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FINAL REPORT

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WASHINGTON, D.C. 20310-0103

"BATTLEFIELD VISUALIZATION"

December 1998

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CONFLICT OF INTEREST

Conflicts of interest did not become apparent as a result of the Panel's recommendations.

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13. ABSTRACT (Maximum 200 words)

A study analyzing battlefield visualization (BV) as a component of information dominance and superiority. This study outlines basic requirements for effective BV in terms of terrain data, information systems (synthetic environment; COA development and analysis tools) and BV development management, with a focus on technology insertion strategies. This study also reports on existing BV systems and provides 16 recommendations for Army BV support efforts, including interested organization, funding levels and duration of effort for each recommended action.

14. SUBJECT TERMS

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EXECUTIVE SUMMARY

The United States military is continuously called upon to perform new and increasingly complex roles in the post-Cold War era. At the same time, we are currently in an era of resource reallocation in which funds are being directed away from military support and towards domestic needs. These conflicting trends require the evolution of a smaller, more cost-effective force structure to fulfill our continuing role in global engagement. An emerging strategy to meet this requirement is to leverage developments in science and technology – especially in the area of information technology. The recent Quadrennial Defense Review (QDR) Report identifies the potential contribution of information technology to a revolution in military affairs (RMA). The Joint Vision 2010 and Army Vision 2010 are documents which recognize information superiority and information dominance as an important force multiplier, and as a key element of our national security strategy.

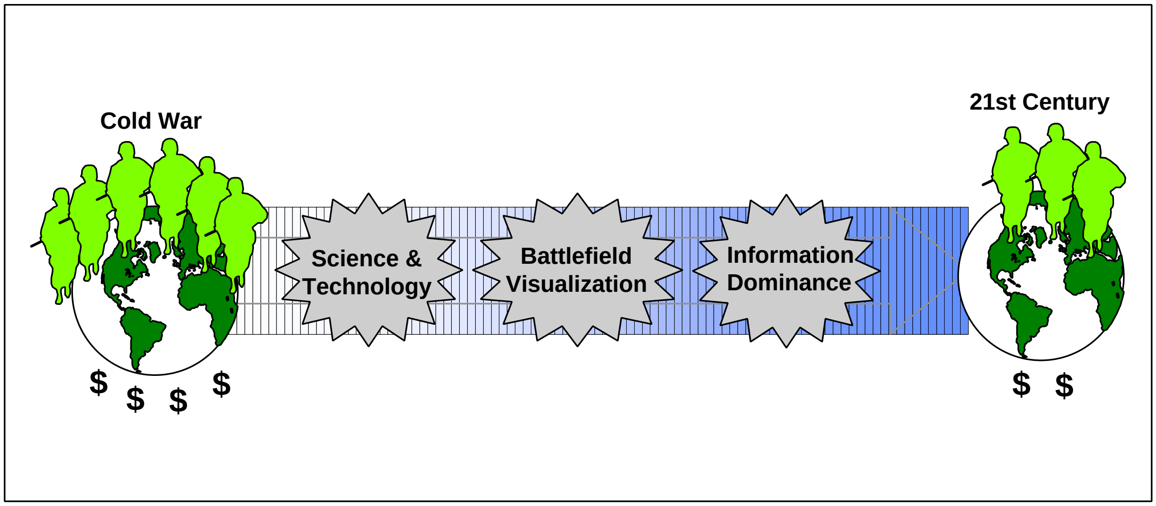
> *"Remarkable advances in information technology, stealth, and precision strike promise a real revolution in military affairs."* – Comments by the Chairman of the Joint Chiefs of Staff, QDR Report, 19 May 1997.

> *"We must have information superiority: the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same."* – Army Vision 2010.

In pursuit of information superiority and information dominance, the Army has recently embraced the concept: "battlefield visualization" (BV). BV greatly enhances the military decision making process (MDMP) of Army commanders and their staffs and enables commanders to get inside of the decision cycle of the enemy. The BV concept is articulated in TRADOC Pamphlet 525-70 which includes the following formal definition of BV:

> *"The process whereby the commander develops a clear understanding of the current state with relation to the enemy and environment, envisions a desired end state which represents mission accomplishment, and then subsequently visualizes the sequence of activities that moves the commander's force from its current state to the end state."* – TRADOC PAM 525-70

Although the term BV is new, the concept is not. Battle commanders have used aspects of BV throughout history. Early BV was achieved by standing on a hilltop and surveying the battlefield. Later improvements included the use of sand tables, then map boards with overlays. Current implementations are based on electronic means (e.g. computers, radar, and networks), although today's visualization often involves moving "yellow stickies" manually around a map. In the last half of the twentieth century, technologies for BV have not kept pace with the size of the battlefield and the lethality and tempo of the battle. It is the availability and application of new advances in information science and technology to the concept that now makes BV so attractive and interesting. The figure below highlights the notion that BV leverages information science and technology to help bring information dominance to the 21st Century Army. BV is a force multiplier that will help our Army to continue fulfilling its role in global engagement with a smaller, more cost-effective force structure.

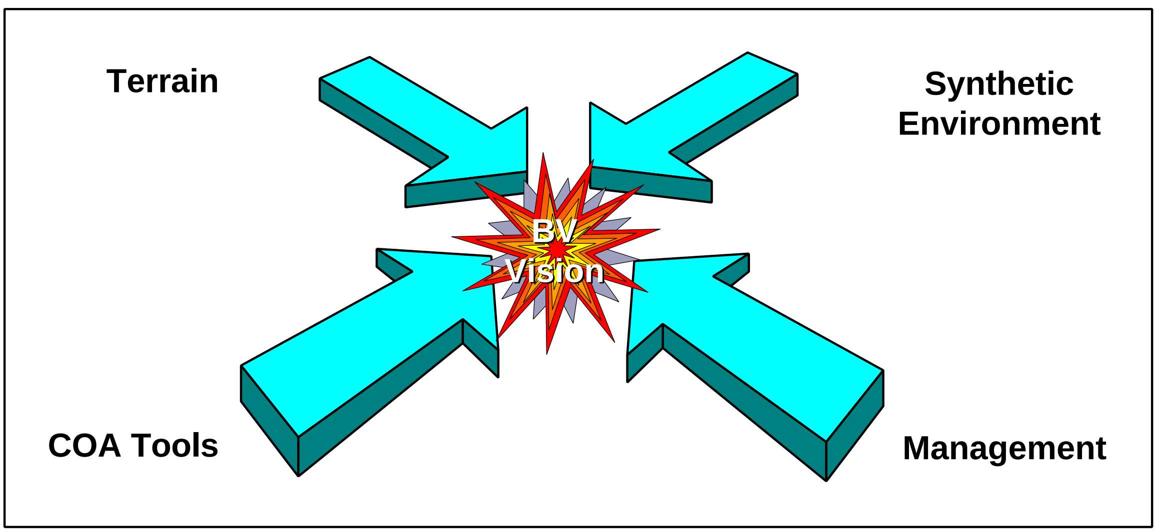


BV Leverages Information Technology to Bring
Information Dominance to the 21st Century Army

BV must be understood to be an integral part of battle command (BC). Its approach may be used by all types of commanders, at all echelons and for all types of missions (e.g., major regional conflicts (MRCs) and operations other than war (OOTW)). BV involves both art and science. The science component can be enhanced by the proper utilization of emerging technologies. The focus of this study is on the emerging technologies for BV and how to apply them to BC systems. The art of BV is essential to the commander's MDMP, but is not addressed here. However, it is important to recognize that the art of BV must be developed in synchronization with progress in the science of BV.

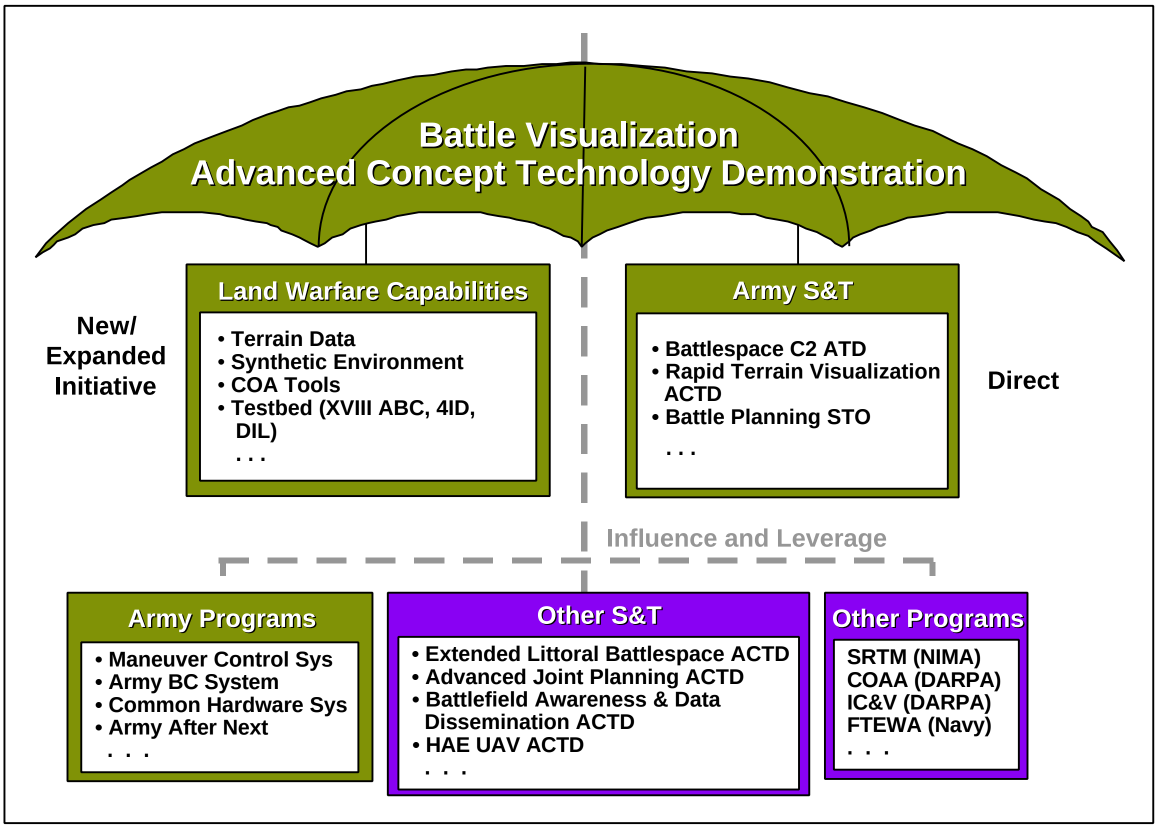
Modern advances in information technology hold the promise of vast improvements in BV in two areas: in the near real-time creation of an accurate, high-fidelity, synthetic representation of the real battle (i.e., which *"develops a clear understanding of the current state…"*); and in greatly improved planning and collaboration tools, including semi-automated course of action (COA) tools (i.e., which *"visualizes the sequence of activities…"*). Progress in information visualization will result in warfighters receiving more information, but presented to them in a more intuitive fashion. As never before, the commander will be able to monitor, in detail, the state of battle and will be able to trust that he has an accurate understanding of the situation. Planning tools will be so effective that plans will be able to be changed and rehearsed after execution has begun, and the changes in plans will be immediately and effectively communicated to the affected units. Thus, planning, rehearsal, and execution will become an iterative process so that changes on the battlefield can be reacted to quickly. BV needs are different at all echelons and for different operations; and the information technology that is the basis of modern BV must allow BV to be tailored to the needs of each echelon and each type of operation. The result will be overwhelming information superiority, increased lethality, and an increase in battle tempo.

BV will utilize a diverse suite of data about the current situation. BV requires information about friendly forces, enemy forces, terrain and weather. These data must be integrated or fused for a concise, coherent common operational picture for warfighters. Computer renderings of this battle data will support monitoring of battle execution; and planning and rehearsing the planned battle. The effective collection, integration, presentation, and use of information about the battlespace results in enhanced battle command. BV is important at all echelons and uses existing command and control systems, specifically the Army Battle Command System (ABCS) components.



Critical Paths for BV Developments

To achieve this vision of BV potential, several technology areas require concentrated effort as shown in the above figure. An accurate terrain data set is the foundation of a synthetic representation of the real battle, and currently the Army does not have a terrain collection and data management capability sufficient to meet its needs. In addition, further work must be done in the creation of the synthetic environment so that it can effectively integrate the multiple and diverse data inputs into a single, coherent representation of battle. Furthermore, there is insufficient work in progress with COA tools to capitalize on the great strides that digitization of the battlefield can bring to the planning and collaboration process. These shortcomings and mitigating recommendations for the direction of further efforts, are discussed herein. There are diverse efforts addressing BV capabilities internal and external to the Army that can substantially benefit from stronger management. Improved management will focus developments on early fielding of BV capabilities with improved support to warfighters. We recommend a funded umbrella program for managing BV-related developments to ensure the success of all of the elements necessary for fielding the BV capability the Army needs.



Recommended "Umbrella" Program

The "umbrella" program, as shown in the above figure, will address critical information technology refinements to fully address capabilities needed for the Army's vision for BV. The Battle Visualization Advanced Concept Technology Demonstration

(ACTD) is proposed to initiate necessary new developments; direct efforts of related programs, i.e., Battlespace Command and Control (BC2) Advanced Technology Demonstration (ATD) and Rapid Terrain Visualization (RTV) ACTD; and exploit program developments outside the Army.

Addendas contain background and resource information for further discussion. They were prepared by ASB panel members but do not represent a consensus view of the panel and are not recommendations to the Army.

SECTION 1:

STUDY BACKGROUND AND FINDINGS

Army Science Board
Briefout

"Battlefield Visualization"

Introduction

The Army Science Board (ASB) Battlefield Visualization (BV) study panel (Panel) produced an initial brief summarizing its findings and recommendations. The brief was prepared during a report writing session in June 1997 and was first presented in a briefout for study sponsors on 26 June 1997. This annotated brief is a revision of the original that addresses recommendations for improvement stemming from the sponsor briefout and presentations to other senior Army leaders. The following are individuals who have been presented the brief:

- Dr. Oscar, Acting Assistant Secretary of the Army for Research, Development and Acquisition (ASA(RDA))
- LTG Holder, Training and Doctrine Command Deputy Commanding General for the Combined Arms Center (TRADOC DCG CAC)

- LTG Miller, Training and Doctrine Command Deputy Commanding General (TRADOC DCG) Futures
- LTG Kennedy, Deputy Chief of Staff for Intelligence (DCSINT)
- LTG Campbell, Director of Information Systems for Command, Control, Computers and Communications (DISC4)
- Mr. Borland, Vice DISC4 (VDISC4)
- LTG Kern, Military Deputy to the ASA(RDA)
- MG Brohm, CG Communications Electronics Command (CECOM) and CECOM Command Group
- Battlefield Visualization (BV) Integrated Concept Team (ICT)
- BG Lewis, Director of Weather (USAF)
- Mr. Hollis, Deputy Under Secretary of the Army for Operations Research (DUSA(OR))
- Ms. Browning, ODISC4
- BG Geis, Commanding General of the Simulation, Training and Instrumentation Command (STRICOM)
- BG Boutelle, Program Executive Officer for Command, Control and Communications (PEO C3S)
- LTG Meigs, TRADOC DCG CAC
- GEN Reimer, Chief of Staff of the Army (CSA)
- LTG Heebner, Assistant Vice Chief of Staff of the Army (AVCSA)
- BG Arnold, DCG Engineering School

On 23 September 1997, a presentation of this brief was made available to interested DoD personnel at the Pentagon. Approximately 100 persons attended this presentation.

Throughout this document, figures with the ASB logo in the upper left-hand corner are charts reproduced from the briefout. Figures without the logo are provided to add detail to the annotation.

Organization of Presentation

- **Study Background and Findings** ✓
- **BV Critical Paths**
  - **Terrain Data**
  - **Synthetic Environment and Information Visualization**
  - **Course of Action (COA) Development and Analysis**
  - **Management**
- **Summary**

Battlefield Visualization

The brief begins with a summary of the study's background which includes the terms of reference, participants and information sources. The introduction also includes findings based on reviews of Army efforts with BV and assessments of those efforts.

Terrain Data; Synthetic Environment and Information Visualization; and Course of Action (COA) Development and Analysis are three technology areas identified as critical paths for BV. As critical paths, the areas require substantial developments in order to achieve Army goals for BV as stated or implied in the BV Concept pamphlet and draft BV Master Plan. Management actions supporting the technology critical paths are recognized and addressed as a fourth critical path.

The summary section outlines an “umbrella” program that addresses recommendations for each of the critical paths. The summary also relates how the ASB recommendations support Army BV goals.

Terms of Reference

- ***Review Background:*** **Identify and review background and ongoing efforts regarding battlefield visualization. Review related Army and DoD documents, initiatives, systems and organizations. Discuss vision and concepts with Army leaders, then comment on issues for a harmonized view.**
- ***Assess Efforts:*** **Assess Army operational concepts, functional requirements, technology requirements and developing capabilities which will enable visualization of the battlefield. Suggest additional functional requirements and alternative technologies. Also, assess Army progress in, and technical and management approaches for development and fielding.**
- ***Investigate Support to Information Dominance:*** **Validate contributions of planned functions which will facilitate battlefield visualization for the Army's objective of gaining information dominance. Investigate TTP and unit task organization for information operations to take advantage of the new capabilities.**
- ***Recommend Technology Insertion Strategy:*** **Recommend a strategy and roadmap for incorporating maturing technologies into the evolutionary architectures and systems of ABCS. Recommend programmatic pursuits that will support fielding of operational capabilities. Suggest ways the Army might best synchronize its related efforts.**
- ***Assess Interoperability and Compliance:*** **Assess plans for integrating battlefield visualization capabilities with existing and emerging Army systems and assess compliance of prototype and planned products with the ATA, JTA and HLA.**

- Tactics,Techniques and Procedures (TTP)
- Army Battle Command Systems (ABCS)
- Army Technical Architecture (ATA)
- Joint Technical Architecture (JTA)
- High Level Architecture (HLA)

Battlefield Visualization

The approved terms of reference (TOR) tasked the study panel to: review Army BV background; assess Army BV efforts; investigate BV support to information dominance; recommend a technology insertion strategy; and assess interoperability and compliance of emerging BV capabilities with relevant information technology architectures. A signed copy of the TOR is included in appendix A.

The brief principally addresses recommendations for technology insertion strategy through the material on critical paths since the panel's substantial efforts address those areas. This introduction briefly addresses the review and assessment of Army BV efforts, and support to information dominance. Architecture compliance is addressed in the annotation for "Synthetic Environment & Information Visualization Recommendations."

Participants

Study Sponsors
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LTG Otto J. Guenther, DISC4
LTG Leonard D. Holder, TRADOC DCG, CAC
MG Ronald E. Adams, ADCSOPS-FD

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Battlefield Visualization

The DCSINT, DISC4, and TRADOC DCG CAC sponsored this study. The Assistant Deputy Chief of Staff for Operations for Force Development (ADCSOPS-FD) is identified in the TOR as a sponsor. The general officers occupying these positions at the time of the briefout on 26 June 1997 are identified in the figure.

The ASB study panel included 14 members from industry and academia. Three panel members are retired general officers who helped provide a warfighter's perspective. Terrain, Synthetic Environment, COA, and Information Dominance subpanels were formed to focus investigations in these areas.

The staff assistants from DISC4, CAC and DCSINT made possible the successful conduct of all meetings and the report writing session. Government advisors from the Communications Electronics Command, Research Development and Engineering Center (CECOM RDEC), National Imagery and Mapping Agency (NIMA), Office of the DISC4 (ODISC4), and Office of the DCSINT (ODCSINT), along with the staff assistants supported conceptualization of issues and recommendations.

A Red Team helped the study panel focus its deliberations and writing during the report writing session. Red Team members included:

- Dr. William H. Evers, Jr. Chair
- Dr. Michael S. Frankel
- LTG John W. Woodmansee, Jr. (USA Ret.)
- Dr. Walter B. Laberge
- Dr. Gregory H. Canavan
- COL Herbert J. Gallagher (USA Ret.)

Information Sources

- LTG Menoher – DCSINT
- LTG Guenther – DISC4
- LTG Holder – TRADOC, CAC
- XVIII Airborne Corps
- TRADOC TPIO-ABCS
- CECOM RDEC
- NIMA
- PEO IEW&S
- ODISC4
- COL Leja – PM ATCCS
- Mr. Crites – OUSD(A&T)
- Task Force XXI AWE
- Mr. Hollis – DUSA(OR)
- TRADOC TPIO-Terrain
- Mr. Kauderer – JHU APL
- Mr. Skurka – STRICOM
- Joint Staff J-3
- National Simulation Center
- Army Research Laboratory
- Army Systems Engineering Office (ASEO)
- American Broadcast Corporation
- Dr. Gershon – MITRE
- Joint Countermine Operational Simulation – MITRE
- Mr. Lunceford – DARPA
- Warfighter Analysis & Integration Center
- BG Lewis – USAF Director of Weather

Battlefield Visualization

Between December 1996 and May 1997, the study panel formally met eight times for meetings averaging two days in length. During these formal meetings and other informal meetings by subpanels and individuals, many briefings and demonstrations were received. The chart lists many of the individuals and organizations who met with the BV study panel.

Highlights:

- Early in the study, each sponsor met with the panel to discuss their interests in BV, topics of interest and expectations for the study panel. The following figures were presented to the panel by the sponsors.

- Check our azimuth:
  - Right technologies?
  - Right strategy?
  - Right players – industry, academia, DoD?
- Sanity check on our timelines; the art of the possible vs. the reality of the affordable
- Warfighter requirements – have we missed key functionalities in our prototyping effort?

Chart to the ASB Panel by LTG Menoher

How do we:

- Inculcate a uniform understanding of BV throughout the force
- Find the right balance between technical means and tactical skills
- Design ATCCS applications that support BV in all disciplines
- Equip and man the force for optimal use of BV tools and techniques
- Get full value from other service and non-military sources
- Validate BV doctrine and expand it through TTP
- Train and evaluate the use of BV tools in simulations and live environments
- Educate and advance leaders who understand and get full potential from BV
- Integrate wargaming technologies into estimates before and during operations

Chart to the ASB Panel by LTG Holder

- The panel met at Ft. Bragg to observe the use of BV capabilities by the XVIII Airborne Corps led by the 525th Military Intelligence Brigade.

- At Ft. Leavenworth, the panel was briefed on BV related efforts by the TRADOC Program Integration Office for Army Battle Command Systems (TPIO ABCS) and other TRADOC organizations.

- The panel also met at Ft. Monmouth to be briefed on related science and technology (S&T) efforts by CECOM RDEC and the Army Research Lab (ARL) and on related developments by PEO C3S.

- NIMA presented many briefs and demonstrations to the ASB during several meetings. The study's terrain subpanel met with representatives of NIMA, Joint Precision Strike Demonstration – Project Office (JPSD-PO) and DCSINT. The capabilities of the

Army's Topographic Engineering Center (TEC) and NIMA to produce these products were also considered.

- The panel was introduced to the Rapid Terrain Visualization (RTV) Advanced Concept Technology Demonstration (ACTD) by the JPSD-PO of the PEO for Intelligence, Electronic Warfare and Sensors (IEW&S).

- The panel traveled to the National Training Center (NTC) to observe the operational use of experimental information systems supporting BV concepts during the conduct of the Task Force XXI Advanced Warfighter Experiment (AWE). At the AWE, the panel observed use of BV capabilities in the Division Tactical Center (TAC) and at Edwards Air Force Base where the XVIII Airborne Corps was staged with its BV capabilities.

- Several study panel members received a demonstration of the Force Threat Evaluation and Weapon Assignment (FTEWA) system at the Johns Hopkins University Applied Physics Laboratory (JHU APL). FTEWA is a prototype system providing BV capabilities for naval operations and is being used aboard the Kitty Hawk aircraft carrier and two other ships. Although naval requirements for BV are substantially different from those of the Army, technology and infrastructure may be leveraged in Army systems.

