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Using Ethnography for Understanding Team Decision-Making in a Time-Sensitive Military Setting

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Abstract

We use two ethnographic methods, situated breakdown analysis and information ecologies, to understand how a group of military decision-makers collaborated as they performed a battle damage assessment (BDA) mission. These methods emphasized analysis of anomalous situations as well as the interdependencies among the people involved. By doing so, we were able to view decision-making beyond "by the book" situations and thus better understand collaboration needs. Further, we determined cases in which the technology provided to the military decision-makers could be improved to better support their collaboration needs. We believe this is the first use of situated breakdown analysis in a military setting.

Keywords:

Uninhabited Aerial Vehicles, Unmanned Aerial Vehicles, UAVs, team decision-making, ethnography, observation, time-sensitive.

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1 Introduction

We were tasked to examine the human element in time-sensitive military command and control situations. Specifically, we were asked: how do people make decisions in these environments? Do we need to change existing technology or re-engineer work practices (also known as tactics, techniques and procedures) to better assist the human decision-making process?

Before going further, it is worthwhile discussing what "time-sensitive" means in the military context, and why the human element is of such interest. The military is increasingly contending with very short timescales, especially when performing "Time-Sensitive Targeting" (TST) -- a relatively new concept. In addition to attacking targets with missions that have taken three days to plan, the military now needs to be able to respond to important and fleeting targets in a matter of a few hours, even a few tens of minutes.

The military has been developing much technology to enable them to shorten the times to prosecute TST targets, and has been engaging in joint exercises to practice how they would share assets and cooperate in critical TST situations. Many military analysts have come to the conclusion, however, that gains in technology alone are not sufficient to reach the challenging goals presented by TST; they must take into account more of the human element. A report prepared for the Air Force stated, "Complex decision making processes consume a far greater proportion of the TST timeline than do communications between sensors, shooters, and other TST process components" (Veridian, 2003). Brown and Duguid (2000) echo the sentiment that technology must be designed to work with people, not replace them: "Some futurists seem continuously anxious to replace humans … in certain tasks without quite appreciating how people accomplish those tasks. In general, it will be better to pursue not substitution but complementarity….But complementarity requires seeing the differences between information-processing agents and human agency" (p. 62).

To examine this "human agency," our approach has been to use a combination of ethnographic observation sessions, structured interviews, and artifact analyses (the latter centering particularly on chat logs). While many studies have been conducted of team decision-making under time stress (e.g., Drillins and Serfaty, 1997; Endsley and Robertson, 2000; Hutchins, 1995; Kanki, 1996; Klein, 1998; Klein, Orasani, Calderwood, and Zsambok (eds.), 1993; Salas and Klein (Editors), 2001), few of these studies have been undertaken in military settings using ethnographic techniques.

Ethnographic observation can be described as the study of a community of people in their home or work context. An ethnographic analysis takes into account social and cultural influences, the physical layout of the environment, the resources available to the people being studied, and any constraints imposed by external forces.

The purpose of this paper is to illustrate the type of insights we have been able to obtain for our military customers through the use of two specific ethnographic observation techniques: information ecology (Nardi and O'Day, 1999) and situated breakdown analysis (Spagnolli, Gamberini, and Gasparini, 2002). To accomplish this purpose, we provide our analysis of a specific series of events pertaining to Uninhabited Aerial Vehicle (UAV; recently known as Unmanned Aerial Vehicle) operations. UAVs are remote-controlled (sometimes called "drone") aircraft that provide sensor data such as a video stream to pilots, controllers, and commanders on the ground. We believe this ethnographic analysis is the first to be done in the UAV domain. We further believe that our effort is the first to use situated breakdown analysis for in a military setting.

After some a description of the ethnography methods used, we present contextual information describing the observation environment, followed by a short description of our data collection methodology. The heart of the paper is an ethnographic observation transcript and our analysis of the discourse that comprises this transcript. Finally, we discuss our findings and conclude with some thoughts on the utility of ethnographic observation in the military environment.

2 Approach

There are numerous approaches to ethnography. We are particularly indebted to the ethnographic work of Bonnie Nardi, who has focused on how people work with each other in the presence of computing technologies. Nardi and O'Day assume that people work with technology as though they are members of an "information ecology": a system of people, practices, values, and technologies in a particular local environment (Nardi and O'Day, 1999). An information ecology can be described using the metaphor of a biological ecology. In both types of ecologies there are "keystone species," entities that make it possible for other entities to survive; a diverse set of species; and strong interrelationships and interdependencies among the species. The information ecology metaphor is appealing because it provides the motivation for taking a holistic approach to understanding systems that include people and technology.

