Bosnia Cantonment Area Monitoring System (BCAMS)

Rapid Response to the Needs of the U.S. Army in Europe

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Abstract

Over a period of five months, a new site monitoring system for synthetic aperture radar imagery was designed, implemented and fielded for use by the U.S. Army in verifying peace treaty compliance in Bosnia-Herzegovina. The system employed an unusual *Build-Deploy-Revise* approach to system development to achieve a quick response to the critical need to get technical help to the soldiers in the field. A combination of new and pre-existing technologies, including a novel image-to-image registration system, Automated Target Cueing and Recognition systems, an efficient and easy-to-learn softcopy Exploitation Light Table, a unique graphics target locating and identifying method, and an automated report generator, were integrated to form the system. The system achieved a significant reduction in per-image exploitation time and a substantial increase in consistency and accuracy of vehicle count reporting.

In 1997, SAIC received the DARPA Award for Sustained Technical Excellence for the development and fielding of the Bosnia Cantonment Area Monitoring System (BCAMS).

1.0 Introduction

In response to a request from the Office of the Secretary of Defense for technological help to aid the multi-national peace-keeping mission in Bosnia, the Defense Advanced Research Projects Agency (DARPA) Information Systems Office (ISO), under the (then) leadership of Dr. Richard P. Wishner, developed the Bosnia Cantonment Area Monitoring System (BCAMS). The Army Space Programs Office (ASPO) actively supported and promoted the development of BCAMS and facilitated its insertion as an advanced technology demonstration into the Army's tactical operations at Taszár Air Base, Hungary. The Technology Research Group of Science Applications International Corporation (SAIC), in Tucson, Arizona, was selected by DARPA as the BCAMS contractor.

On 25 September 1997, the BCAMS project team was awarded the DARPA 1997 Award for Sustained Excellence by a Performer for their outstanding technical excellence, sustained performance at an exceptional level, and outstanding team effort and dedication in the face of significant technical and logistical challenges.

2.0 The Site Monitoring Problem

Under the Dayton Peace Agreement, the North Atlantic Treaty Organization (NATO) is charged with monitoring treaty compliance by the opposing forces in Bosnia-Herzegovina. Among the multi-national forces employed by NATO in its mission, the U.S. Army Europe (USAREUR), V Corps, headquartered in Heidelberg, Germany, is responsible for site monitoring in the American sector of Bosnia in support of the U.S. Army. Under the treaty, all factions are required to confine their heavy armor military equipment within numerous designated cantonment areas scattered throughout the country. Each side is permitted to service and maintain its equipment and to train with it within a local area of operations, but any equipment which leaves the confinement boundary can be seized by NATO enforcement troops.

Allowable monitoring methods include both on-site inspections and exploitation of remotely sensed imagery. In 1996, the number of troops in Bosnia was reduced as the NATO activity transitioned from the Implementation Force (IFOR) to a smaller Stabilization Force (SFOR). Since then, the rate of on-site inspections has been greatly reduced, and the majority of monitoring is performed using information collected by the tactical aircraft of the U.S. and allied countries of the multi-national forces. The almost total reliance on remotely sensed imagery places heavy burdens on the analysts and intelligence resources utilized.

Image Analysts (IAs) are tasked with monitoring more than three hundred specific sites within Bosnia-Herzegovina, including cantonment sites, military bases and training areas, police headquarters and detention facilities, and possible locations of genocide and mass graves. The IAs must periodically review the equipment complement at each site for violations of the Dayton Peace Accords. Analysts are required to catalog by cantonment area the types and locations of stored equipment, and to understand what site activities are permitted and what activities are proscribed by the agreement.

2.1 A Day in the Life of the Image Analyst

To facilitate cantonment site monitoring, the U.S. Air Force Europe (USAFEUR) conducts regular U-2R overflights of Bosnia carrying ASARS-2 synthetic aperture radar. Bravo Company, 302nd Military Intelligence Battalion, 205th Military Intelligence Brigade of V Corps, is stationed at Taszár Air Base, Hungary, a former Soviet Bloc airbase built in early cold-war days. Data transmissions from the ASARS-2 system are downlinked in real time directly into ASPO's Enhanced Tactical Radar Correlator (ETRAC) for image processing. Primary image exploitation is

performed by the image analysts of Bravo Company on the ETRAC system.