- A tour of the broadcast news facilities of the American Broadcast Corporation provided insight to the panel members as to how the entertainment community addresses display requirements and mobile operations.

- The demonstration of the Joint Countermine Operational Simulation (JCOS) facility provided insight as to how synthetic environment and modeling and simulation (M&S) techniques can be applied towards BV capabilities.

- Several panel members traveled to Ft. Hood to observe the operational use of experimental information systems supporting BV concepts during the conduct of the Division XXI AWE (DAWE).

BV Definition

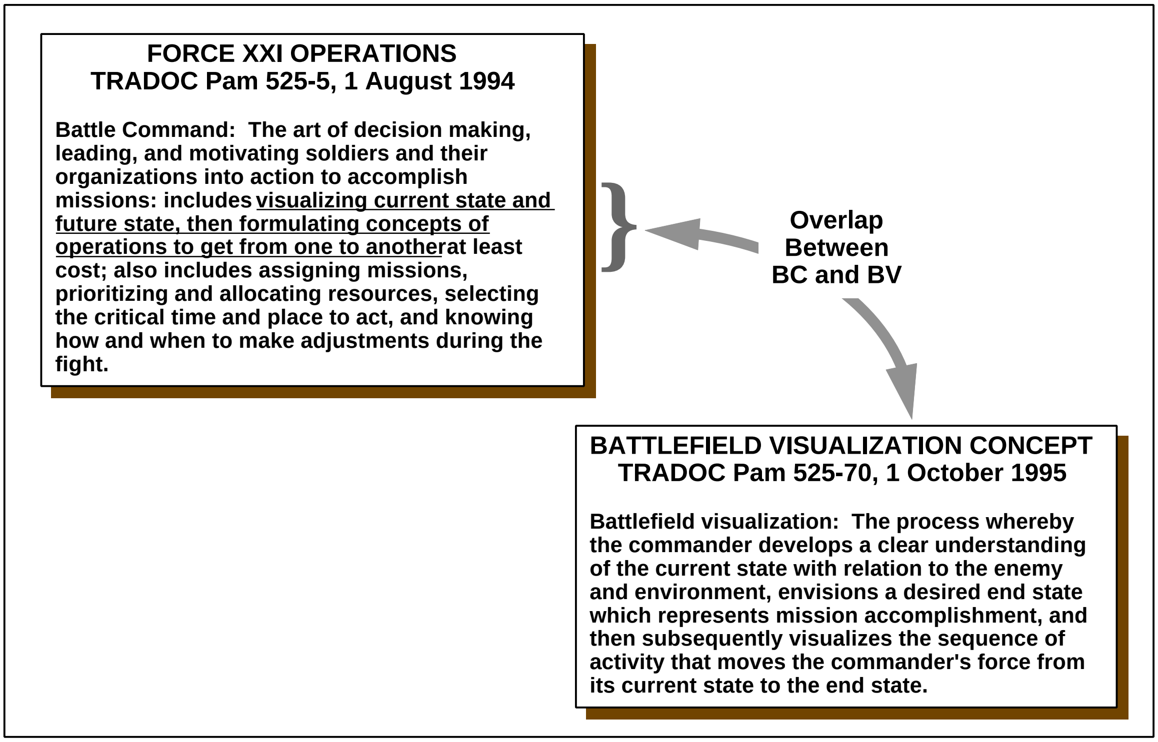
"The process whereby the commander develops a clear understanding of the current state with relation to the enemy and environment, envisions a desired end state which represents mission accomplishment, and then subsequently visualizes the sequence of activities that moves the commander's force from its current state to the end state."

TRADOC Pamphlet 525-70

Battlefield Visualization

TRADOC Pamphlet 525-70, "Battlefield Visualization" includes a definition of BV. Most within the Army have adopted this definition, while its use outside the Army is limited.

It is important to recognize that the definition includes two distinctly different processes. The definition begins with visualizing the current state of the battle. This process is consistent with notions of visualization being pursued by other services and joint organizations. The definition further adds a process to develop sequences of activities leading to a desired end state. *This second process is unique to the Army*. This second process implies the need for course of action (COA) development and analysis functionality not required for visualizing the current state of battle. This COA functionality sets apart the Army's concept for information visualization from others.



Overlap Between BC and BV Needs to be Eliminated

The above figure includes the Army's definition for BV and battle command (BC) and highlights substantial overlap. It is recommended these definitions and their concepts be deconflicted. The Army has also advanced its thinking on BV substantially since the original publication of the BV pamphlet in 1995. An update of 525-70 is warranted to reflect this new thinking and to deconflict and interrelate BV and BC.

BV Role In Information Dominance & Superiority

- **Information dominance and superiority are identified as key elements of our strategy for the 21st century**

"Remarkable advances in information technology, stealth, and precision strike promise a real revolution in military affairs."

Comments by the Chairman of the Joint Chiefs of Staff,
QDR Report, 19 May 1997

"We must have information superiority: the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same."

Army Vision 2010

- **Battle command (BC) is identified as central to information dominance and superiority**
- **BV contributes to a great leap ahead in BC and a major step towards information dominance and superiority**

Battlefield Visualization

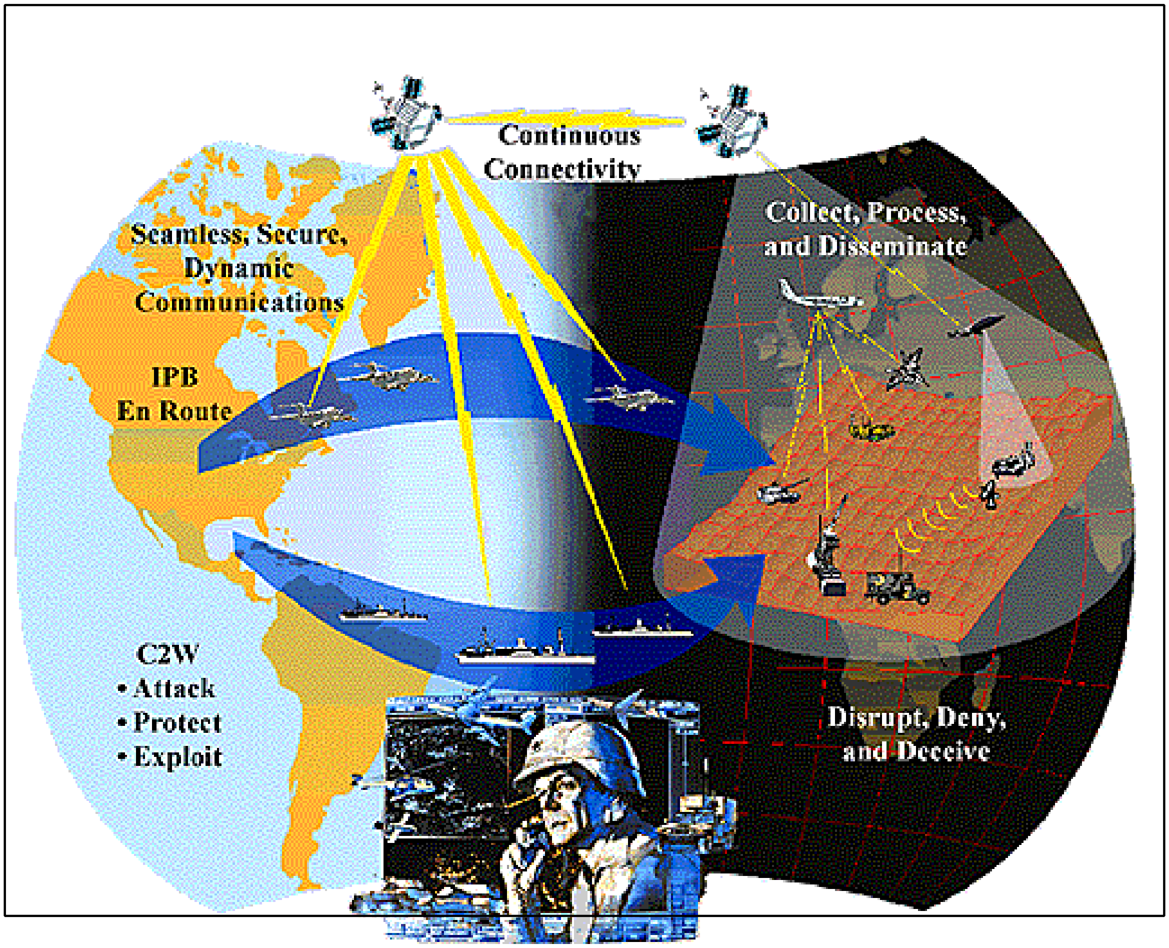
At the request of Headquarters TRADOC, the Panel considered how BV plays a role in information dominance.

BV has a place in the Army's strategy for the 21st Century. Although BV is not specifically mentioned as a key element of that strategy, BV involves information technology that promises a real revolution in military affairs (RMA).

Information dominance and information superiority are specifically identified by senior DoD and Army leadership as key elements of the DoD and Army future strategy. The recent Quadrennial Defense Review (QDR) Report and Army Vision 2010 document exemplify this emphasis. Command and control (C2) or BC is central to both information dominance and superiority. The ASB panel proposes a relationship between BV and BC: *BV is subsumed in BC*. The emerging BV capabilities should add to and integrate with current BC capabilities to provide an augmented BC capability for commanders and their staffs. Therefore, BV contributions enhance BC capabilities which in turn enhance information dominance and superiority.

Background on Information Dominance

Joint Vision 2010 is the 'conceptual template for how America's Armed Forces will channel the vitality and innovation of our people and leverage technological opportunities to achieve new levels of effectiveness in joint warfighting.' The emerging importance of information superiority is identified in the document as a factor that will dramatically impact how well our Armed Forces can perform its duties in 2010. In support of this emphasis, the joint document states, "We must have information superiority: the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same."

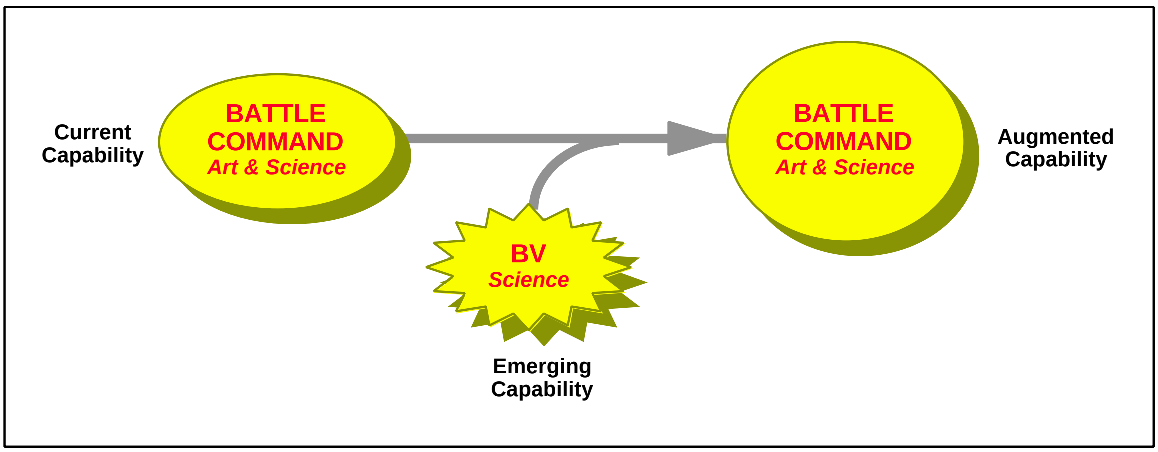


Army Vision 2010 Concepts, Enablers and Technologies
for Information Superiority and Information Dominance

Information superiority is one of the five major patterns of the Army Vision 2010. The above figure from the document identifies supporting concepts, enablers and technologies. The Army document identifies information dominance as being essential to all the patterns of operation. The document further elaborates that, information operations (IO) are conducted to gain information dominance and consists of both offensive and defensive efforts to create a disparity between what we know about our battlespace and operations within it and what the enemy knows about his battlespace.

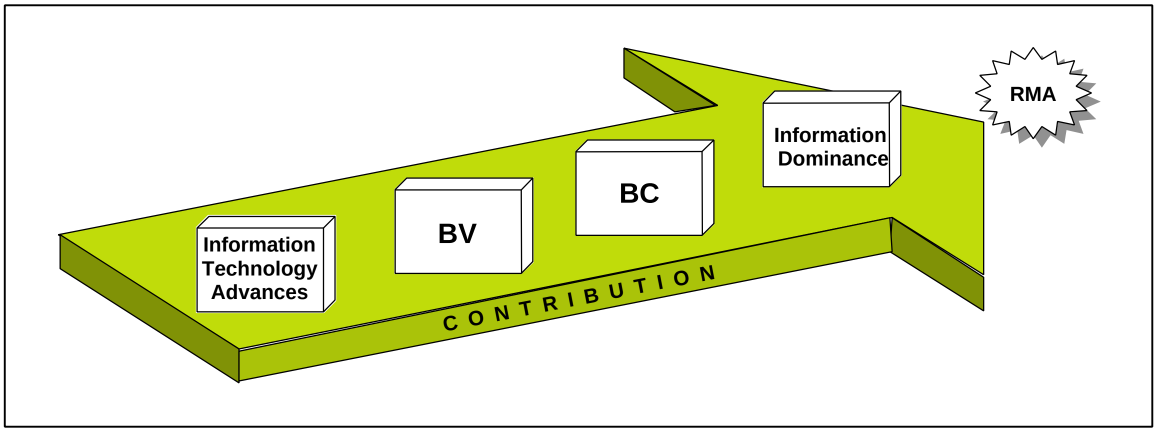
Relationship of BV and BC

Remarkable advances in information technology are leveraged to enable BV. The high performance and low cost of computers and networks supports the science for BV. BV does not stand alone as a process for commanders and staffs, but must be seamlessly integrated into processes for battle command (BC). All contributions of BV to the MDMP are subsumed and encompassed in contributions to BC. The figure below illustrates this relationship between the evolution of BV and the evolution of BC.



BV Contributes to a Great Leap Ahead in BC

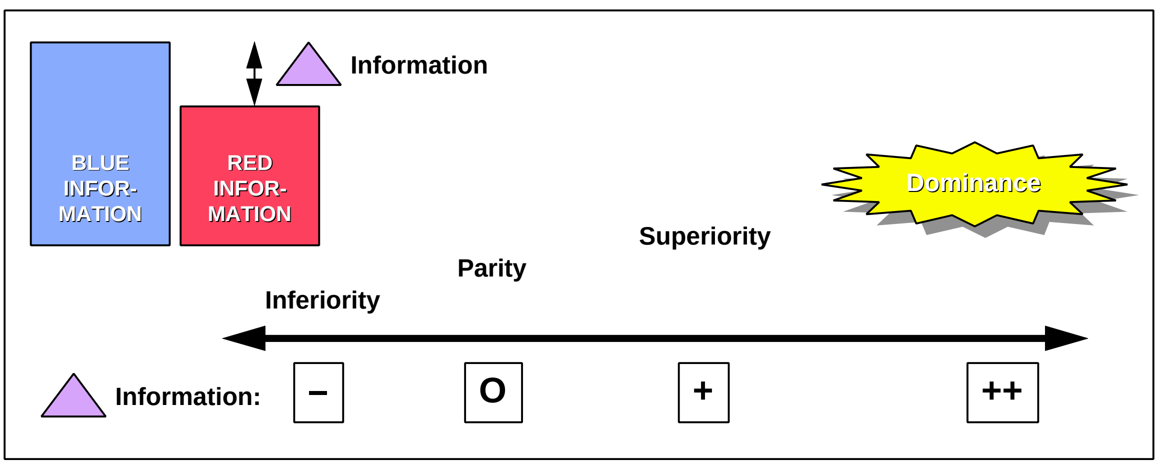
BC is identified as the principal contributor to information dominance. The figure below emphasizes that information technology advances contribute to BV, which contributes to BC, which in turn contributes to information dominance. Ultimately, the application of information technology advances for BV contributes to a revolution in military affairs (RMA) as suggested in the QDR Report.



ASB Vision for BV Contributions

ASB Vision for Information Dominance

Information dominance is a state on a continuum of possibilities. It is achieved by *having* and *acting on* meaningful information while preventing the enemy from doing the same. The difference or "delta" in friendly (blue) and enemy (red) information, as seen in the figure below, can vary over a continuum. That difference can vary from negative (information inferiority) to zero (parity) to positive (superiority). Information dominance is the state achieved when the information delta is overwhelmingly positive. It must be understood that this state is localized: it is transitory, achieved at times and lost at others; it is limited in space, achieved on some parts of the battlefield but not on others; and it is dependent on the echelon and tasking, so that some echelons may achieve it while others do not. Thus, information dominance is a goal that is sometimes achieved in some places, but it is not achieved uniformly across the battlefield.



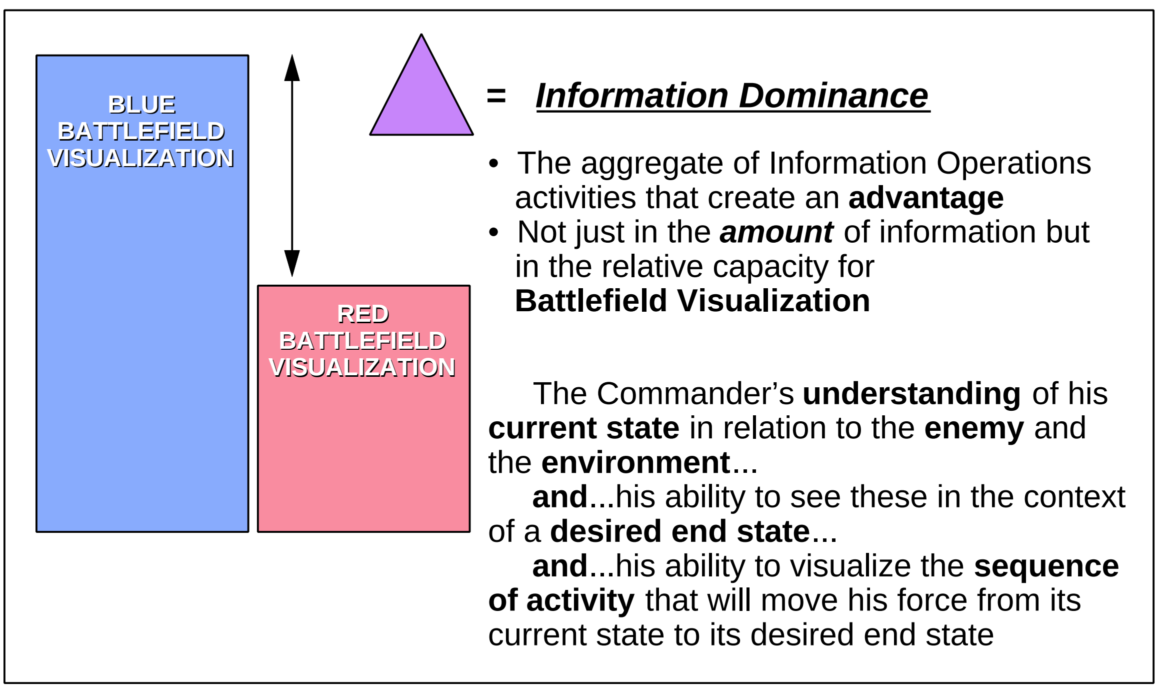
Information Dominance Continuum

BV contributes to the commander and his staff having and acting on meaningful information. Improvements in BV must include the infrastructure and process to support the following areas: the amount, type, quality, and timeliness of both red and blue information available to decision makers; the speed and ease of analysis and presentation of this information; the speed and scope of the decision maker's understanding of the current and potential battle situation; and the ability of commanders to communicate their vision of the current and future battle in a rapid and timely manner. Clearly one of the most important aspects of technology enhancements to BV is the speed with which information can be used effectively by commanders and staffs. This report emphasizes the need to improve several automated (or semi-automated) processes in BV, from automated feature extraction of terrain data, through automated retrieval of ABCS data for use in synthetic environments, to semi-automated course-of-action (COA) tools for planning -- and then monitoring -- the battle.

BV and Information Dominance

BV contributes to achieving information dominance. However, it does not directly contribute to preventing the adversary from having and acting on meaningful information. Therefore, BV is only one of several contributors to information dominance.

The following figure is often used in Army presentations on BV. The figure suggests the role of BV in information dominance. The ASB panel concluded information dominance is more than only the difference between friendly and enemy battlefield visualization.



Often Used Chart Relating BV's Role in Information Dominance

The ASB panel proposes that BV contributes to *having* and *acting on* meaningful information. Modern BV must include infrastructure and process to improve the:

- Amount, type, quality, and timeliness of both red and blue information available to decision makers (i.e., commanders and their staffs),

- Timeliness, speed, ease of analysis and presentation of information to commanders and staffs,

- Speed and scope of decision maker's understanding of current and potential battlefield situation, and

- Ability of a commander to communicate his vision of the current and future battle in a rapid and timely manner.

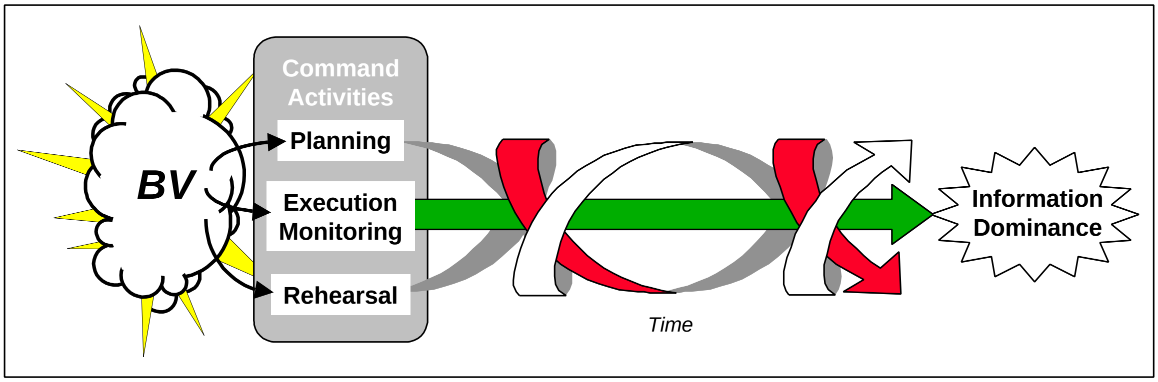
BV does not:

- Remove the "fog of war" (although it reduces it),

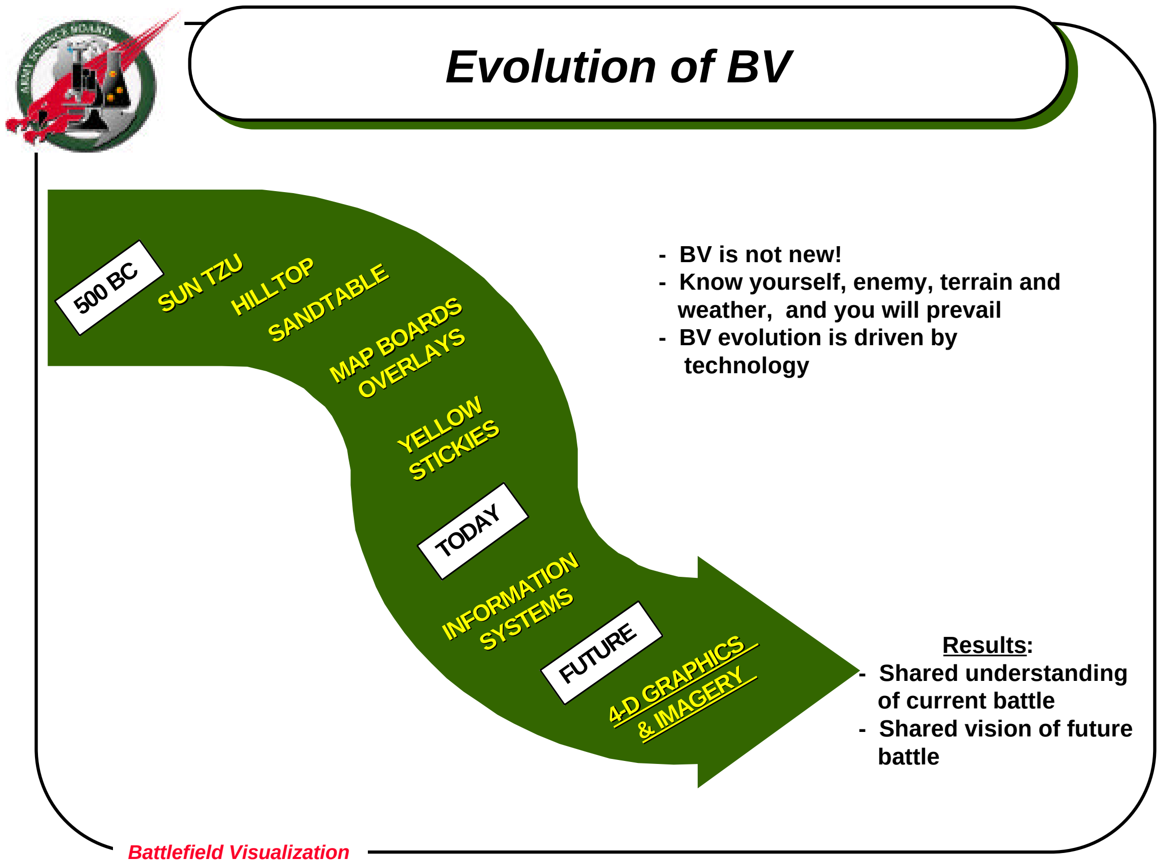
- Include offensive IEW to deny the enemy access to information, or

- Protect friendly information assets (directly).

