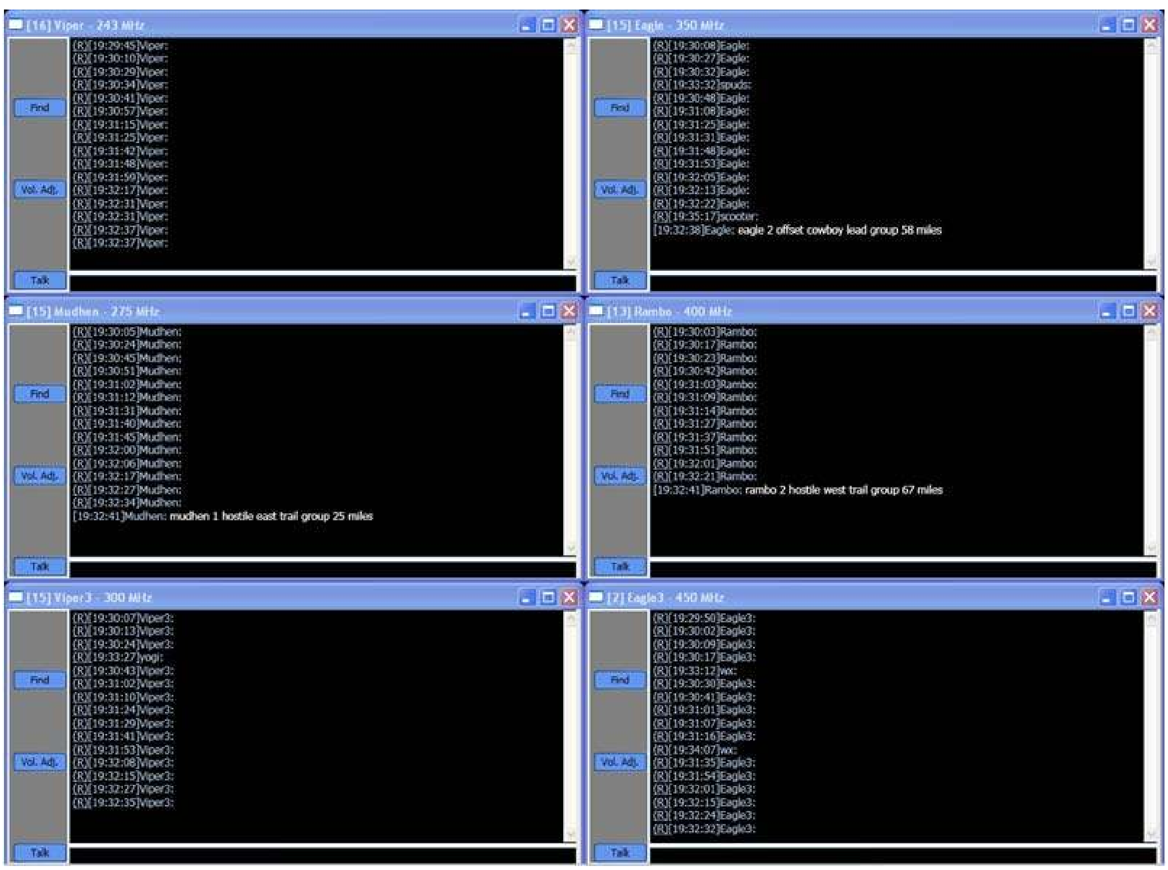

Figure 18. Modified Multi-Modal Communication (MMC) tool.

Figure 18 illustrates the view of the MMC system for the participants. The participants' talk button for the radio is shown on the bottom left, and the box spanning the bottom is the chat dialog box. Verbal communication, participant behavior, and screen captures were recorded using Nuance SDK (version 8.5) and Morae (version 3.2) software.

DDD Scenario

The scenario was developed to simulate inherent demands and complexity of a tactical command and control environment. Development of the scenario was based on multiple knowledge elicitation interviews with experienced ABMs and observations of current Air Force training simulations as described in Chapter 2. Demands and unanticipated events that occurred in the scenario were modeled after real-world command and control events. These are outlined below.

In addition, military personnel with air battle management experience from various locations visited our lab to consult on the study and provide feedback. Those visiting included Colonels, Lieutenant Colonels, and Master Sergeants, some of which had moved up the ranks to commanders, but all had many years of prior ABM experience under their belts. They each walked through the entire study and scrutinized the details. After each meeting, I made the suggested changes to the set-up and scenario, and the study continued to improve and receive more operational validity and buy-in. All elements of this scenario were vetted through multiple operational groups.

Scenario Roles. In each DDD simulation, participants played the role of ABMs aboard a command and control platform. They were tasked with fulfilling a number of command and control tasks, including managing planned missions, coordinating airspace with local Air Traffic Control organizations, deconflicting aircraft, managing resources, and adjusting plans for dynamic, unexpected events that occured. The objective of each mission trial was to carry out as many preplanned missions as possible while simultaneously protecting team assets and reacting to emergent events that threaten the team's safety.

The ABMs had to coordinate actions of other team members in both time and space in order to meet objectives. Teams were composed of two ABM participants and three additional confederate operators who played the roles of multiple simulated players. Each ABM was responsible for a different area of responsibility (AOR) or functionality. The teams determined how to best split the tasks to accomplish their mission. Some teams decided to divide the area into east and west sections, while others split the tasks based on function (e.g., one worked the fighters while one worked UAVs). The ABMs were allowed to change this division of responsibility if they so desired (i.e., split responsibilities by function rather than geography).

Scenario Elements. The scenario contained friendly and enemy aircraft, ground targets, unidentified threats, and friendly ground troops. Ground troops and unmanned air vehicles were not shown on the situation display, rather they were monitored and maintained through the communication channels. The friendly aircraft contained in the scenarios are outlined in Table 8, along with speed and range of each. The participants were given information about the relative speed of each type of friendly aircraft traversing the scenario, as shown in Table 9. They were also given information about characteristics of each friendly element, including the symbol, type of armament, visibility, and ability to attack, as shown in Table 10. Figure 20 contains screenshots of what the aircraft looked like in the scenario.

Aircraft	Type	Speed (knts)	Speed (m/s)	Range (nm)	Range (m)
E-3	AWACS	461	227	4000	7408000
Boeing 737	Civilian Airliner	421	216	1900	3518800
Blackhawk	Army Helicopter	140	72	315	583380
B-52	Bomber	560	288	8764	16230928
KC-135	Tanker	530	272	1300	2407600
F-16	Fighter	1130	668	2280	4222560
UAV	Unmanned Air Vehicle	117	61	2000	3704000

Table 8. Known elements appearing in the scenario.

Strike Packages. Each strike package consisted of two F-16 fighter aircraft and two B-52 bomber aircraft. The strike packages were tasked to carry out preplanned bombing missions and were rerouted to handle a fixed set of emerging situations as necessary.

Civilian Airliners. The civilian airliners used the airspace for arriving to and departing from a local civilian airport in the AOR, as shown in Figure 19.

Army Helicopters. The friendly aircraft contained in the scenario were Army helicopters on humanitarian missions.

Time to Transverse Each Square in Seconds			
Aircraft	**Vertically**	**Horizontally**	**Diagonally**
Fighters	100s	100s	142s
Bombers	240s	240s	340s
UAVs	1100s	1100s	1562s

Table 9. Relative speeds in DDD scenario.

Asset:	Symbol:	Characteristics:	Can Attack:
F-16 Strike Fighter		Air-to-Air missiles Identify Capability	Enemy Aircraft
B-52 Bomber		Air-ground-bombs	Ground Targets
KC-135 Tanker		No Weapons	Nothing
Boeing 737		Fly on predetermined path (per ATC)	Nothing
UAV		Not always visible	Nothing
ROZ		Preplanned – outline defines area	

Table 10. Friendly components of the scenario.

Tankers. The tankers contained in the scenario were KC-135's that are typically utilized for aerial refueling of friendly assets during long missions. Each scenario contained two tankers that had to be coordinated across the airspace. Both tankers were in separate preplanned orbits, but were reallocated to different areas for emerging missions. Aircraft were not refueled during the scenarios, but the ABMs were expected to be prepared for refueling if it became necessary.

Unmanned Aerial Vehicles - Unmanned aerial vehicles (UAV) are small, unmanned, friendly aircraft that are controlled remotely from a separate control station (simulated in this study). Communication was required between the ABMs and the UAV control station to ensure safety of both manned and unmanned aircraft. Each scenario contained fifteen UAVs, and ABMs were required to track their movement. The UAVs did not appear on the radar scope, but the ABMs received messages about their whereabouts and movements. The UAV's presence added to the complexity of the ABMs job.

Restricted Operating Zone. A restricted operating zone (ROZ) is a volume of airspace of defined dimensions designated for a specific set of operational missions and restricted for all others not involved in those missions. Entry into this zone must be approved. The purpose of the ROZ is to deconflict surface attacks or other missions and prevent accidents and fratricide. ROZ's are typically set up for a certain amount of time, depending on mission needs. ROZ's add to the complexity of the airspace controllers have to manage by restricting possible routes for aircraft. Each scenario contained seven different ROZ's with varying times of activity and inactivity (e.g., "hot" or "cold"). Four sample ROZ's are depicted with grey boxes for illustrative purposes in Figure 19 and the full seven are depicted with yellow boxes in Figure 20.

Scenario Background. Each scenario contained a 3x4 grid that was used to designate and communicate location information. The world is mapped into a two-dimensional, flat grid designated by letter and number combinations, and within each grid, additional altitude information is necessary to fully understand where aircraft are relative to others in three-dimensional space. The terrain and grid values for this study were fictional, but modeled after the type and format of information ABMs rely on every day. In Figure 20, the grids are visible and locations are designated by the number and letter combinations in the center of each box. Each trial contained different terrain and location designations to help prevent learning effects for a particular region.

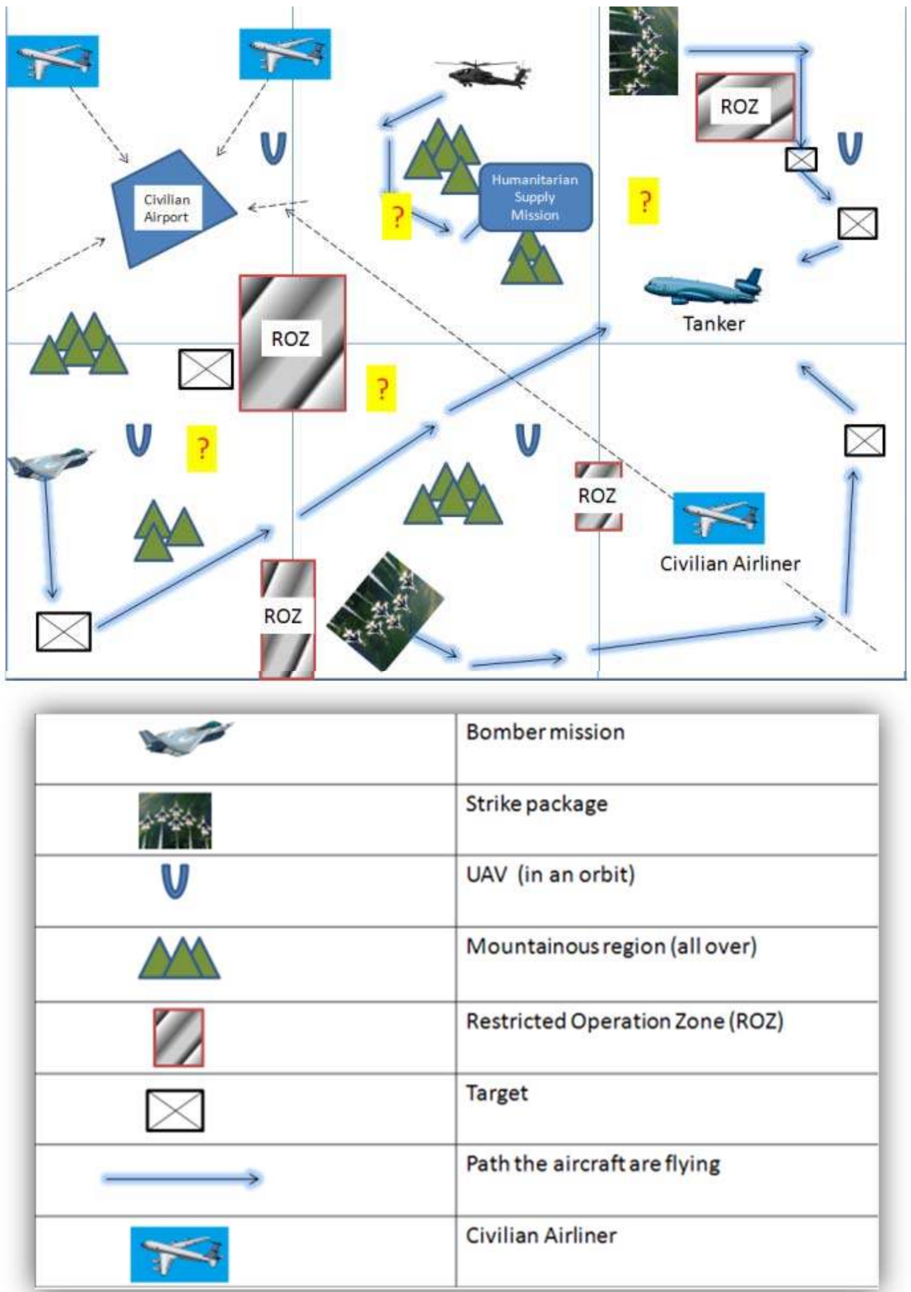

Figure 19. Simplified illustration of the initial scenario assets and locations.

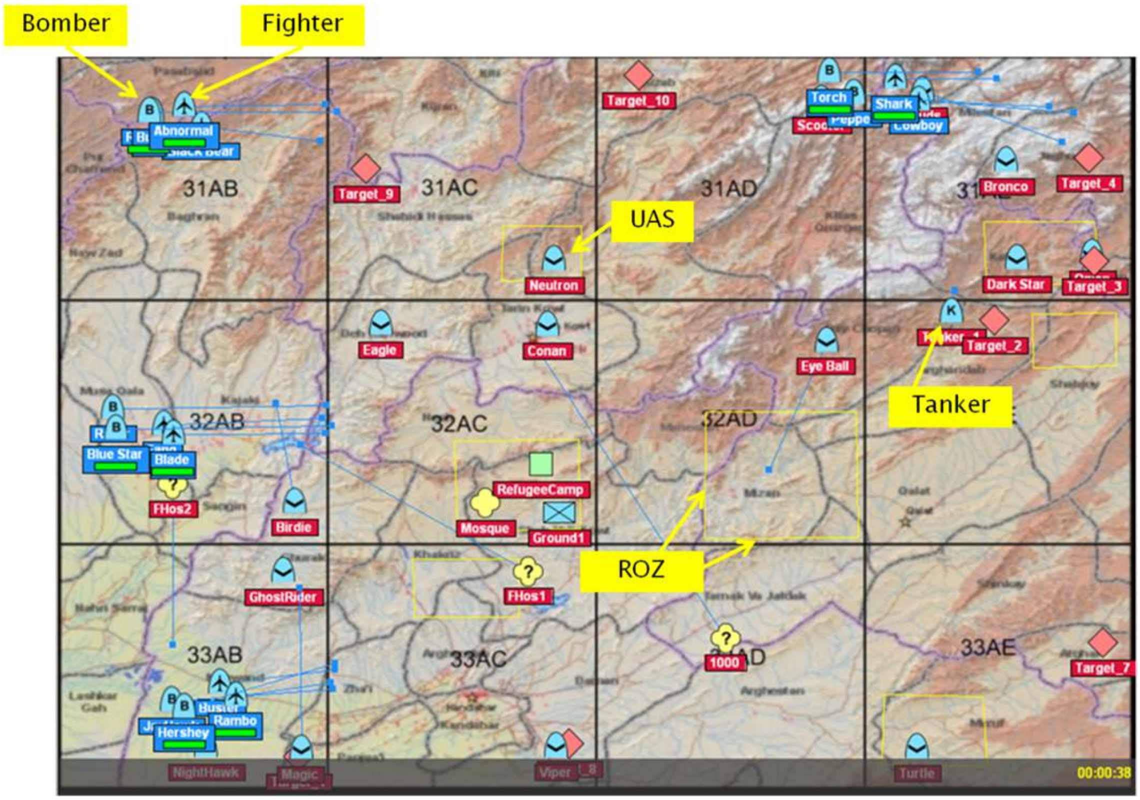

Figure 20. Actual screen shot image of a scenario and included elements.

Scenario Events

Preplanned Missions. At the start of each scenario, four separate Strike Packages began preplanned airstrike missions to engage multiple predetermined target locations, as shown in Figure 20. Each mission was outlined in an Air Tasking Order (ATO) the team received prior to the start of each mission (see *Scenario Aids* for further discussion). Over the course of each scenario, ROZ's activated and deactivated, which constrained different Strike Packages' ingress and egress paths at different times in the scenario.