Besides looking for information ecology elements in the UAV environment, we performed a situated breakdown analysis (Spagnolli, Gamberini, and Gasparini, 2002): an analysis based on observations made in the users' context that focuses on problems or a mismatch between the users' expectations and reality. Note that the term "breakdown" is not used by Spagnolli et al. in the same way as Agar (1982) uses it; Agar uses breakdown to mean a disjunction between the ethnographer and the culture of study.

The situated breakdown analysis method draws upon the situated action model (Suchman, 1987; Lave, 1988). The situated action model focuses on the "everyday activity of persons acting in [a] setting" (Lave, 1988) and includes analyzing this activity in great detail. The relationships between people (termed actors) and their context are also foci, as Suchman (1987) describes: "the organization of situated action is an emergent property of moment-by-moment interactions between actors, and between actors and the environments of their action." Situated breakdown analysis can be thought of as a melding of a situation action model approach with the human-computer interaction community's emphasis on analyzing users' problems with technology (e.g., Carroll, Neale, and Isenhour, 1993).

To a certain extent, situated breakdown analysis relies on "temporal serendipity" (Fine and Deegan, 1996): the situation in which the ethnographer is exposed to a dramatic event by virtue of being present at the right place during the right time. The challenge is then to see a pattern or implication in the breakdown episode.

We feel that situated breakdown analysis is a useful method for understanding how well the various aspects of a military environment support decision-makers because it tends to capture occasions when people must improvise and/or exercise creativity in their decision-making as opposed to strictly following "standard operational procedures" (SOPs). By seeing a variety of decisions being made beyond those prescribed by SOPs, we can understand more about the various influences on decision-making in the environment being studied.

More information on how ethnographic methods fit into our research can be found in Boiney (2005).

3 Observation Context

We had the opportunity to observe live, time-sensitive operations of a Pioneer UAV at a joint (meaning, multi-military service) exercise. UAVs are only now coming into widespread use in the military, and they are playing roles in many different types of operations, including TST. The purpose of this exercise was to better understand how several types of UAVs could be incorporated into the broad context of time-sensitive multi-service military operations. The exact dates, locations, and the name of the exercise are withheld to provide anonymity for the participants.

On the day in question, military personnel were deployed in several locations in a large military facility, with groups of people being separated from each other by several miles. Fighters and bombers were being flown in addition to the Pioneer UAV. Bombers were scheduled to drop live ordnance on the outbuildings of an abandoned airstrip, and the Pioneer was tasked to provide battle damage assessment (BDA): information on whether the bomber had been successful in blowing up buildings next to an airstrip known as NorthTAC.

The people controlling the UAV sat in the Pioneer Ground Control Station (GCS), which was located on a bluff approximately one mile from the airstrip used by the Pioneer for takeoff and landing. Data from the Pioneer's on-board sensors was transmitted to the GCS as well as several other locations.

The truck-mounted GCS shelter was approximately 6' wide by 8' long by 7' high. It was staffed with three officers: a Payload Operator, responsible for controlling and viewing onboard sensors; a Pilot, responsible for flying the aircraft; and a Mission Commander, responsible for supervising the mission and maintaining communications with others outside the GCS. The Mission Commander was Major R. (an O4, or 4th-level officer). The Pilot (Capt. A.) and Payload Operator (Capt. C.) were both Captains (O3s, or 3rd-level officers; one level lower than the Mission Commander). A photo of typical Pioneer Payload Operator and Pilot consoles can be seen in figure 3-1, courtesy of GlobalSecurity.org (see http://www.globalsecurity.org/intell/systems/pioneer.htm).

Quarters were extremely tight in the GCS shelter; the Mission Commander sat on a shelf behind the Pilot because there were only two chairs in the shelter. The Pilot and Payload Operators faced forward, with their back to the Mission Commander, wore headsets (as did the Mission Commander) and primarily directed their attention to the specialized display and data entry consoles integrated into the front wall of the shelter. The Mission Commander peered over the shoulder of the Pilot to view information about the state of the Pioneer UAV.