The figure below emphasizes that BV contributes to command activities of mission planning, mission rehearsal, and execution monitoring. These activities cycle during a battle and contribute to information dominance.



BV Indirectly Contributes to Information Dominance



Although the term 'battlefield visualization' is relatively new, only several years old, concepts for BV are not new. Sun Tzu, circa 500 BC, has been credited for noting that if warfighters know themselves, the enemy, terrain and weather, they will prevail in battle. BV, using information technology, is capable of presenting data, in an intuitive manner, to commanders and their staffs, about friendly forces, enemy forces, terrain and weather. An approach to BV processes in early land warfare was for commanders to look out over a battlefield from a hilltop to observe battle activity or in contemplation of the next day's battle. Visualization capabilities have long been desired by commanders. For example, in 1924 General Patton wrote, *"It was his vision of the future, in which a general observed the battlefield on a television-like monitor, filmed from a helicopter that captured images of tanks fighting each other ..."* Sandtables; map boards with acetate overlays and yellow stickies; and information systems are technologies that have been applied in support of the basic concepts for BV. What is often implied in today's notion of BV is the application of high resolution computer graphics for rendering friendly, enemy, terrain and weather data in three dimensions and over time, i.e., 4-D graphics. Computer generated display of imagery taken with spaceborne, airborne or land-based platforms are also considered an important aspect of BV. Pursuit of intelligently presenting this data is to provide commanders and their staffs a shared understanding of the current battle and a shared vision of future battle.

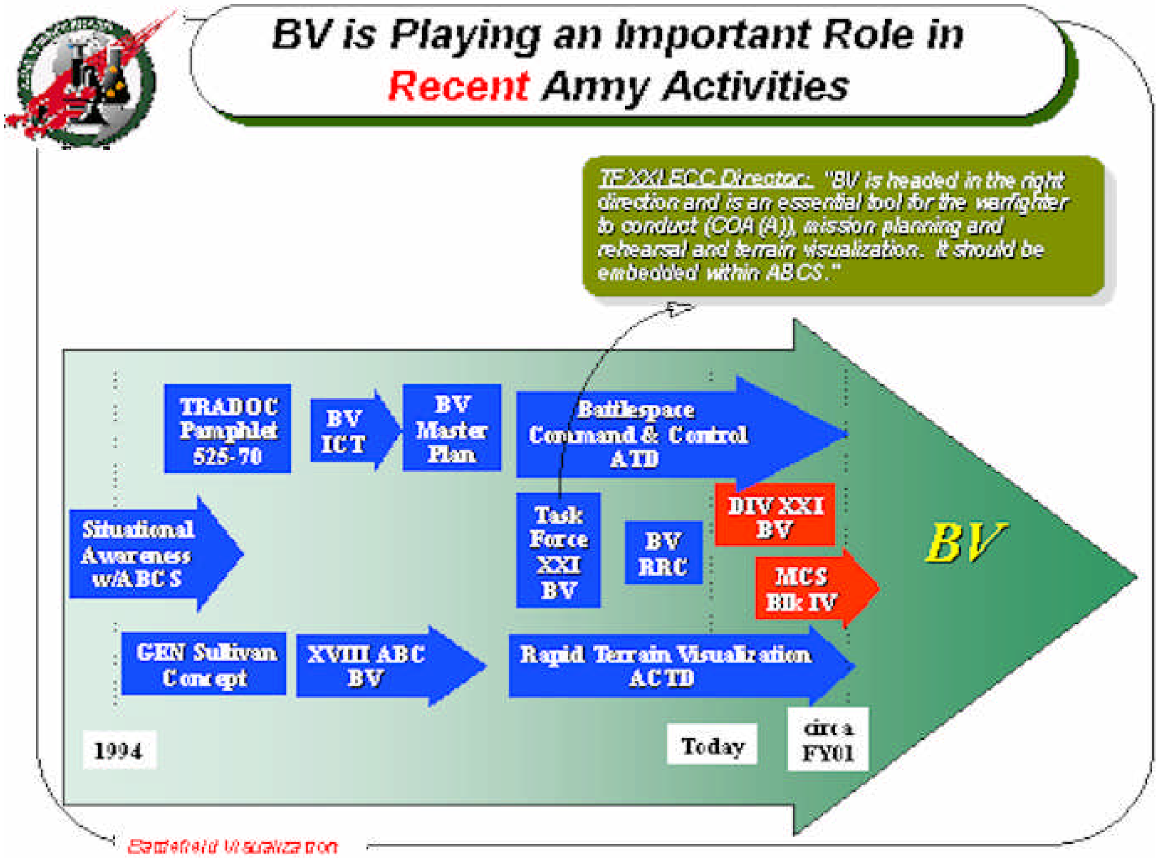
One Commander's Thoughts on BV

"From what we have learned so far with Battlefield Visualization, XVIII Airborne Corps will always incorporate this technology into our Tactical Operations Center. With continued research and development, BV will prove essential to our planning, rehearsing, and executing military operations."

LTG Jack Keane
Commanding General
XVIII Airborne Corps

Battlefield Visualization

The ultimate consumer of BV capabilities is the commander. Rather than attempting to quantify the value of BV, opinions on the value of BV by actual warfighting commanders were sought. Nothing but praises for planned BV capabilities were found. The most supportive thoughts about BV came from LTG Keane, CG XVIII Airborne Corps. The XVIII Airborne Corps has been experimenting with BV capabilities for the past several years. LTG Keane has directly observed BV benefits in XVIII Airborne Corps exercises since 1995. Interest in BV by warfighters such as this support the Army's pursuit for deploying BV capabilities.



A chronicle of efforts relevant to BV puts into perspective the important role BV is playing in recent Army activities.

- Prior to 1994, information technology supported BV capabilities through situational awareness. With situational awareness, data about friendly and enemy forces was available from C2 systems that were predecessors and early versions of today's ABCS components. Icons for friendly and enemy units are overlaid on digitized maps with information systems.

- GEN Sullivan, while CSA, is often credited for conceptualizing how corps commanders might employ information technology to better the MDMP. Based on GEN Sullivan's concepts, experimentation with BV began at the XVIII Airborne Corps. LTG Paul E. Menoher, Jr., while DCSINT, is often credited with orchestrating that experimentation through efforts by the 525th Military Intelligence Brigade. These efforts are substantial and continue today.

- In October 1995, TRADOC published the pamphlet on BV and initiated the BV ICT that continues to operate today. Through the efforts of the ICT, drafts for a BV master plan were staffed.

- The Task Force (TF) XXI AWE, in March 1997, investigated digitization concepts and included limited experimentation with BV capabilities. During the AWE, the division G2 cell used the Battle Planning and Visualization (BPV) system and other applications supporting BV processes. The XVIII Airborne Corps assisted the division G2 cell in using the capabilities and staged their own BV capabilities at Edwards Air Force Base in coordination with the AWE. The quote in the above figure by the TF XXI Exercise Coordination Cell (ECC) Director provides another very positive perspective for BV.

- In March 1997 a Requirements Review Council with GEN Reimer, CSA on BV was held. At that meeting the Battlespace Command & Control (BC2) Advanced Technology Demonstration (ATD) and Rapid Terrain Visualization (RTV) Advanced Concept Technology Demonstration (ACTD) were identified as S&T programs that were developing information technologies for BV.

- Experimentation with BV was conducted during the DAWE. Special interest was drawn to a room of a TOC affectionately referred to as the "Bat Cave." A very large wall screen display was used for briefings. MCS and BPV were among systems driving the display.

- Emerging software and hardware for BV is planned to be incorporated into Block IV of MCS currently under development and expected to be fielded in FY01. PEO C3S plans to leverage the infrastructure from MCS Block IV in all ABCS components. With this approach, BV capabilities will be available through all fielded ABCS components. The ASB panel urged CECOM RDEC and PM ATCCS, responsible for the BC2 ATD and MCS respectively, to ensure their work was properly synchronized to ensure ATD developments could be leveraged in future MCS developments.

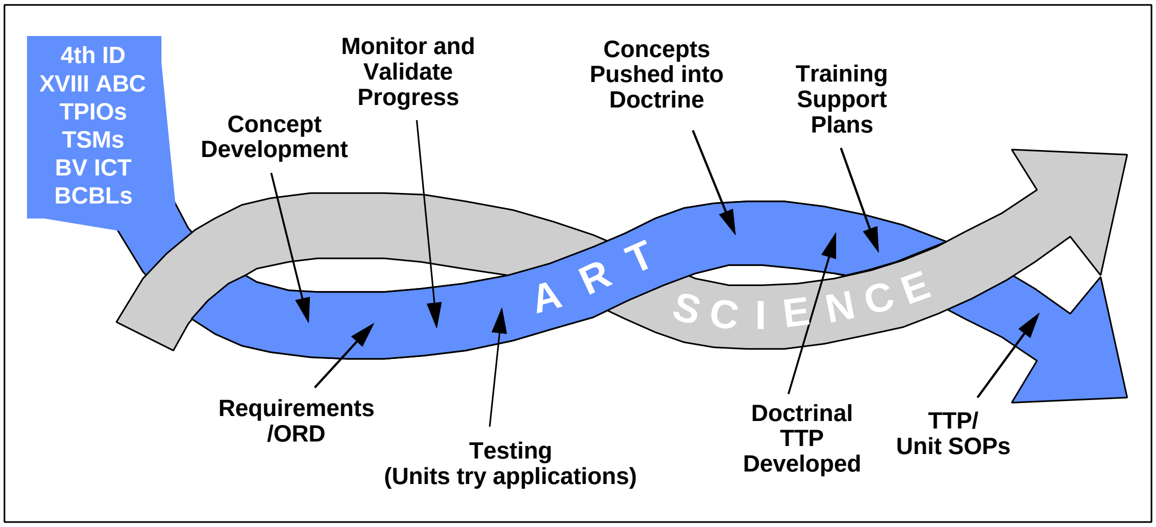
Emerging Vision Of BV

- **Vision for enhanced BV includes:**
  - **<u>Science</u>:**
    - **to create synthetic representations**
    - **to provide automation for planning steps**
  - **<u>Art</u> to use it effectively**
- **BV is for:**
  - **Commanders and staff of all types of units**
  - **All mission types**
  - **All echelons**
- **BV is used in all phases of command**
  - **Mission planning**
  - **Mission rehearsal**
  - **Execution monitoring**

We focused on BV science!

Battlefield Visualization

BV involves both science and technology along with military art. BV science is an enabler of BV art. Science supports the creation of synthetic or virtual representations of the battlefield and battle activity, and provides automation for planning steps i.e., conceiving of sequences of activities leading to a desired, future end state. BV science provides tools and processes to help warfighters extract wisdom from data. Art is critical as it is the method by which warfighters effectively use the science. Methods for developing art are relatively immature and as a result the Army has made substantially less progress with BV art. Art must evolve in tandem with science. As shown in the following figure, warfighters and TRADOC must evolve BV art along with the developments for BV science. The following figure also identifies opportunities for evolving BV art in synchrony with the development of BV science. The ASB study panel focused on BV science since it had greater expertise available in related matters of science.



Art Must Evolve in Synchrony with Science

BV helps commanders command *better*. A common misunderstanding is that BV is principally for intelligence officers in a corps headquarters fighting a major regional conflict (MRC). Although early BV experimentation was with the G2 of the XVIII Airborne Corps, BV has much broader relevance. BV can benefit commanders and staffs of all types of units, at various echelons. Commanders and staffs involved in limited regional conflicts (LRCs) and operations other than war (OOTW) can also beneficially use BV processes. Functions for visualizing the current battle can also support battalion and company commanders.

BV processes and capabilities can be employed in all phases of command.

- During mission planning:
  - the synthetic environment is used to render the battlefield's terrain with impacts of weather forecasts,
  - past battle activities are reviewed using the synthetic environment, and
  - COAs are developed, analyzed and evaluated.

- During mission rehearsal:
  - the selected COA is presented to subordinate commanders to convey the commander's intent and

- subordinate commanders and their staffs review detailed aspects of the selected COA.

- During battle execution:

  - updates of battle command data are monitored using a synthetic environment which provides a level of detail not previously attained, and

  - flagging for replanning and logistic status checks are triggered based on incoming BV data.

It was found that many within the Army believed the advent of BV will be post 2000 resulting from enabled technology. However, BV exists today, supported by situational awareness capabilities. BV has historically been a part of military art and science.

BV Foundation

- **Presentation of battle activity**
  - **Available battle command data is transformed**
    - **Commanders and staff can extract knowledge and find insights more efficiently and more easily**
  - ***Terrain data is necessary***
  - ***Synthetic environment is the principal software capability***
  - **Warfighters get:**
    - **Computer graphic renderings**
    - **Fly-through space and time**

- **Planning and collaboration capability**
  - **Make each step of the decision process easier**
  - **Collaborative application supports iterative discussions and reviews of mission planning products by the staff**
  - ***Course of action (COA) development and analysis is the principal capability***

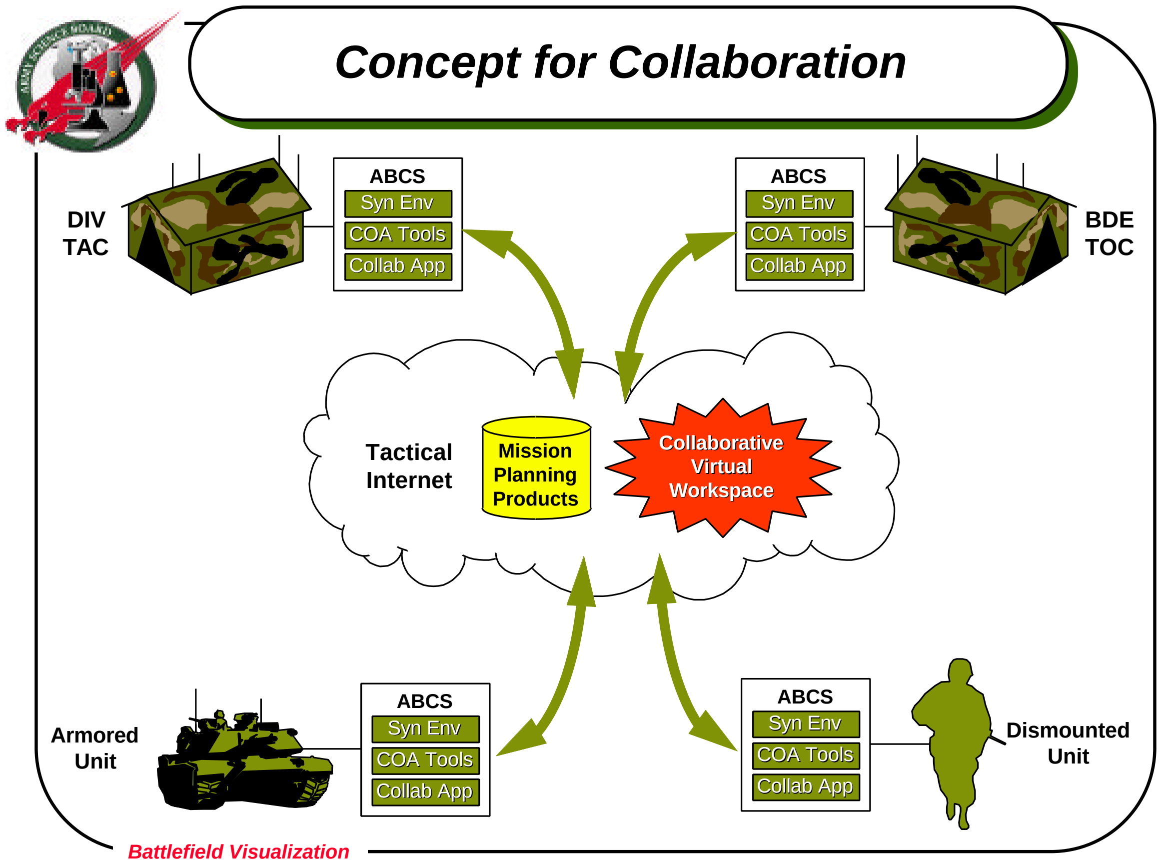
Battlefield Visualization

From the definition of BV, two major functions form its foundation. BV capabilities must support: (1) the presentation of battle activity and (2) planning and collaboration. Although the functions are distinctly different, commanders and staffs will use them seamlessly.

To present battle activity, *available* battle command data is transformed so commanders and their staffs can extract knowledge and find insights more efficiently and more easily. BV takes advantage of battle command data and does not require new sensors and communication capabilities specifically for itself. Since BV is subsumed into BC, new sensors and communications pipes might be required for *battle command*, but should not be required for BV. Terrain data is the backdrop for the synthetic environment. Just as maps are the crucial backdrop for television meteorologists, terrain data is crucial for rendering of the synthetic battlefield environment. Terrain data is essential to planning by providing important relevant data for trafficability assessments, barriers and obstacles, etc. Software for the synthetic environment is the principal enabler for presenting battle activity. With the BC (i.e., red and blue), terrain and weather data, and the synthetic environment software, warfighters get a computer graphic rendering of the battlespace in which they can fly-through in space and time.

The planning and collaboration capability supports mission planning for each step of the military decision process, and coordination and review of mission planning products. A network-based collaborative application supports iterative discussion and reviews of mission planning products between commanders and staffs. Automation supporting COAs is the “long pole” in a BV planning capability. The following chart illustrates the study panel’s concept for collaboration.

The ASB study panel elected to focus on a technology insertion strategy for terrain data, synthetic environment, and COA development and analysis in this study. The panel believed these three technology areas should become the critical paths for Army BV.



The concept for collaboration assumes all commanders and their staffs have access to ABCS components. The ABCS components would all have compatible and interoperable software for the synthetic environment, COA tools and collaboration. The ABCS components in TACs, TOCs, and weapon platforms along with those carried by dismounted soldiers would have connectivity to the Army's Tactical Internet (TI). The TI supports communications and networking for all echelons, extending from the Standard Tactical Entry Point (STEP), to the Mobile Subscriber Network (MSE), down to the support for the Force XXI Battle Command for Brigade and Below (FBCB2). Mission planning products, e.g., operational plans (OPLANs), prepared in the Division TAC could be disseminated via the TI. Subordinate commanders would open the products with their COA tools and review details of the plans using their synthetic environment application. A collaborative virtual workspace, much like an Internet *chat room* or video teleconference, would support interactive discussion of the mission planning products among all. Limited bandwidth available at lower echelons may limit some functionality.

Our Assessment of Army BV Efforts

- **Excellent progress!**
- **Today: Army has an *experimental* capability at XVIII Airborne Corps and 4ID**
- **Today's course (with Battlespace C2 (BC2) ATD and Rapid Terrain Visualization (RTV) ACTD):**
  - **Will produce a *limited* capability for visualizing current battle states**
  - **Will not support COA development and analysis**
- **Army can better *exploit* efforts by others**
  - **Other S&T programs (e.g., Extended Littoral Battlespace ACTD)**
  - **Other programs (e.g., NIMA's SRTM; DARPA's COAA; Navy's FTEWA)**

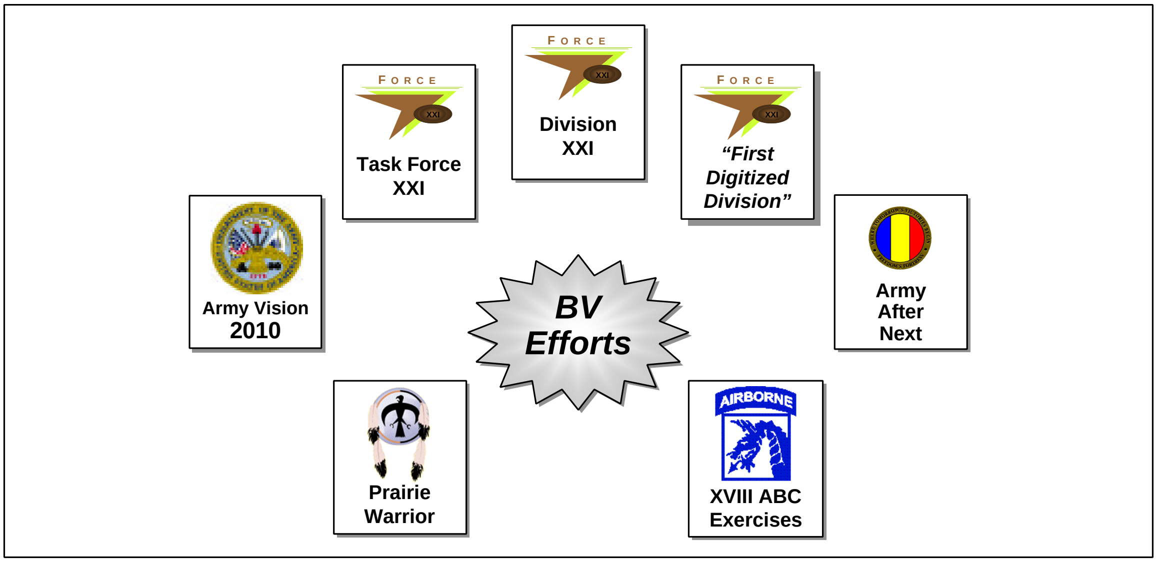
Battlefield Visualization

The ASB study panel finds the Army is making excellent progress with its BV efforts. BV related efforts are having a positive impact on Army visions, experiments and exercises as identified in the following figure. Efforts inside and outside the Army are underway that address, at some level, needed BV capabilities.

However, the Army must be mindful that today, its capabilities at the XVIII Airborne Corps and 4ID are *experimental*. The existing capabilities are beneficial for investigating Army BV needs and processes, and are useful in exercises and experiments. Today's capabilities are not ready for fielding and it will take substantially more progress before the Army has a robust capability that is ready for production and fielding.

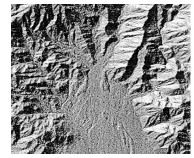
With the BC2 ATD and RTV ACTD, the Army is, today, on course to produce a capability for visualizing current battle states that is *limited* in features and does not address all Army goals. Neither of these efforts will support a complete COA development and analysis capability.

