13TH INTERNATIONAL COMMAND AND CONTROL RESEARCH AND TECHNOLOGY SYMPOSIUM

C2 FOR COMPLEX ENDEAVORS

# EVALUATION OF ADVANCED AUTOMATED GEOSPATIAL TOOLS: AGILITY IN COMPLEX PLANNING

Suggested Topics:
Track 7 – Network-Centric Experimentation and Application
Track 6 – C2 Assessment Tools and Metrics
Track 4 – Cognitive and Social Issues

**Walter A. Powell (STUDENT) - GMU***
**Kathryn Blackmond Laskey - GMU**
**Leonard Adelman - GMU**
**Shiloh Dorgan (STUDENT) - GMU**
**Ryan Johnson (STUDENT) - GMU**
**Craig Klementowski – VIECORE, FSD**
**Rick Yost – VIECORE, FSD**
**Daniel Visone - TEC**
**Kenneth Braswell - TEC**

**GMU**
Center of Excellence in C4I
The Volgenau School of Information Technology and Engineering
George Mason University
4400 University Drive Fairfax, VA 22030-4444 USA
wpowell@gmu.edu
(703) 993-3684



Viecore FSD, Inc.
6 Industrial Way West
Eatontown, NJ 07724 USA

TEC
US Army Engineer Research and Development Center
Topographic Engineering Center
7701 Telegraph Road Alexandria, VA 22315 USA

## Abstract

In an era of limited funding, a rapid development and procurement process is necessary to provide warfighters with performance-enhancing tools. It is essential to accurately assess the value of the tools we develop, and to use this assessment to shape future research and development efforts. To assist its research and development efforts, the U.S. Army Topographic Engineering Center (TEC) is sponsoring a series of experiments to evaluate the value of its suite of Advanced Automated Geospatial Tools (AAGT), the Battlefield Terrain Reasoning and Awareness – Battle Command (BTRA-BC) Tools. The first experiment in this series, which was presented at the 12th ICCRTS, demonstrated the benefits of an AAGT in a strictly terrain analysis scenario. Building upon the results of the first experiment, the second experiment will evaluate the value of an AAGT in a more complex planning environment and with a scenario that requires more complex decision making. This paper discusses the scope of the second experiment, its hypotheses, and the experimental design.

## 1. Background

As researchers and developers strive to provide advanced tools to process faster and more accurate data, it necessitates the assessment of each innovation so that key resources can be allocated to areas that yield the most "bang for the buck." The JGES program of the U.S. Army Engineer Research and Development Center (ERDC) is designed to meet this need by evaluating the value-added to military decision-making through the use of Advanced Automated Geospatial Tools (AAGTs). We define Advanced Automated Geospatial Tools (AAGTs) as tools that display geospatial data and the results of automated analyses of that geospatial data i.e. geospatial information. These tools produce Tactical Spatial Objects (TSOs). TSOs are computationally lightweight objects that provide geospatial information services in the context for which they are developed. The context for which our TSOs are developed is that of military ground operations. In theory, AAGTs can do much more than simply speed up calculations: the potentially superior situation awareness afforded by AAGTs opens up new possibilities for the conduct of military operations. Translating theory into practice requires a build-test-build cycle that channels technology in spiral development that best support the warfighter. This paper reports on the second in a series of experiments designed to assess the value of Geospatial information to the decision-maker. In the case of military AAGTs, the ultimate decision maker is the military commander, and the ultimate goal is to support command decisions in the most effective way.

The first experiment in the series assessed the value of the Battlespace Terrain Reasoning and Awareness – Battle Command (BTRA-BC) AAGT to the terrain analyst performing the Intelligence Preparation of the Battlefield (IPB) planning task using the Army's Digital Topographic Support System (DTSS). Army and Marine Corps enlisted terrain analysts attending the Advanced Terrain Analyst Course (ATAC) were given planning tasks to complete with and without BTRA-BC functionality. The experimental design was very similar to that of our current experiment (described in section 4 below). The results of the experiment demonstrated that using BTRA-BC functionality (1) dramatically decreased the time to perform the terrain analysis tasks, (2) improved the quality of the terrain analysis output, (3) maintained or improved the participants' knowledge of the impact of terrain on planning, (4) maintained or reduced the variability in time to completion and quality of plans, and (5) improved the participants' perception of the quality of their plans.