Exploitation of the collected imagery and situation reporting to multi-national forces in Bosnia is required within twenty-four hours of initial data receipt. The output products from ETRAC are Initial Photographic Interpretation Reports (IPIRs) and Secondary Imagery Dissemination System (SIDS) images, which are transmitted electronically to the recipients. Of the daily ASARS-2 collection, approximately fifty of the images are of cantonment sites. Each cantonment-site image requires an IPIR to be prepared, and those images that show a significant change in vehicle count also generate SIDS reports, which are annotated images documenting the differences between the previous and current conditions. The image analyses are forwarded to multiple locations within Europe via military intelligence channels.

The Bosnia image analyst serves in Taszár on six-month duty tours in a repetitive, production-oriented work environment. Many of the young soldiers are new to field deployment, and are frequently not comfortable with the situation. Changing image collection plans, alternation of IAs between exploitation and guard duties, and regular rotation of analysts into and out of the field, combine to cause a lack of consistency in analysis products. On-site training of new personnel, provided by superiors and coworkers, is critically important to the success of the mission.

Intended for use on the forward battlefield, the standard exploitation tools provided by ETRAC were not very efficient when applied to the Bosnia site-monitoring mission. The analyst was required to begin the exploitation of a new image of a known site each time essentially from scratch, even when the site had not changed from the previous look. In addition, the system tools provided for IPIR and SIDS production required a large amount of manual input. Clearly, technological help was needed if the mission was to succeed with fewer personnel resources.

3.0 System Concept Development

In 1996, the expected pullout of U.S. ground forces led V Corps to release a call for any advanced technologies that would permit them to continue to fulfill their mission with severely reduced manpower. Dr. Thomas M. Strat of DARPA was familiar with the Assisted Target Monitoring System (ATMS), a technology developed by SAIC/Tucson for a NIMA site-monitoring responsibility, and recognized the similarities of the two missions. One of DARPA's proposals to that challenge was a site monitoring system based upon the ATMS concept.

ATMS is an Image Understanding project developed by NIMA and installed at their facility as an operational demonstration in 1996. ATMS uses state-of-the-art automated target recognition (ATR) technology, digital site models, and data base interrogation tools to aid an IA in monitoring facilities of various orders of battle (OBs) using national sensor data. Target recognition algorithms in ATMS count the observable compliment of significant combatants at a facility. These counts are compared to application specific condition thresholds to determine the alert status of a group of facilities, a single facility or a section of a facility. These alerts assist the IA in prioritizing imagery for exploitation.

Dr. Strat and David Guarino of SAIC, assembled a tactical conceptual design from the basic ATMS framework. In the design, site models of the cantonment areas would be stored in a data base, so that the appropriate site model could be retrieved and applied to each newly arrived mission image. Automatic tools, such as an automated target cuer (ATC) and ATR, would be available to assist the analyst with target location and identification. Because the mission is site-monitoring, results from previous exploitations of the site would be available to facilitate the required change detection activity. And finally, the automated reporting facilities of ATMS would be used to build the image report from the exploitation results.

In September 1996, DARPA/ISO and SAIC personnel made an exploratory visit to Taszár Air Base to learn first-hand the details and magnitude of the exploitation task undertaken by Bravo Company analysts. They then presented their design, called BCAMS, to V Corps in Heidelberg. V Corps was intrigued with the plan and made a formal request for the system to the Office of the Secretary of Defense (OSD), and based upon that request, DARPA released a contract to SAIC in October 1996. The BCAMS software was designed and coded, host computer hardware purchased, and the system integrated and shipped to central Europe in April 1997 as an advanced technology demonstration in association with ETRAC.

The BCAMS system is an *imagery exploitation toolkit* aimed at the routine collection of status information on more than three hundred monitored sites (especially armor cantonment areas) in Bosnia important for peace treaty enforcement. The system provides software algorithms and analyst aids that automate much of the mundane work of daily site monitoring and reporting.

Along with providing the IA tools to perform exploitation and analysis of the mission imagery, BCAMS designers concentrated on making available on screen all known data about the site that would be needed to exploit a new image. All of this information is stored in an extensive data base called the softcopy target folder. The folder is intended to eliminate the hardcopy target folders that require so much manual labor to maintain.