Approximately 30 feet from the GCS was a tent containing personnel responsible for collecting various types of sensor data (referred to in this paper as the "Collection Control Point (CCP) tent"). The people in this tent were responsible for verifying that candidate targets were hostile and assessing whether missions that had been waged against targets had been successful. The tent, sketched in figure 3-2, was approximately 8' by 10' and housed five people: the facility's Commanding Officer, Lieutenant Colonel M. (an O5); the chief of the CCP, 1st

Figure 3-1. Typical Pioneer Ground Control Station consoles
(source: GlobalSecurity.org)

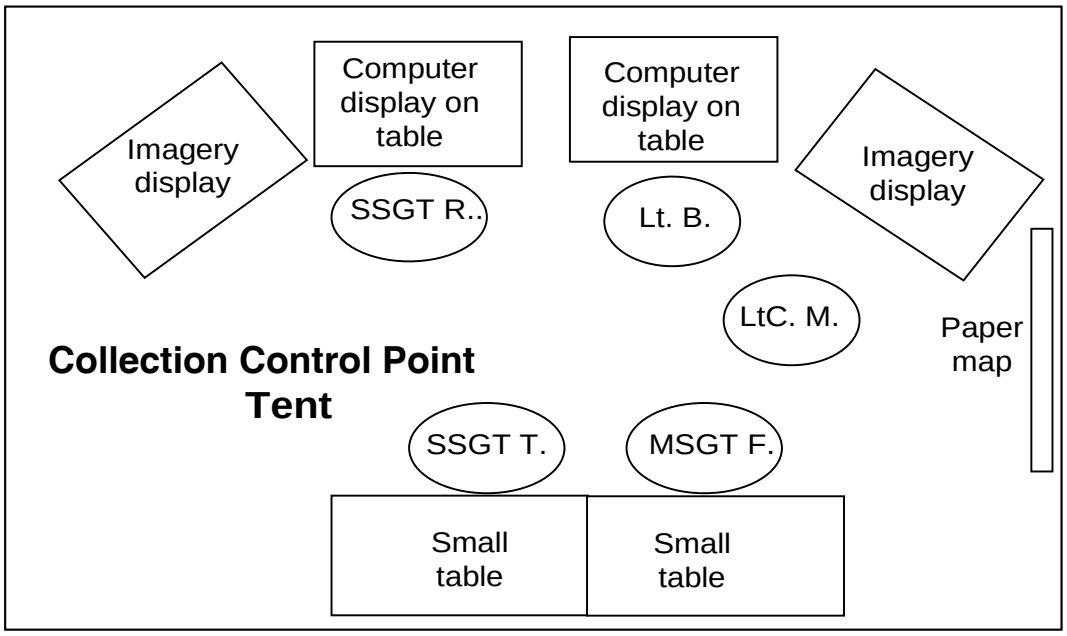

Figure 3-2. Top-Down Layout of the Collection/Control Point Tent

Lieutenant B. (an O2); and three enlisted personnel (Staff Sergeant T., Staff Sergeant R., and Master Sergeant F.).

The two Staff Sergeants acted as aides to Lieutenant Colonel M. and 1st Lieutenant B., while the Master Sergeant was acting as an assessor for the test. The enlisted personnel are all lower in rank than the officers of ranks O1 (2nd Lieutenant) and above, and exhibited their lower rank by addressing Lieutenant B. as "ma'am" and Lieutenant Colonel M. as "sir" at all times.

In addition to the GCS and the CCP tent at this location, there were radar and communications equipment and personnel associated with this equipment. As commander of all the personnel at this location, Lieutenant Colonel M. moved around among the various groups of people as his attention was needed.

All of these facilities were perched on top of a bluff accessible by a one-lane gravel road with no guardrails that was navigable by 4-wheel-drive vehicles only. Electricity was provided by portable generators and there was no running water. Food and water were brought in by truck and the nearest toilet was a chemical-based "porta-potty" at the bottom of the bluff, an approximately 15 minute walk. This particular day, which was sunny and 90 degrees Fahrenheit, occurred towards the end of the exercise; most of the personnel had been sleeping in tents in a camp set up about a mile from the bottom of the bluff for over a week.

4 Data Collection Methodology

The data analyzed in this report was gathered in the CCP tent over a two-hour period during which several interesting decisions were made. We were not able to videotape or audiotape the observation sessions due to concerns that classified data would be captured on the recording media. Further, we were not allowed to bring in computers, hand-held PDAs or any other electronic write-able media. Thus, we took unclassified notes by hand and transcribed them at the end of each day.

The goals of our note-taking were to capture the mood of the people being observed, their work pace, the impact of their military culture on their work processes, their means of collaboration and the effectiveness of each medium, and the bases upon which they made decisions. These goals meant that we watched for (in no particular order):

- Emotions, e.g.: saying "That is *so* frustrating!" or frowning at the computer screen
- Physical manifestations of the work, e.g.: rushing from the tent versus staring quietly at computer screens versus leaning back in chairs tipped away from computer screens
- Evidence of military rank or "standard operating procedures" (SOPs) coloring interactions, e.g.: a Staff Sergeant responding quickly to a Lieutenant's request
- Who used chat versus secure phone versus face-to-face to convey what information to what person, and why they used one means versus another
- Ways the environment impacted their work processes, e.g.: the Pioneer GCS Shelter and CCP Tent were close enough together to walk from one to the other quickly whereas all other command and control facilities were far enough away to require technology to aid collaboration
- Doubt or uncertainty regarding the information they are provided, e.g.: a Lieutenant saying, "I don't believe them"
- Clues they use to determine the veracity of information, e.g.: "NorthTAC [an airstrip] should have a mountain range behind it"
- Ways they cue each other to the current situation, e.g.: a Staff Sergeant counts down the number of minutes until expected bomb impact

Emotional content, expressions of doubt, and deviation from SOPs were normally evidence of breakdowns.