The goal of the current experiment is to continue to assess the benefits of BTRA-BC information and knowledge products. Based on what was learned from the first experiment, this experiment will explore the benefits of AAGTs for planners who perform more complex military decision-making tasks. Because BTRA-BC is an AAGT, the automated analysis functionality is of primary interest. Our current experiment is specifically designed to assess these capabilities. The BTRA-BC capabilities evaluated in this study include all the factors involved in the previous experiment as well as the ability of BTRA-BC to identify battle positions, engagement areas, and assist the planner in determining optimum ambush sites and Named Areas of interest.

The paper is organized as follows. Section 2 describes the overall scope of our research program and the scope of this experiment. Section 3 discusses the primary and secondary hypotheses to be examined. Section 4 lays out the design of the experiment and the reasoning that led to this design. Section 5 discusses the computing environment to be used in the experiment. Section 6 describes the metrics to be used to quantify the results of each trial. Section 7 discusses the expected impact of the experiment. The experiment is expected to be conducted in two phases over the next few months, and we will report the results at ICCRTS 2009

**2. Scope of Experiment**

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 first experiment, presented at last year's conference (Laskey, et.al., 2007), was limited in scope to the terrain analysis portion of Intelligence Preparation of the Battlefield (IPB) process. Our current experiment builds on the first experiment by expanding the scope to include the more complex decision-making required to develop a Course of Action (COA). In this experiment the general scenario will ask military planners, working individually, to plan a battalion movement to seize an objective in the presence of enemy units. Follow on experiments will further address different kinds of planning problems, at various levels of command, and involving collaboration among members of staffs as well as individual decision makers.

**3. Hypotheses**

As we discovered while planning the first experiment, in order to evaluate the military value of BTRA-BC, we needed a clear definition of military value, along with quantifiable metrics of value. Our determination of what constitutes value in this experiment is based on discussions with several experienced military planners. These planners believe that the value of AAGTs lie in their ability to:

(1) Reduce the time spent generating a given tactical decision product. Since the timeframe available to military decision makers is limited, AAGTs which reduce the time required to produce the desired output can free up time for a more thorough 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.

(2) Automate many of the routine planning tasks. Many of the terrain evaluation tasks traditionally performed by military planners with paper maps and acetate overlays are sufficiently rote in nature that an AAGT, given digital information

and the appropriate parameters, can perform these low-level terrain analysis functions more quickly and with less error than a human.

(3) Provide standardized outputs. A well designed AAGT should provide a more flexible, precise, and easily understood display of the information required.
It should display data and the results of analyses in a more readily understandable format than idiosyncratic manual notation.

A danger of automation is that exclusive reliance on a tool for analysis of data might reduce analyst familiarity with the terrain and its impact on military planning. In response to this concern, our experts believe that the automated analyses conducted by the AAGT are procedural and that using the output of the AAGT will not compromise the level of understanding by the analyst. The experiment will test this belief.

It follows from the discussion above that, in comparison with decision-makers using tools without BTRA-BC functionality, we hypothesize that trained and experienced military planners who use BTRA-BC would:

1. Produce a COA *more quickly*. Rationale: The automation and analysis functions in BTRA-BC should allow the participants to complete the repetitive and rote tasks more quickly allowing more time for the generation of more options for the COA and a subsequently higher quality product.

2. Produce a *higher quality* output. Rationale: The automaton in BTRA-BC should minimize errors of omission and calculation. Furthermore, the standardized graphical representation of important terrain features and TSOs will display information more succinctly.

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.

**Formatted:** Bullets and Numbering

As the determination of military value and the design of the experiment evolved, we identified several secondary hypotheses. The automation of previously manual tasks, which adds value to using an AAGT, would 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 secondary hypotheses investigated include:

4. The output generated with BTRA-BC would be *more uniform* i.e. have less variance in the first two of the three categories above (speed and quality), than output 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.

5. There would not be a *learning effect due to experimental design*. Rationale: The participants have previous training and extensive experience using C2 planning tools and the tasks the participants are asked to perform are those that they have performed in the normal course of their duties.