Unplanned Missions (Troops in Contact Events). A Troops in Contact (TIC) event signifies that ground troops have come in contact with enemy fire and need urgent air support. This type of mission is highly dynamic, unplanned, and friendly troops are very near the target. In order to successfully stop the insurgent attack, while avoiding fratricide, great amounts of communication and coordination are necessary. A TIC announcement is made directly through a communication channel and does not appear on any radar display. The C2 element must then communicate this need immediately to those who can support, reallocate assets, deconflict flights, and ensure sufficient fuel. A TIC requires a substantial amount of coordination in a short amount of time. The troops on the ground are in grave danger, so it is essential to respond to these requests immediately. A TIC event is a common event that tactical C2 elements must deal with in current operations and also one of the most serious.

Unidentified Aircraft. In addition to unexpected events in the DDD scenario, there were unexpected aircraft appearing as well. As the missions progressed, unexpected aircraft entered into the scenario. ABMs sometimes had aircraft that appeared on their radar screens that were identified as neither friendly nor enemy. These unidentified aircraft might have posed a serious threat to the safety of all aircraft and ground troops in the vicinity if they were indeed hostile. In these situations, the ABMs had to work to identify the aircraft as soon as possible. In this study, the unknown entities that appeared were hostile enemy aircraft, friendly aircraft, or civilian aircraft.

In order to identify the aircraft, the ABMs were required to reroute a fighter aircraft to the vicinity of the unknown aircraft to visually identify it. After identifying, the pilot passed the information along to the ABM, who then had to make a decision of whether or not to destroy the aircraft. To ensure the safety of other aircraft, all hostile aircraft were supposed to be destroyed. Fighter aircraft were not allowed to engage unless explicitly directed by their ABM.

Scenario Aids

Confederate Information Sheet – Each confederate received a detailed information sheet to help guide them through the scenario (excerpt shown in Table 11). The printed sheet included the name of all players in the scenario, as well as their respective call signs. The confederate sheet also included detailed information about the TICs that would appear in the scenario, including their location, exact time of appearance, and the altitude limits that would be placed on them. ROZ information was also outlined, including name, location, time they would go active, and altitude limits. A miniature ATO was listed for quick reference, as well as detailed information on each tanker's call sign, orbit path, location, altitude, and payload. Confederates could mark on the document as they saw fit. The information sheet for each trial was different, as was the scenario.

Asset	Call sign
Fighter 1	Blade 2-1
Fighter 2	Fang 2-1

TIC	Area	Time	Alt Limit
TIC-51	47DL3	5:25	20
TIC-52	48DK4	9:00	10

ROZ's	Area	Name	Time Hot	Alt Limit
1	49DL3	Alpha	16:00	12
2	48DM1	Bravo	3:30	25

1/ SORTIE	5/Bomber	6/ROUTE	8/DEST
4	Rawhide 2-1	48DL4	0:30
12	Rawhide 2-2	48DJ6	0:55

Tanker Orbit	mission type	a/c callsign	number and type of a/c	altitude	orbit location	payload
Blue Orbit	Fuel Orbit	Hulk 1	KC-135	17000	47DL1+	32000
Green Orbit	Fuel Orbit	Hulk 2	KC-136	26000	49DJ7+	59000

Table 11. Excerpt from Confederate Information Sheet. For full sheet, see Appendix E.

ABM Information Sheet – Each ABM received an information sheet similar to the confederates', except the ABMs' document contained substantially less information. The ABMs' sheet included a list of all players in the scenario, including type of aircraft or organization and respective call sign. They also received a list of the name and location of each ROZ, but no details on the time when each would be active. Table 12 contains an excerpt from one ABM information sheet. The ABM information sheet did not include any information about TICs, tankers, or when ROZs would be going active.

	Call sign	Location
Fighter 1	Blackbear 2-1	66TF1
Fighter 2	Fang 2-1	67TF9
Bomber 7	Jayhawk 2-2	66TF1
Bomber 8	Rawhide 2-2	67TH2

ROZ's	Area	Name
1	66TI4	Alpha
2	67TF1	Bravo
3	67TI1	Charlie

Table 12. Excerpt from ABM Information Sheet. For full sheet, see Appendix F.

Altitude Tracking Sheet – One of the primary duties of an ABM is to deconflict airspace and tracking altitude is a huge part of that duty. ABMs must be able to direct altitude changes dynamically as events evolve. The DDD scenarios were not equipped to handle dynamic altitude changes in real-time, thus the altitude tracking sheet was devised to mimic this requirement (shown in Table 13). The altitude tracking sheet was a physical piece of paper that the confederates used to dynamically "change" the altitudes of the aircraft without relying on the scenario environment itself. The tracking sheet offloads any memory requirements of the confederates to memorize the latest altitude of each aircraft in the scenario.

The sheet listed the starting altitude of each aircraft in the scenario. ABMs were allowed to ask about these altitudes, but did not have a tracking sheet in front of them, although they could take notes about anything they felt was necessary. As ABMs directed aircraft to change their altitudes, the confederates would cross out the starting altitude and add the new altitude into the "change" column. Since the aircraft in the scenario were not able to dynamically change their altitude, this change sheet served as the actual aircraft altitude changes.

Type	Call Sign	Starting Altitude (ft)	Change	Change	Change
Fighter 1	**Fang 2-1**	26000			
Fighter 2	**Pepper 2-2**	~~27500~~	32500		
Bomber4	**Cowboy 2-1**	20000			
RPA7	**GhostRider**	~~16500~~	~~14000~~	9500	

Table 13. Altitude tracking sheet. Full sample page is in Appendix D.

Special Instructions (SPINS) – Both ABMs and confederates received separate information sheets detailing any special instructions they needed to be aware of. The SPINS were general instructions that were applicable to each mission and remained consistent over the different mission sets (see Appendix G and H for full SPINS documents). They received this document during the training phase, and it remained at their work station in hard copy to reference as needed.

Air Tasking Order (ATO) – Both ABMs and confederates received a detailed Air Tasking Order in paper format outlining the flight plans for each known friendly flight path in the scenario. The ATO included details such as the sortie number, mission number, package call sign, number and type of aircraft in the package, individual aircraft names, location of ground targets to engage, type of target, time for ordinance to land on target, flight altitude, and the control agency to communicate with. An excerpt from an ATO is demonstrated in Table 14. Everyone had individual paper copies and could write on them if they felt necessary. This document was loosely modeled after actual ATO documents.

1/ SORTIE	2/MSN	3/CALLSIGN	4/TYPE	5/Bomber	6/ROUTE	7/TGT	8/DEST	9/Alt	10/CTRL
	mission number	a/c callsign	number and type of a/c		Target at:		minute:sec in scenario		
1	2/TGT	Bluestar	F16's(2) / B-2's(2)	Bluestar2-1	33AB3	Building	1:20	21000	10/ AWACS
2	2/TGT	Bluestar	F16's(2) / B-2's(2)	Bluestar2-2	32AB8	Building	6:10	21000	10/ AWACS

Table 14. Excerpt from an ATO. Full ATO sample page is in Appendix C.

Dry Erase boards – In addition to the paper documents they received, ABMs also each had a dry erase board at their disposal. They were able to write down anything they wanted on the white board. This is fairly standard in most C2 platforms. Figure 21 illustrates an example of the types of information participants recorded on the dry erase board. This particular participant listed all the aircraft in specific regions, designated by a box which represents blocks of airspace. The aircraft are listed by call sign, physical location in the block of airspace, and altitude. Generally, the more aircraft listed in a particular box, the greater the complexity of that space, and the greater workload of altitude deconfliction will be.

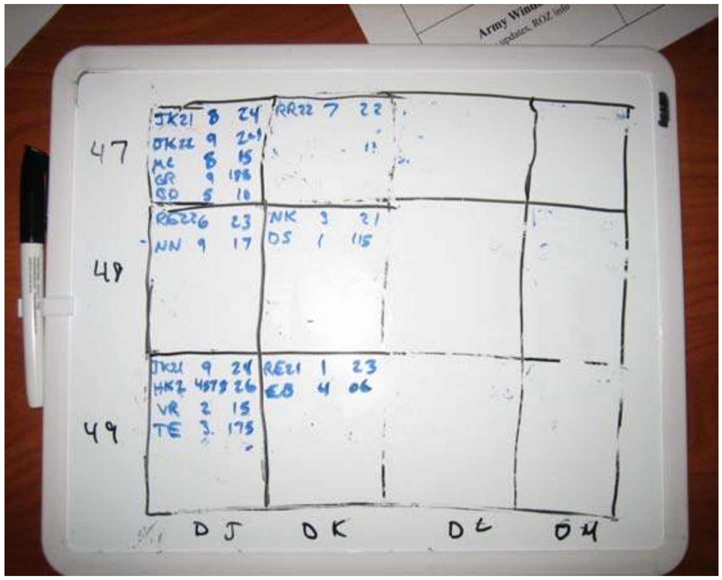

Figure 21. Image of a participant's white board aircraft deconfliction strategy.

Scenario Players and Communication

Communication Rooms. All communication was split into six independent segments, broken down by communication topic (as shown in Table 15). These segments were analogous to radio channels or chat rooms depending on the experimental condition. For radio conditions, the windows represent radio channels that they verbally communicate on, and for chat conditions, the windows represent chat rooms they will type and receive messages in.

The topics listed in each box are representative of common types of communications ABMs generally participate in and were modeled after operational chat room topics. The topics ranged from global and strategic issues, such as attack requests and ROE clarifications, down to very local issues, such as movement coordination (see Table 15). The first room was a high level C2 communication room that included agencies with decision authority. In this room, high priority messages about emergent events were discussed, including requests for TIC support or approval for attacks. Air

Traffic Control was another room, and coordination with the local air traffic control agency for deconfliction of military and civilian flight paths took place here. The Army room contained coordination messages between the ABMs and ground troops, including topics such as movement updates, ROZ instantiations and cancellations, as well as Close Air Support requests. ABMs were tasked to manage both manned and unmanned assets; updates and any relevant unmanned aerial vehicle information took place in the Unmanned Aerial Vehicle room. The C2 Coordination room is aimed at tactical level coordination between individual assets, including issues such as airspace requests and taskings. The last room was an internal channel used for private discussions between the ABMs. This was to ensure all communication between the team was captured and to limit any face-to-face communication. They were seated apart from one another and were instructed to only communicate via the communication tools.

Command and Control (C2) High level priority topics: TICS	**Air Traffic Control** Deconfliction of civilian flight paths
Army Army updates, ROZ info, CAS requests	**Unmanned Aerial Systems** Updates on UAV relevant info
C2 Coordination Lower level topics: movement coordination, aerial refueling	**Internal** Internal ABM communication

Table 15. Communication room topic configuration and details.

Confederate Roles. To simulate different radio channels or chat rooms, three confederate participants played the roles of various entities. They acted as multiple aircraft: fighter aircraft (8 total), bomber aircraft (8 total), unmanned aerial vehicles (15 total), and tankers (2 total). Also simulated by the confederate participants were other command and control agencies and positions: control and reporting center (CRC), civilian air traffic control (ATC), tanker liaison officer, unmanned aerial vehicle operators, army artillery representatives, air support operations center (ASOC), combined air operations center (CAOC), and ROZ owners. The primary role and affiliation of each player dictated which room they were located in. Table 16 illustrates the breakdown of which players were present in each room. If the ABMs used an incorrect room, the "right" individuals would not be privy to the communication and they were directed to resend their message in the right channel.

Confederates broke down the roles and responsibilities by function. One confederate simulated the airborne manned assets (i.e., fighters and bombers). This confederate was in charge of taking directives from the ABMs and maneuvering the manned aircraft in the scenario. The second confederate focused on radio and chat communication for the manned aircraft, responding to ABM directives or inquiries about manned aircraft, but not physically interacting with the aircraft in the scenario. The third confederate was focused on simulating the radio and chat communication for all other players (e.g., unmanned aircraft, C2 organizations, ROZ owners, etc). As such, they were the approval authority for the flight plan directives that required approval (e.g., TIC support plans). The third confederate was also tasked to physically maneuver the UAV assets in the scenario as directed. Table 17 illustrates the division between the three confederates and their primary roles.

Command and Control (C2) Players: Air Support Operations Center (ASOC) Combined Air Operation Center (CAOC) Control & Reporting Center (CRC)	**Air Traffic Control** Players: Air Traffic Control (ATC) Control & Reporting Center (CRC)
Army Players: Army Artillery ROZ Owners Control & Reporting Center	**Unmanned Aerial Systems** Players: Army Artillery UAV Operators Control & Reporting Center
C2 Coordination Players: All fighters (8) All bombers (8) Tanker Liaison Officer Tankers (2) Control & Reporting Center	**Internal** Players: ABM participants

Table 16. Communication room topic with included players.

	Confederate 1	Confederate 2	Confederate 3
Move fighters in DDD	X		
Move bombers in DDD	X		
Communicate as fighters		X	
Communicate as bombers		X	
Communicate as UAV operators			X
Move UAV's in DDD			X
Communicate as larger agencies (e.g., ASOC, ATC, CAOC, CRC)			X
Approve ABMs flight recommendations			X

Table 17. Division of Responsibilities for the Confederates.

Scenario Communication. The scenario contained a large number of entities and events, and the communication between these entities was complex. As such, communication during the trials contained both pre-scripted and real-time generated messages. The messages sent across each trial were different messages, but equivalent in the types of messages and numbers sent. There were a total of sixty-five pre-scripted messages sent each trial. Of those messages, twenty were classified as requests for information, while the other forty-five provided information. The pre-scripted messages were loosely based off actual operator chat logs. They were representative of the volume, frequency, and types of messages operators typically receive, but the actual content of the messages was changed to protect the original chat logs. The experimental pre-scripted messages were vetted through multiple subject matter experts and were representative of actual operator communication.

The pre-scripted messages were automatically injected at specific times in the scenario. For the radio conditions, the "person" sending the message was a prerecorded verbal message that automatically played at the appropriate time. Each of the different roles had a unique voice, including both male and female voices. For the chat conditions, the automatic message appeared as a line of text with the organization or user name as the sender (e.g., ASOC, CRC, etc.), as shown in Figure 23. These messages appeared no different than messages sent in real-time.

All participants' communications were generated in real-time, as well any confederate responses to requests or questions from the participants. The participants were not aware of any pre-scripted messages. After the trial ended, they often searched around for a particular organizational representative they communicated with during the trial, assuming the person was merely sitting in a different location.

In order to communicate, participants pushed and held a "talk" button with their mouse in the appropriate room to communicate during the radio trials (Figure 22). For chat communication conditions, participants typed their messages in the bottom black box (also shown in Figure 22), and then hit the enter key or pushed the talk key with the mouse.

Figure 22. Individual chat room. The talk button is on the bottom left, while the chat dialog box is the black box on the bottom.

For conditions with text, each message appeared as a separate line, with the time stamp and sender's name followed by a colon and the rest of the message (see Figure 23). Each new time stamp signified a new message.

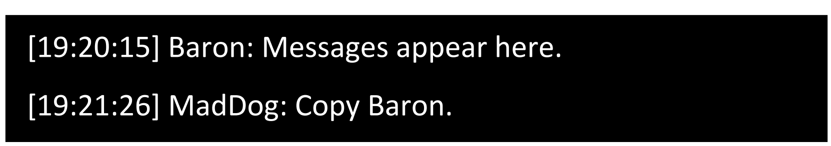

Figure 23. Time stamped chat messages.

The full MMC chat tool, from the ABMs' perspective, is shown in Figure 18. There were six different talk buttons for each individual room. The messages sent from others were in white, while messages sent from the participant appeared in green. Red signified a problem with the transcription, indicating the message may not be accurate. Automatic transcription was only present during the voice with archival log trials.

As previously mentioned, confederates played the role of multiple players. In order to successfully and efficiently mimic chat for multiple players, a software tool was built to interact with the MMC tool. The new tool essentially overlaid the MMC tool and provided a selection of possible users to choose from. The list of names was on the top right of each room (see Figure 24). The confederate first clicked on the player's name they wanted to be, and then sent the message through the MMC tool. The selected name appeared on the transcription or chat message after it was sent. A full view of the confederates MMC tool with additional overlay is shown in Figure 25. The ABMs did not have this extra tool and were not able to change their name. Each ABM was either "ABM1" or "ABM2," depending which physical seat they were in.

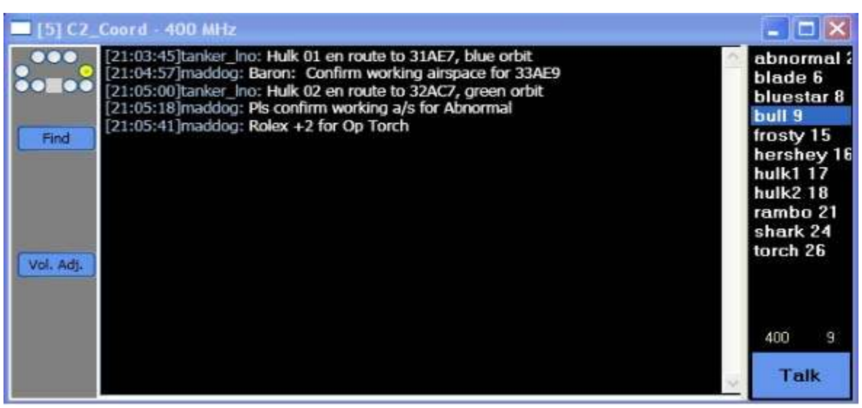

Figure 24. Individual chat room from confederate's perspective. Note the player selection tool listed in the right panel.