4.0 System Technical Design

The BCAMS system delivered to V Corps consists of a Silicon Graphics, Inc., (SGI) Origin 2000 server computer containing eight 195 MHz R10000 processors, 512 megabytes of memory, 90 gigabytes of on-line disk storage on two wide SCSI busses, an FDDI fiber network for networking with ETRAC, and two SGI O2 workstations connected to the server via a 100 megabit-per-second ethernet link. This amount of computing horsepower is required to maintain processing concurrency with the incoming data rate of spot (fine resolution, fixed-targeted) mode images. While the computing equipment is not physically located within the main ETRAC mission van, image analysts can exploit imagery on their ETRAC workstations by remotely logging into one of the O2s using X-windows. This permits them to have BCAMS available on the same screen with all of their usual ETRAC tools.

The system software (Figure 1) contains several subsystems, many developed specifically for BCAMS, with others adapted from pre-existing work by SAIC in image processing and analysis. Software reuse was critical to meeting the very tight development schedule on the project. The software is written primarily in C/C++, and also employs SQL commands and numerous Tcl/Tk and UNIX shell scripts. Computationally intensive applications (such as image registration) were parallelized using the SGI C++ compiler to run across all eight server processors. With the short development schedule, we found that Tcl/Tk, being an interpreted scripting language, was a particularly rapid method for coding and testing modules, as well as for building the X-windows-based graphical user interfaces (GUI). We did not use it for heavily computational tasks, but most of the GUI work and “glue” code of BCAMS is written in Tcl/Tk.

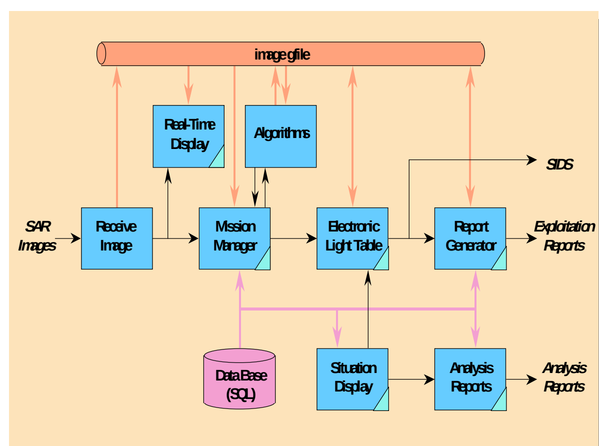

Figure 1. BCAMS Architecture Diagram

Image Receive

Images are received and processed by the ETRAC. When a new image has been generated, an ETRAC subsystem makes it available via UNIX System V sockets to external subsystems that accept and process the images. BCAMS establishes a socket connection over the fiber network to ETRAC at start up and waits for imagery to be pushed from ETRAC. Two files are transferred, an ephemeris record for the collected image, and the raw image file. *Image Receive* is written in C++.

Waterfall Display

The receipt of data from ETRAC signals two modules to respond, the *Waterfall Display* and the *Mission Manager*. The *Waterfall* is a scrolling display window that contains the entire mission collection in order of receipt. Each image has a text header consisting of the image identification information and the image resolution. The window is useful for quickly scrolling to see if a particular site has been imaged, as a review of general mission image quality, or to see if any visually interesting sites have been imaged. The *Waterfall* is written in Tcl/Tk and C code.

Mission Manager

The *Mission Manager* is the overall control system of BCAMS. When an image arrives, the system manager is notified and controls all further automated processing by initiating and tracking each processing function on an image. The *Manager* presentation consists of a scrolling list of received image file names, and the completion status of all processing algorithms for each image. The total numbers of received images and "registered" images are tabulated.

The *Manager* allows control of the types of algorithms to be run against a given image and their order of processing. For example, since BCAMS does not process the search frames (coarse resolution, sweep-targeted images for wide area search), no registration or ATC/ATR functions are run against them. Conversely, immediate spot images (higher-resolution sensor retaskings requested by the analysts based upon an indication they saw in another image) can be set using the *Manager* to highest priority to cause them to jump to the head of the processing queue. Other *Manager* functions available include reprocessing of a directory of source images (as when they have been read from tape), and reprocessing of a single mission image, should its processing have been disrupted by a system event. The *Mission Manager* (written in Tcl/Tk) and the *Waterfall Display* are normally used only on the BCAMS administrator workstation, and are not directly controlled by the image analysts.