**Formatted:** Bullets and Numbering

## 4. Study Design

The study design employs a factorial design with three independent variables: System (with and without BTRA-BC functionality), System Order (whether the first scenario is worked with or without BTRA-BC functionality), and Scenario Order (whether scenario 1 or 2 is worked first). System will be a within-subjects variable because each participant will work one planning scenario with BTRA-BC and one scenario without BTRA-BC. A within-subjects design is particularly valuable when the number of available participants is limited, as in the current case. Results from the sets of tasks can be compared for each participant, thus eliminating participant-specific effects that might add variability to the results.  System Order and Scenario Order will be between-subjects variables because any given participant can only be in one ordered sequence for these variables.

The participants will perform the same tasks on two similar military planning scenarios, using the same underlying planning system, the Commander's Support Environment (CSE). One of the tasks will be performed with BTRA-BC functions added to the basic CSE functions; and the other task will be performed with the basic CSE alone. The two trials are essentially identical except for the use of BTRA-BC functions. The order of the tasks will be randomly selected so that half of the participants perform each of the tasks first. Randomizing the order of the tasks will enable the analysis to control for learning effects.

The instructions, tasks, requested outputs, and evaluation of these outputs are the same in both scenarios 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 repeating their responses from the first scenario when they form responses for the second scenario. The two areas have been carefully selected for their geographic similarity such that the tasks performed by the participants and the expected results will be as nearly identical as possible. Randomization will be used to control for differences between scenarios.

The participants will be Army and Marine Corps officers who have been previously trained in military planning and have operational experience at the battalion (Bn) or brigade (Bde) level. They will be split into two groups that are evenly balanced with respect to ability and knowledge as assessed by our military consultants based on the results of questionnaires detailing the participants' training and experience. Group I will perform the set of tasks first without BTRA-BC and then with BTRA-BC. Group II will perform the tasks in reverse order. The groups will be further divided into two subgroups while maintaining the balance of ability and knowledge. Each subgroup will perform the same tasks for the same two scenarios, but the two subgroups will see the two scenarios in the opposite order. This design will allow us to control for differences due to the order of system use and the scenario order.

The tasks will consist of that portion of the military planning process beginning with analyzing the specific terrain given a Combined Obstacle Overlay (COO) up to the point of generating potential a COA. Specific tasks will include (1) identifying Mobility Corridors (MC), (2) categorizing MCs by size, (3) grouping MCs to form potential Avenues of Approach (AA), (4) evaluating enemy COAs, (5) planning routes for 3 vehicle types, (6) identifying choke points on potential AAs, (7) calculating transit times,

(8) recommending subordinate Areas of responsibility, in this case recommending company battalion boundaries, (9) planning company movement from a line of departure (LD) to an objective (OBJ), (10) recommending Named Areas of Interest (NAI), (11) identifying ambush sites, (12) identifying battle positions, and (13) generating a formatted Operations Order (OPORD).

The participants will produce a graphic overlay depicting the results of the above tasks as well as a written OPORD which explains the reasoning behind their decisions. In order to gather data for the metrics below the participants will also respond to questionnaires: one that will assess their understanding of the effects of terrain on the military planning process and one that will assess their subjective experience with and without BTRA-BC functionality.

Prior to beginning the tasks, both groups of participants will receive standardized training on the use of BTRA-BC and CSE. The training will be sufficient to allow the participants to perform the required tasks and will include training on the modes and features unique to BTRA-BC and CSE. The last phase of the training will require the participants to perform tasks based on the training and similar to those that the participants will encounter during the trials, but of lesser complexity.

**5. Environment**

The evaluation will be conducted using the Commanders Support Environment (CSE) as the Command and Control (C2) planning system. CSE is a robust C2 planning and execution based system developed for experimentation. The CSE has been enhanced to incorporate the BTRA-BC AAGT's. The CSE provides the capability to develop one or more COAs through a graphically oriented interface to represent the units, control measures, and their tasks. The CSE was originally developed for Defense Advanced Research Projects Agency (DARPA)/Army Multi-Cell and Dismount C2 Program (M&D C2) which was continued from the FCS C2 program. M&D C2 program hosted a series of experiments designed to test out network centric warfare concepts. The CSE is primarily written in C++ code for the Microsoft Windows environment. It is built upon the Viecore FSD Decision Support System (VDSS), and the Data Analysis and Visualization Infrastructure for C4i(Davinci) Toolkit. The VDSS architecture enables the quick addition of modules for communication between CSE and other systems and components. The CSE's GIS components are built upon the Commercial Joint Mapping Toolkit(C/JMTK) which includes ESRI's ArcGIS Desktop licensed at the ArcEditor level.