We wrote direct quotes when they were short and addressed one of the points above; otherwise we condensed/paraphrased or wrote summary notes that we expanded that evening. Only notes pertinent to a particular event are included in this analysis: the activities surrounding obtaining an assessment of the live ordnance drop on NorthTAC airstrip (a battle damage assessment, or BDA).

5 Transcript and Interpretation

The table below shows the time of the transcript entry, the transcript entry itself, and explanations and interpretations. Times are shown in the 24-hour military clock (e.g., 1525 is 3:25 p.m.). The same abbreviations for names are used as introduced previously in section 3.

Table 1. Transcript and Interpretation

Time	Transcript Entry	Interpretation
1525	Lieutenant B. silently reads information from a chat window and announces to everyone in the CCP tent that "Harriers have been launched and they will be shooting in approximately 3 minutes."	Harriers are tactical strike aircraft, and they are scheduled to drop bombs ("shoot").
1526	Lieutenant Colonel M. says to Lieutenant B., "but you have about 18 minutes until TOT." Lieutenant Colonel M. and Lieutenant B. discuss whether they believe the bombs are due to drop at 3:30 or 3:45; they do not reach a conclusion	The two officers are confused about when the bombs will drop ("time on target," or TOT). A recently received chat message indicates bombs will drop at 3:30 but their previous orders were for a bomb drop at 3:45. They do not resolve the issue overtly, but elect to remain alert in case the bombs should drop soon. Once it becomes clear that the bombs have not dropped at 3:30, they make the assumption that the bombs will be dropped at 3:45. This is an example of having to make sense of conflicting information, and they contend with the conflict by remaining ready for either possibility, rather than resolving it definitively.
1528	Lieutenant B. sits in front of the video display being sent from the Pioneer, with her back to Lieutenant Colonel M., Staff Sergeant T., and Master Sergeant F.; and on the right side of Staff Sergeant R. She reads latitude/longitude coordinates while looking at the video of an airstrip that is being sent from the Pioneer. Master Sergeant F., who was also looking at the video, said, "That looks like SouthTAC, not NorthTAC. Is that the wrong airstrip? NorthTAC is at the base of a ridge and I don't see any of the ridge in the video." He moves to the topographical map on the East wall of the tent and gestures at the ridge. Lieutenant B. quickly looks at the map, then at the video and at the coordinates of NorthTAC displayed elsewhere on her screen. She verbally agrees that the Pioneer is viewing the wrong airfield.	Master Sergeant F. employs pattern matching to determine whether he is looking at NorthTAC or SouthTAC airstrip, similar to the type of "recognition primed decision-making" defined by Klein and Crandall (1992). As part of the pattern he built from previous experience of looking at NorthTAC airstrip, he expects to see at least part of a ridge behind the airstrip. When he does not see any, he becomes suspicious and matches the terrain visible in the video to the terrain in the area of SouthTAC. He explains his reasoning to Lieutenant B. by showing her the terrain on the topographical wall map, which has been hung there for that purpose. She quickly agrees with him that the Pioneer is looking at the wrong airstrip. If the Pioneer does not move to the correct airstrip or at least reorient its camera, they will not be able to achieve their mission of witnessing the live ordnance drop on the NorthTAC airstrip. Since the clock is counting down towards the time when the bombs will drop, there is urgency to the situation.