At the beginning of the study in December 1996, the panel found the Army was not doing a good job of coordinating and synchronizing its BV efforts. The panel now finds the Army has corrected this deficiency but can do a much better job of exploiting efforts by others. There are S&T and development programs outside the Army that will produce capabilities that can be used for Army BV, but the Army is not actively seeking out those programs and capabilities. Recommendations are offered in section 3.



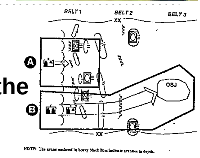
BV Efforts are Contributing to the Army's Evolution

Key Findings



Terrain Data
Key terrain data are not available to provide essential information for the commander's BV.

Synthetic Environment
There is no existing capability to integrate friendly, enemy, terrain and weather data into a single coherent picture which can be displayed and used by the commander for planning and coordination of the battle.



COA Development and Analysis
There are only limited COA development and analysis tools to capitalize on the emerging BV synthetic environment.

Management
Current BV programs are not as well coordinated, focused, and as comprensive as they should be. Army is not organized to take advantage of efforts by others.

Battlefield Visualization

The ASB study panel found three limiting areas requiring substantial technology investment before BV can begin to meet Army expectations for BV. The panel also believes management of BV development by different organizations is not as good as it can be.

- Digital terrain data needed for BV are not available.
- A synthetic environment application which can integrate friendly, enemy, terrain and weather data is not available.
- COA tools are too limited.
- Army programs developing BV capabilities are not well coordinated, and the Army is poorly exploiting efforts by others.

These key findings must be resolved before the Army will have a fieldable BV capability. These findings are critical paths discussed in detail in the sections that follow.

SECTION 2:

BV CRITICAL PATHS

Organization of Presentation

- **Study Background and Summary**
- **BV Critical Paths**
  - **Terrain Data** ✓
  - **Synthetic Environment and Information Visualization**
  - **Course of Action (COA) Development and Analysis**
  - **Management**
- **Summary**

Battlefield Visualization

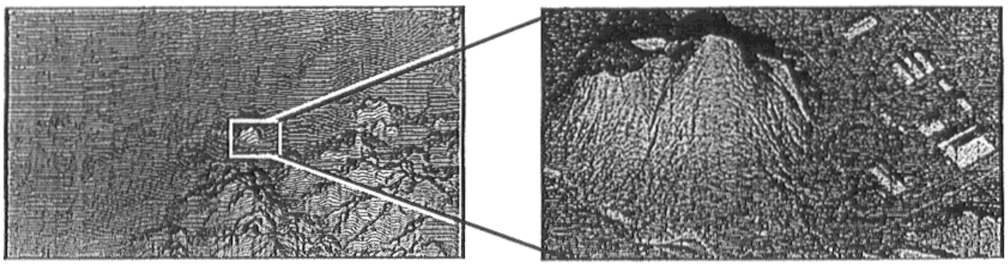
2.1 Terrain Data

Three types of digital terrain data are needed for BV: ***elevation, imagery and feature.*** The Army and DoD lacks adequate data of all three types to support BV. Only three areas have adequate data coverage: the National Training Center (NTC), Bosnia and Ft. Hood. Efforts must be made to ensure the availability or rapid acquisition of all three types of terrain data. Only the requirements for digital terrain data used in BV are addressed herein. Comprehensive Army needs for digital terrain data are not addressed.

Role of Elevation Data in BV

- **Provides basis for 3-D representation of contours**

DTED Level 1 (100 meter) **DTED Level 4 (3 meter)**



Stated Army Requirements:

– **"Digital Terrain Elevation Data Level 2 (DTED 2) (30 m) to support worldwide deployment planning (by 2000)"**

– **"Very high resolution (1-meter) digital topographic data (both *elevation* and feature) to support Force XXI"**

Battlefield Visualization

Elevation data includes the height of the surface of the Earth or of objects, such as buildings or trees, on the Earth at fixed postings. For example, Digital Terrain Elevation Data (DTED) Level 1 provides heights for a grid with posts every 100 meters.

Relevant to BV, elevation data provides the basis for 3-D representation of contours in the synthetic environment. However, elevation data alone does not provide a realistic computer graphic rendering for warfighters, even with graphical texturing.

The above figure illustrates the benefits of higher resolution. On the right, the DTED Level 4 data (3 meter postings) shows buildings to the right of a hill. In contrast, the buildings are not discernible with the lower resolution DTED Level 1 data at 100 meter postings. Intuitively, higher resolution data is more desirable by warfighters, but is more expensive to collect, process and host on computers. With all terrain data types, the lowest resolution data that will adequately meet warfighter needs will best facilitate efficient implementation of BV capabilities.

The Army has stated requirements for elevation data as given in the figure. It is noted that these formal requirements are for *global* terrain. To be more responsive to emerging mission needs, the Army should consider establishing requirements that prioritize geographical areas (based on operational needs) rather than flatly specifying a worldwide requirement. It must be recognized that the Army has needs for digital terrain data beyond that for BV. The Army must coordinate all requirements to support other functions such as targeting.

Role of Imagery in BV

- **Enhances 3-D representation of elevation data**

<u>Stated Army Requirement</u>

Global requirement for 5 m resolution

Battlefield Visualization

Imagery refers to pictures of the Earth, principally taken by satellites or UAVs. Intelligence agencies and commercial firms commonly gather imagery, but their products are not normally processed for inclusion into digital terrain databases.

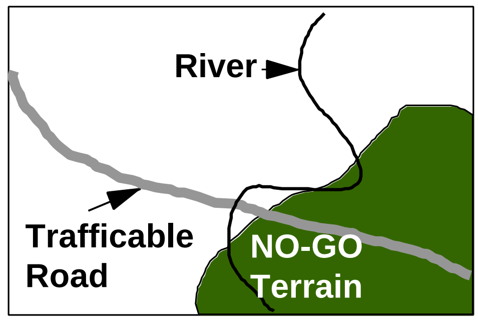
For BV, imagery enhances the 3-D representation of elevation data. Imagery data can be integrated or draped with elevation data to provide better realism for warfighters than textured elevation data alone. In fact, imagery draped over medium resolution elevation data can provide better realism than high resolution elevation data alone. Imagery also supports intelligence preparation of the battlefield, battle damage assessments, etc.

The Army has a stated requirement for imagery as given in the figure. The panel recommends that the Army revisit the requirement and assess whether it adequately supports BV needs.

Role of Feature Data in BV

- **Provides descriptive and location information**
  - **includes: transportation routes, buildings, soil characteristics, etc.**
- **Supports automated analysis regarding impact of terrain on operations**

Example:
M1A1 Trafficability



Stated Army Requirements

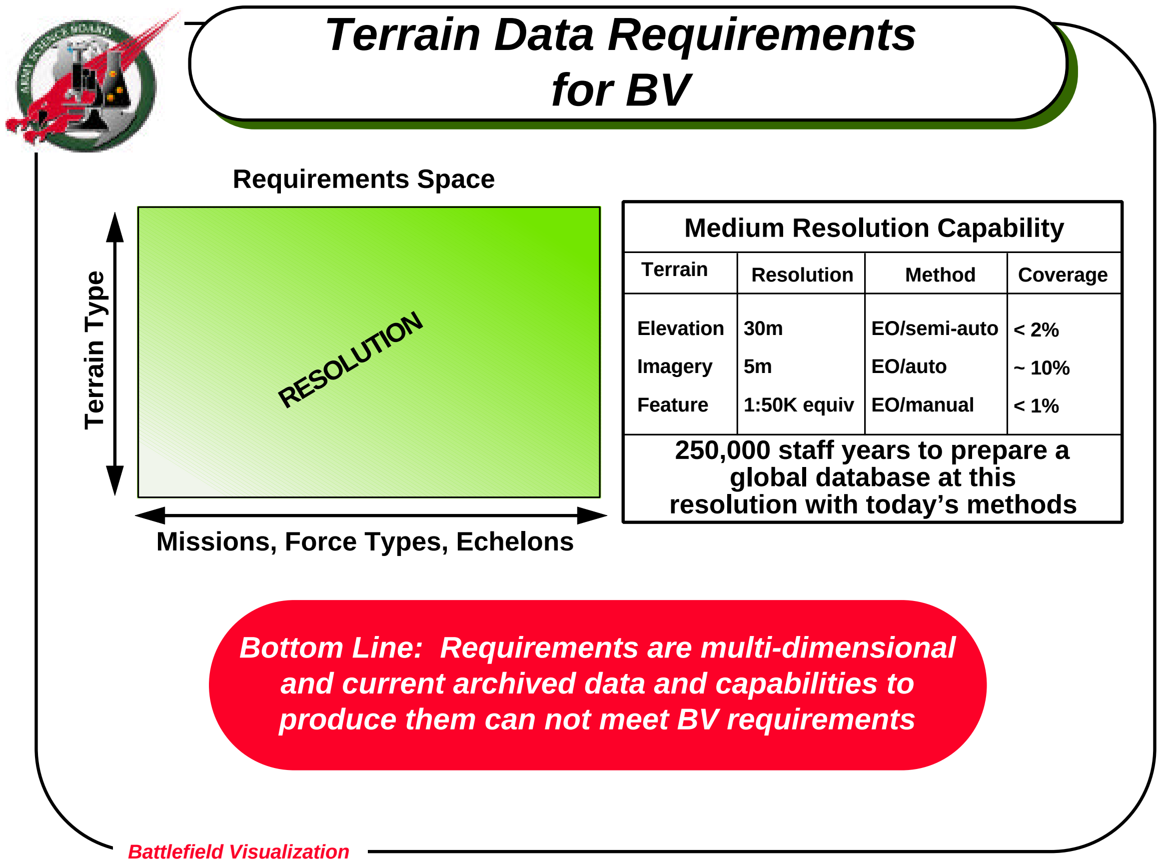
"Very high resolution (1-meter) digital topographic data (both elevation and *feature*) to support Force XXI"

Battlefield Visualization

Feature data provides descriptive and location information about the real-world environment. Feature data, sometimes provided as Digital Feature Analysis Data (DFAD), identifies transportation routes, buildings, soil characteristics, foliage coverage and types,etc. For BV, feature data is integrated with elevation and imagery data for supporting analysis of the impact of terrain on operations.

The figure above presents an example of trafficability for M1A1 tanks. Feature data gives the locations of a road, river and a no-go area (which could be a swamp or minefield). Analysis of the impact of the river and no-go area on an eastward maneuver might indicate the road is a risky choke point.

The Army also has stated requirements for high resolution feature data. The requirement for 1-meter feature data has not been met for any significant portion of the world. Current available technology for the production of high resolution feature data requires a long timeline and is mainly a manual process. Efforts addressing this requirement are not identified. The panel finds that the Army must consider revising its requirement for feature data so that it is realistically achievable.



Medium Resolution Capability			
Terrain	Resolution	Method	Coverage
Elevation	30m	EO/semi-auto	< 2%
Imagery	5m	EO/auto	~ 10%
Feature	1:50K equiv	EO/manual	< 1%
250,000 staff years to prepare a global database at this resolution with today's methods			

The actual resolution needed for digital terrain data types varies depending on the battlespace. For example, the mountainous areas of Bosnia may demand greater resolution than the flat and featureless deserts of Iraq. Similarly, an OOTW needs greater resolution than a MRC. Also, brigade commanders will typically need greater resolution than corps commanders. The panel finds that the Army may be better served with established terrain data requirements varying by mission needs rather than a flat worldwide requirement.

The ASB study panel recommends *medium resolution* terrain data baseline for BV. Higher resolutions may be required for specific mission areas depending on situations cited previously. The recommended terrain data would have 30 m and 5 m resolution for elevation and imagery respectively. Feature data should have sufficient resolution to match a 1:50,000 scale map normally used by the Army. Today, most terrain data is collected by electro-optic means, but the method varies from semi-automatic and automatic to manual for elevation, imagery and feature data respectively. There is very little digital terrain data archived for the Earth at these recommended resolutions. If existing methods are used for collecting and processing the three types of terrain data for the globe at the recommended resolutions, it would take 250,000 staff years to prepare a global database according to NIMA estimates.

The resolution needed for terrain data varies based on multiple dimensions, e.g., terrain type, mission, force type and echelon. Current archived data covers too little of the globe and today's capabilities to collect and process data for remaining parts of the globe will take too long to acquire and are too expensive. The Army must consider alternatives to exploit BV capabilities.

Terrain Data Issues

- *Lack of global terrain data limits opportunities for exploiting BV capabilities*
  - Data available for only a few areas, e.g., Bosnia and NTC
- Employing an Army "contingency" (i.e., just-in-time or rapid response) capability to collect, process and integrate elevation, imagery and feature data for an area of interest is approach to pursue
- Near-term contingency capabilities:
  - ERIM's interferometric synthetic aperture radar (IFSAR) aboard a Lear jet
  - RTV ACTD IFSAR capability aboard a U-2
  - Provide elevation data only and are not assured

Battlefield Visualization

Because of the lack of adequate terrain data, opportunities for exploiting BV capabilities are *very limited*. Data at necessary resolutions are available for only a few areas of interest (AOI), e.g., Bosnia and the NTC.

Rather than seeking global terrain data at the highest requisite resolution, the Army must consider the pursuit of a contingency capability. With the contingency capability, elevation, imagery and feature data for a specific AOI is rapidly collected using sensors, processed into data files and integrated into a geospatial database. The acquisition should take days rather than weeks or months. If BV is an Army priority, the Army must take responsibility for ensuring this contingency capability is available.

The Army has a very limited contingency capability today. The Army can have the Environmental Research Institute of Michigan (ERIM) use its interferometric synthetic aperature radar (IFSAR) aboard a Lear jet to collect elevation data for an AOI that is not under conflict. Through the RTV ACTD, a similar IFSAR capability is planned for a U-2 aircraft. Neither of these capabilities are sufficient because they provide limited resolution elevation data only and are not assured, i.e., the platforms can not be used during conflicts because they are vulnerable to air-to-air and surface-to-air attack. A capability to provide limited feature data should be investigated through the RTV ACTD.

Terrain Data Recommendations

- **Establish within the Army a *tactical* contingency collection, processing and integration capability**
  - **Must be assured, reliable and all-weather**
  - **Identify platforms and sensor suite**
  - **Align RTV ACTD and this initiative**
  - **Establish ground production capability at TEC**
  - **Endorse a *national/strategic* capability**
- **Build global medium resolution terrain database**
  - **Endorse and provide priority to NIMA**
  - **Back completion of Shuttle Radar Topographic Mapping Mission to contain global elevation data by 2001**
  - **Recommend assignment of senior Army personnel at NIMA**
- **Task TRADOC to develop a new requirements statement**
  - **Articulate Army needs for a global medium resolution database**
  - **Develop a comprehensive set spanning spectrum of missions, echelons, force types, and terrain**
- **Establish program at TEC to exploit emerging technologies (e.g., hyperspectral, algorithms)**

Battlefield Visualization

RECOMMENDATION: Establish a Contingency Collection, Processing and Integration Capability

The ASB study panel recommends establishment of a contingency capability to collect, process and integrate elevation, imagery and feature data. The study panel recommends that the Army take responsibility for establishing a capability to ensure timely development and adequate priority in support of *tactical* operations. Alternatively, the Army may endorse NIMA to develop and operate the capability, but the Army takes on the risk of receiving low priority as has happened with past requests. To obtain the assurance, reliability and all-weather capability required, diverse platforms and sensors will be needed. For example, to mitigate vulnerabilities, unmanned aerial vehicles (UAVs) and satellites can augment manned aircraft. Additionally, hyperspectral sensors may be used in addition to IFSAR sensors. Priorities of the RTV ACTD should be aligned with this approach and the level of effort expended on the automation of processes for generating feature data should be commensurate with the effort on automation for the generation of elevation data. Achieving the capability to rapidly produce data sets for three components of the digital terrain database is essential for meeting the stated objectives of the RTV ACTD. The processing and integration of data can be accomplished at a single production facility in the continental United States (CONUS). A production facility by the Topographic Engineering Center (TEC) could support worldwide deployments using satellite communications connectivity of the Global Broadcast Service (GBS). The Army should endorse the establishment of a capability to meet broad national/strategic needs for digital terrain data. Funding of $50M over three years is recommended with lead responsibility given to the JPSD PO.

RECOMMENDATION: Global Medium Resolution Database

The Army should set a high priority on working through NIMA to ensure that a global digital terrain data set at medium resolution is developed by 2002. The first step in this initiative should be the establishment of requirements that are clearly stated in the context of the Army BV needs for the various echelons, missions and types of forces. The recommended database will be a *melting pot* populated with archived data and new data collected and processed in the course of executed missions, experiments and exercises. The objective of building a worldwide digital data set that can be readily fused with other battlefield data can be accomplished in five (5) years under the following conditions and assumptions:

a) The work should be done using the expertise of NIMA and be undertaken soon by aggressively exploiting the limited elevation and imagery data now available.
b) A reliable and survivable platform will be available for data collection over most of the world. The Shuttle Radar Topographic Mapping Mission (SRTM) (under development by NIMA) will be launched in FY99 and should provide medium resolution IFSAR elevation data for 80% of the Earth's surface. The Army needs to be a proponent for SRTM and urge NIMA to adhere to the current schedule.
c) The Army works with the Joint Staff (JS) to establish support for assigning high priority at NIMA for the production of the medium-resolution global digital terrain data set.
d) Senior Army personnel are assigned to NIMA to serve as an effective bridge for collaboration and communication between the user (Army) and the supplier (NIMA) of the terrain data products.

RECOMMENDATION: Terrain Data Requirements Statement

We recommend that TRADOC be tasked to develop and disseminate a comprehensive statement of the Army requirements for digital terrain data. The statement should present requirements in terms that are quantifiable and operationally meaningful to users at each echelon. Funding of $10M over two years is recommended with lead responsibility given to TRADOC.

RECOMMENDATION: Emerging Technology Exploitation

It is recommended that the Topographic Engineering Center (TEC) be tasked and funded to develop a capability that will accelerate the production of elevation and feature data sets from electro-optical and IFSAR measurements. This effort should be coordinated with related work being done at NIMA. Also, emerging technology developments in industry and universities should be exploited. TEC should solicit white papers and use these as means for identifying potential contributors and specific technologies that are likely to lead to automation of key portions of the data processing currently done manually. Funding of $40M over five years is recommended with lead responsibility given to TEC.

Organization of Presentation

- **Study Background and Summary**
- **BV Critical Paths**
  - **Terrain Data**
  - **Synthetic Environment and Information Visualization** ✓
  - **Course of Action (COA) Development and Analysis**
  - **Management**
- **Summary**

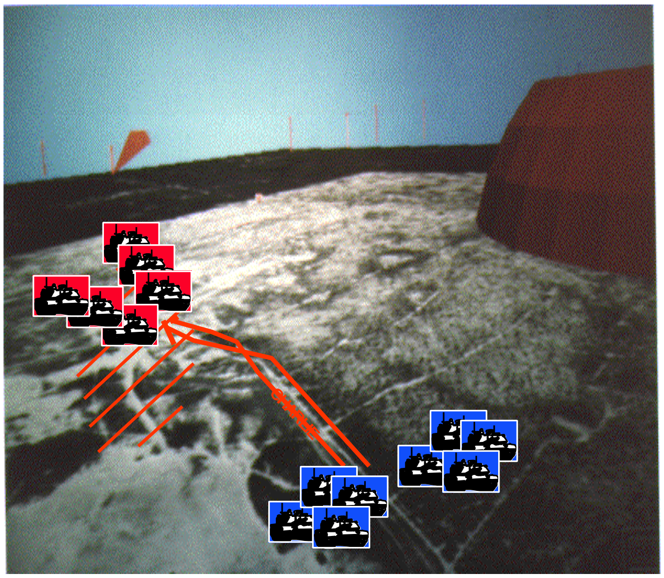
Battlefield Visualization

2.2 Synthetic Environment and Information Visualization

"Synthetic environment" (SE) is a term used by the modeling and simulation (M&S) for training community. It refers to the human-computer interface (HCI) for real soldiers interacting in a computer driven virtual simulation. SEs include software applications for the computer graphic rendering of entity activity and movement overlaid on terrain with weather impacts. Hardware displays are another component of SEs. SEs have been used in training systems since the early 1980s and supporting technologies are considered mature. SEs are being incorporated into ABCS to support battle command training. BV capabilities can leverage the mature technologies from SEs for presentation of battle activity to commanders and staffs.

Dr. Gershon (MITRE) described information visualization to the ASB panel as a science that explores methods of presenting data and information in ways that are intuitive and effective. Information visualization is more than a method of computing and more than pretty pictures. It is a process of transforming data, information, and human experiences and emotions. They are transformed into a visual form enabling people to observe, understand, make sense, experience, and feel. Visualization is pursued to communicate information faster, e.g., scanning a picture can be done much faster than reading text. Additionally, humans have a much higher capacity for remembering pictures than words. BV capabilities can leverage technologies stemming from information visualization.

Synthetic Environment & Information Visualization Requirements



- **Software for computer graphic rendering to war-fighters of friendly, enemy, weather and terrain data**
- **Software to store, manage, and integrate all data for a coherent representation of the battlespace**
- **Information is presented to warfighters using all human cognitive processes and senses (e.g., hearing)**
- **Information visualization presentations are tailored for the specific type of force, echelon and mission**

Battlefield Visualization

A typical display from a synthetic environment for BV might render a perspective of the battlefield from elevation data as shown in the above figure. Imagery could be overlaid on the elevation data to provide increased realism. Feature data could also be *overlaid* to support analysis of the impact of terrain on operations. The field of view (FOV) and many other attributes of the display would be controlled by the soldier. The battlefield might be populated with icons representing the location of friendly and enemy units and weapon platforms. BC or common operational picture (COP) data would be the source for unit locations. Icons would be drawn for easy recognition (versus being drawn for realism as is done for training with virtual simulators). Tracks, COA sketches and threat domes for enemy weapon platforms might also be drawn. Weather effects could be represented (although not shown in the above figure).

BV displays will be realized with software, data, hardware and displays. Software creates the computer graphic rendering from data about friendly forces, enemy forces, terrain and weather. Hardware must have adequate performance to support user interactions. A family of displays is needed to support use of BV capabilities in different rugged environments, in TOCs or command vehicles. Displays will need to simultaneously accommodate multiple sources including workstations, UAV video and video teleconferences. Another software function must also be fielded in support of BV displays. Software is needed to continuously “pull” battle command data updates from ABCS components and to frequently “pull” weather data. This software to store, manage and integrate data supports the presentation of the virtual battlespace.

Information visualization techniques must be employed to ensure information is presented in the most intuitive manner for warfighters. Presentations should be tailorable for the type of force, echelon and mission and should have some flexibility to accommodate individual preferences. Hearing, touch and other senses should be used in addition to vision for conveying information.

Validation of the synthetic environment and associated databases is crucial to successful operational use.

Concept for Video Wall

Battlefield Visualization

The study panel proposes Army consideration for a "video wall" to address many display system issues described below. The concept leverages available technologies to support warfighter consumption of large amounts of information without causing overload.

Many video sources will be available to commanders and staffs of digitized forces. In TACs and TOCs, battle captains will have available to them video from a multitude of ABCS workstations, UAVs, video teleconferences and other sources. The additional display of video from BV capabilities makes the challenge more formidable.

It is possible to tile only several video sources in a single display for a small group in a TAC using today’s commercial-off-the-shelf (COTS) products. Technology trends do not suggest adequate improvements in resolution or brightness for this rugged mobile environment in the near or mid term. To meet near term needs the Army should consider alternatives to using one or two COTS projectors or large monitors to meet the challenges for displays in TACs and TOCs.

The resolution needed for displaying computer-generated maps and synthetic environments exceeds the capabilities of readily available commercial-off-the-shelf (COTS) products. The rugged and mobile demands of TOCs and command vehicles further exacerbates the problem. The Army should continue to experiment with COTS products and non-development items (NDIs) being researched through defense labs and agencies. The experimentation should seek to determine how existing and emerging products can best be employed to support collaboration by small groups with five or more individuals such as at the battle captain's desk or in a command vehicle; or for larger groups in TOCS for briefings or mission rehearsals. Experiments have included the use of commercial large wall screen projectors; groupings of several large monitors fed through a video switcher, and use of very large tiled monitors. These experiments have highlighted the importance of display technology to BV, but have yet to point to an obvious best approach.

