Developing Situation Awareness Software for Army Aviation

Mr. Christopher R. Paulillo
U.S. Army Research Laboratory
Human Research and Engineering Directorate
Attention: AMSRL-HR-ML
Communications and Electronics Command Field Element
Fort Monmouth, New Jersey 07703
USA

Email: cpaulillo@arl.army.mil

ABSTRACT

Until recently, U.S. Army aviation commanders and ground personnel had no way of tracking flights once the helicopter moved out of sight or radio range. With new radio technology, it is now possible to track helicopters that fly nap-of-the-earth profiles, even over great distances. In order to provide this capability, the U.S. Army developed a software application that interfaces with the ground-based communication system. With a simple button push initiated at the airborne radio, aircraft position data are transmitted to the ground radio, processed by the new software, and plotted on a digital map. In addition, the communication system provides aviators the capability to send free-text digital messages to ground systems. U.S. Government civil servants in a flexible, iterative process of develop, test, and refine are modifying the software to add capability and to improve the human-machine interface (HMI). A major challenge in applying human factors engineering methods was identifying the typical user. This was a challenge because there is no predecessor system. Potential users had varied opinions in what should be displayed as well as how the information should be presented, and the problem became more complicated as the system matured and capabilities increased. As the software evolved, an assortment of HMI issues surfaced. A major HMI issue concerned the digital map and map manipulation capabilities. Many users recommended integrating the software with existing map tools used for pre-mission planning. Engineers satisfied this request, but it created additional HMI issues that had to be resolved to include use and interpretation of military standard symbology, display clutter, and information categorization and management. Resolution of each of the HMI issues was critical to improved situation awareness. The unique process used to acquire, evaluate, and refine a software system for improved situation awareness for U.S. Army aviation is described in this paper. In addition, detailed descriptions of the HMI issues that confronted the developers are presented.

1.0 INTRODUCTION

Situation awareness (SA) is a psychological construct that means knowing what is going on around you. It is a mental model of a dynamic environment. Endsley defines SA as, "the perception of the elements in an environment within a volume of time and space, the comprehension of their meaning, and the projection of their states in the near future" [1]. SA is an important component in the human information-processing model as it relates to decision making [2]. Good SA is essential for military commanders to make timely and appropriate decisions during the course of a mission.

Paper presented at the RTO SCI Symposium on "Critical Design Issues for the Human-Machine Interface", held in Prague, Czech Republic, 19-21 May 2003, and published in RTO-MP-112.

With today's technology, users can be provided with an enormous amount of information over a great distance very quickly. Numerous examples exist of commanders being inundated by too much information, especially during periods of high stress and heavy workload associated with combat situations [3]. The challenge for system designers is to provide adequate information in a manner that is cognitively and physically usable by the decision maker. The current effort uses human information processing principles to design and evaluate an SA system for the U.S. Army Aviation community.

2.0 BACKGROUND

Beyond line-of-sight (BLOS) communications has been a problem for U.S. Army aviation since improved performance helicopters were fielded. Extended range operations and missions executed in mountainous environments present problems to radios that rely on line-of-sight (LOS) for communication. To overcome this problem, Army aviation commanders controlled the mission from the air where they were able to see the battlefield. The U.S. Army also adopted tactics to combat this problem such as using relay stations positioned within an effective LOS communication range. However, such tactics made the personnel, who operated the relay stations, vulnerable. A radio capable of BLOS communication was needed.

The High Frequency (HF) Nap-of-the-Earth Communication (NOE COMM) System resolves communication limitations associated with LOS radios. The HF media offers BLOS communication with a range of hundreds of miles. The system is ideal for use in helicopters that fly contour and NOE profiles where the masking effects of rugged terrain make LOS radio communication unreliable. The HF NOE COMM System includes an airborne HF radio and a secure device for data encryption and decryption. The system features a digital message capability that allows the user to send and receive text messages.

Digital messaging permits accurate position reporting. With the radio interfaced to the on-board global positioning system (GPS) receiver, aviators can transmit their current position with a simple button push to a ground-based radio. The communication capabilities that the HF NOE COMM system provides increases commanders' effectiveness and flexibility by keeping them in contact with their units from the ground. This was not possible before. Furthermore, position reporting allows commanders to know the precise location of their aircraft.