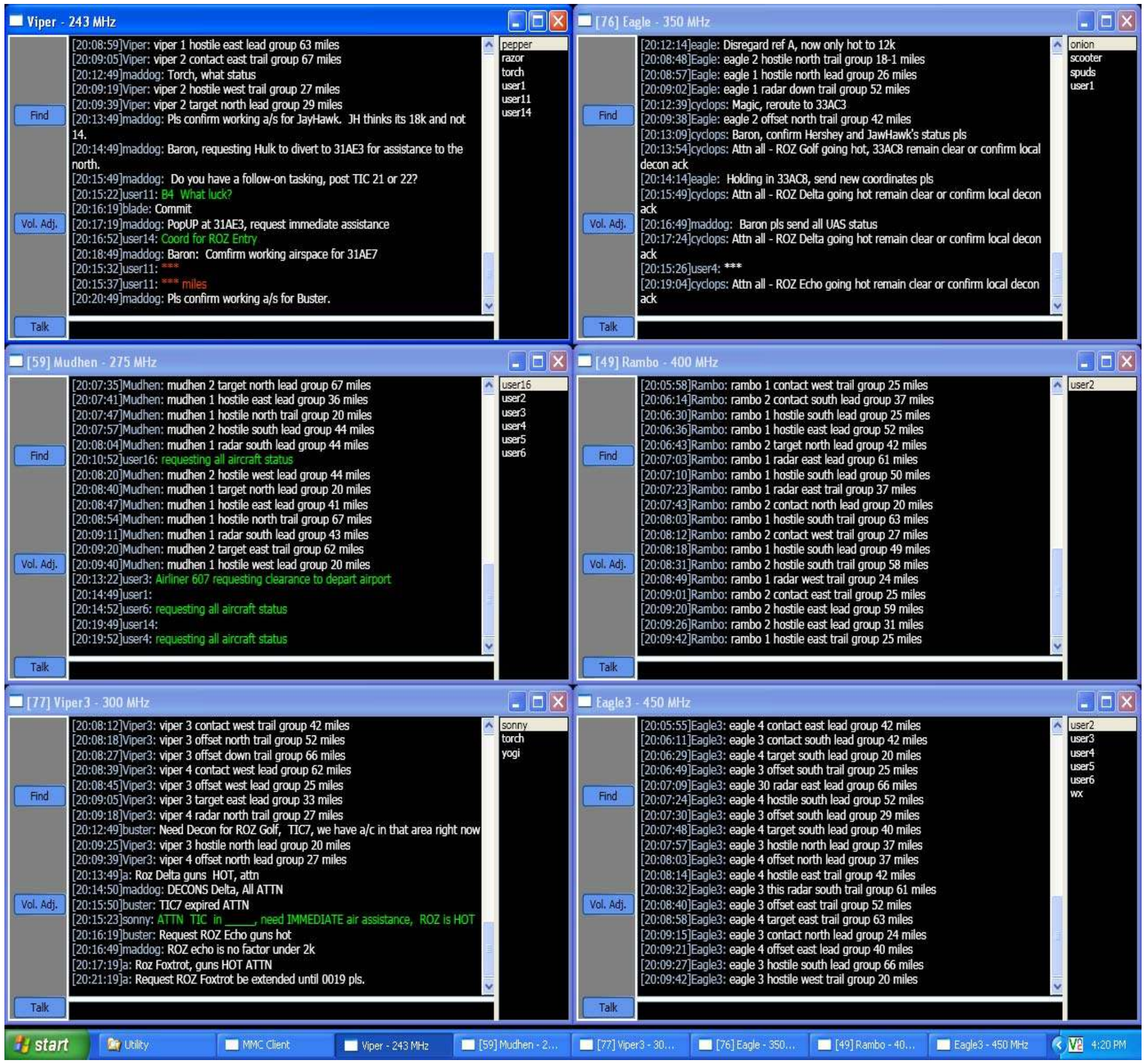

Figure 25. Full MMC tool from confederate's perspective

Secondary Task

In addition to the command and control tasks inherent in each scenario, participants were asked to do an additional related task, the Coordinate Response Measure (CRM) task (Bolia, Nelson, Ericson, & Simpson, 2000). This CRM task was developed to model the demands of real-world complex team communication. It required participants to first listen for a particular call sign ("Baron"). Following each call sign was a color and a number (e.g., "Ready Baron, go to BLUE SEVEN") that differed for each message. ABMs were asked to listen for their call sign and then attend to the color and number information that followed. They were directed to select the appropriate response as quickly as possible on the response grid, as shown in Figure 26 (Bolia et al., 2000).

The CRM task contained 2,048 unique recorded phrases with eight voices, four male and four female. Two messages were presented, each with distinct voices, over the radio with a 10 millisecond delay. One phrase contained a critical call sign (e.g., "Baron"), while the other contained a distracter (e.g., “Charlie” or other name). This task was challenging as both phrases contained a different color and number combination, thus the ABM had to attend to a particular voice and also process the information presented. For example, the phrase "Ready Baron, go to White 4” may happen at nearly the same time another message says “Ready Charlie, go to Blue 7." A correct response would be the one following the target call sign “Baron,” or the number 4 located in the white section. There were 256 possible call sign, color and number combinations (Bolia et al., 2000). The phrases were played over the radio once approximately every 60 seconds. Each participant heard different messages at different times, thus they were not able to collaborate on this secondary task. The response grid was located on the bottom of the right monitor, below the MMC tool (Figure 18).

Figure 26. Response grid for CRM task.

The CRM was a secondary task and was not directly related to the operations in the main DDD scenario. In a real command and control situation, operators are required to listen to multiple conversational streams and digest the information. The CRM task added an additional communication demand to the simulated C2 environment to maintain a high communication stressor, enhancing the representativeness of the scenario. The CRM task allows researchers to make inferences into participants' ability to monitor different verbal communication channels. Interviews with SMEs have suggested this ability is of great value to the C2 population.

Procedure

Training. Participants completed multiple computer-based training modules, which informed them about DDD, the nature of the tasks and responsibilities, chat communication, and the tactical C2 display they would be monitoring. Interleaved with the computer-based instruction, they practiced with the DDD interface, the scenario elements, the MMC communication tool, and the CRM task (details shown in Table 18). Participants received a total of five training DDD scenarios and three computer-based training modules. Researchers monitored the progress of each ABM with a checklist to confirm each was sufficiently trained in each requisite component. Participants received approximately two hours of instruction and practice with the DDD simulation environment. In addition, each participant already had extensive real-world experience and training with performing ABM tasks.

Experimental Data Collection. Participants began data collection following a short break at the completion of the training described above. Data collection took each participant approximately two hours. Participants were randomly assigned into one of the ABM positions. As a team, they completed each of the four experimental conditions, which were controlled for order effects with a balanced latin squares design. The latin squares design was developed for 16 groups of participants, but due to emerging and unexpected operational demands, only 14 groups were able to participate. Each trial lasted twenty minutes, and participants were given breaks between trials. After completing each experimental trial, participants completed a debriefing questionnaire individually, specifically the shortened version of the post-task Dundee Stress State Questionnaire (DSSQ; Matthews, Joyner, Gilliland, Campbell, Huggins, & Falconer, 1999; Matthews, Campbell, Falconer, Joyner, Huggins, Gilliland, Grier, & Warm, 2002). The questionnaire was not part of the current study, but was implemented for use by other researchers.

Training Focus:	**Tasks Completed:**
Pre-work	1. Consent Form 2. Biographical Information /Pre-DSSQ
Initial Overview	3. PowerPoint 1 a. Overview, Basic controls 4. Training Scenario 1 a. Focus: Overview of scenario and controls, Voice only b. Time: 5 min c. Players: Fighters/Bombers/UAV d. Events: Preplanned Targets 5. Training Scenario 2 a. Focus: Overview of scenario and controls, Chat Only b. Time: 5 min c. Players: Fighters/Bombers/UAVs d. Events: Preplanned Targets
Altitude Deconfliction/ Unknowns	6. PowerPoint 2 a. Altitude Deconfliction, Unknown aircraft 7. Training Scenario 3 a. Focus: Learn ABM responsibilities b. Time: 10 min c. Players: All d. Events: Introduce unknown aircraft; No TICS
TICS	8. PowerPoint 3 a. CRM 9. Training Scenario 4 a. Focus: Altitude Deconfliction b. Time: 10 min c. Players: all d. Events: Introduce TICS ; No unknown aircraft
Putting it all together	10. Training Scenario 5 e. Focus: Put it all together, Alt deconfliction f. Time: 10 g. Players: All h. Events: Preplanned targets, unknown aircraft, and TICS

Table 18. Order and focus of training segments.

Dependent Measures

For the current experimental study, the dependent measures attempted to capture team performance at different levels of abstraction to comprise more of a complete picture. Measures include overall performance measures (e.g., total number of targets destroyed, number of friendly aircraft destroyed, etc.), team process measures (e.g., communication content analysis, anticipation ratio, etc.), and individual measures (e.g., individual performance, secondary task performance).

<u>Performance measures</u>

Number of Targets Struck – Planned targets (e.g., ground targets) and emergent targets (e.g., enemy aircraft and ground troop support) that were successfully struck were included. Greater numbers of targets indicated better performance.

Number of Friendly Aircraft Destroyed – This number included a loss of friendly aircraft by way of friendly fire or enemy attacks. Greater numbers indicated lesser performance.

Unknown Aircraft Identified – The percentage of unknown aircraft that were correctly identified by friendly fighter aircraft were counted in this metric.

<u>Process measures</u>

Amount of Communication - The overall number of messages sent and received from the team as a whole (including confederates) were counted.

SME Team Performance Rating – A retired ABM with extensive command and control experience, including multiple deployments and heavy chat communication usage in theater, was recruited to serve as a SME to evaluate the performance of each team. All communication was sent to her in the form of written transcripts (voice trials were transcribed and chat trials were untouched). She was privy to team number and trial number, but had no information about condition or overall team performance. She read through each trial, coded each line according to a guide (see following section for more details), and gave the team an overall performance rating based on their communication. The idea was to rate the quality of their communication processes that ultimately would influence global outcome variables.

Number of Decisions - Decisions were operationalized as any modification an ABM made to the planned trajectory of events. Decisions were inferred from actions ABMs took to alter original plans. Deviations in original plans included things such as commands to divert aircraft from planned missions to emergent issues, modifications to original refueling plans, and changes to current plans. All modifications occurred through communication channels, as the ABMs had no direct physical control over the scenario or the aircraft.

Communication Content Analysis – After data collection was complete, all radio messages between participants were hand transcribed into written text. All communication messages, including both the transcribed radio messages and typed chat messages, were then coded into twelve possible categories based on the content of each message. An ABM SME hand coded all of the communication messages according to a list of twelve possible categories that were customized for this project. The categorization scheme was loosely based on the original work of Bowers, Jentsch, Salas, and Braun (1998). They developed a scheme for pattern analysis of simulated flight task communication data that factored in content of the messages and found strong differences in performance that were not illuminated with simple word counts alone (Bowers et al., 1998). These communication categories were tailored for command and control environments that simulated air battle management tasks (Strang, Funke, Russell, Miller, & Knott, 2011; Russell, Funke, Knott, & Strang, 2012).

In addition to leveraging the coding scheme used in previous C2 studies, the categories for this effort were further shaped by input from an ABM who acted as SME consultant for this effort. Iterative development cycles were conducted with the SME to adapt previous coding schemes to meet the needs of the operational data. The twelve resultant communication categories are found in Table 19.

Anticipation Ratio - The number of voluntary information messages sent ("pushes") divided by the number of information requests ("pulls"). This allows inferences about the team's mutual awareness and ability to anticipate future needs (Entin & Serfaty, 1999). Presumably, if a team has a shared understanding, they are able to anticipate and provide necessary information while limiting the arduous task of asking for all needed information. A ratio of greater than one suggests the team anticipates each other's needs and sends more information than is requested.

Category of Message	**Description**
1. Request for Information	Messages aimed at soliciting information
2. Request Resulting from Confusion	Messages that are repetitively soliciting information
3. Mission/Situation Update	Any information about missions or aircraft status updates (not including TICS)
4. Request for Approval (to move, bomb, attack, etc)	Messages aimed at getting approval for a particular action
5. Approval messages (both affirmative and negative)	All approval messages
6. TIC Request/Repeats	Messages asking for TIC assistance or for TIC updates
7. TIC Updates/Directives	Messages detailing plans for supporting TIC events or updates on status of aircraft supporting
8. Commands/Directives for Assets	Commands/directives for any of the assets, except for TIC directives
9. Coordination Messages	Messages about coordination processes, such as negotiating talk time on the radio or deciding how to split up assets or areas of control.
10. Acknowledgment/Copy	Messages regarding a copy or acknowledgement
11. Chatter	Information not directly related to the task
12. Unknown/Not clear	Information that is unclear or unintelligible

Table 19. Categories for the communication content analysis.

Individual Measures

Percentage of CRM messages correctly identified - This metric considered the percentage of the CRM secondary task messages that were correctly identified within the time limit for each stimulus presented.

Latency - Some of the pre-scripted messages were probes designed to elicit specific responses. For instance, a TIC support request was sent via the communication channels, and the participants were expected to react in very specific ways by seeking approval, requesting more information, deconflicting with Army troops on the ground as well as all manned and unmanned aircraft. The length of time between the critical information presented (e.g., TIC announcement) and actions taken were recorded. This measure is essentially the latency between the first time the message was sent and when the participant responded via the communication channels.

CHAPTER VII.   Results

To examine the impact of communication modality on performance and team behavior, a two-factor (message input and archival log) repeated measures analysis of variance (ANOVA) was performed on overall team performance measures, team process measures, and individual measures. For these analyses, the alpha criterion was set to $p<0.05$. This research is generative in nature and constrained by the total number of operational participants and overall power, thus I will also discuss effects below a generous $p<0.10$ alpha level. Trends at this alpha level need to be explored more deeply in future controlled studies to investigate any lasting effects. In addition, histogram representations are shown for the primary team performance measures as another way to explore and visualize the performance data and distribution among teams.

Performance Measures

Ground Targets Prosecuted (Preplanned Targets). Ground targets were preplanned events and were listed on the ATO (see Appendix C). While these targets required timely action, successful action was not as time-critical as the other performance measures. Overall, chat conditions had the highest number of perfect scores, as shown in the frequency plot of the scores from fourteen teams in Figure 27. The four conditions shown are Chat, Chat-, Voice+ and Voice. These represent typical chat with an archival log, chat without an archival log, voice with an archival log, and typical voice without an archival log respectively. The four lowest scores on this measure were all from the same team, which was an outlier with respect to this task. The other three lowest scores were conditions without an archive capability.

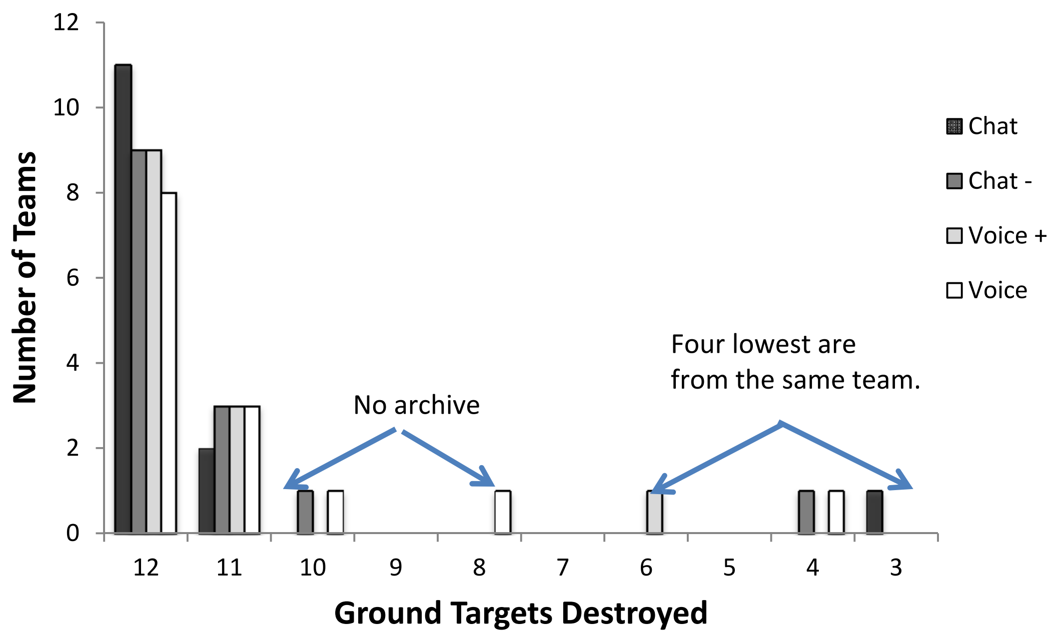

Figure 27. Distribution of teams on number of ground targets destroyed.

The team with the lowest four scores was identified as an outlier on this particular measure, with each score below three standard deviations of the mean. For this reason, this team was excluded from this measure only. The scores for all other measures for this team were within normal limits. In addition, one trial suffered an error and did not record the performance measures, and thus had to be dropped. The resulting data suggests a trend whereby a greater number of ground targets were prosecuted on trials that had archival information (M=11.792, SE=0.074) than transient message trials (M=11.458, SE=0.189), ($F(1, 11) = 3.520$, $p < .10$).

