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# EVALUATION OF ADVANCED AUTOMATED GEOSPATIAL TOOLS

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# Abstract

Geospatial Reasoning has been an essential aspect of military planning since the invention of cartography. Although maps have always been a focal point for developing Situational Awareness, the dawning era of Network Centric Operations brings the promise of unprecedented battlefield advantage due to improved geospatial situational awareness. Automated Geospatial Tools (AGTs) are ubiquitous within current military forces and also civil and humanitarian organizations. Nevertheless, there is too little empirical evidence to quantify the military value of automated geospatial tools to the warfighter. As research and development efforts progress to bring forth the next generation of AGTs, Advanced Automated Geospatial Tools (AAGT), it is vital to inform the development process with sound empirical assessments of the military value of AAGTs within a Network Centric Environment. To this end, the U.S. Army Topographic Engineering Center (TEC) is sponsoring a series of experiments to evaluate the value of its AAGT, the Battlefield Terrain Reasoning and Awareness – Battle Command (BTRA-BC) Tool. This paper discusses the scope of the current experiment, the hypotheses we intend to investigate, and the experimental design. Results of our first set of experiments will be provided at the conference and in a later version of the paper.


## 1. Overview

The focal point of the battlefield command post is the map. Through interactions with the map, the commander and staff collaborate to build a common operating picture. This common operating picture displays the area of operations, the militarily significant features of the terrain, the locations of adversary and friendly forces, and the evolving plan. A generation ago, planning centered on a paper map, its overlays of acetate covered with marks of grease pencils wielded by the staff members congregated around it. Today the paper map has been replaced in brigade and larger headquarters with a digitized map projected onto a large-screen display. The grease pencil has become a mouse that officers use to draw objects or select pre-computed overlays from a pull-down menu of options. The map and overlays are stored in the computer as data structures, are processed by algorithms that can generate in seconds products it would take soldiers many hours of tedious effort to duplicate, and can be sent instantly to relevant consumers anywhere on the Global Information Grid (GIG).

Advanced automated geospatial tools (AAGTs) transform commercial geographic information systems (GIS) into useful military services for Network Centric Operations. Because of their basis in commercial GIS, they have widespread applicability to fire, police, disaster relief, and other problems characterized by a command hierarchy. The advanced situation awareness provided by AAGTs can do much more than simply speed up calculations. They are changing the way military operations are conducted. The development of tools is shaped by military necessity, but as the new century dawns, the decision making process itself is being shaped by the automated tools that provide warfighters with more robust situational awareness.

This reality of 21st Century Command and Control places a major responsibility on researchers who develop tools to support soldiers as they perform their duties. It is essential that we accurately assess the value of the tools we develop with respect to planning processes and situation awareness. These assessments can then be used to shape future research and development efforts.

Intense research and development efforts are underway in many organizations, funded by different agencies, with the goal of moving the state of the art forward and pushing the latest generation of AAGTs into the field to meet the current urgent need. A rapid development and procurement process is necessary if we are to provide warfighters with tools that provide force multipliers and save lives.

Research indicates that sound methodolgies for assessing the value of decision support tools for task performance, coupled with effective development processes that make use of the feedback thus obtained, can dramatically improve the effectiveness of decision support (Adelman, 1992; Boehm, et al., 1984; Hicks and Hartson, 1993).

This paper describes a project underway at the U.S. Army Engineer Research and Development Center to evaluate the value added to military decision making through the use of AAGTs. The specific AAGT to be evaluated is the suite of Battlefield Terrain Reasoning and Awareness – Battle Command (BTRA-BC) Tools (U.S. Army, 2003). The BTRA-BC program, which builds upon a commercial GIS tool (ARCINFO), has resulted in mature components that have been integrated into the Army's Digital Topographic Support System (DTSS), a system that provides topographic engineering support to terrain and topographic technicians as they assist military planners (Herrmann, 2002). DTSS provides geospatial data generation, collection, management, information processing and services. The BTRA-BC tools create information and knowledge products that empower soldiers with information to enhance their understanding of terrain and weather as it impacts their functional responsibilities. The BTRA-BC capabilities evaluated in this study include identification of obstacles, production of a modified Combined Obstacles Overlay (MCOO), and generation of mobility corridors. Our experiments will provide essential information to evaluate the contribution of the BTRA-BC tools in particular, and AAGTs in general, to enhance the military decision making process.