In response to the need for BLOS communications and dissemination of SA information, the Project Manager, Aviation Mission Equipment (PM AME) initiated a software development effort that used the HF NOE COMM System. This effort was designed to provide a gateway to the tactical internet (TI) for US Army Aviation and to meet the requirement to monitor the position of friendly troop assets, called Blue Force tracking. These requirements, developed by the U.S. Army Forces Command, allow the aviation community to provide better support to Operation Enduring Freedom (OEF) and other Central Command operational plans.

The software development effort began in 2001 as a concept experimentation program. The next year, it transitioned to a formal materiel acquisition program. The unique aspect of this materiel acquisition program was that unlike acquisition of most military systems government engineers, rather than defense industry contractors, were used to develop the software. In-house software development permitted flexibility in making changes as needs for new capabilities and requirements evolved. This flexibility also reduced development time and provided greater opportunity for testing and experimentation. The processes used to shape user interface development and the challenges encountered are described in this paper.

3.0 METHODOLOGY

3.1 First Operational Prototype

Early in 2001, the U.S. Army began developing a concept for following helicopter flights via the HF NOE COMM System. Before the introduction of this radio, operations personnel performed the task manually. Aviators used LOS radios to verbally call in their positions, and ground-based radio operators recorded the information on paper. Ground personnel literally marked the appropriate location on a large map. This process was fraught with human error. The position-reporting feature of the HF NOE COMM system allowed this manual process to be automated. To support operational use of the HF NOE COMM system in the aviation tactical operation center (TOC), government engineers developed a software interface to the system. The interface ran on a laptop computer connected to the HF radio in the aviation TOC. It received all radio traffic, including digital messages (e.g., position reports) and converted the textual data to an icon and positioned it at the appropriate location on a digital map display. The PM AME delivered the software to an Army National Guard unit who used it to follow AH-64 flights during HF NOE COMM system testing. At varying points during the flight, the aviator transmitted a position report to the ground station and the software displayed it on the map. The system also captured and logged text messages transmitted by aviators.

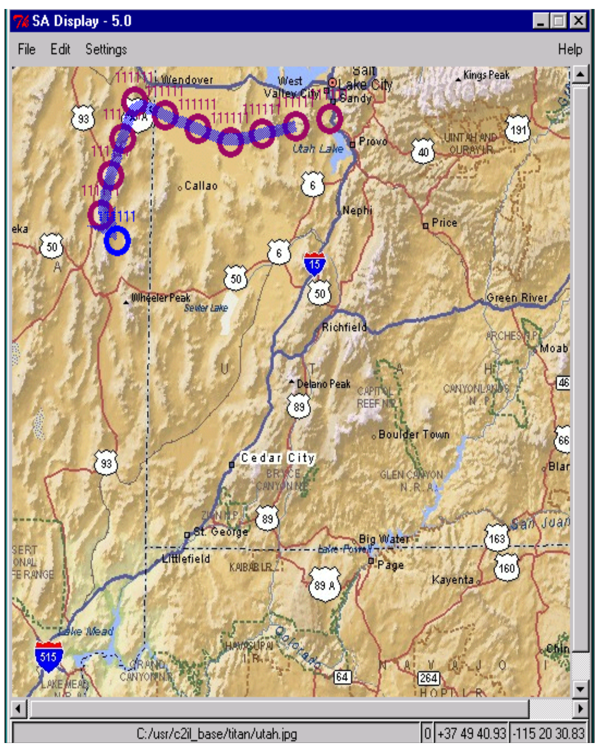

Figure 1: Sample Display of System Receiving and Plotting Position Reports.

3.2 SA Information Requirements Analysis

While the National Guard unit used the system for 5 months of radio testing, methods for analyzing the user-interface were prepared. Our goal was to develop a user-interface to the SA system that would meet four design objectives. The first objective was to provide the user with only the necessary information needed for informed decision making [4] and to avoid interference from extraneous information [5]. The second objective was to provide the information in a manner in which the user could detect and process it quickly and accurately [2]. The third objective was to reduce the demands on the user's working memory [2]. The fourth objective was to reduce display clutter while meeting the first three objectives. In an evaluation of prototype SA systems used in the UH-60 helicopter, aviators frequently complained that displays were too cluttered [6]. This objective was the most important one, but it was also the most challenging.