The CSE provides two main AAGT's: BTRA-BC Movement Projection engine and optimized Line of Sight (LOS) analysis in addition to displaying BTRA-BC TSOs. The BTRA-BC Movement Projection engine provides movement and route analysis. This tool allows the planner to generate various types of routes for his maneuver planning. These routes can then be incorporated into tasks that become part of the plan. The CSE can request and display various Tactical Spatial Objects (TSOs). Development of TSOs and the BTRA-BC interface to the TSO engines is ongoing. To keep things simple for this experiment, we will be utilizing pre-generated TSOs. The CSE is able to load and display these TSOs using several customized symbolizations. The visualizations for TSOs can be changed by the user to support the planning process. The LOS AAGT displays a real-time analysis based on the relevant digital elevation data.

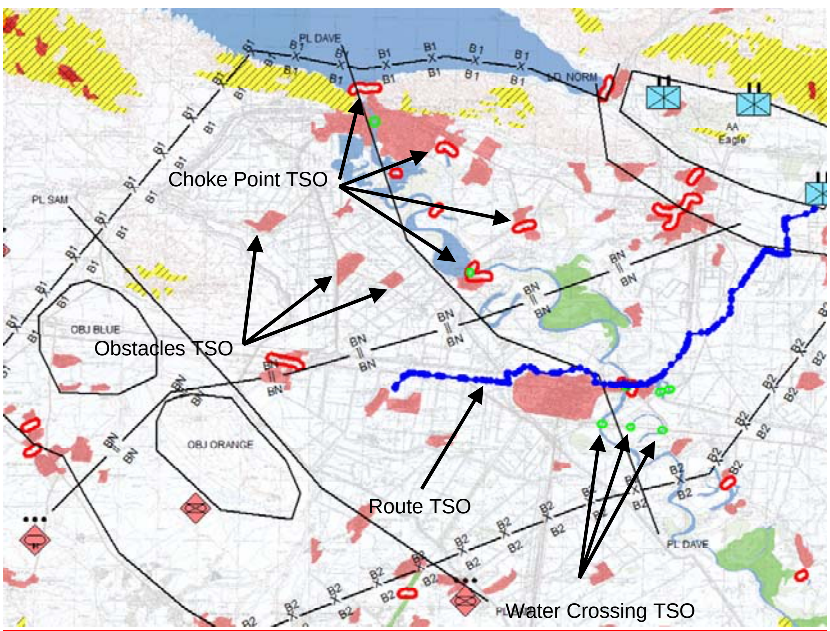


Figure 1: Geospatial Product Including BTRA-BC TSOs

Figure 1 is an example of a geospatial product consisting of several layers including BTRA-BC TSOs. The background is an image of a map geo-referenced to the digital data on which the graphics are based. The second layer consists of operational boundary and unit graphics. The last layer consists of TSOs. The TSOs generate the information from the underlying digital geospatial data. In Figure 1, a route generated by the Route TSO is indicated by the blue line. Water crossings are outlined in green; choke points for Bn-sized units are outlined in red; and natural obstacles are in solid red. Figures 2 and 3 below depict the same geographical region with BTRA-BC TSOs and without BTRA-BC TSOs, respectively.