BCAMS Data Base

The *Manager* stores the results of its processing in the BCAMS data base for retrieval by the analysts during image exploitation. We selected an SQL-based system called *Postgress* for the data base. Postgress, which is freely available over the Internet from various ftp sites, is maintained by a coalition of programmers at several universities around the world. The product has worked well for our application and has a reasonable response time to queries. Information stored in the data base consists of the following tables: active mission images, site identification data, site reference images, site softcopy target folder contents, site target normalcy counts and current target status, and command line calling structure for the various automated algorithms.

Image Registration

Image Registration is the module responsible for identifying the site associated with an incoming mission image and overlaying the site model. The process begins by reading the image ephemeris to obtain the image geo-coordinates, and the closest site model (within an error radius) of that location is pulled from the data base. The mission and reference images are downsampled and a Fourier cross-correlation computed. The image ephemerides and the location of the correlation peak are employed to determine the rotation and translation to be applied to the reference image to warp it onto the mission image. The site model is then copied from the aligned reference image to the mission image, and the site information is copied into the mission image information file.

The algorithm is parallelized to run across all eight processors of the server computer. The registration process runs in three to five seconds on input images of approximately nine megapixels, and achieves alignments of the site model accurate to within a few pixels. The algorithm is sensitive to scene content, and for that reason we try to obtain reference imagery at multiple azimuth angles so that terrain shadows will line up with the mission image in at least one of the reference image candidates.

Image Algorithms

The other automated image algorithms that perform pre-processing steps are the ATC and ATR. The automated target cuer is trained to find ground-order-of-battle (GOB) target signatures in a search or spot image, and to report their positions as graphic tick marks overlaying the target signatures in the image. The ATC could be used, for example, to quickly locate a tank that has moved from inside a cantonment site to another area of the image. The ATC module, known as *Streaker*, consists of an anomalous pixel detector followed by a neural-net classifier trained on GOB signatures in ASARS-2 data. A clustering function identifies a target grouping by drawing a graphic polygon whose vertices are the individual target detections.

The automated target recognizer consists of a simplified version of the ATMS system noted above. An individual target signature is converted into a coded model through a feature measurement process, and the model is then compared against a data base of similarly encoded signatures of known targets at assorted presentation and depression angles. The data base signature with the highest match score becomes the target identification reported for the unknown. The ATR operates on an interactive basis to assist the analyst in identifying difficult target signatures. The ATC and ATR are coded in C and C++.

Image Exploitation

The analysts perform image exploitation on the ETRAC workstations by logging into the BCAMS hardware over the network. We supplied BCAMS with our own *TIPS* electronic light table (ELT), since that product was the most convenient for us to modify and integrate in a short period of time. The analysts found *TIPS* very easy to use, and became quite proficient with its intuitive presentation after just fifteen minutes of instruction. *TIPS* offers most of the usual ELT functions, such as roam/zoom, contrast/brightness stretch, target geolocation/mensuration, and easy-to-create image annotation graphic overlays, all using a wide spectrum of menu pull-downs and tool pallets. Pop-up bubble help identifies the function of a button if the cursor pauses over it.

Since it was built using a Tcl/Tk framework with C language function modules, *TIPS* was easy for us to integrate with the additional capabilities required for BCAMS site monitoring. These functions included display of the site model and site information via graphic overlays, interfacing with the data base and automatic algorithms, generation of image reports from graphic exploitation marks, and creation of single and split-window SIDS products.

Report Generator

Prior to the arrival of BCAMS, analysts had to prepare their image reports almost from scratch on each image. Using a standard template that is updated once daily with mission-specific text fields, BCAMS provides the analyst with a completed image report following exploitation. The system extracts image-specific information needed to complete the report from the image ephemeris record. Target complement count is extracted automatically by the system from the exploitation marks made by the analyst on the image. The only additional action required on the analyst's part is to add a comment line, sign the report, and send it on its way. Three standard report formats are provided, IPIR, GRAPHREP and RECCEXREP. The *Report Generator* is written in Tcl/Tk.