3.3 User Survey

In addressing the first design objective, it was necessary to review draft documentation that the US Army aviation user representatives had prepared to outline SA information requirements. Requirements for an SA system had been prepared in 1996, but the system had not been developed. In addition, aviation personnel were interviewed to determine additional information needs for SA. After the data were compiled, a survey to quantify the user's perceived importance of information items as they related to SA was developed.

The survey used a Likert-type response format in which soldiers were asked to rate the importance of 19 SA information items. The survey asked respondents to envision themselves as a commander of a continuous attack mission, and while considering this context, to rate each item of information in terms of importance. Soldiers responded to each item by choosing one of five possible ratings that ranged from very important to very unimportant. Survey respondents included commanders, aviators, and operations personnel. All survey participants had observed the prototype SA system in operation. Respondents included 11 Apache aviators, three Black Hawk aviators, three commanders, and three operations personnel. Although the sample size was small, it was representative of potential users and consisted of personnel who had participated in the training missions. Each individual had insight into the information needs for the SA system.

Overall, the soldiers judged most of the information listed on the survey as important to SA during a continuous attack mission. High mean scores and low standard deviations indicated that there was agreement among user groups that aircraft position, mission graphics, aircraft group position, and enemy position were important. However, commanders and ground personnel also considered items such as aircraft fuel status, ammunition supply, weather and typography to be important. Overall, results from the survey validated the Army aviation user requirements documented in 1996.

3.4 Prototype Software Evaluation

The prototype SA software being evaluated was called the Tactical Internet Test and Analysis (TITAN) Tracker. Army National Guard personnel used the software during daily operations and training missions during the spring of 2001. The unit deployed to Kuwait during the summer of 2001 and used the system to track aircraft equipped with the HF NOE COMM System. In collaboration with the unit, we observed their use of the system and interviewed key personnel. These observations and interviews were made over a 10-month period.

Map use and management was a major concern. The TITAN Tracker used pre-processed maps that required pre-planning and a substantial amount of effort to process. The method for acquiring maps was time consuming and impractical. Soldiers preferred using maps with which they were accustomed such as those published by the Federal Aviation Administration (FAA).

The TITAN Tracker could not accommodate multiple map scales in a given session and the user did not have the ability to switch between map scales without losing past position data. This limitation caused users some difficulty in differentiating between individuals or determining precise locations when tracking multiple flights.

The TITAN Tracker used a colored circle for the position marker. The user could define the color for all positions but could not define the color for individuals. The TITAN Tracker displayed textual information beside the position marker, but it used an identifier that had meaning for the TI but not for the users. The manner in which the TITAN Tracker identified positions, coupled with its inability to support multiple map scales made tracking multiple aircraft difficult.

Most soldiers expressed a need to create graphics and overlay them on the map. Seeing an aircraft position on a map containing natural topographical features may improve SA, but users often preferred to see the aircraft within the context of mission graphics representing flight routes, items of interest, and areas of responsibility. The TITAN Tracker did not provide the capability to generate graphics.

Aviators suggested that the TITAN Tracker should be adapted to interface with existing flight planning applications. They believed the interface simplifies map management because their flight planning application had sophisticated map management capabilities and graphics generation capabilities. The ability to either import graphics into the TITAN Tracker map display, or send position data from the TITAN Tracker to the flight planning software that manages maps and overlays, would reduce workload and the potential for errors substantially.

3.5 Software Evolution

As the TITAN Tracker transitioned from concept experimentation to a formal program that addressed requirements for Blue Force tracking and transmitting data via the TI to other SA systems, the PM AME developed a blocked approach to software development and renamed the program, the HF Tracker – TI Gateway. The system architecture was defined, and system requirements for the objective SA system were developed. Initial system requirements were modified to address user recommendations for enhancements. In addition to the recommendations for map management and generating mission graphics, users requested additional capabilities with respect to radio control and generating and processing text data messages. The latter augmented SA because it introduced the ability to mix command and control data with position reporting. Government software engineers released Block I software builds monthly.

Beginning in 2002, the team has delivered the software to numerous sites and field exercises. These have included the Utah National Guard since they provided security to the 2002 Winter Olympics, the Army Aviation Association of America Annual Conference, several U.S. Army and National Guard Units conducting local training missions in the United States and Germany, Victory Strike III warfighting exercise conducted in Poland and Operation Enduring Freedom in Afghanistan. During the course of these exercises, the engineering team collected user-feedback to enhance subsequent software builds. This has been a process of iterative software development and usability assessment. Although software development has been evolutionary, it has been functional at each stage of development. The development team was able to employ the system in an operational environment without being obtrusive or distracting to the unit.