The paper is organized as follows. Section 2 describes the overall scope of our research program and the scope of our initial set of experiments. Section 3 discusses the primary and secondary hypotheses which will be examined. Section 4 lays out the design of the experiments and the reasoning which led to this design. Section 5 discusses the computing environment which will be used in the experiments. Section 6 describes the metrics used to allow us to quantify the results of each trial. Sections 7 and 8 present the proposed statistical analysis and a brief discussion of the importance of evaluation during development.

## 2. Scope of Experiments

Our ultimate objective is to evaluate the benefit to commanders at the brigade level and below of combining a fully developed AAGT with currently available Command and Control planning tools. The scope was limited in the first experiment, and will expand successively in later experiments. The experiment with which this paper is concerned is limited to the Intelligence Preparation of the Battlefield (IPB), specifically the terrain analysis portion of IPB.

The baseline for this series of experiments is the currently fielded DTSS suite of tools, as implemented using ARC-GIS 9.1. The DTSS tool suite consists of a package of software tools used to generate tactical decision aids for producing off-road and on-road speed products; combined obstacle overlays (COOs); shaded time distance, and maneuver networks and predictions; masked/visible areas for observation; and fields of fire, cover and concealment, obstacles, key terrain, and avenues of approach

The AAGT under evaluation is the Battlefield Terrain Reasoning and Awareness – Battle Command (BTRA-BC) Tool. Our first experiment evaluates the most current version of BTRA-BC. BTRA-BC, when fully developed, will consist of six information generation components and five decision tools addressing terrain effects. Each of these components utilizes terrain feature data, digital elevation models, and information about tactics, techniques and system performance. BTRA-BC information generating components produce information addressing: (1) Observation, Cover and concealment, Obstacles and mobility, Key terrain and Avenues of approach (OCOKA), (2) integrated products defining operational Positions of Advantage, (3) advanced mobility analysis, (4) digital ground and air maneuver potential and (5) tactical structures relating information produced by the other components. Decision tools support: (1) predictive multi-criteria, multi-objective maneuver, and logistical route analysis for ground platforms and forces, (2) predictive sensor performance (e.g., infrared [IR], millimeter-wave [MMW], seismic, and acoustic), (3) situation assessment and (4) predictive threat assessment

BTRA-BC research, development, products and architectural approach are designed to empower the Joint and Future Force's Battle Command, and Intelligence, Surveillance, and Reconnaissance (ISR) processes and systems in a networked force structure through the incorporation of actionable terrain and weather information and tools. The BTRA-BC approach is wholly consistent with the Army's Future Combat System's (FCS's) System of Systems and the Defense Information Systems Agency's (DISA) Network Centric Enterprise Services concepts. If successful, BTRA-BC will be capable of benefiting the FCS C4ISR appliqué and the Joint Distributed Common Ground Station family of ISR systems.

## 3. Hypotheses

In order to evaluate the “value” of BTRA-BC, we needed to establish what constitutes “value” with respect to military decision making. Discussions with both military operational planners and members of the BTRA-BC development team clarified the areas where AAGTs in general and BTRA-BC in particular would be valuable to the military decision maker. The first and most obvious inherent value of an AAGT is in its ability to reduce the time spent generating a given tactical decision product. Since the timeframe available to military decision makers is limited, the reduced time in which AAGTs require to produce the desired output can free up time for a more through analysis of the large amount of data available. This more complete analysis is expected to result in a higher quality output which will be of more value to the decision maker.

The second value contribution of an AAGT is its automation. Many of the initial tasks traditionally done by terrain analysts with paper maps are sufficiently rote in nature that an AAGT, given digital information and the appropriate parameters, can perform these functions more quickly and with less error than a human. The concern that automating these tasks will reduce the analyst's familiarity with the terrain and understanding of the impact on the military planning may be valid, but the experts we consulted believe that the automated tasks are procedural and not analytical and that using the output of the AAGT will not compromise the analysis of the data or the level of understanding of the analyst. The experiment was designed to test this prediction.