Directors of broadcast news use multiple standard-size monitors arranged against a wall to preview multiple video sources. The array of monitors display tape, camera, graphic, satellite, broadcast and other feeds. The arrangement of displays is intuitively organized for directors. Directors browse the many monitors to preview sources of for composing the broadcast. This same approach can be leveraged for Army battle captains.

A video wall at the battle captain's desk is an approach for meeting display needs with current technology. At TF XXI, three 35" monitors were used at the battle captain's desk in the division TAC. During the Division XXI AWE (DAWE), a display approach using six tiled monitors was demonstrated in the "Bat Cave." Further experiments with a video wall are recommended to support the refinement of requirements and technical approaches for displays. Emerging COTS projectors and panels, such as from Barco, Hughes-JVC, Digital Projection and Fujitsu, hold the potential for supporting viewing by larger groups. The resolution and brightness they afford may be adequate for displaying maps and synthetic environments in TACs and TOCs at division or corps.

Synthetic Environment & Information Visualization Recommendations

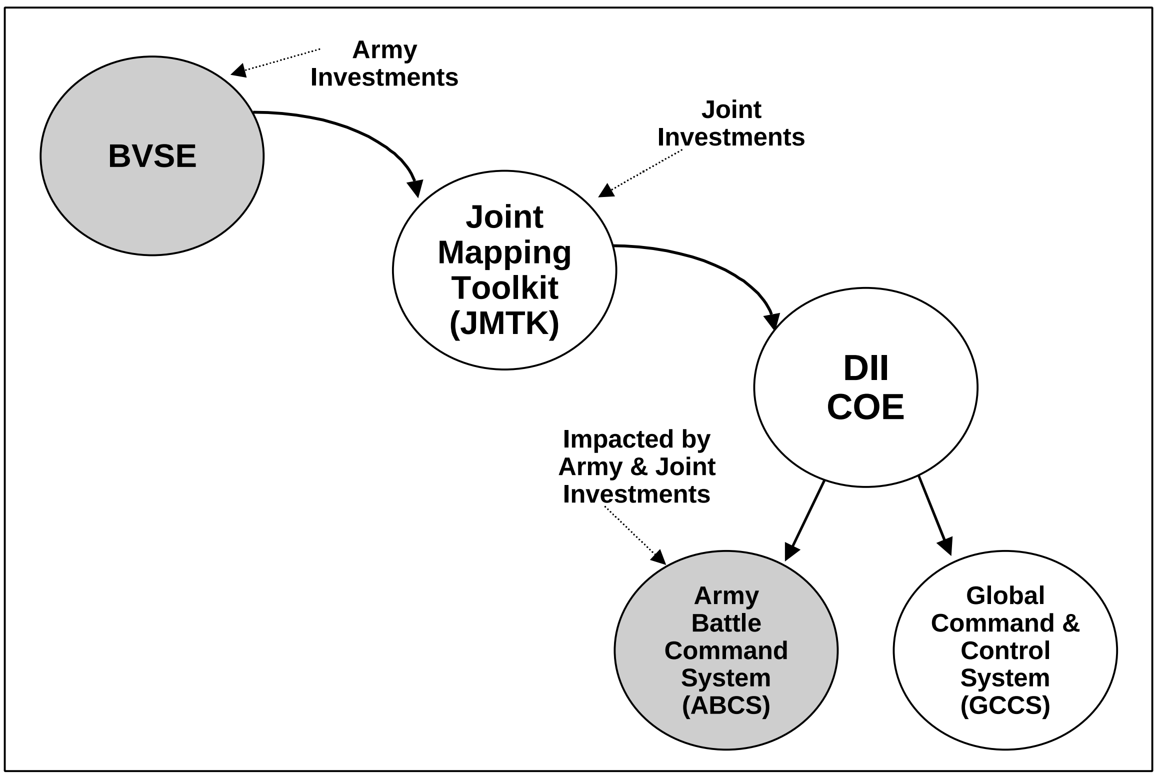
- <u>Develop synthetic environment application</u>
  - Battle Visualization Synthetic Environment (BVSE): software and display capability to be used by warfighters to visualize battle
    - variants for all environments and echelons
  - Leverage from training, entertainment and scientific communities
  - Developments by CECOM RDEC and STRICOM
- <u>Integrate synthetic environment with ABCS</u>
  - Interfaces (e.g., to MCS, ASAS, IMETS): for continuous updates of friendly, enemy and weather data
  - Battle Visualization Database (BVDB): contains all data needed by BVSE
    - data requirements and dictionary established
  - Integration by PM ATCCS
- <u>Continue BV Testbed support</u>
  - At XVIII ABC, 4ID and DIL
  - CECOM RDEC initiative
- <u>Architecture evolution</u>
  - Extend technical architecture, systems architectures and DII COE to accommodate standards, software and capabilities
  - Led by DISC4

Battlefield Visualization

RECOMMENDATION: SE Application

Development of a SE to support BV needs is recommended. The development should produce the Battle Visualization Synthetic Environment (BVSE) which should include software to be used by warfighters. The BVSE must also include all features of a comprehensive human-computer interface (HCI), especially the computer graphic display. Needs for the capability will vary by the operational environment and by echelon. The BVSE should have variants accommodating all environments and echelons; must support appropriate cognitive processes and human senses; and be tailorable for the specific type of force, echelon, mission and commander's preference. Development should leverage experience and products from other communities including the M&S, entertainment and scientific communities. CECOM RDEC and STRICOM should jointly develop the SE supporting BV. Although systems for BV will be fielded by the ABCS or C4I community, the M&S/training community has substantial experience and expertise with SEs and has major programs (e.g., WARSIM 2000) that continue to evolve SEs. Experience with SEs developed through DARPA's Synthetic Theater of War (STOW) efforts should be leveraged. By working together, the Army can eliminate duplication of efforts involving SEs for training and BV. Independent of BV pursuits, WARSIM will bring a SE into Army C4I systems to support BC training. With BV, a second requirement for SE functionality becomes necessary. Although the requirements for SEs by the two communities may differ, it seems reasonable that they can at least leverage the same technologies, infrastructure and expertise. By working together, the SE for BV and SE for C4I training can be common or, better yet, be one in the same. Funding of $50M over a three year period is recommended with lead responsibility given to CECOM RDEC and STRICOM.

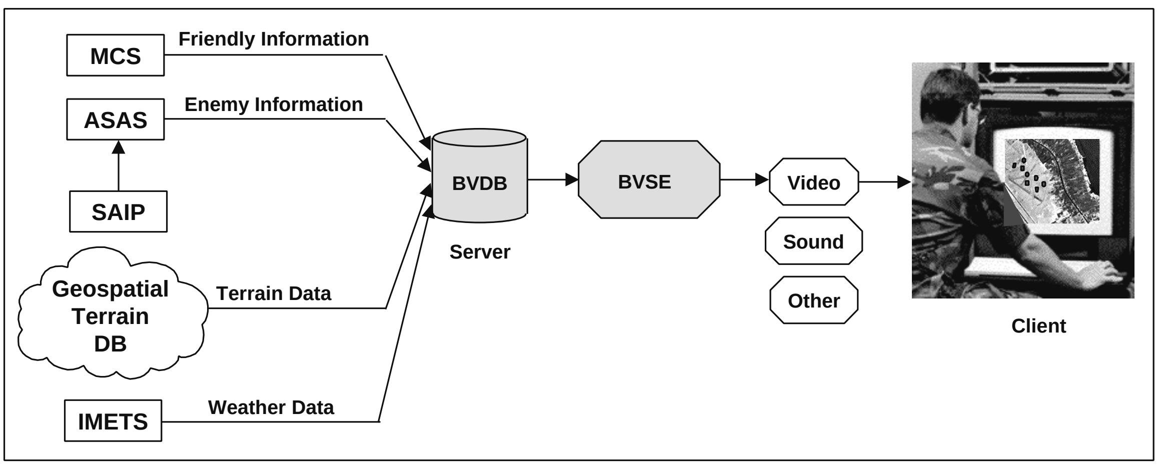
Army SE efforts can be coupled into the Defense Information Systems Agency (DISA) developments for an objective Joint Mapping Tool Kit (JMTK). JMTK currently supports mapping requirements which intersects with many SE capabilities. JMTK will be incorporated into the DII COE which is mandated in the Joint Technical Architecture for the Army (JTA-A). If the Army is successful in getting the BVSE incorporated into the JMTK, all ABCS components will benefit from additional funding by the joint community and other services.



Incorporation of BVSE into JMTK Facilitates Joint Funding

RECOMMENDATION: SE Integration into ABCS

The BVSE must be integrated into the ABCS infrastructure to provide a seamless environment to warfighters. It is recommended that the BVSE pull information on friendly forces from MCS, as MCS is the ABCS component that maintains up-to-date information on friendly forces in TACs/TOCs. Information on enemy forces should be pulled from the All Source Analysis System (ASAS). Automatic target recognition (ATR) capabilities emerging from DARPA's Semi-Automated Image Processing (SAIP) program may additionally provide information on enemy forces. Similarly, the BVSE should pull weather information from the Integrated Meteorological System (IMETS). The development of a Battle Visualization Data Base (BVDB) application is recommended to support data requirements of the BVSE. The database application will interface with the C4I systems to pull information needed by BV clients as shown in the figure below. The database will also manage and store the data. The BVDB precludes each client from needing to pull information from the C4I systems each time new data is required. Data requirements and a data dictionary must be established for this integration. PM ATCCS should be given the integration responsibilities, since that PM is responsible for MCS, ASAS and IMETS. Funding of $45M for three years is recommended with lead responsibility given to PM ATCCS.



BVDB Manages Data for BVSE

RECOMMENDATION: Testbed Support

BV efforts by the XVIII Airborne Corps have demonstrated the value of BV, explored and identified BV requirements, and investigated the utility of related prototype systems. For the next several years, the XVIII Airborne Corps will be the "testbed" for the RTV ACTD. The ACTD has the potential for developing rapid digital terrain data collection and processing techniques crucial for BV exploitation. The 4ID of the III Corps has been a BV "testbed" as the experimental force for the Task Force XXI and Division XXI AWEs. Prototype BV capabilities were used during both experiments by the 4ID. The 4ID will be the first unit to receive fielded digitized systems and systems supporting BV in the FY01 timeframe. The Digital Integration Laboratory (DIL) of CECOM RDEC has supported "testbed" prototyping efforts for both the XVIII Airborne Corps and 4ID. Efforts at each of these testbeds are recommended for continuation. Funding of $50M for five years is recommended with lead responsibility given to CECOM RDEC.

RECOMMENDATION: Architecture Evolution

At the beginning of the study, the ASB panel found disagreement and confusion within the Army BV community over architecture compliance, principally with SE prototypes and their ABCS interfaces. Prototype BV experimentation is subject to the Joint Technical Architecture for the Army (JTA-A) mandate. The panel helped the BV community understand the applicability of the mandate and how to continue its experimentation with the objective of producing compliant information systems. The panel found the JTA-A does not cover some service areas critical to BV. This means other service areas need to be identified along with appropriate standards to ensure technical compliance. Since DISC4 maintains the JTA-A, DISC4 is recommended as the organization to lead modification of the JTA-A to support BV evolution. DISC4 is also recommended to lead the extension of the Army's system architecture to support BV software and capabilities. Funding of $2M for two years is recommended with lead responsibility given to DISC4.

Organization of Presentation

- **Study Background and Findings**
- **BV Critical Paths**
  - **Terrain Data**
  - **Synthetic Environment and Information Visualization**
  - **Course of Action (COA) Development and Analysis** ✓
  - **Management**
- **Summary**

Battlefield Visualization

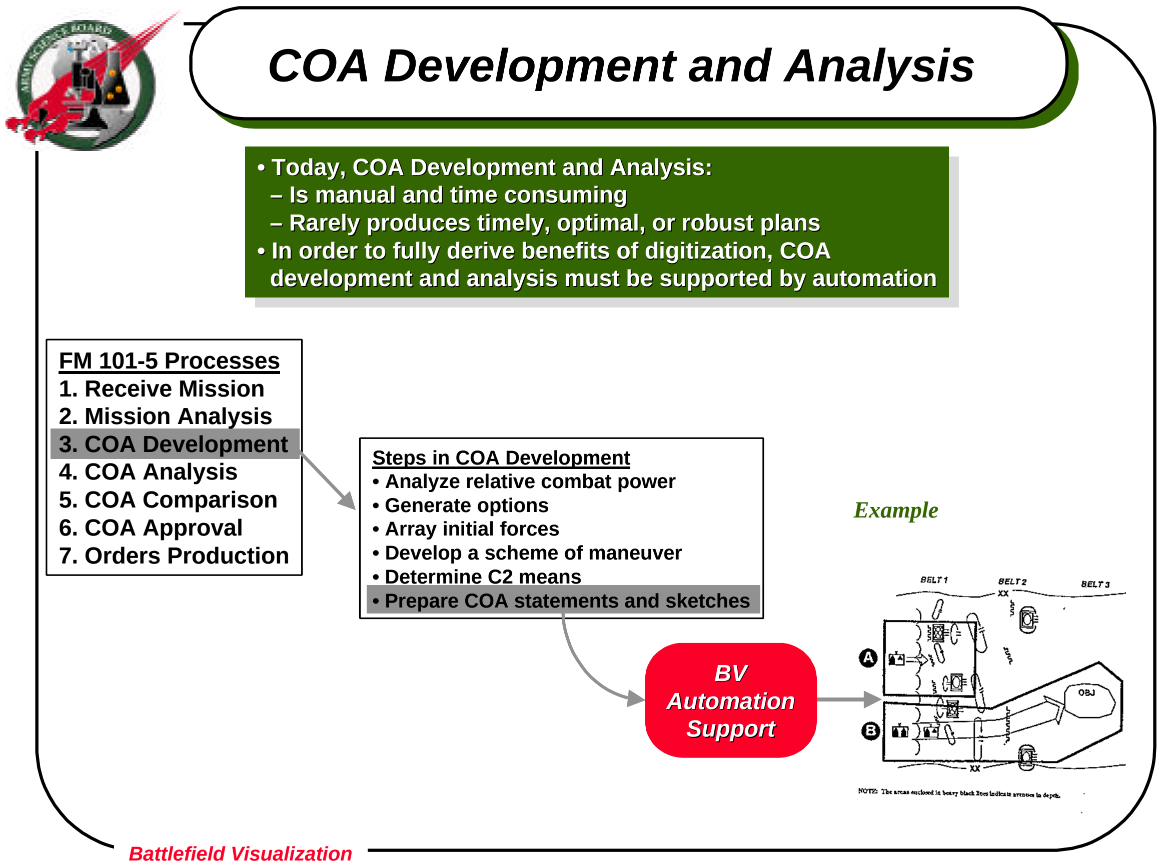
2.3 Course of Action (COA) Development and Analysis

Field Manual 101-5, *Staff Organization and Operations*, is taught to all Army officers at the Command and General Staff College. The document lays out a doctrinal approach to the military decision-making process (MDMP). The deliberate process depends on the thorough examination of friendly and enemy COAs. The following table summarizes the FM 101-5 process. The center column identifies the sequence of the process given staff inputs and outputs identified in the left and right columns respectively. The critical importance of COAs to the process is obvious.

Automation for BC and Force XXI *digitization* supports portions of the FM 101-5 process. BV-related efforts are developing automated tools for steps involving COA. These BV developments are necessary to support the 'envisioning of a desired mission end state' and 'visualizing of sequences of activities leading to an end state' in the BV definition.

Input		Output
• Mission received from high HQs or deduced by the commander/staff	**RECEIVE MISSION**	• Cdr's initial guidance • Warning order 1
• Higher HQ order/plan • Staff estimates	**MISSION ANALYSIS**	• Initial IPB • Restated mission • Cdr's intent • Cdr's guidance • Warning order 2
• Restated mission • Cdr's guidance • Cdr's intent • Staff estimates	**COA DEVELOPMENT**	• COA stmts and sketches • Preliminary movement
• Enemy COA model • COA stmts and sketches • Staff estimates	**COA ANALYSIS (War Game)**	• War game results
• War game results	**COA COMPARISON**	• Decision matrix
• Decision matrix	**COA APPROVAL**	• Approved COA with revised - - Cdr's intent - CCIR • Warning order 3
• Approve COA	**ORDERS PRODUCTION**	• Approve OPLAN/OPORD

Summary of FM 101-5 Process



Critical to the MDMP in FM 101-5 is COA development and analysis as illustrated above. Developing a reasonable set of friendly and enemy courses of action and analyzing them is at the heart of planning and is the spring board for victory in battle.

COA development has six steps, as shown above. The scheme of maneuver is dependent upon the mission and terrain. Factors such as corridor size, obstacles, and trafficability will have a bearing on the schemes developed. Variations in the plethora of variables such as arraying forces on the acceptable corridors, prioritizing fires and considering day/night operations all contribute to a variety of possible courses of action.

Similarly, COA analysis involves a sequence of steps. Included are possible threat responses to the courses of action. When these threat actions are considered, additional variations on courses of action may be developed. This set of alternative future states is further expanded by changes in possible timing of key events, threat behavior, etc. Each of these possibilities must be analyzed and their results portrayed.

A near-term goal of Army BV efforts should be the development of automated tools to facilitate execution of the steps by staffs. This is distinguished from developing software applications that completely automate COA development and analysis steps *without* the staff in the loop. In the example above, a graphic application is used by the staff to prepare a sketch for COA development. This was done by the G2 division staff during TF XXI using the Battle Planning and Visualization (BPV) tool. The sketch was easily prepared and modified and was included in briefings for the battle captain using available equipment. The sketch could be disseminated to subordinate commanders using the Tactical Internet.

As a result of little automation being used in the MDMP today, in the heat of battle, COA development and analysis rarely produces timely, optimal or robust plans. Currently, COA steps are time consuming and manpower intensive for staffs. Further, as was shown in TF XXI, in order to *fully* derive the benefits of digitization, COA steps must be supported by automation to rapidly take action based on current enemy and friendly situation awareness information. The automated support for COAs should lead to better planning and free-up staff for other responsibilities. Additionally, perhaps most importantly, automation may well lead to an evolutionary refinement of the MDMP to produce a superior approach.

COA Development and Analysis Requirements

- **Mission Planning**
  - **Automated support for COA development and analysis**
  - **Modeling for risk assessment**
  - **Collaborative staffing and review of COAs by commander, staff and subordinate echelons**
- **Mission Rehearsal**
  - **Apply COA products to synthetic environment**
  - **4-D fly-through of COA alternatives**
  - **Synchronize staff and subordinate echelons to rehearse as we fight**
- **Execution monitoring**
  - **Near real-time computer monitoring of the battle**
  - **Flag plan variances and aid re-planning**
  - **Continuous assessment and flagging of logistics status**

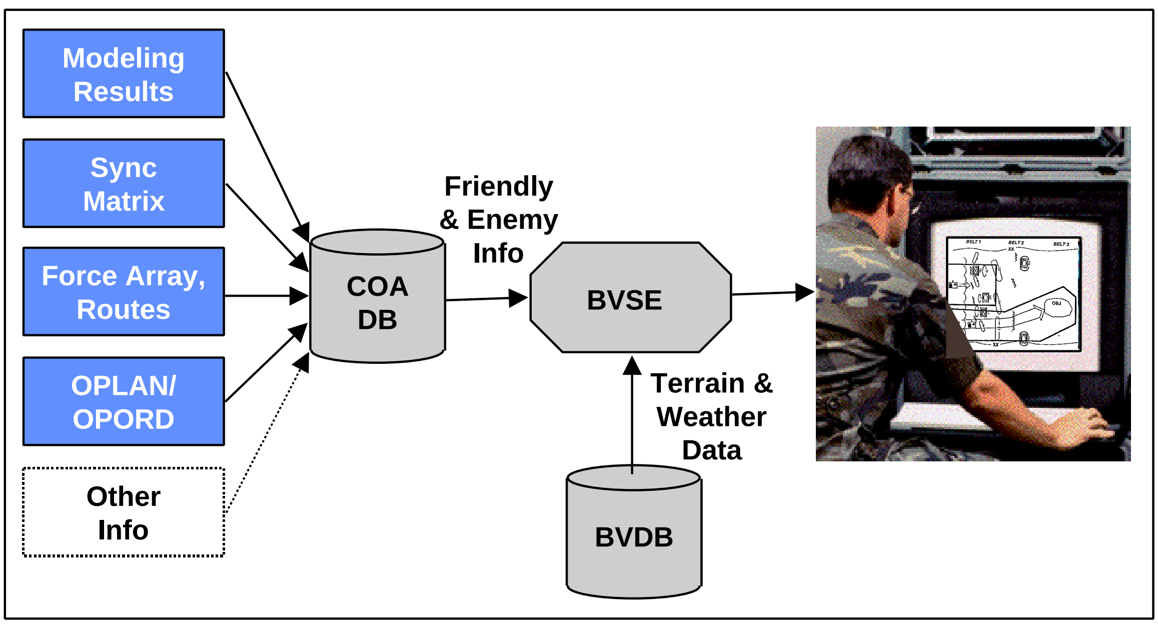
Battlefield Visualization

BV science can potentially support a variety of requirements or functions for COA development and analysis. Requirements are suggested here and are organized by the command activities: mission planning, mission rehearsal and execution monitoring.

COA development and analysis are traditionally considered to be steps conducted for mission planning. With automated BV tools, productivity by staffs should be increased. Functions for COA tools may include:

- Development of combat power values and coefficients of forces
- Preparation of synchronization matrices with triggers for units to aid confirmation that missions are on track
- Array of forces and generation of avenues of approach, formations, logistics re-supply points, and rest stops
- Electronic story boarding and graphical sketching of COA alternatives

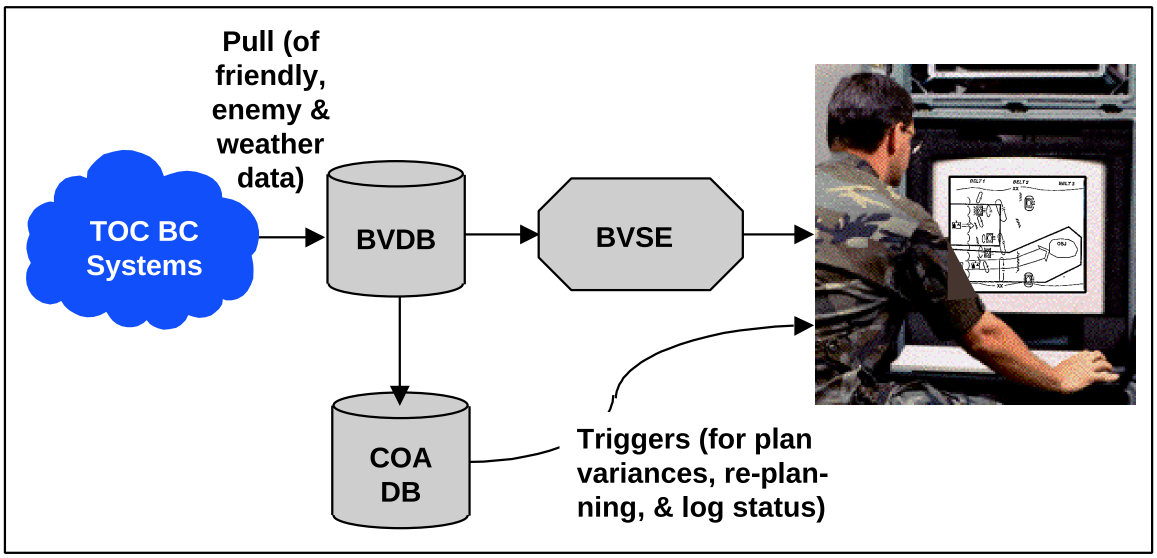
Modeling is needed to assess risks of alternative COAs. The model must use ABCS information and accurate enemy and US weapons systems characteristics and performance data. It is critical that the model address human behavior in combat, be validated and have the analytical rigor of models used by the TRADOC Analysis Center (TRAC). Since the model will be executed during operations, it must be fast running and scenario generation must be easy for soldiers with typical staff backgrounds and require minimal time to setup. The model will portray results for staff review and support sensitivity analyses and plan variations. Existing models to meet these needs could not be identified. Approaches for this modeling is needed to be investigated before developments should commence. The actual development and availability of a BV model is a long term goal. The payoff to mission planning will be more rapid plan generation which, within a given time period, will allow for additional plan iteration. The net result will be a more nearly optimal, robust plan, thereby saving lives and fighting the battle with less total resources. An additional benefit achieved will be to "plan on the move" which relates to increased OPTEMPO. With the network infrastructure of TOCs and the Tactical Internet and COTS teleconference and groupware applications, mission planning can be conducted *collaboratively* among geographically-dispersed and mobile commanders and staffs.