3.6 Current Status

In less than one year, the software has matured and is becoming an effective tool for communicating SA. The development team has compiled approximately 60 user requests for system improvement. Requests fall into six different categories. These categories have included the following: display of map, graphics, and position data, text message management, remote radio control, data log generation, and miscellaneous system enhancements. The development team has continued to compile data and prioritize requests made most frequently by users. This information is used to drive system requirements and software development.

The most substantial change in the software was the interface to FalconView. Because FalconView uses National Imaging and Mapping Agency (NIMA) map products, it provides the TITAN Tracker access to standard symbology. Upon receiving an aircraft position, HF Tracker instructs FalconView to plot the position using the standard symbol stored in its library. Along with the symbol, the system displays an aircraft identifier and the time that the report was sent. HF Tracker users can also take advantage of FalconView's ability to generate mission graphics. FalconView has drawing utilities that allow soldiers to create man-made planning references such as flight routes, boundaries, and areas of responsibility. FalconView also permits users to identify specific items of interest and uses the library of symbols and icons to do so. The symbols and icons in the FalconView library adhere to the U. S. Department of Defense Interface Standard [7]. Graphics depicting mission-planning constructs generally consist of lines and basic geometric shapes. FalconView maintains accurate proportion with respect to these graphics as users switch between map scales of the same coverage area. Users can save the graphic overlay in an electronic format and import the overlay file into another system that has the same map coverage and scales. Users can show or hide graphic overlays, as they desire.

Figure 2: Graphics Shown in Proportion to Map.

FalconView map capabilities also satisfy soldier requests for displaying alternate coordinate systems and range calculation. FalconView displays three formats of the latitude and longitude coordinate system as well as the Military Grid Reference System (MGRS). In addition, FalconView allows soldiers to switch between coordinate systems and formats, regardless of the map or graphic overlay that is displayed. Soldiers can use the FalconView range calculation to determine the distance between any two points on the map and display it as an overlay in three formats (i.e., miles, nautical miles or kilometers). Ground personnel find this capability very useful because they can determine the distance between aircraft position and any other location or object contained on a graphic overlay.

4.0 OUTSTANDING HUMAN FACTORS ISSUES

Although the interface to FalconView satisfied many emerging requirements for SA, there remain many human-factors related issues with this integrated system that merit attention. The FalconView was not developed as a tool for SA; thus, limitations exist with regard to effectively communicating SA information.

4.1 Map Display

FalconView uses NIMA maps for its map display. NIMA creates digital map files by scanning hard copy versions of maps that other U.S. Government agencies such as the FAA have developed. These maps generally include more information than is needed in the TITAN Tracker application. Data relating to commercial airports, air traffic service, and aids for commercial navigation and communication generally will not aid SA for military operations and will merely add display clutter and distract users.

Soldiers can adjust coverage area by two different means. Switching to another map scale is one method. A small-scale map shows a relatively large portion of earth whereas a large-scale map shows a relatively smaller portion of earth. The other method is to reduce or enlarge the image so that the system displays more or less of the map, respectively. When the image is reduced, readability of the static textual data included on the maps becomes difficult because its size is reduced. When the image is enlarged, it becomes more distorted because resolution is lost. Users can de-clutter the display with either method for adjusting coverage area, but de-cluttering can cause other difficulties when flights are being followed.