Time	Transcript Entry	Interpretation
1529	Staff Sergeant R. starts to relay this message to the GCS shelter via her radio headset. She says just a few words to Major R. before falling silent, listens, then says, "yes, sir" and concludes the transmission. She turns to Lieutenant B. on her right and says "They told me they are too busy to listen to me right now." Lieutenant B. makes a sound of frustration, has an irritated look on her face, gets up and announces she will talk to them in person.	The culture of the military includes the custom that lower-ranking people must, in general, defer to higher-ranking people. Staff Sergeant R. did not have a chance to explain why her message was urgent before being told by Major R. that he had no time to listen to her. Because she is significantly lower in rank than Major R., she quickly acquiesced and reported to Lieutenant B. that she could not get her message through. Lieutenant B. is also lower in rank than Major R. but she was given the role of Chief of CCP. In this role, she is responsible for getting the job done even if it means having to tell higher-ranking officers that they need to stop and pay attention to her. She is frustrated that she needs to force them to pay attention to her message –and the message is, in a real sense hers, since she is Chief of CCP, even though the first attempt to relay that message was through someone else. Accordingly, she chooses a means of delivering the message that is harder to ignore or brush aside: face-to-face contact. Luckily, the CCP tent is only 30 feet from the Pioneer GCS so a face-to-face visit is practical.
1530	Lieutenant B. returns to the door of the CCP tent just as Lieutenant Colonel M. calls out her name sharply. She runs back to her workstation and immediately scans the displays while she listens to Lieutenant Colonel M.'s request.	Even though Lieutenant B. was justified in leaving her post to deliver an urgent message to the Pioneer GCS, she feels she must literally run back to her computer console when her Commander speaks her name with an intonation indicating urgency.
1536	Lieutenant Colonel M. says, "TOT is 9 minutes." Lieutenant B. says, "Yes, sir." She is concentrating intently on the video and her other displays, frowning slightly and moving in quick movements. Lieutenant Colonel M. leaves immediately after hearing Lieutenant B.'s reply. Lieutenant B. asks the sergeants in the tent, "Is that what he said, 9 minutes?" They reply "Yes, ma'am." Lieutenant B. says, "The target area is 240 feet high; I need grid 9413." Staff Sergeant T. says, "They're in lat/longs."	Lieutenant B. appears tense and exhibits a short-term memory loss regarding the Lieutenant Colonel's time-on-target countdown. He is reminding her that they have only 9 minutes to solve the problem or their mission will be unsuccessful. This series of utterances also illustrates the difficulties they have with coordinate conversion. They do not have automated coordinate conversion tools to convert from grid references to latitude/longitudes; thus, they are occasionally slowed down while working around this shortcoming. This delay is difficult to handle when time is running out to successfully achieve their mission tasking.

Time	Transcript Entry	Interpretation
1537	Staff Sergeant T. says, "TOT 8 minutes." Lieutenant B. talks to the Payload Operator via her headset, saying "Oh, you need lat/longs? Major S. has a paper with lat/longs….NorthTAC should have a mountain range right behind it….It doesn't match our grids at all….OK, well, we'll see what we can see." She ends the transmission, and turns to the other people in the tent, saying "They claim they're looking at the right airfield already. They said they're sitting on top of the mountain, so that's why the mountain can't be seen in the video; they're looking at a155 degree angle. I don't believe them, though...but we'll see who's right."	The Payload Operator has created an explanation of why he doesn't see the ridge behind NorthTAC: the Pioneer is sitting right on top of the ridge. He exhibits an information bias; this incident illustrates the tendency that most people have to look for confirming evidence rather than disconfirming evidence.
1539	Lieutenant Colonel M. returns. Lieutenant B. tells him about the Payload Operator's conviction that the Pioneer's video is aimed at the right airstrip. They both express disbelief that this is correct. Staff Sergeant T. says, "6 minutes."	The tension continues to mount because the staff in the Pioneer GCS appear firmly wedded to the belief that the Pioneer is in the right location to perform its mission and there is only 6 minutes to correct the problem.
1540	Everyone stares intently at their respective display consoles. Staff Sergeant T. says, "5 minutes.	There is not much conversation at this point, but the tension continues to increase. It is too late for the slow-flying Pioneer to fly to the other airstrip.
1541	The video display shifts abruptly to a different scene. Lieutenant B. says, "Now we're looking at the right airfield! I was right!" Visible on the video screen is the airfield and five small, square buildings in a loose arc around one end of the airfield. Staff Sergeant T. says, "4 minutes." Lieutenant Colonel M. dictates a request for an update on TOT while Lieutenant B. types into a chat window.	The abrupt shift in scene was caused by the Pioneer slewing its cameras to the north and zooming in despite the distance. This was a low-risk action for the Pioneer GCS crew to take, because it only takes a few seconds to move the camera in a different direction. If they had done so and not seen NorthTAC, they would have returned the camera to its original position and continued to look at the airstrip they had been focusing on. As a result of their trial camera-slewing, they realized that they were flying over SouthTAC but that they could keep their camera trained carefully on NorthTAC to accomplish the mission. The mood in the CCP tent abruptly becomes more positive, but all people are still concentrating intently on the video downlink.
1543	Staff Sergeant T. says, "4 minutes."	Not much conversation occurs while all eyes are trained on the video picture. Staff Sergeant T. is actually off by one or two minutes in his countdown to bomb release but no one corrects him. It is not clear that anyone notices, but, even if they did notice, it is easier for them to remain ready for the bombs at any moment than to argue about what time it really is.