SIDS Report Production

Since the forward troops in Bosnia are not trained radar image analysts, production of annotated image products is an important step in informing them of a change at a cantonment site. SIDS report production is done using the graphics annotation facilities provided by *TIPS*, such as text overlays of vehicle identifications and counts with arrows pointing toward target signature clusters. Another type of common SIDS product uses the split-screen capability of *TIPS* to pair a radar image side-by-side with an electro-optical image of the same site in which target identifications and locations can be more easily visualized. Annotations can even be drawn across the split screen. Current output formats for SIDS products include Postscript, CVL, TIFF and NITF 2.0.

Image Archive

Much of the ninety gigabytes of disk storage volume provided with BCAMS is used for the image archive. Three types of files are stored in the archive. Source imagery directly from ETRAC is preserved for possible reprocessing at a later time. BCAMS-processed imagery is stored for use in future exploitations of new site images and in SIDS products. Reference imagery with site model overlays is cataloged in the data base for use by *Image Registration*.

Site Normalcy and Alert Reports

A function available to the analysts is the ability to record current target complement on a site-by-site basis in the data base, and compare that with expected values of target counts and identities for each site. Current status for an active site is available graphically as a color overlay on a digital map of Bosnia or as colored tables of values, where a red color in both cases indicates an alarm situation exists at a site.

On-Line Training

Since the turnover of image analysts is high while ETRAC is downrange, a means of quickly training new personnel in BCAMS was important. While much of the training is being done one-to-one by the departing personnel, we have augmented this personal training with an on-line, web-based training course that the analyst can study at his or her own pace. The course is broken down by functional tasks, and offers side-by-side presentations of a written description of the task, its purpose, and how to perform it, as well as the sequence of procedural steps for accomplishing the task.

5.0 Mission Exploitation Using BCAMS

During a typical mission, imagery is received by ETRAC in real time from the sensor as it flies over Bosnian territory. ETRAC processes the imagery and relays it to BCAMS for display on the *Waterfall* and processing by the *Mission Manager*. BCAMS attempts to identify a site model for the image, and if successful, aligns the site model overlay on top of the mission image. The newly registered image is stored on disk for retrieval by an analyst.

The IA begins exploitation of an image by loading it into his *TIPS* window. The screen presentation contains the image data, a registered site model overlay, and annotation boxes containing the site identification data: name, identifying number, and geolocation. The analyst immediately possesses on his workstation all the information needed to exploit the site. To orient himself to the site and its target complement, the analyst can open the softcopy target folder and retrieve electro-optical imagery, digital maps of the site, intelligence reports, and previously exploited SAR images of the site, all of which are displayed in separate windows on his screen.

The next step is to retrieve a previous exploitation of the site as another graphic overlay of the current image, using colored circles indicating where vehicles were previously seen. The color indicates the type of vehicle/equipment present at the location. Changes in the quantity or location of military equipment at the site are then readily apparent by visually aligning exploitation marks with target signatures. Using the ELT tools, the analyst can move the exploitation marks around, or add and delete marks of the appropriate classes in order to match the overlay presentation to the current site target status. Since many of the cantonment sites are now static, little work is required to perform site exploitation in most cases. After the analyst is happy with the overlay picture, it is saved in a companion data file for use the next time the site is imaged.

To create the report, BCAMS loads the report template for the mission, ferrets out of its data base the image time and site information, and retrieves and counts the target exploitation marks. That information is parsed and inserted into the standard report format, and presented in a text window on the IA's screen for review. The analyst checks the report, adds a comment line and his or her name, and electronically transmits it to its recipients.

Despite its rapid development cycle, BCAMS is heavily oriented towards hands-on learning and user-friendly operation. The on-line, web-based training manual allows the analyst to use mouse clicks to find the procedure to perform any BCAMS function. Hierarchical menus provide a straightforward, logical path to all functions for the inexperienced IA, while the veteran BCAMS operator can shortcut directly to a function using direct key bypasses.

During the first six months of system operation, DARPA provided a full-time, on-site, Field Support Representative (FSR) for BCAMS in Taszár. Along with performing user training in BCAMS operations, the engineer was available to fine-tune the system in response to user feedback and suggestions. Subsequently, V Corps has provided funding for contractor site visits on an as-needed basis, and Army personnel, under guidance from SAIC, have performed much of the BCAMS maintenance. Instructions and software updates have been transmitted to Hungary using e-mail on the Internet.