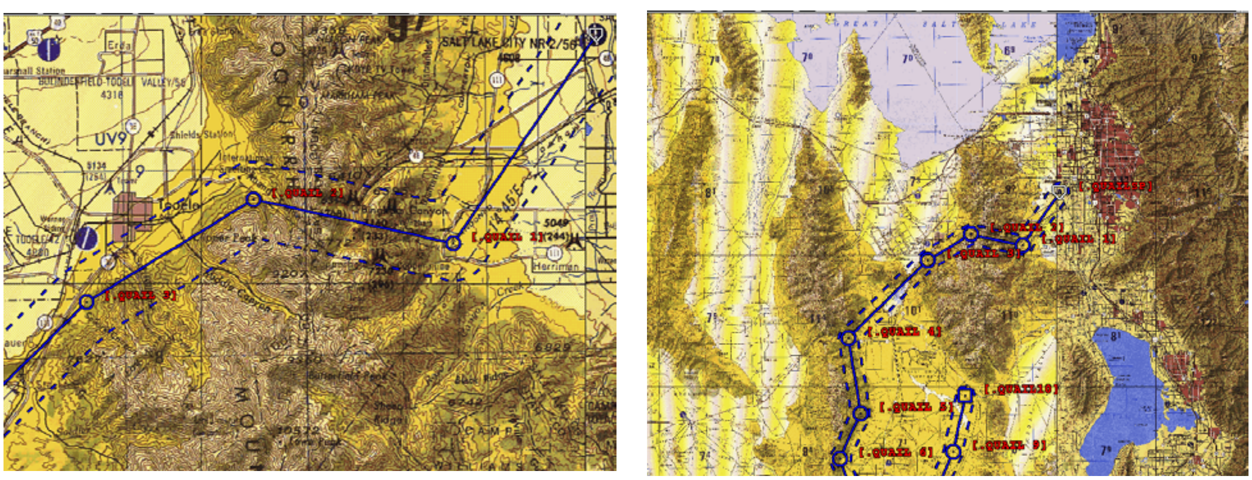

Figure 3: Both Maps are of the Same Scale.
(Map displayed on the right is reduced from 100% to 25%).

4.2 Icon Use

The system is effective in communicating SA information when one is tracking few aircraft transmitting infrequent reports. If too many aircraft are tracked or the reports are too frequently, position icons and supporting text may start to overlap, making the maps difficult to read. The supporting text is particularly vulnerable because it is displayed outside the standard symbol. Developers are working to correct readability of the supporting text by increasing font size and placing it on a contrasting background. This should improve readability, but overlapping may still occur if the system displays multiple position reports on a small-scale map. See Figure 4 for an example of overlapping text.

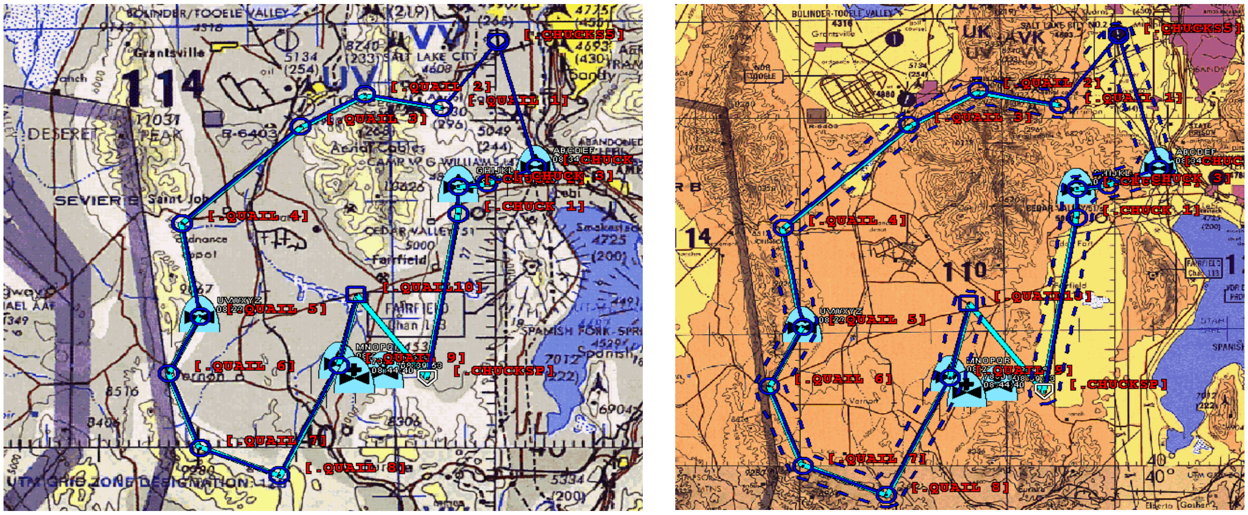

Figure 4: Sample Display Showing Six Aircraft Depicted by Large Icons on Two Different Map Scales.