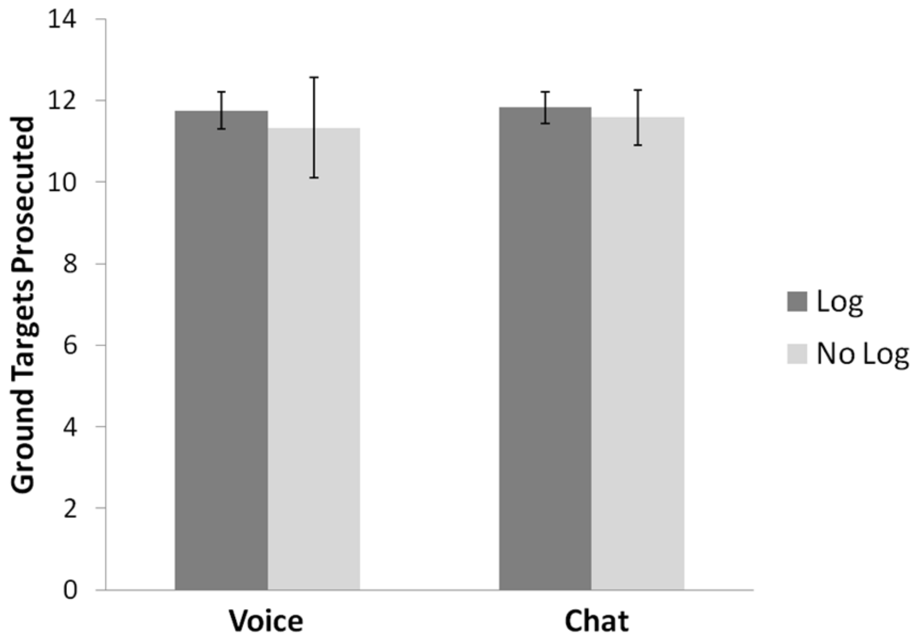

Figure 28. Trend of archival log on the overall number of ground targets prosecuted.

In addition, there was a statistically significant interaction between experience and archival information on ground targets prosecuted. Post hoc analyses broke the teams into three categories: teams where both members were CMR (4), teams where only one member was CMR (5), and teams where both members were not CMR (4). These were post hoc analyses as the CMR level was not controlled for during participant recruitment or assignment to teams.

Interestingly, post hoc analyses showed a significant main effect of archival log, $F(1, 9) = 13.488$, $p < .05$ when CMR status was included as a between subjects factor, as well as a significant interaction between CMR status and archival information, $F(2, 9) = 9.220$, $p < .05$, on the number of ground targets prosecuted as shown in Figure 29. Groups that had at least one individual with CMR status or more did well on conditions both with and without archival information. Groups where both individuals were not

CMR greatly improved their performance on prosecuting ground targets when they had access to archival information.

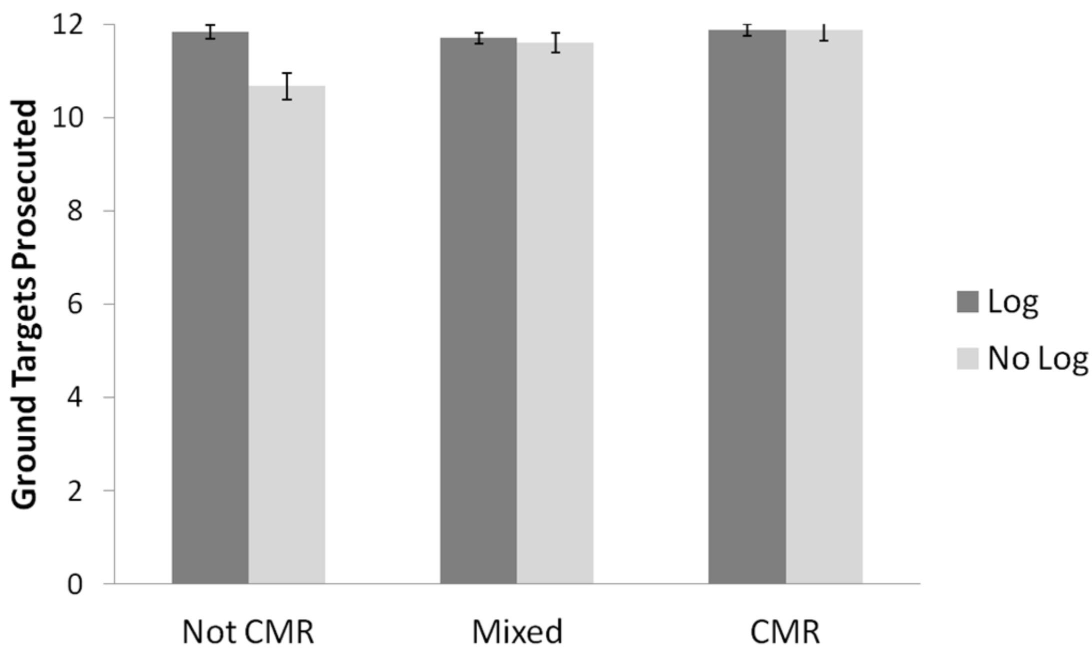

Figure 29. Interaction between CMR status and archival log on the prosecution of ground targets.

TICs Prosecuted (Emergent Threat). Troops in Contact events were unplanned, emergent events that required rapid communication and coordination efforts to effectively mitigate the danger to troops on the ground. TIC requests were only evident in the communication channels through verbal or chat requests from troops on the ground. There were four total TIC events for each trial. The histogram of the TICs prosecuted, as shown in Figure 30, illustrates a clear distinction between chat and voice conditions. Six of the seven lowest scores are from chat conditions. This suggests an advantage for the voice channel.

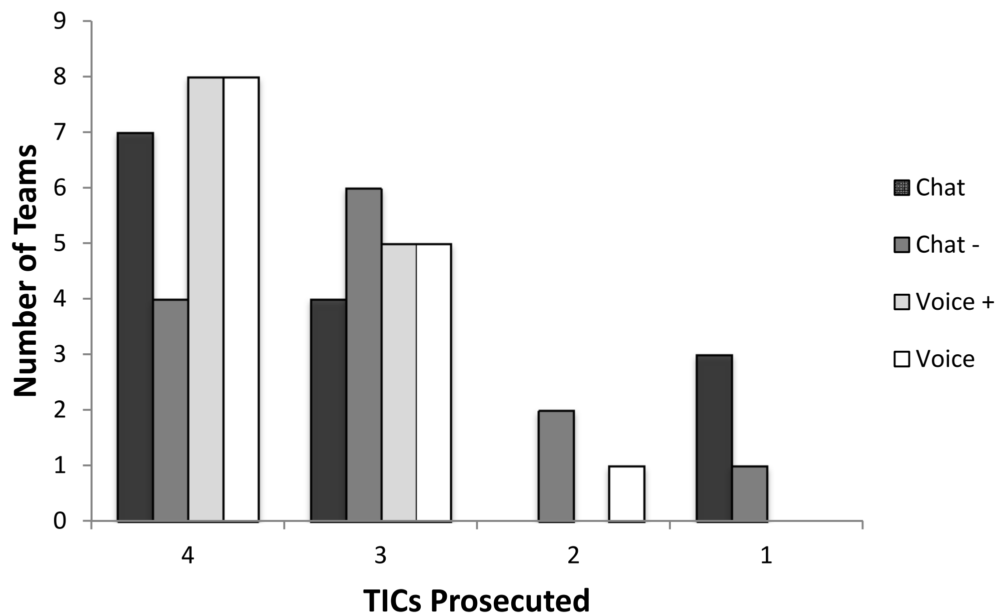

Figure 30. Distribution of teams on TIC prosecution.

A trend within the data demonstrates that voice trials resulted in a greater number of TICs supported (M=3.538, SE=0.120) when compared to chat trials (M=3.115, SE=0.197), ($F(1, 12) = 4.714$, $p < .10$), as shown in Figure 31.

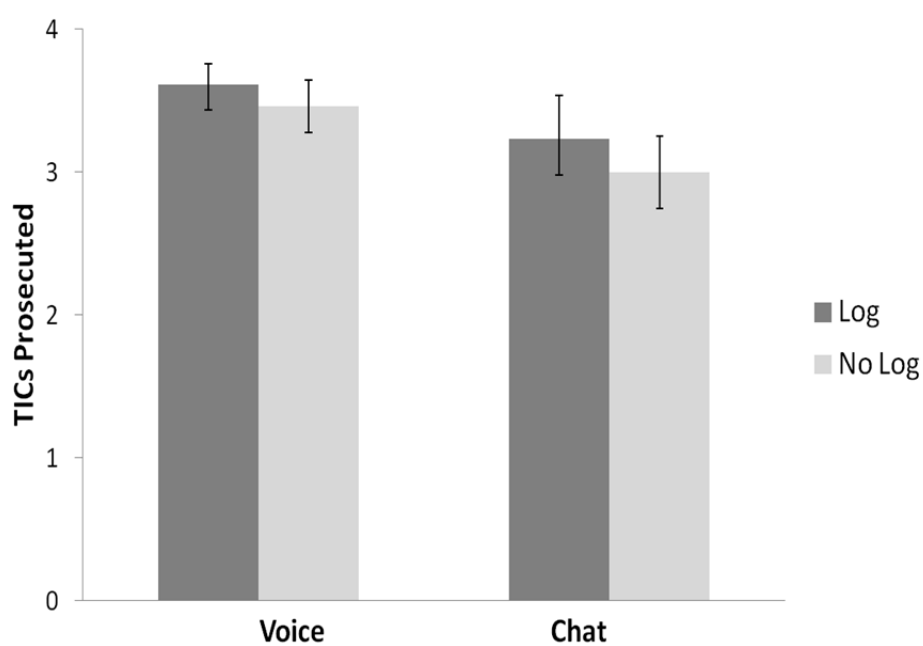

Figure 31. Trend of message input on the number of TICs prosecuted.

Unknown Aircraft Identified (Emergent Threats). Unknown aircraft appeared in the scenario on the radar display screen (DDD display). These aircraft represented unplanned, emergent threats that appeared at various times throughout the scenario. Unknown aircraft posed a time-critical threat and had to be responded to immediately. The frequency plot for unknown aircraft identification also demonstrates an advantage for voice conditions, as shown in Figure 32. All but two voice trials achieved scores above 90%. Chat trials without an archive capability resulted in poorest performance.

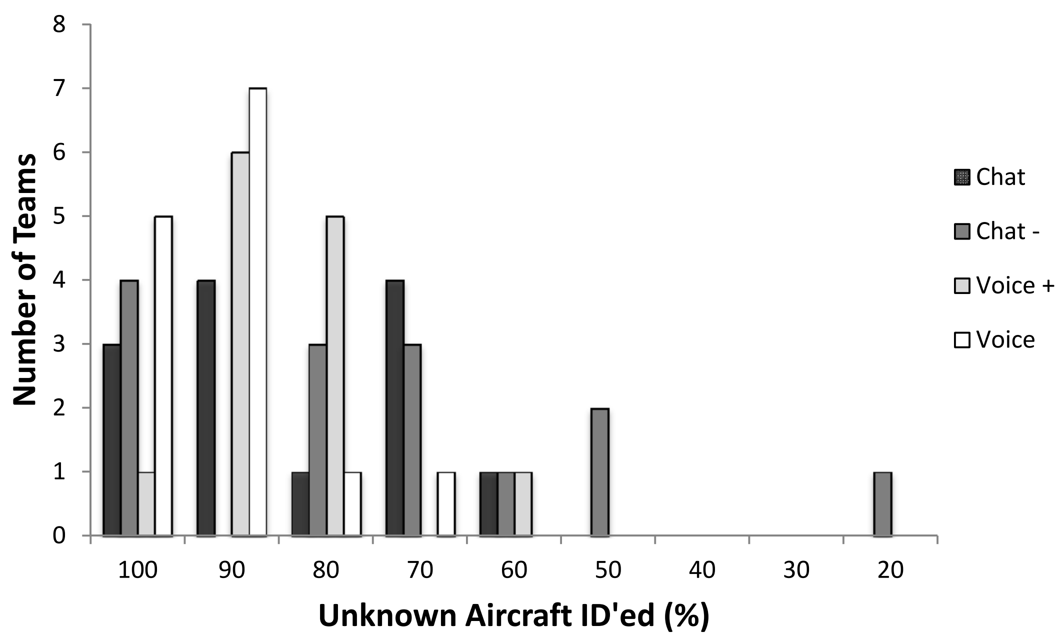

Figure 32. Distribution of teams on unknown aircraft identified

A statistically significant main effect of input of information on the percentage of unknown aircraft identified was detected, $F(1, 12) = 5.867$, $p < .05$. A greater percentage of unknown aircraft were identified on trials using voice input rather than chat (Figure 33).

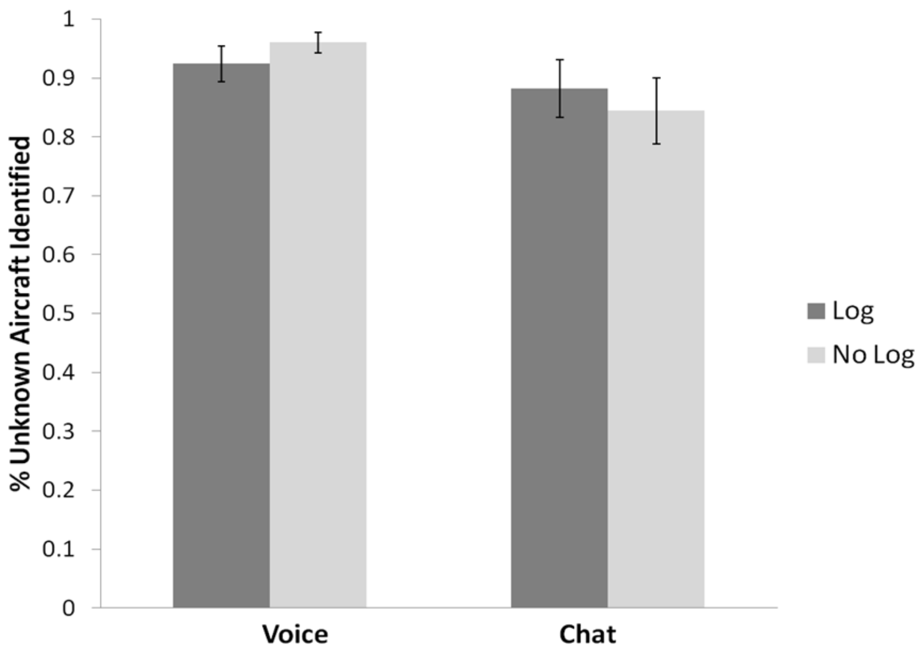

Figure 33. Main effect of message input on the percentage of unknown aircraft successfully identified.

Number of Friendly Aircraft Destroyed – There were no friendly aircraft destroyed in any of the scenarios, and thus analyses resulted in no significant differences between any of the conditions.

Process Measures

Overall Communication Analyses

Total Messages Sent. A statistically significant main effect of input of information was detected, $F(1, 13) = 21.489$, $p < .05$. Specifically, voice input trials resulted in greater messages (300) sent per trial than chat input trials (267). The main effect of archival information was also significant on the total messages sent, $F(1, 13) = 5.091$, $p <$

.05. Trials with an archival log resulted in fewer messages sent (276) when compared to trials without an archival log (291).

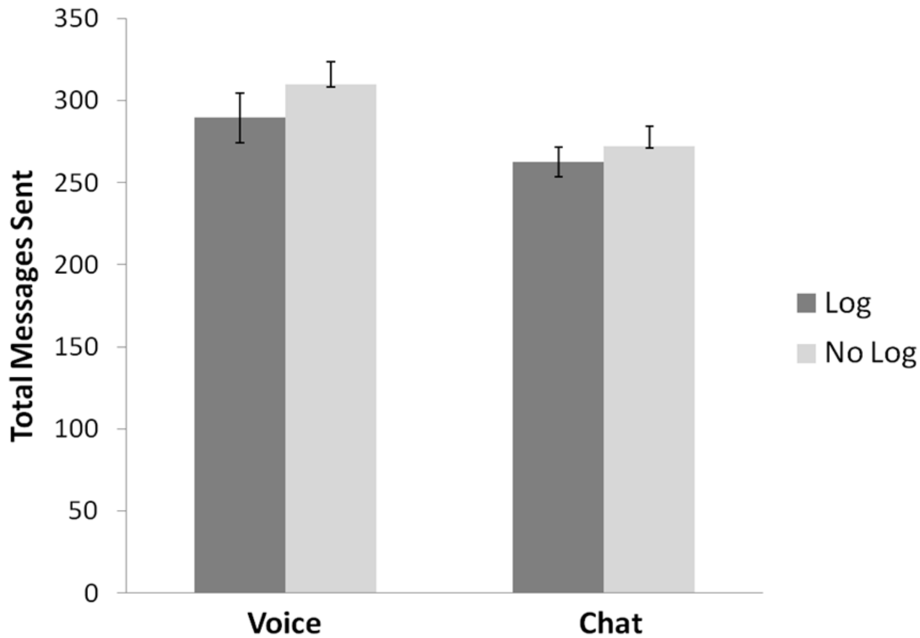

Figure 34. Main effects of message input and archival log on the overall number of messages sent.