COA Development and Analysis Products are Used With the Synthetic Environment for Mission Rehearsal

During mission rehearsal, products from COA development and analysis can be used with the BVSE by warfighters as shown in the figure above. The friendly and enemy information for the BVSE will come from a COA Database (COA DB) rather than the BVDB. The COA DB will be populated from the modeling results, synchronization matrix, arrayed forces, generated routes, OPLAN/OPORD and other information. Terrain and weather data will come from the BVDB. By flying-through the synthetic environment, warfighters will be able to visualize the commander's intent and gain better insight of planned mission activities. Using the network infrastructure and teleconferencing and groupware applications, groups of warfighters can rehearse *together* to refine details without needing to assemble at one location.

During battle, the BV capability can support execution monitoring as shown in the figure below. The BVDB will be continuously updated with data from ABCS components (e.g., MCS, ASAS and IMETS). With this near real-time BC data, soldiers can fly through a virtual battlefield using the BVSE and reap the benefits of information visualization. Throughout execution, the BVDB is constantly checked against triggers established for units in the COA DB during mission planning. Soldiers can be notified if variances to the COA are triggered. Then, needs for re-planning or checking logistics status can be flagged based on the triggers. The important payoff of execution monitoring would be to accelerate reaction to unplanned events.



Fly Throughs and Triggers are Supported During Execution Monitoring

COA Development and Analysis Recommendations

- Accelerate COA tool development
  - Review and refine requirements
  - Capabilities: development of alternatives; analysis and evaluation; collaborative planning (including Joint); 4-D battle synchronization; monitor, flag, and re-plan the battle
  - Develop an approach for risk assessment
  - Task CECOM RDEC with CAC support
- Leverage DARPA COAA program with Army funding and participation
  - Task CAC, CECOM RDEC
- Support program with DARPA to automate planning for ground commanders
  - Task CECOM RDEC, CAC, DARPA
- Integrate COA tools into ABCS
  - Task PEO C3S/PM ATCCS
- Establish metrics for COA evaluation
  - Initiate an ASB study
- Plan integration of modeling and simulation products (e.g., WARSIM, JSIMS, JWARS)
  - Make TPIO SE, CECOM RDEC, STRICOM responsible

RECOMMENDATION: COA Tool Development

The principal recommendation is that the Army should take the necessary actions to accelerate COA tool development with appropriate priority and adequate funding. This should start with a review and refinement of Army BC requirements for COA tools. This review must span the use of COA in planning and analysis, rehearsal and execution monitoring in order to address the totality of needed tools and their interaction with each other. A long-term goal must be the development of an appropriate model for COA war gaming. The model along with other BV functions should be incorporated into ABCS. CECOM RDEC and TRADOC CAC are already jointly pursuing COA tools. CECOM RDEC is the developer with TRADOC CAC serving the role of customer or "user" representative. CECOM RDEC/TRADOC CAC needs to expand their existing work to aggressively pursue the development of automated COA tools for evaluation in BV testbeds and Army battle labs (e.g., the Battle Command Battle Labs and Mounted Maneuver Battle Lab). Funding of $50M for COA tool development over a 4 year period is recommended with lead responsibility given to CECOM RDEC and TRADOC CAC.

RECOMMENDATION: DARPA COAA Program

The Army needs to be much more proactive in working with DARPA in pursuit of COA tools. DARPA's COA Analysis (COAA) program is the logical starting point for joint efforts. The COAA program was established by DARPA with $7M as a Concept Evaluation Program for execution in the FY97/98 timeframe. The COAA program is examining risk/failure points to mitigate risks and to examine issues associated with linking COA generation with the simulation environment. It should be possible to leverage developments from this DARPA program to an Army program led by CECOM RDEC and TRADOC CAC in the 1999 timeframe. <u>Army funding of $5M over a year is recommended with lead responsibility given to CECOM RDEC and TRADOC CAC.</u>

RECOMMENDATION: DARPA JFLCC DTO

DARPA and the Army should continue their pursuit of a joint program to develop automated planning tools, i.e., the Joint Force Land Component Commander (JFLCC) Defense Technology Objective (DTO). DARPA and the Air Force have embarked on a joint program for the Joint Force Air Component Commander (JFACC) to develop planning tools for the air component. The planning requirements for air and land component commanders differ sufficiently to justify the JFLCC DTO. The proposed program would add a land component to aid in planning joint air and ground operations for any level of crisis. A key difference between Air Force planning and Army planning is directly tied to their differing missions. The Army must plan to seize and occupy territory including urban areas. The joint DARPA/Army initiative should address planning horizontally and vertically down to brigade/battalion. Robust assessment tools for the development and risk assessment of alternative courses of action should be emphasized. <u>Army funding of $10M over two years is recommended with lead responsibility given to CECOM RDEC and TRADOC CAC. DARPA funding of $90M should be considered.</u> Additionally, increased Army participation in joint collaboration planning efforts is recommended.

RECOMMENDATION: COA Tool Integration into ABCS

ABCS components must support a seamless HCI between COA and other BC applications. COA tools must be developed to be integrated with and hosted on ABCS software and hardware. At this panel's urging, CECOM RDEC and PM ATCCS have implemented a plan to integrate COA tools being developed through the BC2 ATD into the MCS infrastructure. All Army developments for COA tools must be similarly integrated. <u>Funding of $28M over five years is recommended with lead responsibility given to PM ATCCS.</u>

RECOMMENDATION: Metrics for COA Comparison

In order to compare one COA against another, metrics are needed. The development of COA metrics will need a concerted effort to define metrics which are quantifiable and reliable for quick measurement of the intrinsic qualities of a COA against another. It is recommended that the ASB investigate COA metrics in a future study.

RECOMMENDATION: Plan Integration of M&S Products

The Army as well as other Services are making considerable investments in the WARSIM 2000, Joint Simulation System (JSIMS) and Joint Warfare System (JWARS). The Army needs to better understand how these efforts can contribute to the MDMP supported by automation. As necessary, the Army must influence the evolution of the joint programs. Modeling is viewed by the ASB as an important component for the development and evaluation of alternative COAs. TPIO-SE and CECOM RDEC need to work with STRICOM to define how simulation can be used to support COA development and analysis and to formulate a plan of action to integrate simulation tools with BV tools.

Organization of Presentation

- **Study Background and Findings**
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- **Summary**

Battlefield Visualization

2.4 Management

Technology pursuits for terrain data, synthetic environment and COA tools should be supported with the combined focused efforts by many organizations inside and outside the Army. New initiatives need to be put in place. Ongoing S&T efforts need to be synchronized and oriented towards rapid fielding of an Army BV capability. Wherever possible, the Army should influence the direction of ongoing Army, joint and national programs towards adding capabilities to BV science so that emerging products can be leveraged and exploited in the future.

Deliberate management actions are necessary to ensure BV technology is efficiently and effectively pursued. With dozens of organizations contributing to BV efforts, a clear understanding of research, developments, funding, and organizational responsibilities and relationships is critical to avoid requirements not being addressed and duplication of efforts. An assessment of management for BV pursuits and management issues are identified. Recommendations for managing BV efforts are proposed herein.

Management

- **Assessment:**
  - **Lots of BV players within the Army**
  - **Key BV activities and players are outside the Army**
  - **ABCS has evolved an effective management structure**
- **Issues:**
  - **Initial coordination was not as good as it could be**
    - ***gotten better -- ASB has helped***
  - **Need to tie on-going and new initiatives into a coherent effort**
- **Recommendations:**
  - **Manage BV within ABCS structure**
    - **Commander CAC, remain proponent for BV**
    - **TPIO ABCS coordinates all activities for Commander CAC**
    - **PEO C3S must lead BV acquisition**
    - **DA staff monitors all of BV with DCSOPS lead supported by DCSINT, DISC4 and SARDA**
  - **Establish "umbrella" program**
    - **address recommendations**
    - **focus Army S&T programs**
    - **influence and leverage external activities**

Battlefield Visualization

The panel found a multitude of organizations within the Army involved with BV. The Army's BV ICT helps guide BV efforts. BV ICT meetings are representative of the wide spread involvement throughout the Army as shown in the table below. Approximately 100 persons from 50 Army organizations attend these meetings. Critical support efforts for BV also come from players outside the Army including NIMA and DARPA. The panel found the existing management structure for ABCS to be effective, and it is evolving to institutionalize the development approach used for the TF XXI AWE.

TPIO-ABCS	DCSINT	PM ATCSS
INTCEN DCD	DCSPER	PM MCS
TRADOC C4I	DA, OCE-P	PM ASAS
NSC	HQ TRADOC	PM FATDS
TRAC	FORSCOM G2	PM TACT
CASCOM	CECOM C2SID	PM CHS
CGSC-CDD	SPACCOM	PM SATCOM
ADACEN DCD	BCBL	I Corsp G3
INFCEN DCD	DBBL	III Corps G3
SIGCEN DCD	BCTP	XVIII ABC G3
FACEN DCD	CHEMCEN	525 MI BDE
ARMCEN DCD	PEO C3S	JPSD
AVNCEN DCD	PEO IEW&S	SSDC
TRADOC BLITCD	TSM MCS	ADO
TRADOC DCSSA	TSM FSC3	USAFISA
TRADOC ODCG-DOC	TSM ASAS	FDD
ENGCEN DCD	TSM TACCOM	CAC
MPCEN DCD	TSM FAADC2	ARL
DCSOPS	TSM CSSCS	OPTEC

Some Organizations Involved with BV Evolution

At the onset of this study, the panel found the Army was poorly coordinated and lacked harmony amongst involved organizations. Over the course of the study, the panel found coordination and harmony within the Army to be greatly improved. Perhaps the ASB panel helped by bringing together Army principals involved with BV to help the ASB with this study. Although the BV ICT is important for managing BV efforts, the panel continues to believe the Army can substantially benefit from stronger ties between its BV-related programs and efforts.

RECOMMENDATION: BV Management with ABCS Structure

The panel recommends that the Army should manage its BV efforts within the ABCS structure rather than a new or modified management structure. Through this structure, the TRADOC DCG CAC would remain as the Army proponent for BV with support from TPIO ABCS to coordinate all activities. Acquisition of systems in support of BV would be led by PEO C3S. At the HQDA level, DCSOPS would lead monitoring of BV efforts with support from the DCSINT, DISC4 and SARDA. As the ABCS management structure adopts the successful TF XXI development approach involving the Central Technical Support Facility (CTSF), BV developments should likewise evolve.

Since the existing management structure is used, additional funding should not be required for managing BV.

RECOMMENDATION: "Umbrella" Program

To provide stronger management for efforts in support of BV developments, a new "umbrella" program is recommended. This program would be established to address the recommendations for terrain data, synthetic environment and COA tools proposed previously and other related initiatives. This program would focus existing Army S&T programs to ensure synchronization of developments and duplications of efforts are eliminated. There are many programs and activities inside and outside the Army that were not initiated to support Army BV goals but which can contribute to those goals. This umbrella program would ensure the Army fully exploits such programs. Through this umbrella, Army interests would be brought to managers of the external activities with the intent of influencing their developments and with hopes that the leveraged results would be more supportive of Army BV goals. CECOM RDEC is recommended to lead this umbrella. A six year program is recommended where the first four years is oriented towards research in the critical paths and developments for fielding. The last two years would be in support of a leave-behind capability for one or more corps. Funding of $16M is proposed for management of the umbrella program. Tech base developments stemming from the program are to transition to PEO C3S for acquisition and fielding. MCS Block IV is the appropriate target for this transition as it is planned to be the infrastructure for all of ABCS.

SECTION 3:

SUMMARY

Organization of Presentation

- **Study Background and Findings**
- **BV Critical Paths**
  - **Terrain Data**
  - **Synthetic Environment and Information Visualization**
  - **Course of Action (COA) Development and Analysis**
  - **Management**
- **Summary** ✓

Battlefield Visualization

The Panel identified four critical paths that should be addressed on the road to a fielded Army BV capability. The preceding material for the critical paths include recommendations for meeting the identified shortfalls in: capabilities of fielded or soon-to-be-fielded systems; technologies needed for integration into systems; and management in focusing associated programs to support Army goals for BV. Each recommendation included a description of efforts to be undertaken; organizations to take lead responsibility; and rough orders of magnitude for the time and funding needed to accomplish the efforts. This summary provides an encompassing perspective of all this information and relates how the recommendations support Army BV goals.

Summary of Recommendations

CRITICAL PATH	RECOMMENDATIONS	RESPONSIBILITY	YRS	ARMY FUNDS ($M)
Terrain Data	Contingency Collection, Processing and Integration Capability	JPSD-PO	3	50
	Global Medium Resolution Database	TRADOC	5	– (NIMA 1,500)
	Terrain Data Requirements Statement	TRADOC	2	10
	Emerging Technology Exploitation	TEC	5	40
Synthetic Environment	SE Application	CECOM RDEC, STRICOM	3	50
	SE Integration into ABCS	PM ATCCS	3	45
	Testbed Support	CECOM RDEC	5	50
	Architecture Evolution	DISC4	2	2
COA Development and Analysis	COA Tool Development	CECOM RDEC, TRADOC CAC	4	50
	DARPA COAA Program	CECOM RDEC, TRADOC CAC	1	5 (DARPA 7)
	DARPA JFLCC DTO	CECOM RDEC, TRADOC CAC, DARPA	2	10 (DARPA 90)
	COA Tool Integration into ABCS	PM ATCCS	5	28
	Metrics for COA Comparison	ASB	1	–
	Plan Integration of M&S Products	TPIO SE, CECOM RDEC STRICOM	1	–
Management	BV Management within ABCS Structure	TPIO ABCS, PEO C3S, DCSOPS	–	–
	"Umbrella" Program	CECOM RDEC	6	16

Army must establish priorities and program multi-year efforts

Battlefield Visualization

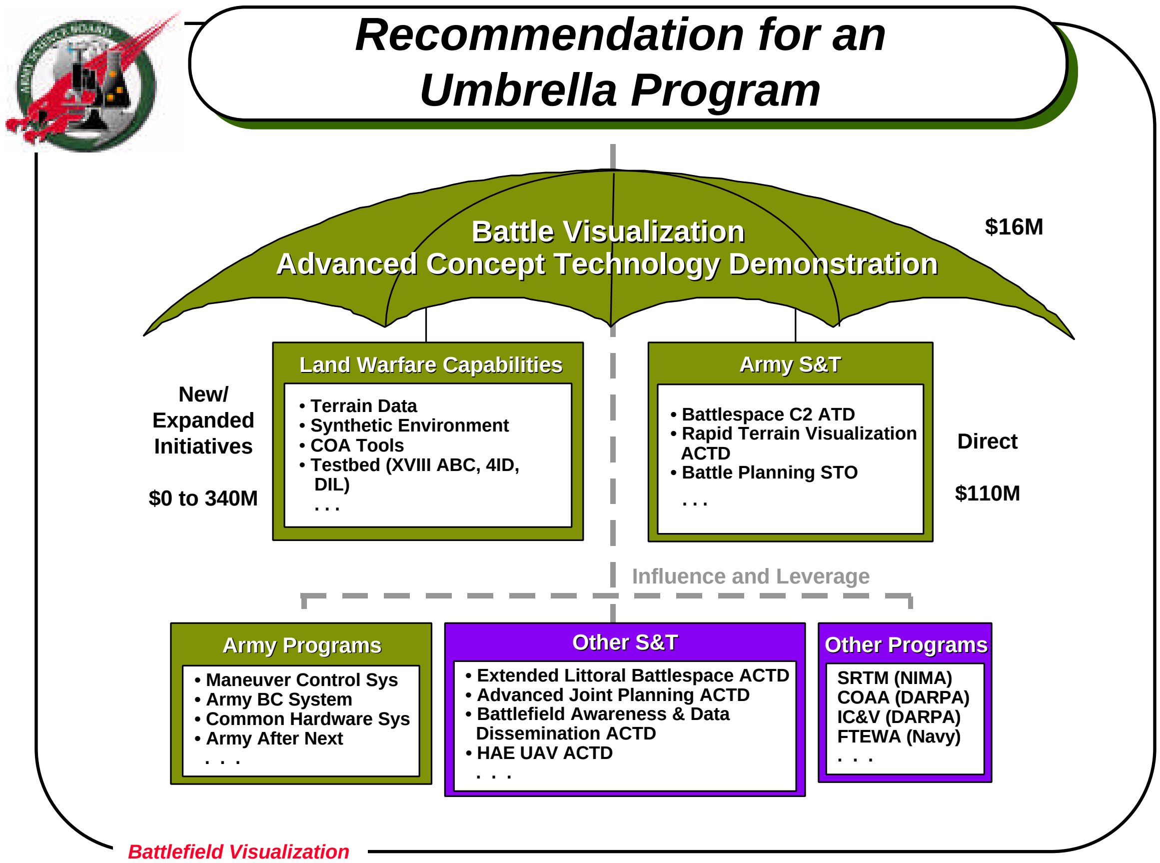
The Army must take responsibility to establish a capability to collect, process and integrate digital terrain data for an AOI in a contingency. This data is merged into a geospatial database that serves as a depository. A set of terrain data is downloaded from this depository for use with ABCS applications to support a specific operation. Digital terrain data requirements to support various types of missions must be identified for the prioritization of terrain data collection. The Army must be proactive in the exploitation of emerging commercial technologies to meet this contingency capability.

An application and display capability must be developed to create a SE from available BC, terrain and weather data. Interfaces to the SE from ABCS components are necessary for pulling near real-time BC data so warfighters can monitor battle execution at resolutions not achievable with today's systems. Continued support of testbeds at the XVIII Airborne Corps, 4ID and DIL will help evolve warfighter requirements and evaluate potential technologies and techniques for BV. The JTA-A and DII COE required for all ABCS components must evolve to support BV.

For better support of the MDMP, development of COA development and analysis tools is recommended. The Army should support and participate in DARPA's COAA program and proposed JFLCC DTO. Successful COA tools should be integrated into the ABCS infrastructure to provide a seamless capability with BC functions. Metrics for comparing alternative COAs are needed. To reuse functionality, the Army must ensure developments for BV are integrated with M&S efforts.

The management structure for ABCS should be used in the oversight of BV developments. An umbrella program is proposed to: initiate developments for technology shortfalls; tightly couple related Army programs; and leverage external efforts. The umbrella should be a ***"program-of-programs"*** that leverages diverse yet related efforts to field early a BV capability.

Although the Army has made excellent progress towards its BV goals, much work remains. The Army can continue on its present course without supporting these recommendations, but the resulting products will be useful only to those units involved with the experimentation and prototyping and will provide a deployable capability only in the long term. The ASB recommendations were crafted to address the *major* technology needs that must be fulfilled in order to meet Army goals for BV. Investments in other technology areas may also be required. The ASB recommends that the Army evaluate the potential benefits of BV towards its information dominance vision and prioritize the ASB recommendations with other funded and unfunded requirements. The recommendations build on one another so if necessary they can be pursued on separate tracks to accommodate the Army's budget process. It is incumbent upon the Army to program the recommendations into a multi-year effort to achieve its goals for BV.



An umbrella "Battle Visualization" program is proposed to address the recommendations for the identified critical paths. The word *battle* is recommended rather than *battlefield* to emphasize the focus on the *engagement* in addition to the *terrain*. A possible form for the umbrella is an ACTD to address the large scale and wide scope of the S&T initiatives and to provide a usable residual capability. The "program-of-programs" structure for the ACTD was borrowed from the Extended Littoral Battlespace (ELB) ACTD. Other program forms may also support the ASB recommendations. The proposed program has a four year main effort with two additional years to support the leave-behind. Management costs for the total six year effort are estimated to be $16 million.

New and expanded initiatives for land warfare capabilities will be undertaken through the umbrella. The new tasks would address some or all of the recommendations proposed in the previous summary chart. If all recommendations are pursued, the initiatives would cost $340 million. The initiatives would address technologies for terrain data, synthetic environment, COA tools, testbeds and others. It is envisioned that the initiatives might be undertaken by different organizations, but management for the umbrella would have responsibility for focusing and coupling the efforts. Management for the umbrella would be responsible to a team of general officers comprised from the ABCS management structure. The ABCS Integration General Officer (GO) - In Process Review

(IPR), comprised of CAC, Army Digitization Office (ADO), PEO C3S, DISC4 and MILDEP SARD, might provide this oversight function.

The umbrella would also *direct* existing Army S&T programs, including the BC2 ATD, RTV ACTD and Battle Planning Science and Technology Objective (STO), totaling $110 million. Management would have the responsibility for *influencing* developments in identified Army development programs (e.g., MCS), S&T programs outside the Army (e.g., ELB ACTD), and development programs outside the Army (e.g., JFLCC DTO).

Conclusions

- **Our recommendations suggest an approach for evolving the Army's capability**
  - **From a diffuse, loosely organized one**
  - **To a cohesive, comprehensive one aimed at early fielding**
- **The recommendations lead to:**
  - **Availability of necessary terrain data and robust synthetic environment tied to real world data**
  - **Automated COA tools**
  - **Management for synchronizing Army efforts, and influencing and leveraging developments outside the Army**
- **Commanders will be able to optimally apply BV capability to support their:**
  - **Mission planning**
  - **Mission rehearsal**
  - **Monitoring of battle execution**
- **Funding ASB proposed BV initiatives is a major step toward information dominance and superiority**

Battlefield Visualization

In conclusion, the ASB recommendations are offered to help the Army in its pursuit of a comprehensive BV capability through efforts aimed at early fielding. The recommendations should lead to the availability of necessary terrain data, a SE fed by battle command data, COA tools and management to synchronize Army efforts and influence and leverage developments outside the Army. With the resulting capability, commanders and staffs will be able to apply BV for mission planning and rehearsal, and for monitoring battle execution. A major step toward information dominance and superiority will be achieved through funding of the ASB proposed initiatives.

A summary of the briefout was presented to GEN Reimer (CSA) on 19 December 1997. In preparation for this briefout the following comments were prepared by LTG Meigs (TRADOC DCG CAC). BG Boutelle (PEO C3S) previewed the comments and concurred. The comments are supportive of the ASB recommendations. During the briefout, GEN Reimer discussed the need for the Army to pursue the recommendations and requested the initiation of the proposed umbrella program.