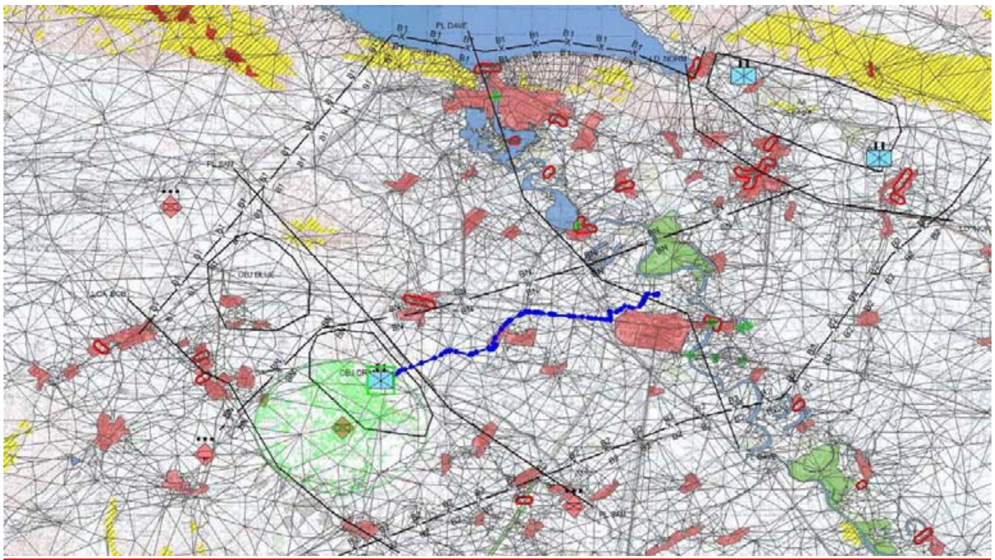

Figure 2 – With BTRA-BC TSOs

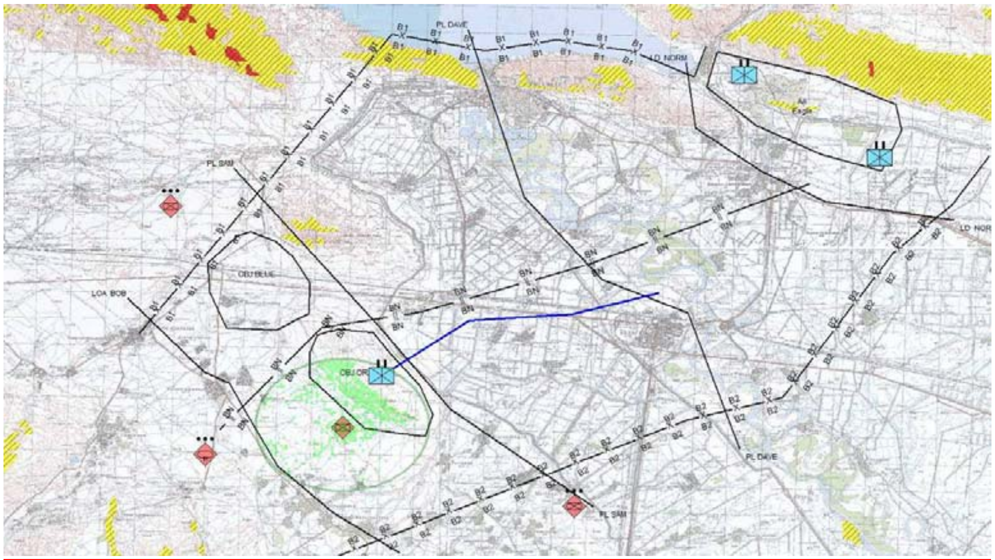

Figure 3 – without BTRA-BC TSOs

**6. Metrics**

Due to the differences in the graphical representation between CSE alone and CSE with BTRA-BC, blind scoring may be infeasible. BTRA-BC's graphics are not easily replicated manually in CSE and, although the evaluators will not be told which of the products were produced using BTRA-BC, given the number of products they will grade, it is likely that they will be able to determine which were produced with BTRA-BC. Although the outputs are distinguishable as to their source, the evaluators are Subject Matter Experts (SMEs) who will have no connection to the development of BTRA-BC, and we will assume the subjective evaluations are unbiased.

The criteria for evaluation of the BTRA-BC tools will be (1) a comparison of the rapidity with which the requested outputs can be produced, (2) the quality of those outputs, (3) the level of understanding of the participants of the impact of the terrain on the military decision making, and (4) the perception of the participants regarding the merits of the additional BTRA-BC functionality.

**Time to Completion.** The evaluation of how quickly the desired outputs are produced will be measured objectively and independently of the experimental condition by logging the amount of time it takes participants to complete the tasks. The maximum duration of each trial will 3.5 hours. The actual time will be calculated by taking the difference between the start and stop times and subtracting any break time.