Overall SME team rating. The SME team rating was a subjective rating of the quality of each team's communication process on a 1-10 scale. The SME rating was based exclusively from the team communication, as there was no information provided about neither trial conditions nor performance results.

A statistically significant main effect of input of information was detected, $F(1, 13) = 5.789$, $p < .05$. Specifically, voice input trials were rated higher than chat input trials. The main effect of archival information was also statistically significant on the SME team rating, $F(1, 13) = 7.811$, $p < .05$. Trials with an archival log were rated higher than trials without a log.

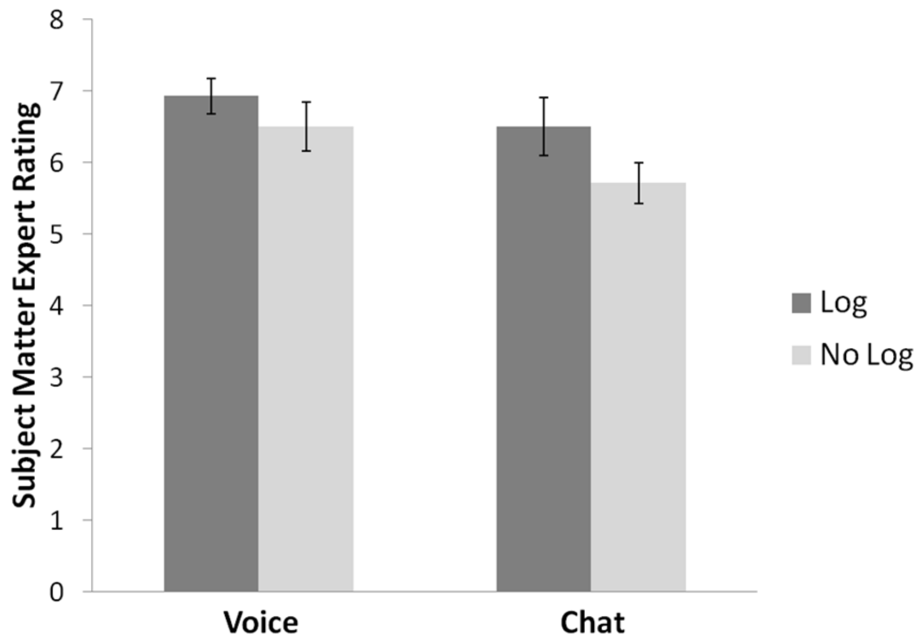

Figure 35. Main effects of message input and archival log on the overall expert rating.

In addition, post hoc analyses suggested a trend between input of information and CMR status on the overall expert rating ($F(2, 11) = 3.343$, $p < .10$). Specifically, the most expert teams (i.e., both CMR status) were rated highest with chat trials (M=7.125, SE=.489) compared to voice trials (M=6.875, SE=.430). Less expert teams (those with 0 or 1 team member that were CMR) had an opposite pattern with higher ratings during voice trials (M=6.25, SE=.430 and M=6.917, SE= .351 respectively) than during chat trials (M=5.5, SE=.489 and M=5.833, SE= .399 respectively). This is depicted in Figure 36. It should be noted that the SME had no knowledge of the background or training experience of the participants.

Number of Decisions. The analyses resulted in no significant main effects on the overall number of decisions between conditions.

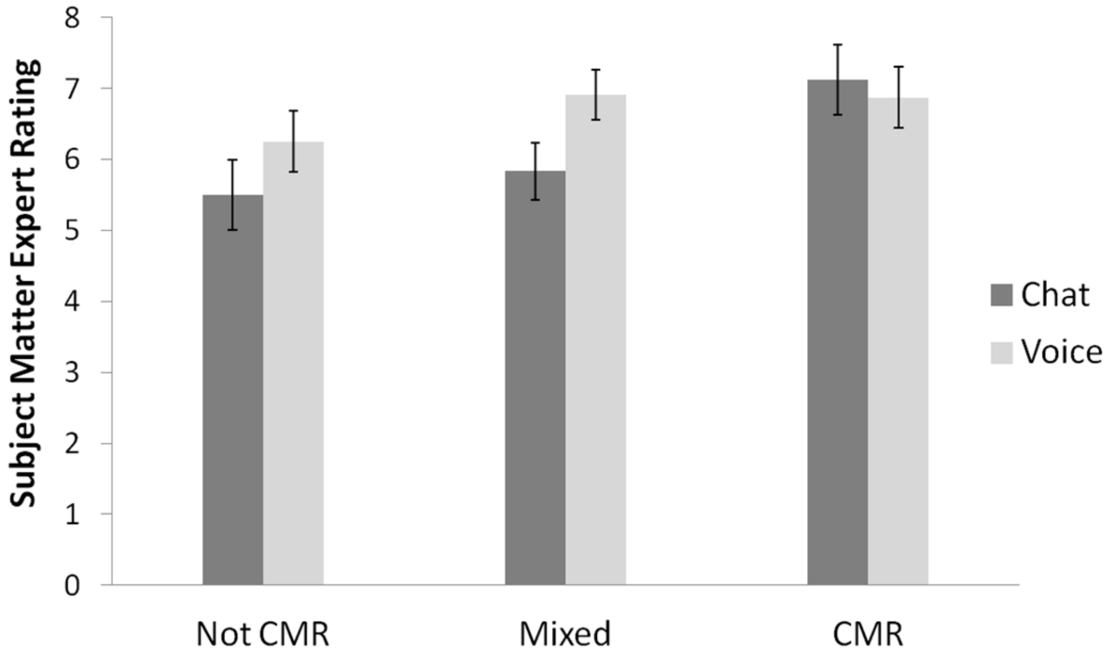

Figure 36. Interaction between message input and CMR status on the overall expert rating.

Communication Content Analyses.

The following analyses are based on the SME's coding of each communication message into twelve possible categories, as outlined in the Method's section. To categorize the communication, two raters independently conducted the coding. The primary coder was an expert in ABM communication, while the secondary coder was familiar with ABM communication and provided an independent check on the consistency of ratings. The primary rater coded all of the communication messages (15,872 messages total), while the secondary coder coded a random sample of the communication messages (225 or 1.4% of the total). From the random sample, the two raters had an agreement rate of 91%. This agreement rate was considered acceptable and is comparable to levels found in previous communication work (Funke, Dukes, Hyson, Miller, Russell, Knott, & Galster, 2012).

Requests for Information (1). The main effect of message input was statistically significant on the number of requests for information, $F(1, 13) = 4.755$, $p < .05$. Specifically, voice trials had more overall requests for information than chat trials.

For the archival information variable, all sources of variance in the analysis were not statistically significant ($p > .05$); however, a trend within the data suggested that more requests for information were made without archival information condition (M=29.536, SE=1.190) compared to the archival information condition (M=26.321, SE=1.347) ($F(1, 13) = 4.511$, $p < .10$).

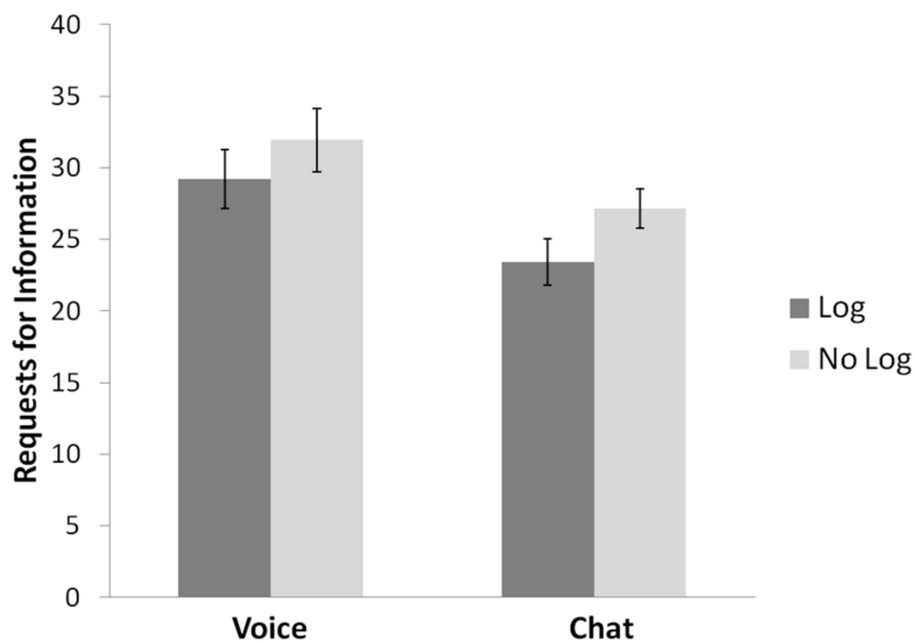

Figure 37. Main effects of message input and archival log on the number of requests for information.

Requests Resulting from Confusion (2). A statistically significant main effect of input of information was detected, $F(1, 13) = 43.406$, $p < .01$. Voice trials had more requests resulting from confusion than chat trials. A statistically significant main effect was also found for archival information, $F(1, 13) = 7.196$, $p < .05$. Trials without an archival log had more requests resulting from confusion than archival information trials.

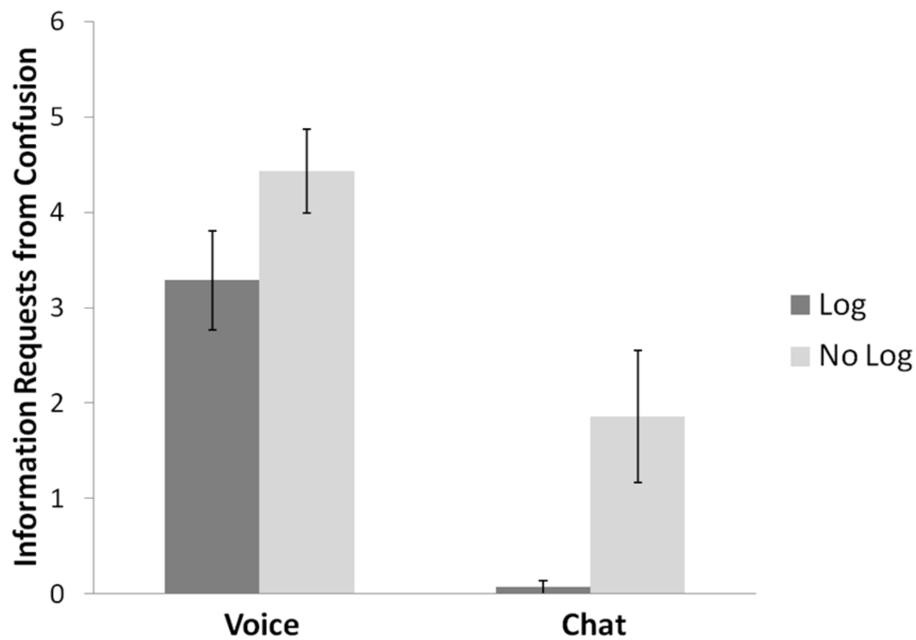

Figure 38. Main effects of message input and archival log on the information requests resulting from confusion.

Mission/Situation Update (3). The analyses resulted in no statistically significant differences on the overall number of mission/situation updates between any of the conditions.

Requests for Approval (4). The main effect of message input was statistically significant on the number of requests for approval messages, $F(1, 13) = 7.112$, $p < .05$. Specifically, chat trials had more overall approval requests than voice trials.

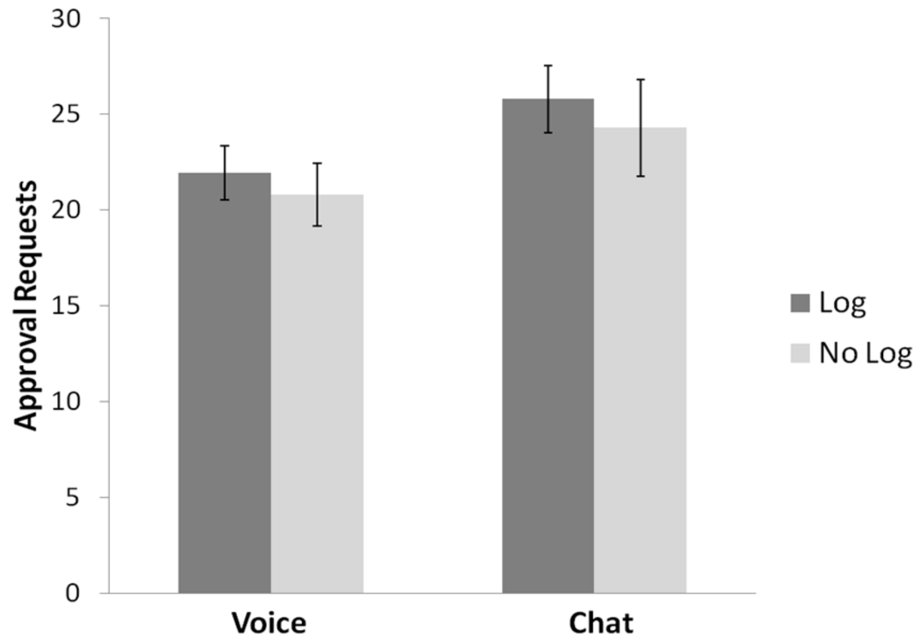

Figure 39. Main effect of message input on number of approval requests.

Approval messages (5). The analyses resulted in no statistically significant differences on the number of approval messages on neither the message input nor archival log conditions.

TIC Request/Repeats (6). TICs requests are critical and time-sensitive. The timeliness of reactions to these requests often means the difference between life and death of many soldiers. For that reason, this measure holds more weight than the others. There were four automated TIC events that were announced during each trial that required a response. If a participant immediately responded to each TIC event as it was announced, his/her total TIC request would be four (i.e., perfect performance). Anything above a four suggests the request for TIC support had to be repeated before the ABM appropriately responded. A greater number of TIC requests signifies a slower the response to the TIC event, thus poorer performance. In the current study, chat conditions had significantly greater numbers of TIC requests than the voice conditions, $F(1, 13) = 55.582$, $p < .05$.

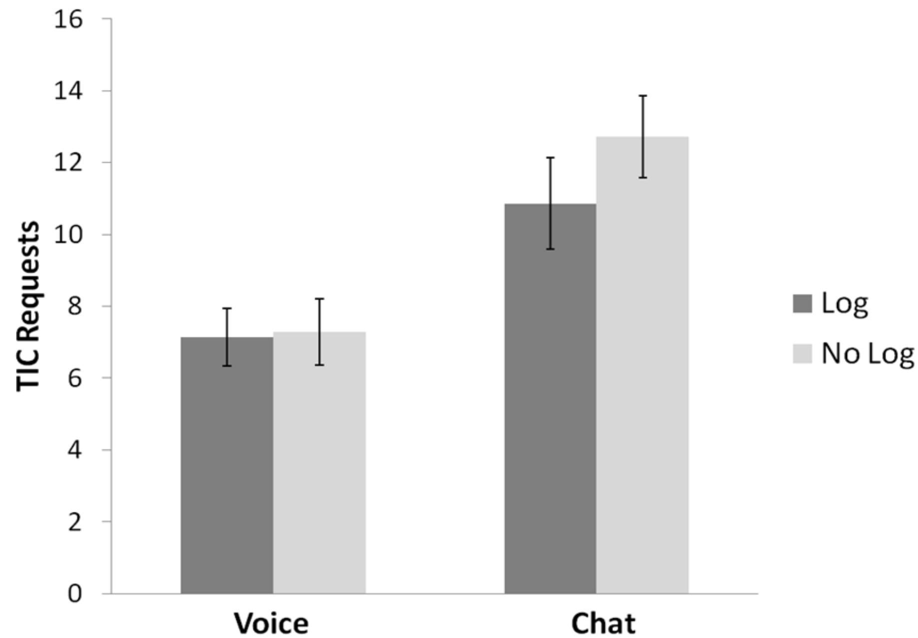

Figure 40. Main effect of message input on TIC repeat requests. Greater number of repeat requests indicates lesser performance.

TIC Directives/Updates (7). Analyses demonstrated a significant main effect of message input on the number of TIC specific update and directive messages, $F(1, 13) = 18.032$, $p < .05$. Chat trials resulted in a greater number of TIC updates and directives than voice communication trials

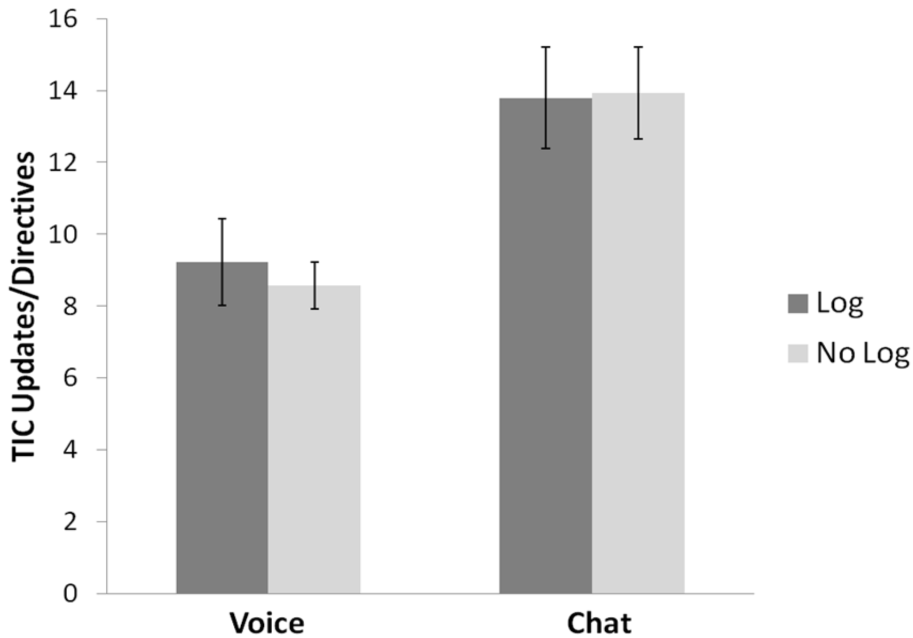

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Figure 41. Main effect of message input on total numbers of TIC related updates and directives.