Time	Transcript Entry	Interpretation
1544	Staff Sergeant T. says, "3 minutes."	While earlier there was tension based on the prospect of failing in their mission, the tension now is based on anticipation and the desire to observe all possible details about the impending live ordnance release.
1545	Staff Sergeant T. says, "2 minutes." Visible on the video, the 3rd building becomes engulfed in smoke as it is bombed. Staff Sergeant R. announces the impact. Lieutenant B. is dividing her attention between the video display and chat windows. She says with a note of disbelief in her voice, "RTB?? Just when we were seeing impacts??" Lieutenant Colonel M. says, "Who's SAC?" Lieutenant B. uses the headsets to pass on the RTB order to the Mission Commander in the GCS. Lieutenant B. says to Lieutenant Colonel M., "That is so frustrating. Right when we are getting impacts!"	Lieutenant B. reads via chat that the Pioneer has been ordered to return to base (RTB). This is puzzling to her because it means that they will not be able to complete their mission if they break off the Pioneer at this point and fly back to its landing strip. Lieutenant Colonel M. wants to know the identity of the person giving the order; he can see his or her chat nickname ("SAC") but doesn't know who is fulfilling that role at this time. If he knows the person's identity, he will have a better feel for whether he can trust this information. Despite her puzzlement over the order, and in accordance with the military culture that dictates following orders at all times, Lieutenant B. complies promptly.
1546	Lieutenant Colonel M. says to Lieutenant B., "Can you copy that RTB order out of chat so we can show it when we get yelled at?" The video camera is still trained on the airstrip. The first building is now engulfed in smoke. Lieutenant B. and Staff Sergeant R. discuss how many buildings were destroyed. Lieutenant B. says she believes at least three buildings were destroyed but does not mention any building specifically other than the 1st and the 3rd buildings.	Lieutenant Colonel M. feels personally accountable for the success of the Pioneer's mission and feels others will hold him accountable, as well. Accordingly, he wants evidence that he was told to break off the mission prior to its successful completion. Meanwhile, the Pioneer is managing to keep its camera trained on the airstrip even though it has begun returning to its takeoff and landing point. Despite the distraction of the RTB order, CCP tent personnel are trying to accurately reconstruct how many of the five outbuildings were bombed. Lieutenant B. does not waver in her stated belief that three were bombed, but when I later asked her which buildings were destroyed, all she was sure of was that the first and third buildings were destroyed. This difficulty illustrates the challenge of accurately observing activities that occur in a transitory or fleeting manner, even when observers are conscientious and highly trained.
1547	Lieutenant B. asks Staff Sergeant T. to take a BDA report. He says, "Already starting it, ma'am."	The formal notification of the bomb damage is filed in a BDA report. This report is evidence that they have completed their mission. How successful they are depends upon the accuracy of their report.

Time	Transcript Entry	Interpretation
1548	The tension in the room lessens significantly now that the immediate mission has been accomplished. Lieutenant B. has time for a question at this point so I ask her, "Why was there an RTB order given?" She says it is due to EMI (electromagnetic interference). She and the other sergeants joke that it is due to EMP (electromagnetic pulse, normally caused by a nuclear detonation).	This is the first of three reasons given for the RTB order. They return to the subject several more times during the afternoon. They exhibit a wish to make sense of a situation that they did not expect. This is the first use of humor during this episode, and is indicative of the fact that the intense concentration and focus during the BDA observation is no longer needed. The smiles that accompany this joke seem all the more welcome after the seriousness of the previous hour.
1607	Lieutenant B. is asking, "Tasking for CENT3?" She is typing into a chat window and saying, "I don't understand why." Lieutenant B. gets out of her chair and crosses to the table behind her to pick up the secure telephone. Lieutenant Colonel M. says, "Call Q." While she places the call, Lieutenant Colonel M. looks at the chat window and asks Staff Sergeant R., "All I have to do is type and enter, right?" She says, "Yes, sir" and he commences typing with two fingers. Lieutenant B. hangs up the phone without successfully getting through to Q., and then reinitiates the dialing sequence to try again. Lieutenant B. says to Lieutenant Colonel M., "Tell him it's too hard to chat. Tell him I'm calling him."	This series of utterances pertains to the officers making sense of the series of actions surrounding the RTB order. They read something in chat that causes them to take on puzzled looks and Lieutenant B. feels that the subject is better addressed on the phone rather than via chat, which becomes "too hard" to use in this situation. Meanwhile, Lieutenant Colonel M. feels that it is so important to get through to Q. that he tries to chat to him even though he is not familiar with or comfortable with the chat system they are using.
1615	Lieutenant B. has successfully gotten through to Q. and says, "Don't pass DASC stuff through chat; you should have called the 3 over there and had them give it to us. There's restricted airspace to the north." She concludes the conversation and returns to her chair.	Lieutenant B. is discussing a procedural question with Q. (see below under 4:15 p.m.). "The 3" refers to a person.