It follows from the discussion above that the primary hypotheses to be tested in the initial evaluation are the following. In comparison with analysts using currently available tools, we hypothesize that trained and experienced terrain technicians who use BTRA-BC will:

1. Produce certain terrain-dependent Intelligence Preparation of the Battlefield outputs *more quickly*. Rationale: The automation in BTRA-BC should allow the subjects to complete the repetitive, tedious, and rote tasks more quickly.

2. Produce a *higher quality* output. Rationale: The automaton in BTRA-BC should minimize errors of omission and in calculation and standardize the graphical representation of important terrain features. and

3. Display *as good an understanding* of the impact of the given terrain on military decision making. Rationale: The judgment required to complete the required tasks will still be required when using BTRA-BC.

The secondary hypotheses to be investigated became apparent as the determination of "value" and the design of the experiment evolved. The automation of previously manual tasks, which adds value to using an AAGT, will likely reduce the variation in the output. As this reduction in variation does not necessarily add value, this was not considered a primary hypothesis. The structure of the experiments requires the repetition of various tasks and there was concern that a learning effect my might skew the results of the experiment. The consensus of experts in terrain analysis indicated that this would be a very minor effect and as such learning effects are considered secondary hypotheses. The secondary hypotheses to be investigated include:

1. The output generated with BTRA-BC will be *more uniform* i.e. have less variance in the first two of the three categories above (speed and quality), than that generated without the use of BTRA-BC. Less variation in the output when using BTRA-BC is expected due to the level of automation incorporated in BTRA-BC.

2. There will not be a *learning effect due to the subjects gaining experience with the C2 planning tools* during the first trial. The subjects have previous training and extensive experience using the C2 planning environment used in the experiment. The tasks the subjects are asked to perform are those that they

normally perform with the C2 planning tools. A single additional usage will not be evidenced as a learning effect.

3. There will be *little or no learning effect due to the repetition of the tasks* required in each trial as the subjects have performed similar tasks numerous times prior to the evaluation.

4. There will be *little or no learning effect on the subjects' cognitive process due to using BTRA-BC in the first trial*. BTRA-BC automates processes with which the subjects are extremely familiar and will provide no additional insight into these processes.

## 4. Study Design

The general study design will remain consistent throughout the series of experiments and will employ a within subjects design. A within subjects design is one in which each subject performs both sets of tasks. A within subjects design is particularly valuable when the number of available subjects is limited, as in the current case. In addition, the results from the sets of tasks can be compared for each subject thus eliminating subject specific effects that might skew or add variability to the results. The within subjects design is superior to the between subjects design (subjects only perform one task) especially if there are no learning effects.

The participants performed the same tasks on two similar military planning scenarios, where one of the tasks is performed with BTRA-BC functions in addition to DTSS functions and the other task with DTSS functions only. The two trials are essentially identical except for the use of BTRA-BC in addition to currently deployed geospatial tools. The order of the tasks was randomly selected so that half of the subjects perform each of the tasks first. Randomizing the order of the tasks enables the analysis to control for learning effects.

The instructions, tasks, requested outputs, and evaluation of these outputs were the same in both trials with the exception of geographic references necessitated by the requirement to have different geographic areas for each trial. Different geographic areas are required to prevent participants from just repeating their responses from the first trial when they form responses for the second trial. The two areas were carefully selected for their geographic similarity such that the tasks performed by the participants and the expected results were as nearly identical as possible.

The participants, Army non-commissioned officers trained as terrain technicians, were split into four groups that are evenly balanced as to the experience of the participants. Two of these groups performed the tasks first without BTRA-BC and then with BTRA-BC. The other two groups reversed the order of the use of BTRA-BC. Within each of these pairs of groups, the two groups differed on which scenario was used on the first day and which on the second day. This design allows the analysis to control for any variance in results due to the experience of the subjects and the order of the sets of tasks or the experience level of the participants.

The tasks consisted of that portion of the IPB beginning with analyzing the specific terrain given a Consolidated Obstacle Overlay (COO) up to the point of generating potential AAs. Specific tasks included:

1. Identify Mobility Corridors (MC)
2. Categorize mobility Corridors by type of force
3. Group Mobility Corridors to form potential Avenues of Approach (AA)
4. Identify choke points on potential Avenues of Approach

The participants produced a graphic overlay depicting (1) all Mobility Corridors (MC), (2) four potential AAs, (3) Choke Points on potential AAs, (4) recommended AA, and (5) recommended 2nd echelon Areas of Operations (AOO).