6.0 Field Results

Acceptance of BCAMS by the image analysts was slow at its introduction due to several factors. The IAs were being asked to change their normal methods of exploitation, BCAMS was a new system and its benefits were not readily apparent, and it required a significant amount of initial preparation to build the site models and softcopy target folders for the active sites. In addition, the system was initially not directly connected to ETRAC, requiring imagery to be recorded on tape and then loaded onto BCAMS for processing. This procedure significantly lengthened the analysts' workday since they were unable to exploit during the data collection time.

On 25 May 1997, BCAMS was used to generate its first SIDS report on a tape-transferred image. This event demonstrated to the IAs that, by using BCAMS, they could save about twenty minutes preparing, reviewing, and dispatching a SIDS report that was also more informative. The time savings was achieved with the easy-to-use image annotation tools provided in the ELT, and with BCAMS' automatic insertion of site descriptive information onto the mission image.

By late July 1997, the direct connection between ETRAC and BCAMS had been made, and the Officer in Charge (OIC) directed that site models be constructed for all active sites during a time period when the aircraft was down for annual maintenance. These events led to BCAMS being used as the primary mission exploitation system several times during August 1997. Mission exploitation included processing the entire day's take of mission imagery and generating the necessary image reports and several SIDS products. The analysts began to see the laborsaving advantages provided by the BCAMS software, and its acceptance by them increased substantially. Shortly thereafter, BCAMS became the primary exploitation system at ETRAC, replacing the MATRIX system previously in use. In October 1997, BCAMS suffered a server hardware problem and one mission had to be exploited using the old system, an event that made the analysts quite unhappy, demonstrating their acceptance of and reliance on BCAMS for performing their mission.

Table 1 presents analyst performance statistics for 1997, spanning a total of some ninety missions, divided when BCAMS became the primary exploitation system at ETRAC. The IPIRs could be produced approximately five times faster (including exploitation time) with BCAMS than when using the standard ETRAC exploitation environment MATRIX.

Table 1. Analyst Performance Statistics

Statistic	Pre-BCAMS	Post-BCAMS
Avg Time / IPIR [min.]	25-30	4-5
Avg IPIRs / Mission	32	34
Avg SIDS / Mission	0.8	1.1

The increased production performance is due to several factors. The graphic overlays using site models and previous target locations eliminates much of the work an analyst is required to perform on each image. Since the majority of the cantonment areas are static, the analyst is basically done with these sites at this point – the computer prepares the IPIR from the previous exploitation results. For sites that show changes, the softcopy target folder permit the analyst to do all of his site research on-line at his workstation. The time spent fishing around to find a hardcopy target folder is eliminated, and the softcopy target folder is also easier to maintain. Finally, the pre-filled report generator saves a considerable amount of time preparing the IPIR. After the analyst modifies the graphic target overlays to match the site situation, the report is automatically completed except for the remark line and signature. The old IPIR-building procedure of cutting and pasting sections from the previous IPIR is eliminated.

Figure 2 is a plot of the number of SIDS images created per mission for 1997. The number of SIDS products being produced increased with BCAMS, indicating that significant site changes were now easier to find, and that more free time to do them existed because the analysts were finishing the mission earlier in the day. SIDS are normally done only when a significant change has occurred at a cantonment site. The spike in the graph at the introduction of BCAMS represents a one-time activity that was undertaken to establish a baseline set of SIDS images (using BCAMS) for a number of important sites.