- **CG, CAC is TRADOC Proponent for Battlefield Visualization**
- **Reviewed Briefing with Dr. Neal on 9 Dec 97**
- **Specific Comments on “Umbrella Program” for Battlefield Visualization**
    - **Agree that there should be an Umbrella Program**
    - **Agree that CECOM RDEC Can Manage the Tech Base Effort**
    - **CECOM RDEC Transitions into PEO-C3S for Acquisition and Fielding (MCS Block IV)**
- **Large Scale Display is a Worthy Effort**
    - **Current Technology Does Not Provide What We Need**
    - **TPIO-ABCS Writing Requirement to Define Tactical Display including Large Scale Display**
- **CAC Supports Developing Data Base and Data Base Manager Which Portrays the Common Picture**
    - **Include “Triggers” to Alert Commander**

TRADOC CAC Comments on ASB BV Briefout

APPENDIX A

TERMS OF REFERENCE

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH DEVELOPMENT AND ACQUISITION
103 ARMY PENTAGON
WASHINGTON DC 20310-0103

REPLY TO
ATTENTION OF

16 JAN 1997

Dr. Michael S. Frankel
Chair, Army Science Board
Research, Development and Acquisition
103 Army Pentagon
Washington, DC 20310-0103

Dear Dr. Frankel:

I request that you initiate an Army Science Board (ASB) Summer Study on "Battlefield Visualization." This study should address, as a minimum, the Terms of Reference (TOR) described below. The ASB members appointed should consider the TOR only as guidelines and may include in their discussions related issues deemed important or suggested by the Co-Sponsors. Modifications to the TOR must be coordinated with the ASB Office.

Background.

a. Battlefield visualization is an important concept for Force XXI operations, It leverages information technology to support the commander's ability to visualize the future battlefield. The Training and Doctrine Command (TRADOC) Pamphlet 525-70 "Battlefield Visualization Concept" explains battlefield visualization as: "The process whereby the commander develops a clear understanding of the current state with relation to the enemy and environment, envisions a desired end state which represents mission accomplishment, and then subsequently visualizes the sequence of activity that moves the commander's force from its current state to the end state." Multiple Army and DOD efforts are directly advancing battlefield visualization capabilities.

b. Efforts are being pursued to mature the 'art and science' of battlefield visualization. The Army is organizing itself to evolve necessary operational concepts and functional requirements, as well as technology requirements. Exemplary initiatives identifying approaches and producing early capabilities are in process: by the TRADOC Program Integration Office - Army Battle Command Systems (TPIO-ABCS); by the 525th Military Intelligence Brigade; and in the Rapid Battlefield Visualization Advanced Concepts Technology Demonstration. Technical and management approaches to develop operational capabilities are being established by the Army in management and master plans.

c. FM 100-6, "Information Operations" defines information dominance as: "The degree of information superiority that allows the possessor to use information systems and capabilities to achieve an operational advantage in a conflict or to control the situation in operations short of war, while denying those capabilities to the adversary." The difference between friendly and enemy battlefield visualization is also considered to be information dominance. Battlefield visualization must include functions that help Army command staff manage and assess information in support of offensive and defensive information operations. Tactics, techniques and procedures (TTP) and unit task organization for information operations must accommodate Army battlefield visualization capabilities.

d. The implementation of the science for Army battlefield visualization will depend on leveraging diverse, advanced information technologies. Some of the relevant technologies will be maturing at the same time the Army is developing its capabilities. An evolutionary approach is needed for architectures and systems to accommodate DOD, Army and commercial technologies and products as they emerge. To effectively field operational capabilities, the Army must take advantage of opportunities in various development programs.

e. The Army Battle Command Systems (ABCS) will provide battle visualization capabilities and will integrate with existing and emerging Army information systems, e.g.: Warfighter Information Network and WARSIM 2000. Since all Army information systems must comply with the Army Technical Architecture (ATA), the Joint Technical Architecture (JTA), and all DOD modeling and simulation systems must comply with the mandated High Level Architecture (HLA) standards, the ABCS must comply with the ATA, JTA and HLA.

Terms of Reference.

a. Identify and review background and ongoing efforts regarding battlefield visualization. Review related Army and DOD documents, initiatives, systems and organizations. Discuss vision and concepts with Army leaders, then comment on issues for a harmonized view.

b. Assess Army operational concepts, functional requirements, technology requirements and developing capabilities which enable visualization of the battlefield. Suggest additional functional requirements and alternative technologies. Also, assess Army progress in, and technical and management approaches for, development and fielding.

c. Validate contributions of planned functions which facilitate battlefield visualization and contribute to the Army's objective of gaining information dominance. Investigate TTP and unit task organization for information operations to take advantage of the new capabilities.

d. Recommend a strategy and roadmap for incorporating maturing technologies into the evolutionary architectures and systems of ABCS. Recommend programmatic pursuits that will support fielding of operational capabilities. Suggest ways the Army might best synchronize its related efforts.

e. Assess plans for integrating capabilities which facilitate battlefield visualization with existing and emerging Army systems and assess compliance of prototype and planned products with the ATA, JTA and HLA.

Study Support. Co-Sponsors of this study will be Lieutenant General Paul E. Menoher Jr., Deputy Chief of Staff for Intelligence (DCSINT); Lieutenant General Otto J. Guenther, Director of Information Systems for Command, Control, Communications, and Computers (DISC4); Lieutenant General Leonard D. Holder, Jr., Deputy Commanding General for Combined Arms, TRADOC; and Major General Ronald E. Adams, Assistant Deputy Chief of Staff for Operations and Plans, Force Development (ADCSOPS-FD). The Staff Assistants will be Dr. Bertram B. Smith, Jr. (ODCSINT), Mr. Errol K. Cox (ODISC4), Mr. Dick Brown (Combined Arms Center, Ft. Leavenworth) and CPT(P) Valerie Jircitano-Garcia (ODCSOPS-FD).

Schedule. The study panel will initiate the study immediately and conclude its effort at the eleven-day report writing session on June 16-26, 1997 at the Beckman Center in Irvine, California. As a first step, the Study Co-Chairs should prepare a Study Plan for presentation to the Co-Sponsors that outlines the study approach and study schedule.

Special Provisions. It is not anticipated that this inquiry will go into any "particular matters" within the meaning of Section 208, Title 18 of the United States Code.

Sincerely,

Gilbert F. Decker
Assistant Secretary of the Army
(Research, Development and Acquisition)

APPENDIX B

PARTICIPANTS LIST

PARTICIPANTS LIST

ARMY SCIENCE BOARD'S

SUMMER STUDY ON

"BATTLEFIELD VISUALIZATION"

Co-Chairs

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Special Assistant for Integrated Army C4I
The MITRE Corporation

LTG Sidney T. (Tom) Weinstein (USA Ret.)
Sr. Vice President
Electronic Warfare Associates, Inc.

ASB Panel Members

Professor Amy E. Alving
Aerospace Engineering & Mechanics
University of Minnesota

Dr. John H. Cafarella
President
MICRILOR, Inc.

Mr. John Cittadino
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JCC Technology Associates, Inc.

Dr. Robert E. Douglas
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ITT Federal Service Corp.

GEN Louis C. Wagner, Jr. (USA, Ret.)
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Gov't Advisors

Dr. James Heath
ODCSINT

LTC Calvin Mayfield
ODISC4

Mr. Kurt Kovac
CECOM RDEC

APPENDIX C

ACRONYMS

APPENDIX D:

GLOSSARY

AAN:	Army After Next
ABCS:	Army Battle Command Systems
ACTD:	Advanced Concept Technology Demonstration
ADO:	Army Digitization Office
AOI:	area of interest
ARL:	Army Research Laboratory
ASA(RDA):	Assistant Secretary of the Army for Research Development and Acquisition
ASB:	Army Science Board
ATD:	Advanced Technology Demonstration
ATR:	automatic target recognition
ASAS:	All Source Analysis System
ASEO:	Army Systems Engineering Office
ATA:	Army Technical Architecture
ATCCS:	Army Tactical Command and Control Systems
ATD:	Advanced Technology Demonstration
AWE:	Advanced Warfighter Experiment
BADD:	Battlespace Awareness and Data Dissemination
BC:	battle command
BC2:	Battle Command and Control
BCBL:	Battle Command Battle Lab
BDA:	battle damage assessment
BPV:	Battle Planning and Visualization
BV:	battlefield visualization
BVDB:	Battle Visualization Database
BVSE:	Battle Visualization Synthetic Environment
C2:	command and control
C3S:	Command, Control, and Communication Systems
C4ISR:	command, control, computers, communications, intelligence, surveillance and reconnaissance
CAC:	Combined Arms Center
CECOM:	Communications Electronics Command
CG:	commanding general
CSA:	Chief of Staff of the Army
COA:	course of action
COAA:	Course of Action Analysis
COTS:	commercial-off-the-shelf
CONUS:	continental United States

COP: common operational picture
CPU: central processing unit
CTSF: Central Technical Support Facility

DARPA: Defense Advanced Research Projects Agency
DAWE: Division XXI Advanced Warfighter Experiment
DB: database
DCG: Deputy Commanding General
DCSINT: Deputy Chief of Staff for Intelligence
DFAD: Digital Feature Analysis Data
DII COE: Defense Information Infrastructure Common Operating Environment
DIL: Digital Integration Laboratory
DISA: Defense Information Systems Agencey
DISC4: Director of Information Systems for Command, Control, Computers and Communications
DoD: Department of Defense
DTED: Digital Terrain Elevation Data
DTO: Defense Technology Objective
DUSA(OR): Deputy Undersecretary of the Army for Operations Research

ELB: Extended Littoral Battlespace
EO: electro-optic
ERIM: Environmental Research Institute of Michigan

FOV: field of view
FTEWA: Force Threat Evaluation and weapon Assignment
FY: fiscal year

GBS: Global Broadcast Service
GO: general officer

HCI: human-computer interface
HLA: High Level Architecture
HQDA: Headquarters Department of the Army

ICT: Integrated concept team
IEW&S: Intelligence, Electronic Warfare and Sensors
IFSAR: interferometric synthetic aperature radar
IMETS: Integrated Meteorological System
IO: information operation
IPR: in process review
ISO: Information Systems Office

JCOS: Joint Countermine Operational Simulation

JHU APL:	Johns Hopkins University Applied Physics Laboratory
JFACC:	Joint Force Air Component Commander
JFLCC:	Joint Force Land Component Commander
JMTK:	Joint Mapping Tool Kit
JPSD-PO:	Joint Precision Strike Demonstration Project Office
JS:	Joint Staff
JSIMS:	Joint Simulation System
JTA:	Joint Technical Architecture
JTA-A:	Joint Technical Architecture - Army
JWARS:	Joint Warfare System
LAN:	local area network
LRC:	limited regional conflict
m:	meters
M&S:	modeling and simulation
MCS:	Maneuver Control System
MDMP:	military decision-making process
MILDEP:	military deputy
MOOTW:	military operations other than war
MRC:	major regional conflict
NDI:	non development items
NIMA:	National Imagery and Mapping Agency
NSC:	National Simulation Center
NTC:	National Training Center
ODCSINT:	Office of the Deputy Chief of Staff for Intelligence
ODISC4:	Office of the Director of Information Systems for Command, Control, Computers and Communications
OOTW:	operations other than war
OPLAN:	operational plan
OUSD:	Office of the Under Secretary of Defense
PEO:	Program Executive Office
PM:	Program Manager
QDR:	Quadrennial Defense Review
RDEC:	Research, Development and Engineering Center
RMA:	revolution in military affairs
RRC:	Requirements Review Council
RTV:	Rapid Terrain Visualization
S&T:	science and technology

SAIP:	Semi-Automatic Image Processing
SARD:	
SE:	synthetic environment
SRTM:	Shuttle Radar Topographic Mapping Mission
Starlite:	Surveillance, Targeting and Reconnaissance Satellite
STO:	Science and Technology Objective
STOW:	Synthetic Theater of War
STRICOM:	Simulation, Training and Instrumentation Command
TAC:	tactical center
TEC:	Topographic Engineering Center
TF:	Task Force
TI:	Tactical Internet
TOC:	tactical operations center
TOR:	terms of reference
TPIO:	TRADOC Program Integration Office
TRAC:	TRADOC Analysis Center
TRADOC:	Training and Doctrine Command
TSM:	TRADOC Systems Manager
TTP:	tactics, techniques and procedures
UAV:	unmanned aerial vehicle
USA:	United States Army
USAF:	United States Air Force
VCSA:	Vice Chief of Staff of the Army
VDISC4:	Vice Director of Information Systems for Command, Control, Computers and Communications
WAIC:	Warfighter Analysis and Integration Center
WAN:	wide area network
WARSIM:	Warfighter Simulation

APPENDIX D

BV AFTER NEXT

APPENDIX D:

BATTLEFIELD VISUALIZATION AFTER NEXT

by William J. Neal, Ph.D.

1. Introduction

In today's Army, i.e., the ***Army of Excellence*** (AOE), staff operations and information systems are employed which support battlefield visualization (BV) by commanders and staffs. On-going Army experimentation, science and technology (S&T), and prototyping for BV is producing enhanced warfighting capabilities that will be candidates for future fielding in the Army of the 21st century. For ***Army XXI***, i.e., the doctrine, training, leaders, organization, materiel and soldiers (DTLOMS) for the Army of 2010, art and science for BV will be enabled by information technologies emerging from today's efforts. In addition to developments being made for Army XXI, the Army is engaged in the ***Army After Next*** (AAN) project which is conceptualizing DTLOMS for land warfare beyond 2010 and out to 2025. Goals for AAN include identifying S&T initiatives and experimentation that might lead to far-term capabilities. Considerations for future BV capabilities are being investigated in AAN conceptualization. Potential BV capabilities, over the transition from the AOE to Army XXI, and through to AAN, are addressed here. Concepts for BV in the AAN timeframe are offered to stimulate endeavors for future experimentation, S&T, and prototyping. The perspective of an AAN-era commander is used to contrast differences in BV capabilities available for today's AOE, tomorrow's Army XXI, and the future's AAN.

2. Terrain Data

Computer graphic rendering of battle activity with synthetic environments is generally assumed as a key function of BV. Terrain data is crucial to this function. Available terrain data that is potentially useful for a mission: may come from different types of sensors and previously collected for different purposes; may have different resolutions; and may have different data formats. ***Global geospatial databases*** could serve as a depository from which terrain data relevant to a mission could be quickly extracted. Particularly for contingency operations, the organization of terrain data using distributed databases will accommodate responsive access to consistent, authoritative and accurate information needed for unanticipated areas of interest. Global geospatial databases will grow substantially over time as global coverage and resolution of available terrain data increases from the AOE through to AAN. Means for contingency ***collection*** are also critical to ensure terrain data is up to date for specific missions and to accommodate higher fidelity for synthetic environments needed by lower echelons. Army XXI and AAN collection means should afford additional opportunities for contingency collections and greater resolution of collected data. The following subsections predict new capabilities that will support terrain data. Table A-1 summarizes those capabilities from the AOE to AAN.

2.1 Global Geospatial Database

Future commanders and staffs will be able to pull from global geospatial databases all terrain data needed to support BV for their missions. Included in the databases will be elevation, registered imagery, and feature data. Database structure will support rapid export and dissemination, and the import of newly collected data. If such global geospatial databases existed today and were populated with global data available today, they would include elevation data with 100 m posting or resolution. For Army XXI, 30 m data should be available globally. In 2025, AAN commanders will have global elevation data at less than 1 m resolution. Additionally for AAN, ground-base collection using truck might be used to support BV in urban areas and over complex terrain. New techniques will be needed to manage and disseminate such large amounts of elevation data. Imagery resolution for BV will also improve. Although AOE commanders have 5 m imagery, Army XXI commanders will expect 1 m resolution. Sub-meter resolution imagery will be available for AAN commanders in 2025. Similarly, AAN commanders will have available to them feature data equivalent to a 1:5 k map, whereas Army XXI and AOE commanders had feature data equivalent to 1:50 k and 1:250 k maps respectively.

2.2 Terrain Data Collection

AOE commanders depend on commercial aircraft to collect 30 m resolution elevation data. However, commercial aircraft collections are limited to opportunities prior to hostilities since commercial aircraft can not be flown when there is a threat of it being shot down. For the AOE, National satellites provide imagery, but those capabilities are unresponsive to echelons at brigade and below due to the inability of Army commanders to task or request collections by those limited assets. The Rapid Terrain Visualization (RTV) Advanced Concept Technology Demonstration (ACTD) should afford Army XXI commanders a capability to collect elevation data with high-altitude military aircraft, e.g., U-2. Collections can be made by military aircraft whenever there is air superiority, which should increase collection opportunities for updates. In addition, Army XXI commanders should be able to get 1 m resolution elevation data with improved remote sensing payloads. In support of BV needs, Army XXI commanders should also be able to get 1 m resolution registered imagery with future National satellites. AAN-era commanders may wonder how AOE and Army XXI commanders could accomplish their contingency planning without being able to task military high altitude and endurance (HAE) unmanned aerial vehicles (UAVs), and National and commercial satellites. With military UAVs, collections can be made in times of air superiority without the fear for loss of human life. With satellites, collections can be made at all times. Commercial satellites should provide a source for terrain data that can meet the surge needs by lower echelons. AAN commanders will have available sub-meter elevation and imagery data derived from radar, electro-optic (EO) and infrared (IR) sensor payloads. These sensors along with hyperspectral imagery (HSI) payloads will support the generation of feature data.

Table A-1: Evolution of Capabilities Supporting Terrain Data			
	Army of Excellence	**Army XXI**	**Army After Next**
Global Geospatial Database	100 m Elevation; 5 m Registered Imagery; 1:250 k Equiv Maps	30 m Elevation; 1 m Registered Imagery; 1:50 k Equiv Maps	<1m Elevation; <1 m Registered Imagery; 1:5 k Equiv Maps
Collection	30 m Radar w/Commercial Aircraft; 5 m Registered EO w/National Satellites	1 m Radar w/Military Aircraft; 1 m Registered EO w/National Satellites	<1 m Radar with Military UAVs, National & Commercial Satellites, and Trucks; <1 m EO, IR, and Hyperspectral Imagery with National & Commercial Satellites

3. Synthetic Environment

Commanders and staffs use synthetic environments to view computer graphic renderings of battle activity for BV. Synthetic environments include software applications for visualization, and hardware and software for the man-machine interface. More capable software applications, faster computers, higher resolution displays, and higher bandwidth networking will all contribute to enhanced synthetic environments. The following subsections predict new synthetic environment capabilities. Table A-2 summarizes those capabilities from the AOE to AAN.

3.1 Visualization Applications

Military symbology identifies different types of units and weapon platforms. AOE command, control, computer, communication, intelligence, surveillance and reconnaissance (C4ISR) systems, e.g., the Maneuver Control System (MCS) and All Source Analysis System (ASAS), display icons of military symbology over maps. Usually, the maps are scanned and registered images from standard *paper* maps. The selection and locations of icons in the two-dimensional displays are derived from situational awareness data. This geospatial visualization capability will be improved for Army XXI. To give an additional sense of battle activity, this *'God's eye view'* for Army XXI commanders and staffs will also accommodate viewing of icons displayed over elevation, imagery or weather. These additional views facilitate the important assessments of terrain and weather impacts on operations. Increases in computing and graphic display performance will support three-dimensional projections for AAN commanders. Elevation draped with imagery, features and weather will be another overlay for AAN BV. Elevation draped with imagery can provide a more realistic display than elevation data alone and supports visualization of scenes at the platform level.

AOE C4ISR systems accommodate terrain analysis. For example, commanders and staffs can view terrain with overlays for line-of-sight (LOS), and mobility or trafficability by dismounted soldiers and heavy vehicles. This AOE capability supports assessment of terrain independent of the battlefield situation. Army XXI systems will integrate this function with situational awareness information. Linking situational awareness information to terrain analysis capabilities will make it possible for commanders and staffs to additionally view terrain impacts for specific units and weapon platforms at specific points in time. In the AAN era, environmental effects will be represented in synthetic displays. Terrain surface features, impacts of weather and climate, and illumination and transmittance will be depicted in synthetic environment displays. For example, early morning fog will be displayed if appropriate for an AAN unit's mission rehearsal. Environmental reasoning can be supported with AAN C4ISR systems. Automation can offer alternative courses of action that take terrain and weather into account. For example, a C4ISR system may sketch avenues of approach for units to maneuver around muddy terrain that heavy vehicles can not traverse.

Status displays afford simple data visualization in AOE C4ISR systems. For example, 'stoplight' charts depict status as red, yellow or green, which allows commanders and staffs to gain an overview of force status at a glance. Soldiers can drill into the data from which the charts are derived to gain a detailed understanding. Army XXI data visualization may emphasize the temporal aspects of events in situational awareness and status displays. For example, track histories and predicted positions can be shown for moving entities on situational awareness displays, and entity locations that have not been updated recently may be displayed with gray icons rather than the normal blue or red. Data visualization with AAN-era C4ISR systems should provide commanders with abstract views of courses of action and patterns of battle activity which convey information more quickly and concisely. Additionally, uncertainties in situational awareness data may be portrayed.

3.2 Man-Machine Interface

Group displays are needed to support collaboration in the decision making process. AOE commanders and staffs use computer monitors and medium resolution projection systems today in tactical operation centers (TOCs). High resolution projection systems will be used for Army XXI. Also for Army XXI, video walls with multiple large-size monitors will support simultaneous display of multiple computer and video sources. AAN commanders will have additional display systems available. Flat panels, 3-D systems, and sandtables will be used. Virtual reality eye wear will also be employed for en route and on-the-move use.

Collaboration among commanders and staffs in the decision making process must be accomplished even when members of the staff can not be at the same TOC or location. AOE staffs have available voice communication principally using terrestrial radios. Army XXI commanders and staff will have the Tactical Internet (TI), which includes satellite-based reachback communications, to support distributed collaboration. The TI must provide the communications and networking to support commercially available applications for video teleconferencing, whiteboards, chat rooms, and bulletin boards. AAN commanders and staffs will use split-based operations to minimize forward soldiers, equipment, and logistics support. Connectivity will support collaboration between forward staff and staff operating a terrain feature back. Connectivity must also support collaboration with staff operating in CONUS. All Army capabilities must be integrated and interoperable with similar C4ISR systems used by Joint and Coalition partners. Satellite communications will enable many new collaboration applications that will enable mobile TOCs composed of vehicles operating while on-the-move.

Input and output devices for AOE C4ISR systems include the keyboard, mouse and monitor. For a more intuitive man-machine interface, touch screens will be available for Army XXI commanders and staffs. AAN commanders and staffs will benefit from speech interfaces that will support the high noise environments of weapon platforms. Natural language interfaces will free AAN soldiers from having to read monitors to access textual information. Through video interfaces, AAN C4ISR systems will recognize the gaze and gesture of soldiers to rapidly gain intent without typing or speech.

Table A-2:
Evolution of Synthetic Environment Capabilities

	Army of Excellence	Army XXI	Army After Next
Geospatial Visualization	Symbology Displayed Over 2-D Maps	Symbology Displayed Over 2-D Elevation or Imagery	Symbology Displayed In 3-D Perspective Of Elevation Draped With Imagery and Weather
Terrain Analysis	Viewing of Overlays for Line-Of-Sight and Mobility	Integration with Situ-ational Awareness Data	Environmental Mod-eling and Reasoning
Data Visualization	Status Displays	Temporal Aspects of Events Displayed	Abstract Views of COAs; Abstract Views of Patterns; Uncer-tainties Portrayed
Group Displays	Monitors; Medium Resolution Projection	Video Wall; High Resolution Projection	Flat Panels; 3-D Dis-plays; Sandtables; Virtual Reality Eye Wear
Distributed Collaboration	Terrestrial Radio, Voice	VTC; Whiteboard; Chat Room; Bulletin Board	Split-Based Opera-tions, Mobile TOCs; On-the-Move Com-munications, Joint/Coalition Staff Integration
Input/ Output	Keyboard/Mouse	Touch Screen	Speech; Gaze; Ges-ture; Natural Lan-guage

4. Course of Action (COA)

Information systems can assist commanders and staffs in 'visualizing sequences of activities that move their forces from the current state to a desired end state'. Software tools and applications can automate steps for the development and analysis of COAs by commanders and staffs. During battle execution, situational awareness data and information can be used in tracking battle progress against a COA. Once battle has commenced, software applications and agents can monitor incoming situational awareness data, compare the situation to COA checkpoints, and alert commanders and staffs of variances. The following subsections predict new COA capabilities. Table A-3 summarizes those capabilities for the AOE to AAN.