Prior to beginning the tasks, both groups of participants received standardized training on the use of BTRA-BC and the DTSS planning tools to be used in the experiment. The training was sufficient to perform the required tasks given the subjects' level of experience with automated systems and included training on the modes and features unique to BTRA-BC. The last phase of the training required the participants to perform tasks based on the training and similar to those that the subjects will encounter during the trials, but of lesser complexity.

## 5. Environment

The evaluation was conducted using the Digital Topographic Support System (DTSS) as the baseline technology. DTSS can be categorized as an Automated Geospatial tool (AGT) as opposed to a next generation AAGT, such as the BTRA-BC tool we are evaluating. DTSS is the currently fielded set of geospatial tools used to support the IPB. Modules of the BTRA-BC are compatible with DTSS and were embedded in the version of DTSS used in this experiment. During the trials in which the subjects are using BTRA-BC, the BTRA-BC modules were enabled. During the trials in which the subjects do not use BTRA-BC, these modules were disabled. DTSS was chosen specifically because it is the current state of the art in AGTs, it is currently fielded, and the potential subjects are familiar with its use.

## 6. Metrics

Because trials were conducted in DTSS, it may be possible to do blind scoring for some of the hypotheses. The criteria for evaluation of the BTRA-BC will be (1) a comparison of the rapidity with which the requested outputs can be produced, (2) the quality of those outputs, and (3) the level of understanding of the participants of the impact of the terrain on the military decision making.

The evaluation of how quickly the desired outputs are produced can be measured objectively independently of the experimental condition by logging the amount of time it takes participants to finish the task. Thus, blindness is not an issue for the speed measure.

The evaluation of the quality of the outputs may be affected by the evaluator's ability to distinguish between BTRA-BC outputs and non-BTRA-BC outputs. If the outputs are distinguishable as to their source, then the evaluation of quality can not be treated as blind. We use two measures of quality of output: the first consists of objective metrics such as the number and validity of mobility corridors and choke points, and is relatively independent of whether blind scoring is achievable. The second part of the evaluation of quality, which is still in progress, will be a subjective evaluation by impartial experts. The evaluators will judge the quality of the output with respect to the usefulness to the commander. Criteria to guide the evaluators are under development. Evaluators will provide numerical ratings of quality of output, according to the criteria provided to them.

To evaluate the subjects' understanding of the impact of the specific terrain on military decision making, we administered a questionnaire. The answers to the questions were not outputs of DTSS or BTRA-BC. The answers required judgment and reasoning about the terrain and its effect on the military decision making not just regurgitating data presented by DTSS or BTRA-BC. Topics included in the questionnaire included justification for recommend AAs, key terrain features, cover and concealment, potential locations for support bases. A rubric for grading the questionnaire responses is under development.

The assessment of the second and third primary hypotheses and the secondary hypotheses was augmented by the recorded comments of observers. A statistical analysis will be conducted to test each of these hypotheses, and the combined results will determine the evaluation of the value-added of BTRA-BC versus the currently fielded system.

## 7. Analyses of Results

The first of the experiments has been completed. Results from the first round of experiments will be published in a later version of this paper and will be presented at the conference. Analysis of variance will be performed to provide quantitative estimates of the degree of statistical support for (or against) the hypotheses.

## 8. Discussion

Evaluation of complex systems should start in the development phase as well as continuing through the procurement process. Evaluation started early in the development process allows developers to choose design options with the greatest potential value as well as identifying specific problem within the design. It is well known that problems found early in the design and development process can be addressed with orders of magnitude less impact on cost than if they are not identified until a later stage. Additionally, evaluation results may provide insights into possible system design enhancements not previously identified. A key factor in providing the best possible feedback to the designers is to perform evaluation with subjects who are actual users. This is often somewhat difficult to achieve in the research setting, but true "value" can only be determined by those who actually use the system.

A properly designed evaluation program can build upon initial results to conduct follow-on evaluations at each step in the design process. Once the value of the system at any point is determined, the resulting follow-on evaluations can be easily combined with previous results to form a coherent overall evaluation. The ultimate goal of the design and procurement process is the fielding of the most "valuable" system to the military decision maker.

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