Commands/Directives (8). Analyses did not reveal any significant effects of number of command messages from either condition.

Coordination Messages (9). The main effect of message input was statistically significant for the number of coordination messages sent, $F(1, 13) = 32.212$, $p < .05$. Voice trials resulted in greater numbers of coordination messages.

Acknowledgment/Copy (10). Analyses demonstrated a significant main effect of message input on the number of acknowledgement messages, $F(1, 13) = 14.655$, $p < .05$. Voice conditions had a greater number of acknowledgement messages than chat trials.

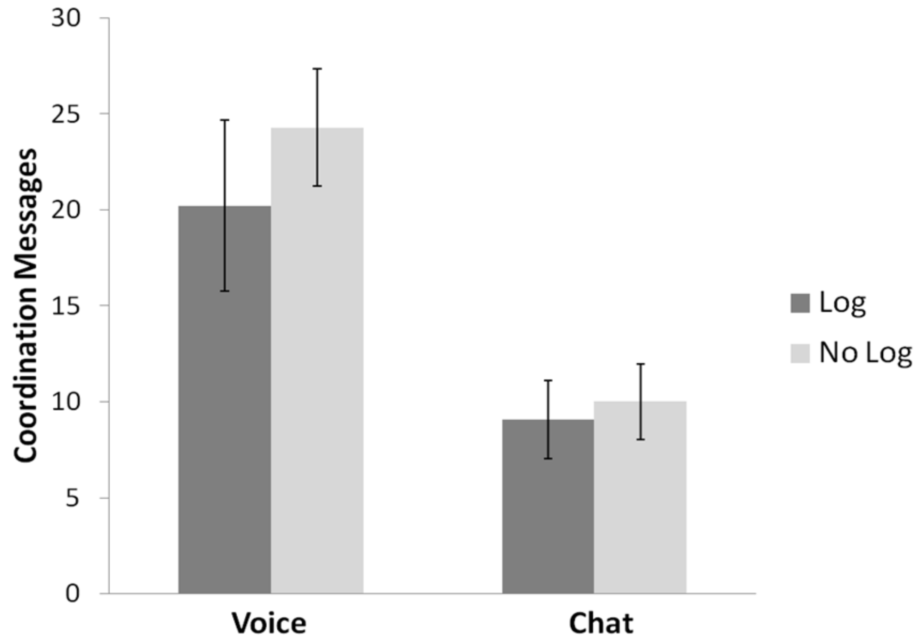

Figure 42. Main effect of message input on number of coordination messages.

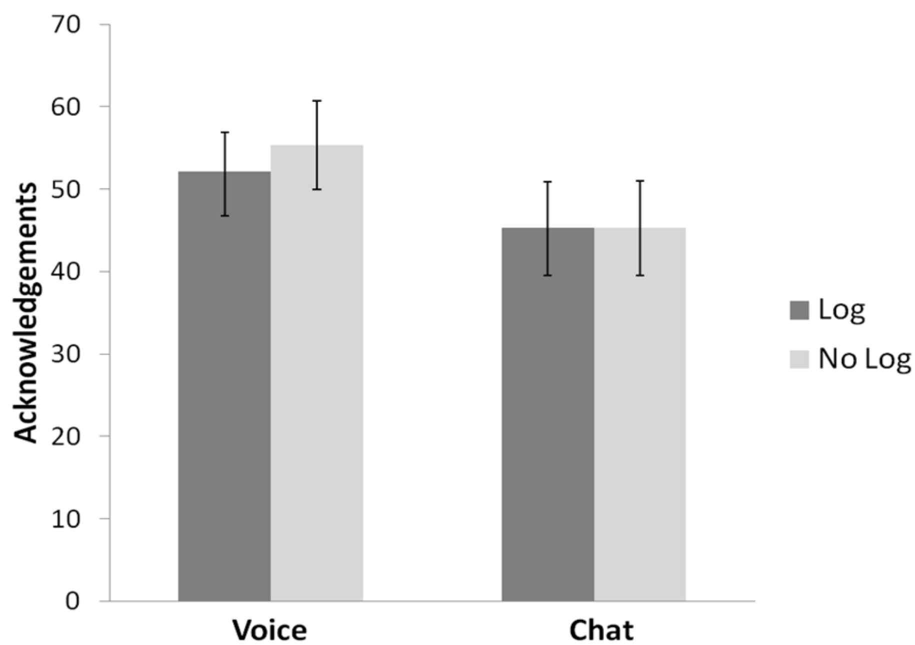

Figure 43. Main effect of message input on number of acknowledgement messages.

Chatter (11). There was a main effect of archival log of messages on the amount of chatter, or non-task related communication messages, $F(1,13)=8.00$, $p<.05$. Transient conditions had more chatter messages than archival message conditions.

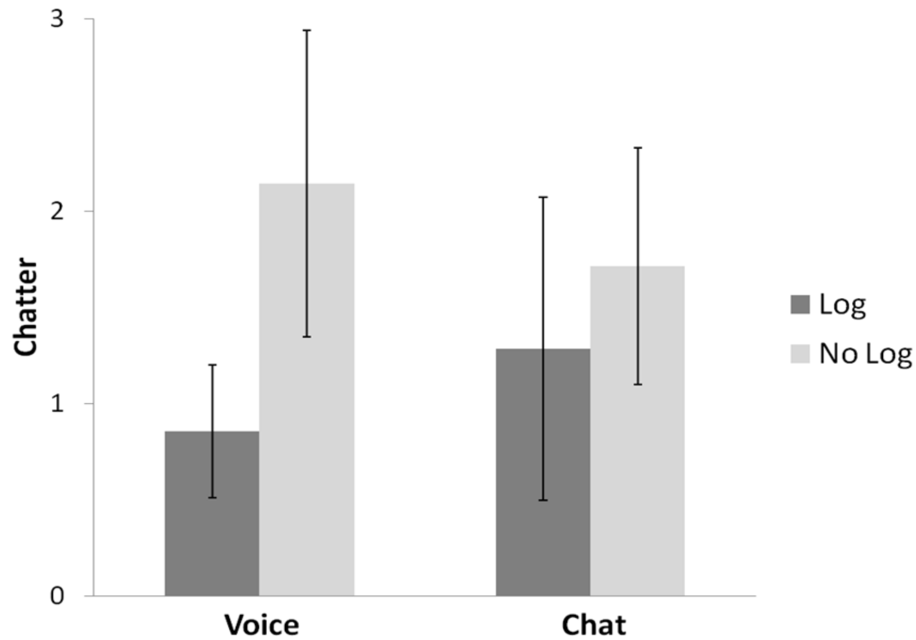

Figure 44. Main effect of archival log on the number of chatter messages.

Unknown/Not clear (12). There was a main effect of message input on the number of unclear messages, $F(1,13)= 129.986$, $p<.05$. There were substantially more unknown or unclear messages in voice trials than chat trials. Chat messages tend to be more clear in terms of the words typed (not necessarily the meaning) than radio messages. Voice messages may be muffled or unintelligible, and thus this result may simply confirm that chat messages are clearer than voice messages, as far as literal words are concerned.

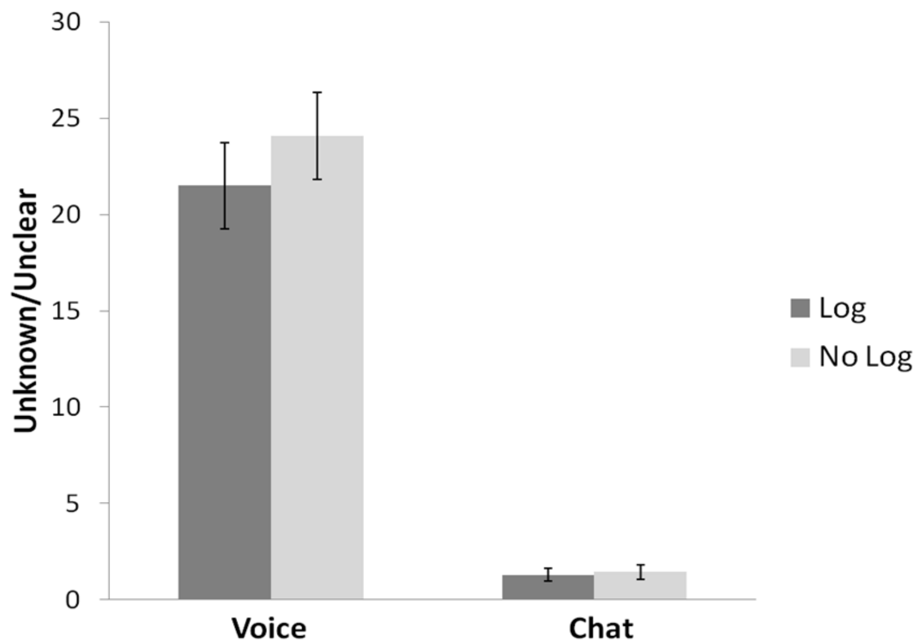

Figure 45. Main effect of message input on the number of unclear messages.

Anticipation Ratio

Anticipation Ratio - The number of information messages sent divided by the number of information requests. Higher anticipation ratios are indicative of greater levels of team coordination. There were significant main effects of input of information and archival information on the anticipation ratio, $F(1,13)=4.725$, $p<.05$ and $F(1, 13) = 10.197$, $p <.05$, respectively. Specifically, trials with chat input had higher anticipation ratios than trials with voice communication. In addition, trials with archival logs had higher levels of anticipation ratios than trials without archival logs. While not statistically significant, the data suggested an interaction trend between input of information and archival log of the data on anticipation ratios, $F(1,13)=3.697$, $p<.10$. Overall, chat trials had higher anticipation ratios (M=3.296, SE=.247 and M=2.710, SE=.158) than talking trials (M=2.685, SE=.178 and M=2.477, SE=.133), but this was more pronounced in the trials with an archival log than without.

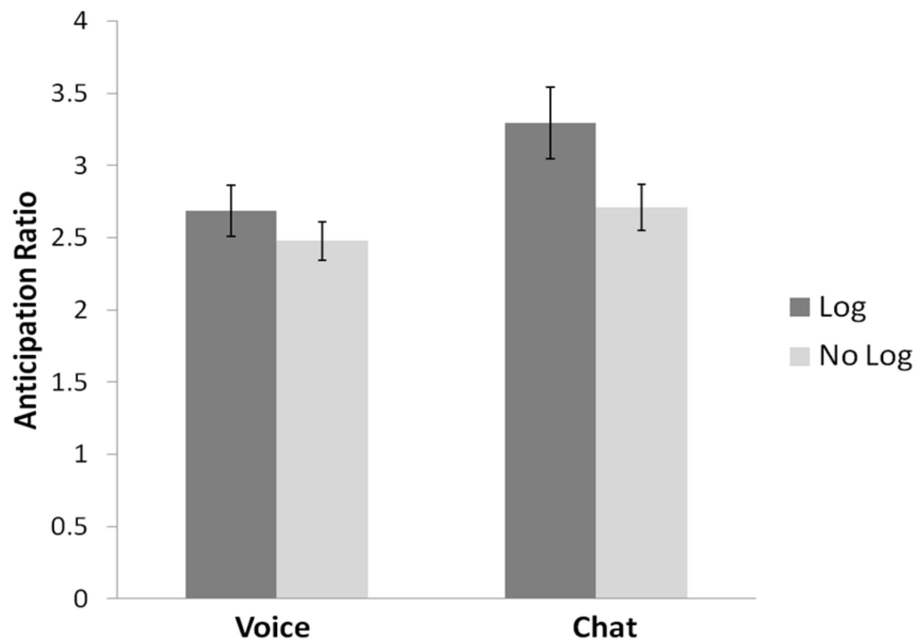

Figure 46. Interaction of message input and archival log on anticipation ratio.

Individual Measures

Percentage of CRM messages correctly identified - A main effect of message input was statistically significant on the percentage of correct CRM responses, $F(1, 27) = 27.901$, $p < .05$. Chat trials resulted in a greater percentage of correct responses to the CRM task than talking trials.

Percentage of CRM message responses – A statistically significant main effect on the percentage of CRM stimuli responded to (regardless if it was correct or not) was found on input type, $F(1, 27) = 57.564$, $p < .05$. Chat trials resulted in a greater number of CRM responses than talking trials. In addition, there was a significant interaction between input and archival log on the total number of CRM responses, $F(1, 27) = 5.589$, $p < .05$.

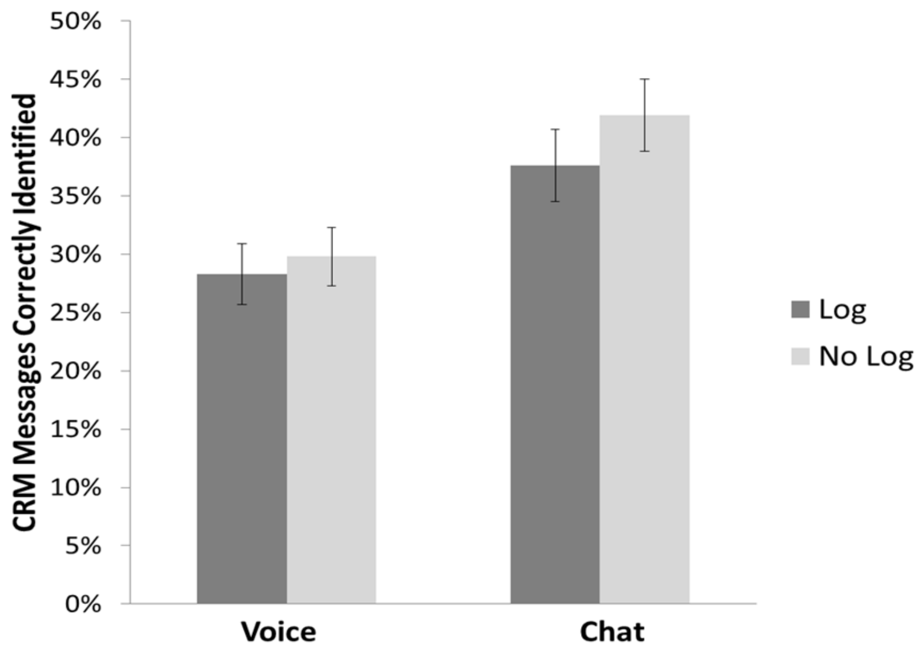

Figure 47. Main effect of message input on the percentage of correct CRM responses.

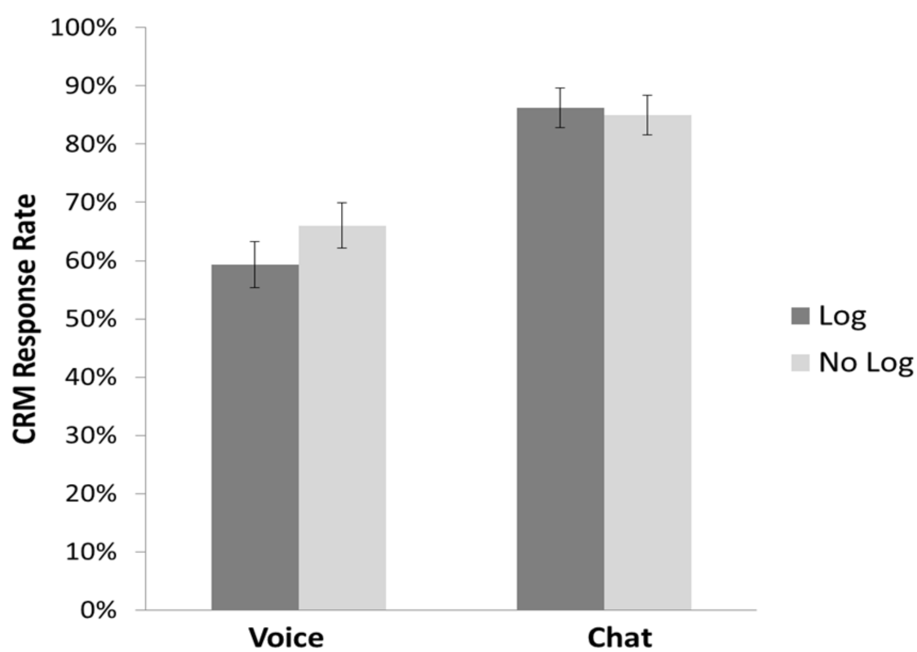

Figure 48. Interaction between message input and archival log on the CRM response rate.