Icon size also contributes to display clutter. The dimensions and attributes of the icons are fixed. Users can control icon size to some degree (e.g., small, medium, and large), but the setting is global for all maps. If the system is displaying a small-scale map, the large position icon will occupy a very large area. Displaying multiple position reports sent by multiple aircraft will cause difficulty in differentiation between aircraft and their past reports. One solution is to resize the icon in proportion to the map scale displayed in the same manner that the system resizes mission graphics. Satisfying this request will require a substantial engineering effort. See Figure 4 for an example of problems associated with displaying a large icon.

Color-coding is an effective method to present quantitative information [8]. Developers are experimenting with using color-coding to communicate the age of position reports. The HF Tracker instructs the FalconView to display the most recent position icon in a deep blue color. When the aircraft reports a new position, the HF Tracker instructs the FalconView to change previous position icons to a lighter shade of blue. Users can ascertain movement direction by noting the change in position between the current, fully saturated, icon depicting most recent aircraft position and the previously reported position with reduced saturation. (Note: Figure 4 was generated with a software version that does not show past position reports as icons.) Working with soldiers, the development team is examining the utility of displaying the age of position data and exploring various display methods.

4.3 Position Tracks

The display of flight tracks is another area in which soldier opinions vary. The issue is the extent to which the flight track or flight path actually shows the path of the flight. The line that results from connecting position icons forms an accurate picture of the flight track only if aviators transmit their position when they deviate from their current course. Aviators could fly a zigzag pattern but transmit position on the same latitude or longitude resulting in a straight-line display. The illusion gives unsuspecting users a false impression. Another problem with displaying the flight track is that it causes difficulty discriminating between tracks when aircraft send positions while following the same route (see Figure 4). Developers are currently modifying the software so that it provides the user with the ability to show or hide flight tracks.

4.4 Flight Following

The SA system has limits with respect to the display area. The limitations are driven by physical display size and coverage area. The ability to quickly adjust the map display is very important when flights are followed in which position reports appear in unexpected areas or when multiple flights are tracked that cover different and distant geographic areas. If the user does not set the display coverage area correctly, there is a risk that some positions will not appear on the map. Time spent adjusting the coverage area to find the new position reduces the time the user has to fulfill other responsibilities. This issue is especially problematic when he is dealing with aircraft traveling at high rates of speed.

The team is investigating methods to facilitate flight following. One software solution involves centering the map display on the most recent position report. The system should allow users to disable this capability if they must keep a particular view in focus. A procedural technique has been developed that uses a FalconView capability. Before the mission, the soldier sets the first view that is most suitable for a given part of the mission. Once set, the soldier adds the view to a “favorites list” in the same manner that a web browser allows Internet users to save a favorite web site. The procedure is repeated as many times as is necessary. Having pre-defined views of areas of interest allows soldiers to quickly switch between displays.

4.5 Data Messages

The HF NOE COMM System has the ability to transmit and receive data messages. Data messages are important for command and control and can improve SA for ground-based commanders. Developers are currently modifying HF tracker’s message management area so that it more resembles commercial e-mail applications. With the added capability of text messaging, users will spend more time viewing HF Tracker display pages, which may create problems with workload or attentional tunneling.

4.6 Future Plans

Receiving text messages from the air is a very powerful capability that will change the role of the HF Tracker tremendously. As the HF Tracker evolves, SA data will include much more than the Blue Force tracking capability. The HF Tracker will convert pre-defined text-based situation report information it receives from aviators to an icon. In addition to displaying friendly icons, the system will display enemy locations. The system can display hundreds of friendly and enemy icons. Additional icons on the display will enhance SA but may also add to display clutter. Also, timing will be a critical parameter in the display of friendly and enemy locations. SA systems receiving data from the HF Tracker may not display position data if the latency exceeds a specific threshold or if the systems use different time standards. In this case, position icons would show on the HF Tracker at the local side, but the same positions would not show on SA systems at remote sites, which could create confusion. Finally, although all icons should be designed to military standards, some SA system developers interpret the standards differently. Differences among SA systems with respect to color saturation coding, icon shape, and symbols embedded within the icons have been seen. There is a potential for confusion when users interpret information displayed on different SA systems.

Our results indicate that managing display clutter presents the biggest challenge to users of the SA system. An automated approach to address display clutter is the “info tip” technique [9]. The “info tip” technique is ideal for situations when there is a need to label or show attributes of objects that are very close to each other. When the user places the cursor over an object, its label or attributes are displayed along with a line that connects the label with the object. Another technique is known as "excentric labeling". Excentric labeling is a dynamic technique of labeling for visualization similar to the info tip technique. When the user places the cursor over a specified region (or attributes), the system displays all objects in the region [9].