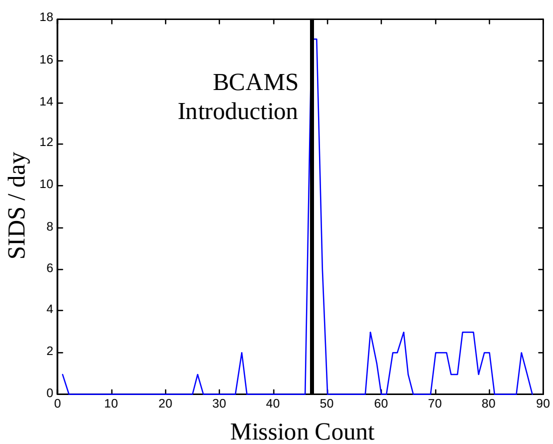

Figure 2. Number of SIDS per Day

The more important statistic is the enhanced accuracy and consistency of target reporting achieved using BCAMS. Since the system indicates the location of the cantonment area with the site model, and the previous target content of the site via the exploitation markings, an analyst unfamiliar with the site already has a strong starting position from which to begin his work. The exploitation marks indicate the locations and types of previous target detections at the site. Prior to BCAMS, different areas of the site containing different sets of vehicles may have been counted by the series of analysts who exploited the site over time. In addition, human errors in sorting and counting targets are eliminated because the computer automatically tabulates target counts and enters them into the report.

7.0 Conclusions

The BCAMS project serves to demonstrate that a quick technical response by industry to a critical need of deployed troops is possible. The rapid development and fielding of BCAMS was a result of the efficient *Build-Deploy-Revise* strategy utilized. Because of the critical need for help in the Bosnian theater, time was not available for the traditional, but slower, *Build-Test-Deploy* approach to system development. Understanding that BCAMS was a prototype system, our customers were perhaps more tolerant of minor performance defects in the system, knowing that in return they could participate in developing the functionality of the system to better suit their operational requirements. Keeping future users of a system closely coupled during development provides them an ownership role in the system and a commitment toward making a successful product introduction.

The extensive use of interpreted Tcl/Tk code throughout the construction of BCAMS permitted rapid, on-site code changes in response to design or performance problems, or to quickly add new features and capabilities requested by the users. Coordination of code changes between Taszár and

Tucson was a significant problem, eased through careful use of the Revision Control System (RCS) software product and synchronization of the source code at regular intervals, combined with regression testing to ensure that code changes on either side did not introduce new problems.

The logistics of managing a complex system halfway around the world was a significant effort. Because of the nine-hour time difference, which meant that the European staff was just finishing the normal duty day when the Arizonans were arriving at work in the morning, much of the support had to be handled through e-mail. During our stay, Internet service providers (ISPs) were just getting established in the areas of the country outside of Budapest. While data rates were quite slow by U.S. standards, access to the Internet from Hungary was a significant aid to the success of the project, given that FedEx-type deliveries required anywhere from one to two weeks to transit and sit in Hungarian Customs. Sending code patches via tape could not have been responsive to the users, who were depending upon BCAMS being 100% available for each mission.

An additional problem was maintenance of our advanced computer equipment in a former Eastern Bloc country. We received one of SGI's first production Origin 2000 computers, and while obtaining replacement parts was relatively easy in the United States, it would still take a day or two to fly them in. In eastern Europe, no installed base of these computers existed to support a board-level support center. Parts would be dispatched from San Francisco to Tucson, and then re-shipped by air carrier to Hungary, encountering at least a week of shipping and customs delay. Fortunately the equipment has been very reliable in spite of the field environment the soldiers work in.

Neither was the language barrier an insignificant problem. In southwestern Hungary, fluent speakers of English are rare, and communicating to obtain lodging, food, cars, and supplies was challenging at times. The U.S. Army uses interpreter soldiers for dealing on the local economy, but they were not available to contractors. We found that learning Hungarian was not a practical solution because of the difficulty of this unique language.

BCAMS was both a challenge and a lot of hard work for everyone involved in its development, and we are gratified that we have significantly assisted an important national endeavor, aiding the cause of peace in Bosnia-Herzegovina. We appreciate the warm acceptance and support of the system by V Corps, and are grateful for the national recognition of our work by DARPA. And for those of us fortunate enough to have traveled to Hungary to work with the system, the adventure is one never to be forgotten.

Acknowledgments

This work was funded by DARPA under contract #F33615-95-C-1642. Continued support is being provided by U.S. Army V Corps under contract #GS-35F-4461G. We also wish to thank Dr. Richard P. Wishner, then manager of DARPA/ISO for initiating the project; Dr. Thomas M. Strat for his guidance and support as the project COTR; ASPO and COL McFarland, V Corps G2, for allowing an advanced technology demonstration in an operational environment; and Mr. David Guarino, SAIC program manager, for his leadership during the development and fielding of BCAMS.