Latency - Statistical analyses did not reveal any significant effects on the latency between TIC announcements and the response actions taken during either condition.

Summary

Statistically significant results are summarized and organized by the two experimental factors (message input and archival log) in Table 20. The + symbol denotes a statistically significant difference with better performance demonstrated in the particular category where the symbols reside. This symbol does not necessarily signify which had greater or lesser values in each category, as better performance may result from lesser numbers of the items (e.g., less TIC requests reflects better performance). The +* symbol denotes a trend in the data, but the value did not reach statistical significance at the $p<.05$ level. The symbol ^ signifies a statistically significant difference with a greater number in the particular category, but a greater value may not be directly tied to greater performance (e.g., number of coordination messages may reflect more overall coordination or a lack of SA about the current plan). Essentially + means "better", but not necessarily "greater," while ^ means "greater", but not necessarily "better." Table 21 presents the mean values for each category.

Significant Main Effects by Factor	**Input**		**Archive**	
	Voice	**Chat**	**Log**	**No Log**
Performance Measures				
Preplanned Targets			+*	
Emergent Threats (TICS)	+*			
Emergent Threats (Unknown Aircraft)	+			
Process Measures				
SME Team Rating	+		+	
Total Messages		+	+	
Requests for Information		+	^	
Requests from Confusion		+	+	
Approval Requests		^		
TIC Repeated Requests	+			
TIC Directives/Updates		+		
Coordination Messages	+			
Acknowledgement/Copy	^			
Chatter				^
Unclear messages		+		
Anticipation Ratio		+	+	
Individual Measures				
CRM performance (secondary task)		+		
CRM response rate		+		

Table 20. Overall summary of statistically significant main effects.

	Voice		Chat	
	Log	**No Log**	**Log**	**No Log**
Performance Measures				
Preplanned Targets	11.75 (.45)	11.33 (1.23)	11.83 (.39)	11.58 (.67)
Emergent Threats (TICS)	3.62 (.14)	3.46 (.18)	3.23 (.30)	3.00 (.25)
Emergent Threats (% Unknown Aircraft)	92.4 (3.0)	96.0 (1.7)	88.2 (4.9)	84.5 (5.6)
Process Measures				
SME Team Rating	6.93 (.25)	6.50 (.34)	6.50 (.40)	5.71 (.29)
Total Messages	289.57 (15.07)	309.71 (13.67)	262.5 (9.10)	271.93 (12.35)
Requests for Information	29.21 (2.04)	31.93 (2.20)	23.43 (1.63)	27.14 (1.36)
Requests from Confusion	3.29 (.52)	4.43 (.44)	.07 (.07)	1.86 (.69)
Approval Requests	21.93 (1.42)	20.79 (1.65)	25.79 (1.76)	24.29 (2.51)
TIC Repeated Requests	7.14 (.80)	7.29 (.92)	10.86 (1.27)	12.71 (1.15)
TIC Directives/Updates	9.21 (1.21)	8.57 (.66)	13.79 (1.41)	13.93 (1.28)
Coordination Messages	20.21 (4.45)	24.29 (3.06)	9.07 (2.05)	10.00 (1.98)
Acknowledgement / Copy	52.14 (4.76)	55.36 (5.38)	45.29 (5.63)	45.29 (5.77)
Chatter	.86 (.35)	2.14 (.80)	1.29 (.79)	1.71 (.62)
Unclear messages	21.5 (2.24)	24.07 (2.26)	1.29 (.34)	1.43 (.37)
Anticipation Ratio	2.69 (.18)	2.48 (.13)	3.30 (.25)	2.71 (.16)
Individual Measures				
CRM % Correct	28.3 (2.6)	29.8 (2.5)	37.6 (3.1)	41.9 (3.1)
CRM response rate	59.2 (3.9)	66.0 (3.9)	86.3 (3.4)	85.0 (3.4)

Table 21. Mean team and individual performance scores as a function of the two independent variables. Standard errors are listed in parentheses.

Overall, the results showed advantages for both voice and chat communication and varied in terms of different task demands. Voice communication outperformed chat communication for time-critical measures that required high levels of coordination. In particular, overall team responses to TIC requests and subsequent coordination were more successful for trials with voice communication. Chat communication demonstrated strengths through the process measures. There were less messages overall and fewer requests for information. Trials with chat communication also allowed participants to better anticipate the information needs of their teammates and provide information before it was requested.

The results concerning archival information were more unidirectional. Trials where participants were provided an archival log of communication outperformed those without a log on preplanned mission execution, overall SME team ratings, amount of communication and confusion, and increased anticipatory behaviors. For trials without an archival log, the only greater result was the number of chatter messages.

CHAPTER XIII. Discussion

Chat communication research is typically posed as "chat versus voice," but after digging deeper into the operational community, I realized that this dichotomy is neither the operational issue nor particularly useful. Through the survey and observations of live operations, it became clear that chat communication is an instrumental tool to support the work Air Battle Managers perform. The issue is not choosing between the two different methods of communication, but rather understanding which modality to use when, based on the strengths and weaknesses of each and the operational environment and needs. The purpose of conducting this empirical study was to help bridge the gap between operational and research communities, as well as to understand the operational usage of chat communication to provide useful data to inform operational tactics, techniques, and procedures for C2 chat implementation. This section will compare the results of the current study with results from both the operational survey and previous research studies reviewed in the introduction.

In the operational command and control environment, chat communication is widely used and here to stay. The majority of survey respondents use chat communication in their current role, and of those who use it, the majority use it frequently, either throughout missions or for long durations of time. Typically, individuals using chat communication will monitor six or more chat rooms at a time, are comfortable with this number, and unanimously claim chat communication helps them perform their job duties. Despite the unanimous claim that chat communication helps, some felt chat had only low or moderate importance. The bulk of respondents felt chat is essential to performing their job duties though, and the majority of those who do not currently have access to chat in their job positions felt having access to the technology would further help them perform their work. For individuals who use chat in their current role, operators felt chat communication is safe, reliable, and efficient. Generally, operators trust that those they communicate with in their regular chat rooms are the people they claim to be. Overall, operators have very positive things to say about what chat communication can add to their job.

Despite the glowing report, chat communication is not the panacea to all C2 communication challenges. There are negative attributes reported with chat communication as well. Because of the distributed nature and vast number of communicators in any one chat room, there could be multiple conversational threads occurring at the same time. With multiple threads, there is a risk of individuals becoming lost in any one conversation, and this was reported to happen somewhere between "sometimes" to "rarely." This experience is consistent with the research literature on potential risks of chat communication (Cornelius & Boos, 2003; Holmer, 2008). Other negative events were reported, resulting from too much information coming through a chat room too quickly, inappropriate scan patterns, time delays between messages sent and messages received, and distractions with personal information rather than operational information in the chat rooms.

Many of these reported attributes of chat communication, both positive and negative, were also demonstrated in the empirical study. Voice has been shown to be quick and efficient, while chat is lasting and reduces the need for repetition. While using voice communication, participants performed better on time-critical, emergent events, including TICs and unknown aircraft identification. Greater numbers of each were accomplished during the speaking trials versus the chat trials. Furthermore, the histogram representation of both TICs and unknown aircraft identification scores suggest a clear advantage of voice communication on time-critical events. Six of the seven lowest TIC scores were from chat communication trials. Twelve of the fourteen lowest unknown aircraft identification scores were from chat communication trials. SME ratings supported this advantage as well, with voice input trials rated higher than chat input trials. The voice advantage demonstrated could be due to a combination of lower visual interference from the auditory communication method and a greater efficiency at which people can speak over type. In addition, voice communication is rich with verbal cues that individuals rely on as part of their communication process.

Communication trials with lasting archival information resulted in greater performance on preplanned missions. Preplanned missions in the current study were less time-critical than the emergent events, and participants had more time to digest the information and review the plans that were made. Archival logs afford the ability to review information in a non-synchronous manner. In addition, Combat Mission Ready (CMR) groups did well on both conditions with and without archival information. Groups that were not CMR did much better when they were given archival information. These results suggest archival information may be able to help mitigate lack of training. Future controlled research is needed examine this possibility. In terms of SME ratings, archival log trials were rated higher than no log trials. For situations where archival information is useful, it seems there are performance advantages to having access to it in real-time.

In terms of the amount of communication, there were significant main effects on the total number of messages sent. Voice trials resulted in a greater number of overall communication messages sent than during chat trials, which may be a result of the efficiency with which people are able to speak. Message generation costs for speaking have been shown to be lower than those of typing (Munzer & Holmer, 2009), and previous studies have shown chat messaging results in fewer overall remarks (Hiltz, et al., 1986, Kiesler, Zubrow, & Moses, 1985; McGuire et al., 1987; Siegel et al., 1986; Bordia, 1997).

This efficiency may not have been the only driving factor for a greater number of messages. Voice communication trials also had a greater number of information requests resulting from confusion than did chat communication trials. Despite this confusion, there were no significant differences in the number of mission or situation updates between any of the conditions. There were a greater number of questions, but not necessarily a greater number of answers. With voice communication trials, there were a greater number of coordination messages sent than with chat trials. The coordination messages could have helped clarify some of the confusion, but likely not as much as mission updates would have.

For trials with archival information, fewer communication messages were sent overall. Trials with archival logs also resulted in a lower number of requests for information and fewer requests for information resulting from confusion than trials with no archival log. Participants were able to scroll through previous posts and review critical information without having to send repetitive requests for information. Operators have reported using archival chat logs in this manner. This reduction in communication may help lessen the burden on current plagued and overloaded communication channels that operators have frequently reported.

In addition, there were also main effects of both input of information and archival log on the overall anticipation ratio, which is the ratio of information "pushes" divided by information "pulls." In other words, this demonstrates how much information is being conveyed relative to how much information is requested. Ratios above one demonstrate teams that are able to successfully anticipate each other's needs (Entin & Serfaty, 1999). In this study, the ratios were more than double or triple that value, and thus ABMs are clearly skilled at anticipating their teammates' information needs.

Trials with typing input and archival logs tended to see the highest anticipation ratio values. What this suggests is that ABMs are using chat communication to push out information ahead of time, trying to get "ahead of the curve" so to speak. An archival log not only allows participants to retroactively review information that has been previously sent, but it also allows participants to send information in anticipation of future needs. The recipient can consume the information according to their own schedule, thus the sender is free to proactively provide information without fear of interrupting critical tasks as would be the case with voice communication.

This proactive behavior was not only witnessed during trials with archival information, but also during typing without an archival capability (e.g., messages would disappear after 15 seconds as to not be "archived"). Some participants were observed typing their messages into the send boxes and then waiting until a more appropriate time to hit enter. In a sense, they had created their own smaller scale ability to save information for a future time. Knowing their messages would disappear if they sent them too early, they proactively gathered and prepared the relevant information for transmission and then waited until the information was needed to hit send. This behavior seemed to be an emergent property of the task demand and communication modality and is consistent with my original hypothesis that the value of chat lies in the ability to archive information.

Anecdotally, the value of archival information was shown through participant behavior as well. One example was of a participant who continually tried to create an archive capability during the no archival log conditions. During the training phase, one participant was disgruntled that the messages would disappear in the no archival log condition, thus he decided it would be best to create his own log by copying and pasting messages from the chat room into a hidden Microsoft Word document to "save" them for later. He felt saving these messages was critical to his success as a participant. The research team continually corrected his behavior during training and repeatedly instructed him to close his Microsoft Word document. The participant become increasingly frustrated with the research team, even angrily claiming the team was in fact limiting his ability to do his job. Clearly the archival log was valuable to the participants.

The operational interviews, survey responses, communication research literature, and empirical data from this study are all peppered with positive and negative attributes of chat communication. As with any technology, there are features of command and control tasks that chat communication readily supports and other limitations that it has. The overarching positives are that it provides access to archival data, enables the review of previous data, supports both asynchronous and synchronous communication, and lessens coordination overhead with multiple players in the same room, especially high-level decision makers. The negatives include the labor intensive typing of messages, possibilities for missing messages, lack of verbal cues, and potential for ambiguity.

The unique value of chat technology is that it is a nonintrusive form of communication. The archive capability that it offers allows the operator flexibility in prioritizing the information flow. For example, s/he can defer attention from the lower priority tasks, when higher priority tasks demand attention, without losing the information. The operator controls the sampling rate of information, and this flexibility allows the operator to avoid interruptions of high priority tasks while they are occurring. Operators can make decisions about how to sample information based on content, priority, and topic. As a result of this flexibility, the preplanned missions with archival information outperformed those without the information. Emergent events automatically took first priority. When these high-priority tasks were completed, the operator was able to refer back to the chat logs to investigate the status of the lesser time-pressured events and catch back up. The control over information is the greatest asset of chat and is valuable enough to show clear performance benefits, even despite the visual attentional resources chat may consume.

Voice and chat communication can be complementary with careful implementation. Again, the research question is not a question of chat versus voice. Thus, the design question should not be chat or voice, but rather how to help operators to leverage the flexibility that chat provides for prioritizing information access. It is clear that voice communication is an extremely valuable, high bandwidth channel that is essential for coordination in the face of complexity. The challenge in operational settings, however, is to protect the voice channel to ensure it is available when the situation demands it. Current radio channels are plagued with overcrowding, interference, and noise. A benefit of chat communication is that it allows the operator to protect the voice channel from routine communication situations and demands to ensure this high-value medium is available when needed. In other words, the true operational value of chat communication seems to be that it allows ABMs to use voice communication more effectively.

With these unique benefits in mind, the focus of future training and design should be helping the operator to make smart choices in how they utilize the various communication channels available to them. For example, creating tactics in which the most time-critical tasks are free to communicate over the radio channels while more routine tasks leverage the benefits of chat communication could be one possible instantiation. In this respect, understanding how to manage the various communication channels in real time to make sure that information is available at the time that it is needed becomes part of communication discipline.

Future research should be aimed at exploring specific situations where chat communication can provide the greatest impact (e.g., routine, less-time critical, contains rich details to be used later, etc), and also situations where voice communication would be preferable (e.g., safety-dependent, time-critical, etc). Defining and ranking different situations in terms of the criticality and time-sensitive nature of information demands should help drive tactics, techniques, and procedures (TTPs) for implementation and illustrate the best cases for leveraging the speed voice communication affords, while protecting the voice channel from overload with situations that are not as time or safety-critical.

Another critical aspect of successfully implementing communication tools is training operators on how to use them, as well informing them about the positive and negative attributes. When asked about training for chat communication, there was surprisingly little to report. Only 4.3% of the respondents listed any training at all, and this figure included on-the-job training, as well as overall security briefings. There was no reported training on how to employ chat communication in tactical situations. Leveraging the power of chat communication while minimizing any negative attributes must start with training and clearly defined tactics, techniques, and procedures.

Through extensive consideration of research literature, operational surveys, operational observations, and the current study, I believe chat communication can be a powerful communication tool in complex environments when archival information is important and when time is valuable. A careful examination of the situational context for use coupled with the attributes of the technology should help drive the implementation and guidelines. The combination of chat communication and voice communication can lead to a powerful communication suite when implemented and used properly to balance contextual demands while leveraging the strengths and minimizing the weaknesses of each.

CHAPTER IX. References

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CHAPTER X. Appendices

A. Acronym List
B. Survey
C. Air Tasking Order
D. Altitude tracking sheet
E. Confederate info sheet
F. ABM info sheet
G. Confederate Special Instructions (SPINS)
H. ABM Special Instruction (SPINS)

APPENDIX A. Acronym List

A/c	Aircraft
A/s	Airspace
ABM	Air Battle Manager
ALCEC	Anticipate, Listen, Correlate, Evaluate, and Communicate
AOC	Air Operation Center
AOR	Area of Responsibility
ASOC	Air Support Operations Center
ATC	Air Traffic Control
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
C2	Command and Control
CAF	Combat Air Force
CAS	Close Air Support
CAOC	Combined Air Operation Center
CMR	Combat Mission Ready
CRC	Control & Reporting Center
CRM	Coordinate Response Measure task
CTRL	Control (listed on ATO, agency who owns the flight)
DDD	Distributed Dynamic Decision Making software program
DEST	Destination
GCS	Ground Control Station
IQT	Initial Qualification Training
ISR	Intelligence, Surveillance, Reconnaissance
JSTARS	Joint Surveillance Target Attack Radar Systems

JTF	Joint Test Force
LNO	Liaison Officer
mIRC	My Internet Relay Chat software
MMC	Multi-modal Communication Tool
MQT	Mission Qualification Training
MSN	Mission
NATO	North Atlantic Treaty Organization
NASA	National Aeronautics and Space Administration
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OODA	Observe, Orient, Decide, and Act
ROE	Rules of Engagement
ROLEX	Roll exercise (push back)
ROZ	Restricted Operating Zone - a volume of airspace of defined dimensions designated for a specific set of operational missions and restricted for all others not involved in those missions.
RPA	Remotely Piloted Aircraft, used interchangeably with UAS and UAV
SATCOM	satellite communications
SME	Subject Matter Expert
SPINS	Special Instructions - general instructions that were applicable to each mission and remained consistent over the different mission sets
TIC	Troops in Contact - signifies ground troops have come in contact with enemy fire and request urgent air support
TGT	Target
TTPs	Tactics, techniques, and procedures
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle (used interchangeably with UAS and RPA)

APPENDIX B. Survey

Chat Communication Survey

1. Overview

This questionnaire is an opportunity for you to provide candid feedback regarding chat technologies, as they stand now and in the future. Your responses will allow us to better understand the benefits and costs associated with this technology. You will be able to inform us about what kinds of information you prefer to send using different types of communication tools (e.g., voice versus chat). To the greatest degree possible while answering the following questions, please think about the tasks you perform in your position and how you typically communicate different types of information.