Time	Transcript Entry	Interpretation
1615	I asked Lieutenant B. why she said "it's too hard to chat." She said that Lieutenant G., her counterpart at the TAC Intell organization, had relayed the RTB order that he got from the operations people at the DASC through to her with the expectation that she would relay it to the Pioneer mission commander. Thus, the order went from DASC operations to TAC Intell (Lieutenant G.), to Pioneer Intell (Lieutenant B.), to Pioneer Operations (Major R.). She said that this is the wrong process; it should have gone directly from the DASC operations people to the Pioneer Operations person (Major R.) so that if there is some question about it, it can be addressed directly instead of having to be relayed through many links in the chain. She said that this was too difficult a procedural issue to explain over chat, so she needed to do so via secure telephone. [Later, I talked to another observer who was at the TAC during this time period. She said that the order originated from the TAC and not the DASC. Lieutenant B. was under the impression that the order came from the DASC, however.]	This is an example of a case when military procedures were not followed correctly and the complex path that the information followed was too difficult to critique using chat. (Note that the TAC and DASC are command and control centers at two other locations within the military facilities being used by the exercise.) Also, unless a "private chat" session is used, chat can be seen by any number of people and can leave a permanent record via logs or cuts-and-pastes into reports. Thus using the normal chat channels to point out failures to follow accepted procedures is tantamount to public chastisement, which is not generally practiced in the military unless the offense is egregious or an officer wishes to make an example of someone's unacceptable behavior. Plus, Q. and Lieutenant G. were peers of Lieutenant B.'s and she did not wish to do anything that could be construed as public criticism of them.

Time	Transcript Entry	Interpretation
1700	Personnel in the CCP tent talk about how the RTB order was caused by C130s transiting through the area.	This is the second reason advanced for the RTB order. Later I received more information about the situation surrounding the RTB order from observers in other areas. At that time, they were experiencing communications delays of up to 9 minutes between sending chat from the CCP tent and receiving it at the TAC. When the CCP tent received the RTB order, their chatted response was delayed. Plus, it was not clear to TAC people, who could also see Pioneer video, that the Pioneer was complying with the order because it was able to keep the video camera slaved onto the NorthTAC airstrip for some time even while it was retreating, by zooming in tighter and tighter as the aircraft moved away. Thus, people at the TAC had the impression that the Pioneer GCS was not complying with the RTB order. While Lieutenant B. first thought the RTB was called due to an EMI problem, then due to C130 cargo aircraft transiting through the area, the people at the TAC said that the RTB order was called due to a perceived potential airspace management issue involving F5 aircraft. In other words, someone at the DASC or TAC felt the Pioneer may have been in danger of getting too close to the F5s. If the latter explanation is true, it is interesting because this indicates the difficulty of the Pioneer operators achieving a complete understanding of the airspace near the Pioneer (what operators call "situation awareness"). None of the Pioneer GCS or CCP personnel were ever aware of F5s being anywhere near the Pioneer.

Time	Transcript Entry	Interpretation
1721	In response to my questions about how the Pioneer pilot thought he was over NorthTAC when he was over SouthTAC, Staff Sergeant T. walked to the wall and gestured at a map. He showed me how they crossed major UTM grid zones on the way to the target (starting in 7, going through 2, then 3). Each of these represents a different numbering system. When they worked with UTMs they have to range in kilometers, and when they use latitude/longitudes they have to use nautical miles. He said they are handicapped because a "moving map display" in the GCS was not working and they normally rely on this heavily. He said they have to fly off of dead reckoning while using the metric system on the map on the wall while reading nautical miles off the video. He also said they had drifted south in the process of moving back and forth to acquire the communication signal because they were having communications problems.	This explanation illustrates how easy it is to lose situation awareness (perception, comprehension, and projection of the state of the environment, according to Endsley (1988)) when handling a pressing problem, which in this case was a loss of communications.