Research findings indicate that users will have difficulty in using displays that contain too much information. Systems should limit displaying unnecessary information. However, the use of de-cluttering techniques may interfere with access to needed information [2]. A better solution is a system that makes all information constantly available, but information of immediate importance is highlighted [10]. These techniques have serious implications for map makers and their existing products. Layering or highlighting of static information on the NIMA map will require development of a new product, which will be very costly. Before an effort of this scale is pursued, additional research is needed.

Research findings show that an icon supported with text is an effective method for enhancing SA [11,12]. The standards are very clear with respect to specifying icon shape, size, color and embedded symbols but they are not clear with regard to specifying text descriptors. Emerging technologies provide new capability for generating and transmitting a great deal of data. Many of these data will be very valuable for SA. Each icon representing an entity may have numerous attributes or qualifiers such as information contained in telemetry data. The standards that govern information display should be modified to support this additional information.

More research is needed to determine how to effectively use saturation as a coding mechanism. If it is necessary to communicate multiple levels of a quantitative variable such as time, developers must determine the maximum number of saturation levels a user can distinguish meaningfully. Icons that adhere to the military standard are easy to see, but they are so large, they contribute to display clutter. Use of smaller icons will mitigate clutter problems, but the textual support data must adjust as well. There are hundreds of icons that represent enemy forces. The threat type is communicated by a symbol embedded in the icon (see Figure 5). Interpreting the meaning of these icons will be very difficult on cluttered displays. The standards state that developers should consider the size dimensions as guidelines, but they also encourage usability testing to determine the optimum symbol size at which user performance is most effective.

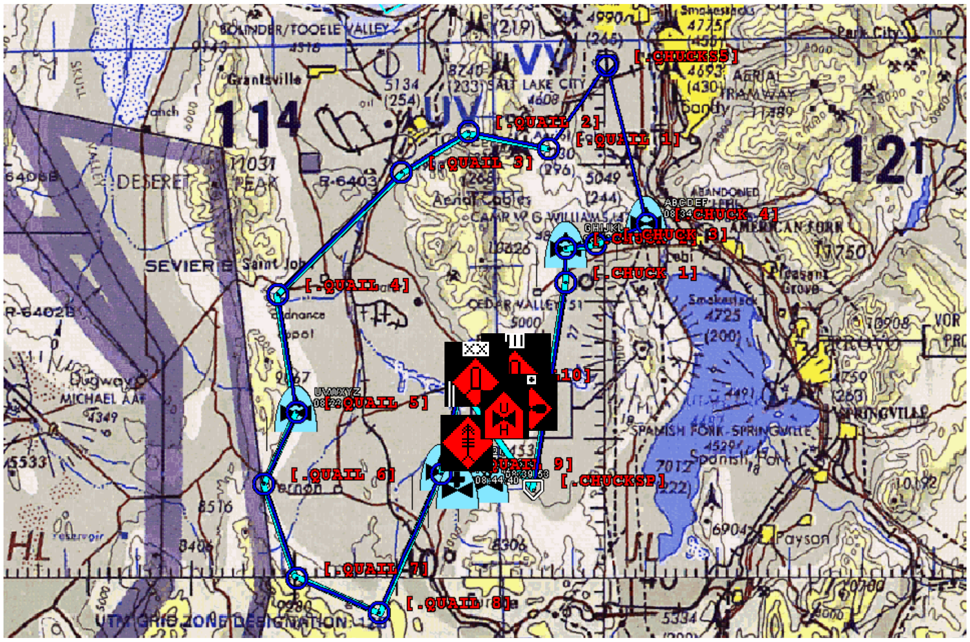

Figure 5: Example of Cluttered Display Containing Enemy Icons.

5.0 DISCUSSION AND CONCLUSION

The manner in which the HF Tracker-TI Gateway software evolved is not typical of how the Army acquires software. The process allowed developers the freedom to conduct iterative usability tests with user feedback directly influencing system design. This process afforded substantial opportunity with respect to user-interface development, but unexpected challenges were encountered. Lack of a predecessor system was one of the biggest obstacles confronted. Without a predecessor system, identifying the target user was difficult. Lack of a well-defined target user could limit validity of the experimental results. However, a systematic data collection process that included multiple observations and interviews with a variety of potential users was used to manage this risk.