Please answer all of the questions you feel comfortable with. Your responses to these questions will only be used for research purposes. Your name, any identifying information, and your responses will be kept strictly confidential and will not be released. Questions or inquires can be directed to Ms. April Courtice, april.courtice@wpafb.af.mil.

2. Biographical Information

1. What is your age?

2. What is your gender?

- Male
- Female

3. How many years of Military experience do you have?

4. How much experience do you have with general computer use?

- Beginner
- Intermediate
- Advanced

5. How much experience do you have with chat?

- Beginner
- Intermediate
- Advanced

Chat Communication Survey

6. How much experience do you have with text messaging on mobile devices (e.g., cell phone, blackberry, etc.)?

- ◯ Beginner
- ◯ Intermediate
- ◯ Advanced

3. Background Information

1. What country are you from?

- ◯ United States
- ◯ Australia
- ◯ United Kingdom

Other (please specify)

2. Which branch of the military are you in?

Other (please specify)

3. What is your rank?

US Air Force Officer	US Air Force Enlisted

Other (please specify)

4. What is your current Weapons System?

5. What career field are you in?

6. What chat communication training have you received?

4. Chat Usage

Page 2

Chat Communication Survey

1. Do you use chat on your current platform? Why or why not?

- ◯ Yes
- ◯ No

Why or why not?

2. If yes, how often do you use chat in your current position?

	Frequently (used throughout mission or for long durations)			Neither Frequent, Nor Infrequent			Infrequently (few times or short durations)
I use it:	◯	◯	◯	◯	◯	◯	◯

3. How many chat windows or conversations do you monitor regularly?

4. Are you comfortable monitoring the above number of chat windows?

- ◯ Yes
- ◯ No

Why or why not?

5. If you do not use chat on your current platform, do you feel that having access to chat would help you perform your duties?

- ◯ Yes it would help me perform my duties
- ◯ No, it would not help me perform my duties

Why or why not?

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Chat Communication Survey

6. Have you used chat in theater?

◯ Yes

◯ No

7. Additional Comments?

5. Content of Chat Messages

1. What types of messages/information do you communicate using chat? Why?

2. During what types of situations/missions/circumstances is chat useful to you (e.g., aerial refueling, CAS, low-fuel, targeting, etc)? Why?

3. What types of messages/information do you AVOID sending using chat? Why?

4. During what types of situations/missions/circumstances is chat NOT useful to you? Why?

6. Opinions of Chat

1. Do you feel using chat is essential to performing your job duties?

◯ Yes

◯ NO

Chat Communication Survey

2. How important is chat to performing your duties?

	Low Importance			Moderate Importance			High Importance
It is:	◯	◯	◯	◯	◯	◯	◯

3. How satisfied are you with communication by chat?

	Not at all Satisfied			Moderately Satisfied			Very Satisfied
I am:	◯	◯	◯	◯	◯	◯	◯

4. How safe do you feel communicating with chat is?

	Serious Safety Concerns			Somewhat Safe			Extremely Safe
.	◯	◯	◯	◯	◯	◯	◯

5. How reliable do you feel chat communication is?

	Not at all Reliable			Somewhat Reliable			Extremely Reliable
.	◯	◯	◯	◯	◯	◯	◯

6. Is chat an efficient method of communication?

◯ Yes

◯ No

7. Overall, which is easier to understand: chat or voice messages?

◯ Chat messages are easier to understand

◯ Voice messages are easier to understand

◯ About the same

Why?

8. How reliable do you feel voice (radio) communication is?

	Not at all Reliable			Somewhat Reliable			Extremely Reliable
.	◯	◯	◯	◯	◯	◯	◯

9. Additional Comments?

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Chat Communication Survey

7. Consequences of Chat

1. Has chat ever put you or your team into a negative and/or preventable situation?

- ◯ Yes
- ◯ No

Why or why not? Other comments?

2. Have you ever used chat logs to detect patterns over time?

- ◯ Yes
- ◯ No

Comments?

3. Do you feel comfortable giving or receiving official orders over chat communication?

- ◯ Yes
- ◯ No

Why or why not?

4. How often do you feel you or others "get lost" in chat rooms?

- ◯ Often
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

Chat Communication Survey

5. True or False: I feel confident that others in my chat room are who they claim to be.

- ○ True
- ○ False

6. How would you improve the current chat system?

7. Are there other communication tools you wish were available to use in completing the duties of your position?

8. Any additional comments/suggestions/concerns?

8. End

Thank you for completing this survey!

Questions or inquires can be directed to Ms. April Courtice, april.courtice@wpafb.af.mil.

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APPENDIX C . Sample Air Tasking Order

Air Tasking Order, Squadron Four

1/ SORTIE	2/MSN	3/CALLSIGN	4/TYPE	5/Bomber	6/ROUTE	7/TGT	8/DEST	9/Alt	10/CTRL
	mission number	a/c callsign	number and type of a/c		Target at:		minute:sec in scenario		
1	2/TGT	Jayhawk	F16's(2) / B-2's(2)	Jayhawk 2-1	66TH9	Building	16:00	21000	10/ AWACS
2	2/TGT	Hershey	F16's(2) / B-2's(2)	Hershey 2-1	67TI4	Building	2:50	22500	10/ AWACS
3	2/TGT	Hershey	F16's(2) / B-2's(2)	Hershey 2-2	67TH1	Overpass	5:20	22500	10/ AWACS
4	2/TGT	Jayhawk	F16's(2) / B-2's(2)	Jayhawk 2-2	66TI1	Overpass	14:00	21000	10/ AWACS
5	2/TGT	Hershey	F16's(2) / B-2's(2)	Hershey 2-2	67TG4	Bridge	6:00	22500	10/ AWACS
6	2/TGT	Bull	F16's(2) / B-2's(2)	Bull 2-1	66TF8	Overpass	6:30	20000	10/ AWACS
7	2/TGT	Bull	F16's(2) / B-2's(2)	Bull 2-2	67TF1	Road	7:40	20000	10/ AWACS
8	2/TGT	Rawhide	F16's(2) / B-2's(2)	Rawhide 2-1	65TG5	Road	3:10	23500	10/ AWACS
9	2/TGT	Rawhide	F16's(2) / B-2's(2)	Rawhide 2-1	66TF6	Bridge	5:45	23500	10/ AWACS
10	2/TGT	Rawhide	F16's(2) / B-2's(2)	Rawhide 2-2	66TG7	Building	4:50	23500	10/ AWACS
11	2/TGT	Jayhawk	F16's(2) / B-2's(2)	Jayhawk 2-1	65TH3	Road	1:20	21000	10/ AWACS
12	2/TGT	Jayhawk	F16's(2) / B-2's(2)	Jayhawk 2-2	65TH4	Bridge	2:30	21000	10/ AWACS

Tanker Orbit	mission type	a/c callsign	number and type of a/c	altitude	orbit location
Blue Orbit	Fuel Orbit	Hulk 1	KC-135	15000	67TF3+
Green Orbit	Fuel Orbit	Hulk 2	KC-136	22000	65TI6+

Last known UAV position:

UAV Orbit	mission type	a/c callsign	number and type of a/c	altitude	orbit location
1	Orbit	Magic	UAV	6500	67TI2
2	Orbit	Eye Ball	UAV	9000	66TG4
3	Orbit	Spuds	UAV	12500	67TF1
4	Orbit	Birdie	UAV	13000	65TH5
5	Orbit	NightHawk	UAV	16500	66TG4
6	Orbit	GhostRider	UAV	19000	65TG5
7	Orbit	Neutron	UAV	17500	65TH1
8	Orbit	Onion	UAV	14500	66TF7
9	Orbit	Bronco	UAV	16500	67TH4
10	Orbit	Eagle	UAV	17000	66TI2
11	Orbit	Scooter	UAV	9000	66TG6
12	Orbit	Dark Star	UAV	8500	66TH9
13	Orbit	Viper	UAV	18500	67TG3
14	Orbit	Conan	UAV	11500	67TH3
15	Orbit	Turtle	UAV	10500	66TH6

APPENDIX D. Sample Altitude Tracking Sheet

Type	Call Sign	Starting Altitude (ft)	Change	Change	Change
Fighter 1	Blackbear 2-1	26000			
Fighter 2	Blackbear 2-2	27500			
Fighter 3	Cowboy 2-1	29000			
Fighter 4	Cowboy 2-2	28500			
Fighter 5	Fang 2-1	28000			
Fighter 6	Fang 2-2	25500			
Fighter 7	Shark 2-1	26500			
Fighter 8	Shark 2-2	28000			
Bomber 1	Bull 2-1	20000			
Bomber 2	Bull 2-2	24000			
Bomber 3	Hershey 2-1	22500			
Bomber 4	Hershey 2-2	23000			
Bomber 5	Jayhawk 2-1	21000			
Bomber 6	Jayhawk 2-2	21500			
Bomber 7	Rawhide 2-1	23500			
Bomber 8	Rawhide 2-2	22000			
UAV1	Magic	8000			
UAV2	Eye Ball	11000			
UAV3	Spuds	12500			
UAV4	Birdie	13000			
UAV5	NightHawk	16500			
UAV6	GhostRider	19000			
UAV7	Neutron	15000			
UAV8	Onion	14500			
UAV9	Bronco	16500			
UAV10	Eagle	17000			
UAV11	Scooter	9000			
UAV12	Dark Star	6000			
UAV13	Viper	18500			
UAV14	Conan	11500			
UAV15	Turtle	10500			

APPENDIX E . Sample Confederate Information Sheet

Scenario 1	
	Call sign
Fighter 1	Blade 2-1
Fighter 2	Blade 2-2
Fighter 3	Shark 2-1
Fighter 4	Shark 2-2
Fighter 5	Rambo 2-1
Fighter 6	Rambo 2-2
Fighter 7	Abnormal 2-1
Fighter 8	Abnormal 2-2
Bomber 1	Blue Star 2-1
Bomber 2	Blue Star 2-2
Bomber 3	Torch 2-1
Bomber 4	Torch 2-2
Bomber 5	Hershey 2-1
Bomber 6	Hershey 2-2
Bomber 7	Bull 2-1
Bomber 8	Bull 2-2
UAV1	Magic
UAV2	Eye Ball
UAV3	Spuds
UAV4	Birdie
UAV5	NightHawk
UAV6	GhostRider
UAV7	Neutron
UAV8	Onion
UAV9	Bronco
UAV10	Eagle
UAV11	Scooter
UAV12	Dark Star
UAV13	Viper
UAV14	Conan
UAV15	Turtle
CRC	Mad Dog
AWACS	Baron
Tanker 1	Hulk 1
Tanker 2	Hulk 2
Tanker LNO	Tanker LNO
ATC	ATC
UAS Operators	Cyclops
Army Artillery	Frosty
ASOC	ASOC
CAOC	CAOC
Roz Owner	Yogi

TIC	Area	Time	Alt Limit
TIC-21	32AD8	3:40	14
TIC -22	32AB3	7:00	18
TIC-23	31AD5	10:30	12
TIC-24	33AB6	14:30	22

ROZ's	Area	Name	Time Hot	Alt Limit
1	33AE7	Alpha	0:10	15
2	32AD3	Bravo	0:30	19
3	31AE9	Charlie	3:30	12
4	31AE2	Delta	1:20	20
5	32AC9	Echo	12:30	8
6	31AC6	Foxtrot	13:30	14
7	33AC8	Golf	9:00	20

1/ SORTIE	5/Bomber	6/ROUTE	8/DEST
1	Bluestar2-1	33AB3	1:20
3	Torch 2-1	31AE3	3:30
4	Torch 2-2	31AE6	4:30
2	Bluestar2-2	32AB8	6:10
8	Bull 2-1	31AC3	7:10
9	Bull 2-2	31AC6	7:40
5	Hershey 2-1	33AE7	9:00
10	Bull 2-2	31AD7	9:20
6	Hershey 2-2	33AE6	9:30
7	Hershey 2-1	33AE6	9:50
12	Bluestar 2-2	32AE8	11:00
11	Torch 2-1	32AC6	14:00

Tanker Orbit	mission type	a/c callsign	number and type of a/c	altitude	orbit location	payload
1	Fuel Orbit	Hulk 1	KC-135	15000	31AE7+	69000
2	Fuel Orbit	Hulk 2	KC-136	20000	32AC7+	38000

APPENDIX F. Sample ABM Information Sheet

	Call sign
Fighter 1	Blackbear 2-1
Fighter 2	Fang 2-1
Fighter 3	Shark 2-1
Fighter 4	Cowboy 2-1
Fighter 5	Blackbear 2-2
Fighter 6	Fang 2-2
Fighter 7	Shark 2-2
Fighter 8	Cowboy 2-2
Bomber 1	Bull 2-1
Bomber 2	Bull 2-2
Bomber 3	Hershey 2-1
Bomber 4	Hershey 2-2
Bomber 5	Jayhawk 2-1
Bomber 6	Jayhawk 2-2
Bomber 7	Rawhide 2-1
Bomber 8	Rawhide 2-2
UAV1	Magic
UAV2	Eye Ball
UAV3	Spuds
UAV4	Birdie
UAV5	NightHawk
UAV6	GhostRider
UAV7	Neutron
UAV8	Onion
UAV9	Bronco
UAV10	Eagle
UAV11	Scooter
UAV12	Dark Star
UAV13	Viper
UAV14	Conan
UAV15	Turtle
CRC	Mad Dog
AWACS	Baron
Tanker 1	Hulk 1
Tanker 2	Hulk 2
Tanker LNO	Tanker LNO
ATC	ATC
UAS Operators	Cyclops
Army Artillery	Frosty
ASOC	ASOC
CAOC	CAOC
Roz Owner	Yogi

Information Sheet for ABMs

ROZ's	Area	Name
1	66TI4	Alpha
2	67TF1	Bravo
3	67TI1	Charlie
4	67TH1	Delta
5	65TH5	Echo
6	66TG7	Foxtrot
7	65TG7	Golf

APPENDIX G . Confederate Special Instructions (SPINS)

Special Instructions (SPINS) for Confederates:

TIC Situations

1. TIC will be announced automatically
2. ABM will recommend flight
3. ASOC (YOU) should approve the recommended flight
4. Once fighter is directed to take care of TIC, bomb the appropriate location.

Identify Situations

1. Fighter(s) will be sent to the area to identify
2. When you arrive, perform ID functions
3. If hostile, WAIT until authorized to shoot down (by ABM).

Altitude

1. Track all altitude changes on your tracking sheet.
2. Update ABM's only when asked.

APPENDIX H. ABM Special Instructions (SPINS)

<u>Special Instructions (SPINS) for ABM's:</u>

1. ABMs
   a. There are 2 of you total. Distribute tasks amongst yourself as you see fit. You can split duties by location or function. It's your call.
   b. You will be asked to use voice (radio) and chat communication at different times in the scenarios. Do not deviate from the communication modality you are asked to use.
2. Friendly Assets
   a. Controlled by white force
   b. Speak directly to whichever asset you have questions/commands for, regardless of the communication modality. In these scenarios, bombers/fighters will be in the chat rooms.
   c. You will not be able to see any aircraft's altitude on your radar, but will need to keep track of it on your own (including bombers/fighters/unmanned systems). Each asset will know its own altitude.
3. UASs
   a. Small systems – so these are likely **<u>not visible</u>** to you on your radar. You must keep track of location and altitude of all UAS's in your area. The location/altitude listed on the ATO may no longer be accurate. Pay attention to the communication to make any necessary changes to your information.
   b. You must respond to requests for a/s from UAS controllers as appropriate.
   c. You may be asked to recall locations of all UAS's at any time.
4. Preplanned Missions

a. These are listed on the ATO – your job is to support and manage the bombing of the preplanned targets.
b. If you need assets to redirect for urgent missions (TIC or Unidentified), feel free to move them, but after the mission, **redirect them to the preplanned targets**.
c. ROLEX – sometimes the preplanned missions will be pushed forward or back, monitor communication for this command and act accordingly.

5. ROZs
   a. Seven per scenario, labeled on the radar screen.
   b. Will go hot/cold at different times during the scenario.
   c. You must keep track of each ROZ status and its alt limit if hot.
6. Unidentified:
   a. Upon detection, aircraft must be redirected to identify aircraft
   b. To identify, an "identify" command must be given to at least one fighter.
   c. After identification, you must either have a fighter attack the identified jet or proceed to a new tasking.
7. TICs:
   a. When a TIC occurs, recommend flight to support in C2 Window.
   b. Await ASOC's approval.
   c. After approval (or disapproval), redirect flight(s) to appropriate area or suggest new flight.
   d. Coordinate/deconflict airspace and also try to bring a tanker aircraft to the area for possible refueling.
   e. Fighter aircraft must be present to attack the area.