**Quality.** We will consider two factors that contribute to the quality of a participant's output: (1) the information presented and (2) how the information is presented. The method of scoring quality will be subjective scoring; the scores for each participants output will be assigned by independent Subject Matter Experts (SMEs). The SMEs will judge the quality of the output with respect to the usefulness to the commander and will base their evaluations on criteria developed beforehand. The focus of the subjective evaluation will be relatively broad but focused on the BTRA-BC TSOs being evaluated. The participants' outputs will be scored in fifteen categories with a total of 29 sub-categories that encompass both the graphic and written portions of each output. The scoring will be done on a 5-point Likert scale.

**Terrain Knowledge.** We will administer a questionnaire to evaluate the participants' knowledge of the terrain and understanding of the impact of the specific terrain on military decision making. The answers to the questions will not be outputs of CSE or BTRA-BC. Answering the questionnaire will require judgment and reasoning about the terrain and its effect on the military decision making, and not just regurgitating data presented by the system (CSE with or without BTRA-BC). Like the subjective evaluation, the SMEs will evaluate the participants' answers on a 5-point Likert scale. The questions will address reasoning about the general geography of the area, vehicle routing considerations, the selection of battle positions, engagement areas, and ambush sites.

## 7. Conclusions

The experiment is currently planned to be conducted within the next few months. Results from the experiment will be published in a later version of this paper and be presented at the ICCRTS conference. Plots and charts of the data will be presented supporting or rejecting the primary and secondary hypotheses. Analysis of variance will be performed to provide quantitative estimates of the degree of statistical support for the hypotheses. Confidence intervals will be provided for the magnitude of the effects associated with the hypotheses.

The experiment describe in this paper is scheduled to be conducted in the next few month and based on the results of the firsts experiment we are confident that this design will be a valid test of the hypotheses. The first experiment in this series tested very similar hypotheses with approximately the same number of subjects and provided statistically significant results to support the majority of our hypothesis. The results of that experiment and of the current experiment, both those that support the hypotheses and those that don't provide statistically significant results, provide valuable information to the developers of BTRA-BC

Evaluation of complex systems should start in the development phase as well as continuing through the procurement process. Evaluation starting early in the development process allows developers to choose design options with the greatest potential benefit as well as identifying specific problems 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 drawn from the target user population. This is often difficult to achieve in a research setting, but a true measure of value can be determined only 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 a tool at any point is determined, the resulting follow-on evaluations can be combined with previous results to form a coherent overall evaluation. The ultimate goal of the design and procurement process is the fielding of system that provides the best value to the military decision maker.

## References


Adelman, L. *Evaluating Decision Support and Expert Systems*, Wiley, 1992.

Boar, B. Application Prototyping: A Requirements Definition Strategy for the 80s. New York: Wiley Interscience, 1984.

Boehm, B.W., Gray, T.E. and Seewaldt, T. Prototyping vs. Specification: A Multi-Project Experiment. Proceedings of Seventh International Conference on Software Engineering, New York: ACM and IEEE, 473-484, 1984.

Campbell, D. T. and Stanley, J.C. Experimental and Quasi-Experimental Design for Research, Rand McNally, Chicago, 1986.

Herrmann, C.G. (Maj). DTSS Puts the "Visual" in Battlespace Visualization, *Military Intelligence Professional Bulletin*, Oct-Dec, 2002.

Hicks, D. and Hartson, H.R. Developing User Interfaces: Ensuring Usability Through Product and Process. Wiley, 1993.

Laskey, K.B., Powell, W.A., Adelman, L., Michael Hieb, M.R., Kleiner. Evaluation of Advanced Automated Geospatial Tools. Proceedings of the 12th International Command and Control Research and Technology Symposium in Newport, June 19-21, 2007

Montgomery, D., Design and Analysis of Experiments, Wiley, 2004.

Sage, A. Decision Support Systems Engineering, New York: Wiley, 1991.

U.S. Army Corps of Engineers, *Battlefield Terrain Reasoning and Awareness (BTRA) Fact Sheet*, U.S. Army Engineer Research and Development Center, Topographic Engineering Center, 2003, http://www.tec.army.mil/fact_sheet/BTRA.pdf.