The analysis and design concepts provided in this paper barely scratch the surface in studying SA from a human information processing and user-interface design perspective. Despite the effort invested in developing the user-interface, there is much work left to do. The user data we collected in surveys, interviews, and iterative usability assessment of prototype and operational software have allowed us to identify the issues. With this level of understanding, we can identify specific areas for research. We can offer design alternatives that address human factors issues we have identified and perform more quantitative usability tests. Endsley describes a very thorough methodology for assessing SA quantitatively [5]. Usability testing with a systematic, quantitative SA methodology should be conducted, especially in relationship to re-design recommendations that have serious implications for development cost and schedule.

6.0 ACKNOWLEDGEMENTS

I would like to thank LTC Jack Koster, MAJ John Moorhead, MAJ John O’Neal, Mr. Arlie Keister, and Mr. Barry Solomon, representing PM AME for their great support throughout this effort. I thank software engineers Jim Hennig and Debbie Siquieros. They have been extremely receptive to soldier-feedback and it has been a pleasure working with them. I would like to thank the 1/211 Aviation Regiment – Utah National Guard for their time, cooperation and the valuable insight that they provided during this study. In particular, I thank CW3 Will Gummersall who helped me greatly with his insight and assistance in gaining access to key personnel. Finally, I thank all the U.S. soldiers who made the time in their busy schedules to assist in this development effort. There are too many individuals to list, but I am grateful for their support and I am eager to support them in the future.

7.0 REFERENCES

[1] Endsley, M.R. "Toward a Theory of Situation Awareness." *Human Factors*, 37(1), 32-64, 1995.

[2] Wickens, C.D. and Hollands, J. *Engineering Psychology and Human Performance (3rd ed.)*. Saddle Brook, NJ: Prentice-Hall, 2000.

[3] Talcott, Martinez, Bennett, Stansifer and Shattuck. "Graphical Decision Support for Army TOCs II: Maneuver Control System Symbology." *Fifth Annual Symposium of Advanced Displays and Interactive Displays Federated Laboratory, Army Research Laboratory*, *College Park, MD*., (193-197), 2001.

[4] Gillan, D.J and Richman, E.H. "Minimalism and the Syntax of Graphs." *Human Factors*, 36(4), 619-644, 1994.

[5] Endsley, M.R. "Situation Awareness." In *Situation Awareness Analysis and Measurement*, edited by M.R. Endsley and D.J. Garland, Mahwah, NJ: Lawrence Erlbaum Associates, 2000.

[6] Durbin, D.B. and Armstrong, R.N. "Abbreviated Assessment of Three Moving Map Displays for the UH-60 Helicopter" *(ARL-TN-174). Aberdeen Proving Ground, MD: US Army Research Laboratory*, 2000.

[7] Department of Defense Interface Standard (MIL-STD) No. 2525B. (1999). *Common Warfighting Symbology*. Fort Monroe, VA: Headquarters, U.S. Army Training and Doctrine Command (TRADOC).

[8] Grossman, J.D. "Color Conventions and Application Standards". In H. *Color in Electronic Displays*, edited by Widdel and D.L. Post, (pp. 209-217). New York: Plenum, 1992.

[9] Fekete, J.D. and Plaisant, C. "Excentric Labeling: Dynamic Neighborhood Labeling for Data Visualization." *Proceedings of ACM CHI99 Conference: Human Factors in Computing Systems*, (pp. 512-519), Pittsburgh PA, 1999.

[10] Yeh, C.D. and Wickens, C.D. "Attentional Filtering and Decluttering Techniques in Battlefield Map Interpretation." *First Annual Symposium of Advanced Displays and Interactive Display Federated Laboratory, Army Research Laboratory, Adlphi, MD*, (pp. 35-42), 1997.

[11] Wickens, C.D. and Andre, A.D. "Proximity Compatibility and Information Display: Effects of Color, Space and Objectness of Information Integration." *Human Factors*, 32(1), 61-67, 1990.

[12] Brems, D.J. and Whitten, W.B. "Learning and Preference for Icon Based Interface." *Proceedings of the 31st Annual Human Factors Society,* (pp. 125-129). Santa Monica CA: Human Factors Society, 1987.