6 Analysis and Recommendations

When viewing the UAV operations environment as an information ecology, we can identify the role of *leader* as a keystone species. The test of a keystone species is that it is critical to enabling the other species to survive and thrive; the military places such emphasis on leadership and command that the whole hierarchical structure is predicated on the leadership concept. Note that leadership is a quality separate from rank; some high-ranking military commanders are poor leaders and some low-ranking officers are natural leaders. Three leaders in this episode are readily identifiable: Major R., who was in charge of where the Pioneer flew; Lieutenant Colonel M., who was commander of all operations at that location; and Lieutenant B., who was leading the CCP effort. The most effective leader in this episode was Lieutenant B. because she was actively involved in directing the BDA collection mission, listened to her subordinates and quickly agreed with them regarding the problem with the Pioneer's geographical orientation, and did her best to persuade Major R. to change the Pioneer's location despite his higher rank.

Also from an ecological viewpoint, we can identify several interdependencies among the species (different types of people). The CCP people needed the cooperation of the people in the Pioneer GCS to direct the Pioneer and aim video cameras correctly to provide the necessary information. The officers in the Pioneer GCS needed the help of the CCP people to train the Pioneer's video camera on the correct airstrip. Despite SOPs to the contrary, the people in the other command and control locations who issued the RTB order depended upon the CCP people to relay the order. While not captured in this particular transcript, the communications people were working very hard to ensure that the people in the Pioneer GCS maintained communications with the Pioneer. These examples also illustrate the diversity of species involved in the ecological system.

From the viewpoint of the situated breakdown analysis, we can make the following points.

- It is easy to lose an understanding of where the UAV is in the geographical space (i.e. "situation awareness") when dealing with pressing problems.
- Time pressure makes it difficult to focus attention and retain multiple information inputs, as illustrated by Lieutenant B. not remembering Lieutenant Colonel M.'s warning that only nine minutes remain.
- The command hierarchy made it difficult for lower-ranking people to gain the attention of higher-ranking people at stressful moments, just when getting someone's attention can be extremely important. Staff Sergeant R. was unable to gain Major R.'s attention, and Lieutenant B. was able to do so by using the most powerful collaboration mechanism she had at her disposal: face-to-face.

- The choice of collaboration mechanism must be paired to the situation at hand to be effective. When radio telephone (compounded by the effect of Staff Sergeant R.'s relatively low rank) was insufficient to communicate an urgent message, Lieutenant B. chose face-to-face communication to convey her perception that the Pioneer was located over the wrong airstrip. Further, Lieutenant B. chose to discuss her critique of a complicated procedural question over the secure telephone rather than via chat.
- People need to know who they are collaborating with, not just the role of the collaborator. Knowing the person behind the message helps them to know how much the message can be trusted, and also plays into issues of personal accountability.
- It is challenging to change one's view once they have formed a mental picture. When the Pioneer crew was told about the problem, they were reluctant to change their view of the situation because they fit the available data (i.e., no ridgeline being visible in the video) to their belief that they were at NorthTAC by assuming that the UAV was located on top of the ridge.

From this observation experience and others, we have made a number of recommendations. Note that before we make recommendations we compare analyses from several different observation venues to determine that we have seen a pattern rather than an isolated incident; describing how we piece together patterns across observation opportunities is, however, beyond the scope of this paper. A few recommendations that can be traced in part to this situated breakdown analysis are listed below.

- Modify the human interface to the UAV to provide operators with more contextual information; that is, more information about the area immediately surrounding the UAV to provide more situation awareness.
- Provide collaboration technologies that include richer, more subtle cues about the activities of collaborators. In particular, provide a means of being able to discern the urgency of the incoming message so the proper amount of attention can be paid to the message. This may at least partially counteract the effect of differences in rank, especially if SOPs reinforce paying prompt attention to "high priority" requests regardless of the rank of the requester.
- Continue to provide a variety of collaboration mechanisms, to include such basic means as telephone, because "one size" does not fit all.
- Ensure that collaboration mechanisms allow for users to easily discern the identities of their fellow collaborators when appropriate.
- Provide decision-support tools that help decision-makers form more accurate mental pictures of their situation.

7 Discussion

By being alert for breakdowns and observing them in detail, we obtained a rich data set during a short period (two hours). We were prepared for this serendipitous experience because we understood the context in which they were working. A team of us had spent approximately a week at this exercise and had spent many weeks at similar exercises; and some of our team members had either been in the military or had spent decades working with the military on related work. Despite all the preparation in the world, however, sometimes observation opportunities do not include interesting breakdowns and it can be much more difficult to sift through the observations to find noteworthy implications and patterns.

The military environment normally carries with it a strong set of expectations: e.g., that enlisted personnel will defer to officers, personnel will follow orders given to them by people with higher rank, and that everyone will follow SOPs unless safety concerns intervene or the mission is in jeopardy. Because there are such strong norms, deviations from those norms are often readily visible to the careful observer and interesting to analyze because they indicate a breakdown.

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