4.1 COA Development and Analysis

AOE commanders and staffs have commercial desktop applications that can document COA information. Word processing and business graphics, e.g., Microsoft Office, support the preparation of today's COA documents. On-going BV developments should provide Army XXI commanders and staffs tools to facilitate the computation and integration of data need for preparing and updating COA documents. Such tools will allow COA sketches to be overlaid on maps or terrain data. Army XXI staffs will use tools in the development of synchronization matrices that establish the schedule of tasks and mission activites by functional area and unit. Applications will also automate the preparation and dissemination of operational orders (OPORDs) for all units. AAN staffs will use a plethora of tools to support COA development. For example, tools will be able to assist staffs in preparing lay downs. AAN commanders and staffs will have the first *true* capabilities to analyze COAs. Models, suitable for use by staffs from battalion to corps, will be employed to wargame COA alternates. Additional tools will check COA feasibility and acceptability, and analyze COA risk and sensitivity against user-defined evaluation criteria.

4.2 Execution Monitoring

Situational awareness displays are used in most AOE C4ISR systems. Unfortunately, today's systems were developed as stovepipes and primarily support commanders and staffs looking at a single dimension of the battle at a time. Maneuver, intelligence and logistics are supported by different applications in the family of Army Tactical Command and Control Systems (ATCCS), for example. Army XXI C4ISR systems will have integrated applications allowing commanders and staffs to work with information regarding enemy and friendly forces simultaneously if need be. Information fusion capabilities for AAN will merge received situational awareness data and check for consistency and accuracy. AAN commanders, from battalion to corps, will have access to collection managers enabling the tasking of satellites, UAVs and other sensors. Through collection management, commanders will be able to obtain data critical for their understanding of battlefield activity. Intelligent agents will actively search for patterns in situational awareness data indicative of trouble. Dynamic database triggers will monitor situational awareness data for deviations with established COAs. For example, a trigger may issue an alert to a commander if situational awareness data shows that Bravo Company has not reached phase line Zebra by 2130.

Table A-3:
Evolution of Course Of Action (COA) Capabilities

	Army of Excellence	Army XXI	Army After Next
Development and Analysis	Word Processing; Business Graphics	COA Sketch Tool, CoFM and Synch Matrix Tool, Electronic OPORD	Tools for: Force Position, TO&E, Mission-to-Task, Terrain Analysis, Decision Matrix; Wargaming Model; Knowledge Tools; Mission Rehearsal; ATR
Execution Monitoring	Situational Awareness Displays	Integration of Enemy and Friendly Situation	Information Fusion; Collection management; Intelligent Alerts; Dynamic Database Triggers

APPENDIX E

MODERN FICTIONS:

HOW TWO BIG WRONG IDEAS ARE BLURRING THE VISION OF BATTLEFIELD VISUALIZATION

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By Bran Ferren
edited by Gershon Weltman

INTRODUCTION

The purpose of this White Paper is to set the record straight, so to speak. I'm sure the following represents two minority positions (in fact, that's why I'm writing this), but I'm equally sure these positions are correct. My dissertation derives from two widely held (and interrelated) pieces of conventional wisdom within the Army and Defense communities; these are:

1) AS A CONSEQUENCE OF THE DRAMATIC INCREASE IN AVAILABLE BV DATA (FROM ALL OF THOSE SPIFFY HIGH-TECH WIDE-BAND SENSOR SYSTEMS) OUR INFORMATION WARRIORS ARE VERGING ON COMPLETE INFORMATION OVERLOAD. THIS WILL BE A KEY LIMITATION IN THE CAPACITY AND EFFECTIVENESS OF ALL FUTURE BV SYSTEMS. The representation is that if us mere humans have to process just one more bit of electronic information, we will degenerate into babbling idiots, incapable of making adult decisions, let alone surviving (and winning) on the modern battlefield. THEREFORE, we need to simplify the displays and limit the amount of information transferred from our sensor and information processing systems to our personnel. This means simplified graphics, more Icons, Autonomous ATR, and heavy electronic data filtering and screening.

2) YOU CAN'T HAVE A GEO-SPATIAL DATABASE OF THE WHOLE WORLD - IT'S JUST TOO BIG! The representation is we'll never have a complete and current high-resolution 3D database of the entire land mass of the world, because it's just too big of a problem. "Do you realize that it would take 300,000 CD ROM's" etc., etc. THEREFORE, the argument continues, it is essential that we develop robust "Just In Time" precision mapping capability to service our local BV needs. It's just the only practical solution for the foreseeable future.

Well, folks, I will argue that these sensible sounding positions are <u>wrong and dangerous</u>! My concern is twofold. First, holding these beliefs creates a mind set that could lead us to the wrong conclusions (we might very well end up with the correct answers to the wrong questions). Second, it may cause us not to pursue fruitful technology paths that could give the United States and its Allies truly unique advantages on the battlefields of the future, especially in nontraditional operations like MOOTW.

If I can get consensus that the current positions are fundamentally wrong, I'm confident it will lead to an altogether different (and superior) evolutionary path for BV. That path is based on two fundamentally different representations; namely: we need to display vastly MORE information to the human, and much of it will come from ONE HUGE DYNAMIC DATABASE of the entire planet. I believe the new path can support the Vision of BV well into the next century, and will provide the American warfighter with a unique and sustainable advantage.

(Although its discussion is beyond the scope of this paper, I'm convinced that such a database could also become a remarkable National Asset with great direct and indirect benefits to society at large. Obviously there would be political, ethical, legal and technical issues surrounding this project which would require critical study and debate.)

INFORMATION OVERLOAD IN HUMANS – NOT!

A Simple Thought Experiment

Please humor me and try this little thought experiment: Imagine you're carefully exploring visually the room you're now in. You get down on your hands and knees and look closely at the carpet. Pretty complicated, isn't it? Lots of colored fibers, pile structure, weaving patterns, seams, stains, dirt, resiliency, and a bunch of objects distributed across it. Lots of places to hide from your enemies -- if you're a flea or dust mite. You get up (or people might start to stare) and look at the walls. Notice not just the paint and the wall covering, but all of the little blemishes, penetrations, fenestration, hung objects, seams, and pinholes. Quite a mess, huh? Assuming you didn't have a whole heck of a lot to do with yourself, you could spend the better part of the afternoon exploring this comparatively basic room.

Now just imagine how many pixels and DTED "posts" it would take to describe digitally your average room at the maximum resolution observable by a human being (especially a mobile and inquisitive one). It would require at least several terabytes.

But think back to what happened the very moment you first entered this complicated and detailed room. Were you overwhelmed by having to load a multi-terrabyte database? Did the multiple sensor channels streaming data into your brain cause any undue stress? Did you have any trouble fusing the 3D audio signals with the 3D visual cues? Did you experience any distress at the amount of data you had to process and then store? Of course not. You just walked into the room and learned as much about it as necessary to accomplish the tasks at hand.

You just effortlessly accomplished what no computer/sensor system (other than living ones) has ever remotely been able to do. But before you spend too much time congratulating yourself, remember that while no supercomputer can do this (yet), most of the billions of people living on this planet can.

We humans perform this magic because we don't approach the problem the way we ask our computers to (or our BV systems, for that matter). We don't deal with the world in bits and bytes, we take an object-oriented view. You formed a "concept" of the carpet based upon your prior understanding of what other carpets are, and modified it by your quick scan of its colors, structure, and condition. You further contextualized this by your common sense understanding of how carpets are used, as well as a sense of the history of the structure (was it original to the building, supplied by the lowest bidder, meets local fire codes, gets cleaned regularly, etc.). From this vantage point you pay attention to whether or not your current observations agree with or deviate from your internal model of the concept of "Carpet". You pay attention to the "deltas" between your assumptions and past experiences, and your current observations.

But Let's Make The Experiment A Bit Harder. . .

Imagine now that I've now asked you to do a straightforward perceptual/motor task, such as: "Please bring me the cup of coffee I left in the room a few minutes ago." Would you start by looking on the ceiling, or behind the objects on the top book shelf, or prying up the carpet? Probably not. Why? Because you possess a common sense understanding of how the object class called "a cup of coffee" fits into the real world, and you will optimize your search accordingly. You might eventually pry up that carpet, but most of us wouldn't begin our search that way. The odds are:

a) You would start by looking for things that resemble cups or other containers that commonly hold coffee.
b) You would likely start looking on the tables because that's where filled cups are most often found.
c) You would ignore cups that were inverted or on their sides because you know how cups work - and don't work. - with liquids in them.
d) You would pass up the cup filled with a clear liquid because you know the spectral signature of most coffee - be it black, regular, or cappuccino.
e) You would ignore the cup filled with what looks like coffee, but that has an old cigar butt in it because you can guess my lack of enthusiasm for desecrated coffee.
f) Having narrowed it down to two likely candidates - a paper cup with what and looks like coffee and a mug that says Army Science Board on it -- you reach for the paper cup because you figure if I had meant some funny mug that I would have said so.
g) Once your hand makes contact, the thermal sensors in your fingers confirm the cup is warm, so you grab it and bring it to me.
h) You may or may not have made the right choice, but you quickly and reflexively made a REASONABLE choice and didn't waste time processing unnecessary elements of the room, the chemical composition of Joe, etc.

Although radically more complex than just looking around the room, this new task wasn't that much harder -- was it? And did you experience sensory overload this time? Did you have trouble parsing what was important and getting through the environmental complexity to accomplish your goal? I'll bet you could even do this while talking to a third person, or singing, or even singing and dancing and looking out the window to see if it is about to rain.

Aren't We Wonderful?

Yes, we are. Human beings are born sensor fusers. We use common sense and the concept of *context* to make good decisions. We do an amazing job of this and under most (not all) circumstances, the more data we get (and the faster we get it), the better! Trust me. Likewise, sensory overload just doesn't occur at anywhere near the levels people would like you to believe. It usually happens when we present people with incomplete or low resolution data with a high degree of abstraction (that requires additional non-instinctive thought to understand - i.e. we have to "work for it").

So What Does This Have To Do With BV?

The problem at this stage of our evolution as a species isn't too much information, it's too little and/or bad and incomplete information! To get serious about BV we need to start thinking about <u>Interactive Presentation Environments</u> (not just visual display systems) that give us the information we need to make informed decisions. Not only do we have a poor understanding of how to do this, but I would argue that we've barely scratched the surface of BV display requirements. Look at examples of other display environments like Television, Movies, Theme parks, Motion simulators, and LIFE. In each of these situations two or more human sensory channels are simultaneously fused and correlated by the participants to gain a deeper understanding of the presentation. Storytelling skills are often employed to format and sequence the raw information into what becomes knowledge. There's a good reason that silent movies died as a method of storytelling. "Talkies" get the job done better. Why would we want silent BV to tell the story of what's happening on our battlefields?

Worse still, most people I've talked to working in BV don't think there is a problem and further believe that COTS solutions to the Army's BV display challenges are just around the corner. It is little comfort that history abounds with great examples of the lack of technical vision in display technology. Back to the film business, I'm reminded of what Jack Warner, then the head of Hollywood's biggest motion picture studio, said when approached about the desirability of adding sound technology to silent movies. His answer was: "Why would anyone ever want to hear an actor talk?" This man was also convinced later in his career that color would never catch on. Go figure... I can't help but wonder if some of the directions we are presently taking on BV displays and geo-spatial database technology will be looked on any more kindly by future historians.

It Can't Really Be This Simple, Can It?

Yes, I believe it is, to a large extent. There's also another big part that has to do with how information is represented, or abstracted, on a display system, including what might be distracting your attention and how rapidly things are changing. More about that part later, but first, let's go a bit deeper into the singular question of performing tasks within complex and dynamically changing environments -- but using only limited sensory inputs. The information overload gang would suggest that this should make things easier. It does not.

Let's go back to our coffee cup room and the same coffee cup retrieval experiment, but with a new twist: Decrease your sensory input by plugging up your ears, wearing heavy gloves and boots, and looking at the room through one soda straw. Go ahead, try it (I'll wait). Much harder, isn't it? What you just did was limit the amount of information you're getting about the coffee cup room to about the same rate and quality being proposed for modern battlefield visualization.

Not only do I believe we are nowhere near the point of information overload in our BV technology, I maintain that we're effectively crippling our warfighter by forcing them to view the battlefield through soda straws! It's a good thing our soldiers can adapt so easily to adverse, information-limited display environments (and our opponents generally have it worse than we do)! Let's put in place the tools necessary to widen this gap between what we have and what they have.

This is not rocket science. It's how we work in the real world, and I think it's directly relevant to the way we can accomplish the next generation of Battlefield Visualization. Please don't be distracted by the superficiality of my coffee cup room example. It was just for illustration, and if you've got the patience, I can give you a list of Army examples as long as your arm. *Why do you think the normal position of a tank commander is hatch up and head out?* Other than the minor inconvenience of getting your head shot off, it's the best way to figure out what's going on around you. It's a full-fidelity, multi-sensory view, just not a well-filtered electronic one.

Sometimes I hear people talking about the difference between the ART and SCIENCE of Battlefield Visualization. I believe this to be absolutely true. The science alone just isn't enough. This is why computers, while valuable tools, are just not going to replace human commanders on our battlefields for the foreseeable future. What I'd like to get you to believe is that there is equivalent ART and SCIENCE in information display and electronic interactivity, and that understanding this is an essential part of the process of achieving BV. It always has been, and it always will be.

BV isn't a new idea. It's just going digital, and we need to understand the opportunities and challenges that this change will present.

A Note On Abstraction And Too Many Icons

The human being has a remarkable ability to deal with, process and appreciate abstraction. However, this requires a lot of neuron firings (and training) to accomplish. Our ability to deal with abstract representational schemes is why we can effectively use graphical icons, acronyms, written language, and semantic names to represent real objects and ideas. We know instinctively to be afraid of a snake; we have to learn to be afraid of a Radiation Warning icon.

The objective of ICONOGRAPHY is to provide a simplified method of representing more complex ideas. This was particularly useful at the beginning of the computer era (because of the lack of image processing power) and for simple tasks (such as those associated with word processing). We can learn to deal efficiently with iconography (witness the success of the Mac-type computer interface) -- BUT, it isn't a natural way for our brain to work and too much of it CAN lead to information overload.

For example, it's much faster for our brains to recognize the identity of six people in a room by just looking at them than by reading their name tags. We are wired to recognize faces, but we must be taught how to read. The two functions actually seem to reflect two distinct types of brain mechanism. In this sense, humans are just the opposite of computers, which can be accessorized to read name tags at the speed of light but might take seconds or minutes to recognize faces or, to quote Marvin Minsky, "...tell the difference between a cat and a dog".

When we design the BV systems of the future, we need to remember what computers do well and what <u>we</u> humans do well -- and then let each do its own "thing" best. This means don't fill a screen with jumbled-up and overlapping ICONS if you want the viewer to spot a critical object quickly, and don't ask the computer to fuse complex contradictory information or to exhibit common sense (yet). Now that we have the computing and display technology to do it, why shouldn't an unknown plane look like a plane, or a cat like a cat, or a dog like a dog? There may in fact be some good answers as to why not, but they ought to be our willful choices, not defaults based upon old paradigms.

Another Example - Seeing The Trees In The Forest

Let me give you another example out of respect for the principle that no horse is too dead to beat! On your way to work this morning you passed, say, a million trees. Your memory of this experience was not a mental log book of trees 0 to 999999, but rather you were left with the impression "Gee, lots of trees." This is probably an entirely adequate description of that experience unless you happen to be an arborist, in which case you could have a more detailed recollection of tree types, condition, method of planting, etc. Arborists have a different contextual filter with which to parse the sensory stream of tree images.

Now imagine you saw on inverted pine tree on your journey. That's right, inverted - the tree was balanced on its tip with the roots up in the air and no visible means of support. You would certainly remember this particular tree, perhaps for the rest of your life. Why? All you witnessed was a 180 degree geometric rotation of one out of a million objects. This is so statistically unimportant that in most data reduction operations (unless for some reason you had an algorithm tuned to look for inverted trees) it would disappear into the noise. This particular tree is so memorable because it violated your internal model of how trees grow and appear in our world. Painting it Gold, making it luminescent or having it covered with snow (in the summertime) would have the same effect.

This attribute of human reasoning and perception is often called common sense. We not only have it, but are masters of using it to compress data (for example, recording only the deltas from the norm) as well as to make sense of our complex dynamic world. Let's also remember that despite decades of AI work (not enough on common sense, incidentally) computing machines don't yet have it, and can't fake it well. The one major common sense reasoning project I know (Cyc) seems to have had made little useful progress to date.

So, Putting It All Together. . .

If you believe that understanding what's happening on the Battlefield is essential to winning, and that people are the only systems on the horizon that are capable of accomplishing this task, then let's make it easier for the people to do it efficiently. Let's concentrate on presenting the current state of the battlefield environment to the human decision makers in the ways that make it easiest for them to understand. This means we should give them MORE information (ideally using all six human senses in a multisensory presentation) so their brains can do the fusing and understanding.

Conversely, let's not let primitive computer systems, running primitive algorithms, filter out essential information necessary for our people to make good decisions. Why do you think the folks at NORAD nearly put us at a state of war a few years ago? The operators couldn't tell they were looking at simulation data that had contaminated the system because a wrong reel of tape was mounted. It happened before and it could happen again -- if we continue along with our present methods of processing and displaying BV information. Unfortunately, it appears this is still the thrust of much of the Army's current thinking in information processing and display.

Information Presentation In Future Army BV Systems

In considering an alternative future course for BV information presentation, it's important to remember three things:

1. The main task is to provide effective information transfer into and out of human beings. It is NOT just to design better graphics displays; that is only one piece of the problem.

2. While industry is providing a continuously improved series of components that are useful in accomplishing pieces of the main task, they are NOT specifically thinking about BV information presentation environment at a systems or human factors level. This just isn't their focus as the Army BV sector is just too small a market to drive much original technology. To guarantee a satisfactory end result, the Army must take re-

sponsibility FOR this "BV technology vision" and high level display systems oversight task itself (either internally or by funding appropriate external entities). If not, the solutions developed by outsiders with other agendas are likely to be sub-optimal for the Army's long term needs.

3. There is an inseparable relationship between Art, Science, Doctrine and Technology in BV. You can't work the solutions independently, or the final product will suffer. This is a highly iterative and synergistic challenge that will be continuously evolving for the foreseeable future.

In the realm of iconography, we should be able to combine advantageously the new processing power of our computers with new understanding of what our brain is capable of. For example, every Icon used for BV could include natural coding (so the information is apparent without further query) covering:

1. What it is (plane, boat, man, emitter, target, etc.) along with confidence level
2. Geo-spatial (and perhaps relative) position
3. Age of information (fresh or outdated)
4. Intent (friendly or hostile or unknown and perhaps mission- if known)
5. Threat level (will it hurt you?)
6. Quality of data (degree of uncertainty)
7. Relationship to something bigger (like a battalion or brigade)

In the area of graphics display screens, here are some other simple ideas also based on what we know of human data processing: Display screens should ALWAYS be de-cluttered and have the labeling optimized for the mission and viewing scale. You shouldn't have to request a de-clutter. This is the opposite of how the Army's current systems work: they always come up as a complete mess, and provide the option to declutter. This just wastes precious time and requires greater operator interaction to accomplish what should be automatic).

Likewise, the displays should use colors optimized to communicate the important information at hand. While it's fine for simulation based training, in a BV display situation we should never see (or rather, try to see) another green tank on a green mountain. Make the blue side tanks blue and the red tanks red. We should be trying to communicate information here, not giving the commander an eye test. In that regard, we should also learn to customize the display presentation to the specific user as appropriate. Statistically, about 11% of all of our military commanders have defects in their color vision. Why wouldn't we optimize the color pallet in their (the color deficient community) displays to make it easier for them to read and comprehend? Finally, we should just stop using CRT's to display data that can be displayed on LCD's. Color CRT's flicker, go out of convergence, radiate, are fragile big and heavy, and are hard to package efficiently; LCD's are just better for most BV applications. End of story.

Presentation Is More Than Just Visual Displays

We have extraordinary capability in 3D sound localization and signal processing. Just try closing your eyes for a while during a meeting and use your hearing to build a picture of your environment. Or try picking out a single conversation during a noisy cocktail party. Notice in the party environment that if you can see the person’s lips while they are talking, it helps you “hear” them. In another example, doctors listening to the Doppler products of an ultrasound machine derive enormous amounts of hidden information. Or, if you take away a sonar operator’s hearing they effectively become “half blind”. The BV environment is the perfect application to use 3D sound enhancement. Just as a commander wants to hear the COM nets coming out of *different* speakers in his command post in order to keep track of the activities of his or her troops (they associate the particular unit with the direction from which they hear the voice), spatially relevant audio can assist in a whole spectrum of BV tasks.

Touch feedback in joysticks or trackballs could be another unexploited information transfer tool. In much of the same manner that you can determine if you’re on a carpeted, or wood, or concrete floor by just feeling your foot move across it or touching it, the touch sensors in our body can be brought into the information display environment. Imagine if your trackball vibrated slightly every time your cursor came near a potentially hostile target. You could then confirm by looking at the icon more closely. Touch is a very active human input channel; let’s use it. Also, the closely related sense of temperature could also be a useful cue in certain applications. For example, the electronic equivalent of the coffee cup verification example. Thermoelectric modules using the Peltier effect and IR radiators are good candidate technologies for BV applications.

Smell is a field which has received little attention in terms of displays, but is routinely used by soldiers on the battlefield: the smell of diesel exhaust, gas, and even occasionally the enemy (as in how the Vietcong sensed US soldiers in the fields) has been part of warfare since ancient times. It’s conceivable that if a CBW sensor suite detected a hazardous agent that a surrogate odorant would be introduced into the display environment as a warning that says “put on your gas masks!” in an unmistakable and unambiguous manner. Taste seems like a long shot; but if it’s another sensory channel, it's probably worth at least a cursory look.

So Is There A Unifying Principle? Try The Art Of Storytelling!

There is a technology originated by our ancestors around the same time language was developed. Its purpose was to make ideas portable (so they could be communicated from “self” to “others”) and to also make those ideas permanent enough to survive their originators. We call it storytelling, and it’s integral to how we humans function with each other in our world. It has been argued that we can’t even remember an idea unless we organize it into story-like form. In my particular case, I believe this to be true. Call them stories, myths, fables, or whatever, they have been with us since the beginning, and in fact provide the only basis for our cultural memory before the development of writing.

It's interesting to note that every time an effective new storytelling technology has been introduced, it has changed our world. Examples include Language, Writing, the Telephone and Telegraph, Radio, Newspapers, Television, and most recently, the Internet. And I have never met a great leader (military or otherwise) who was not a great storyteller. Ronald Reagan, often referred to as "the great communicator" was professionally trained as a storyteller (that's what acting is). Since the underlying principal of BV is the ability to effectively and efficiently COMMUNICATE information, we could use a bit more focus on just how high quality communication of ideas to people takes place.

If you take a storyteller's view of information display and database management, you get a wholly different picture than if you just look at the basic technical challenges in a vacuum. What I am suggesting is that there are a whole bunch of people out there who make their living by doing great storytelling. We need to involve these people (whether from the military, journalism, or entertainment communities) in the BV issues discussions to gain and incorporate their observations and relevant insights. Professional storytellers just think about the world and communicating ideas differently (and they're better at it!).

Did you ever notice that the real advances in high fidelity visual simulation occurred not to satisfy the requirements of the military and aerospace communities who invented it, but rather those of the entertainment industry? These folks are now driving the most demanding future imaging requirements and providing the technology "pull" for Computer Generated Imagery. These folks are the professional storytellers; they know what they need to spin a good tale.

THE ULTRA-LARGE GEO-SPATIAL DATABASE

Ask almost anyone about the feasibility of making a master database of the entire world and they will tell you that it's just not practical. They are almost right: at this moment in time, it is not practical to do it, but it is entirely practical to design and organize it. And in some number of relatively predictable years (more than five, less than twenty) it will be eminently practical to execute those designs to assist the modern warfighter. We need to buy into this today. Why? Two reasons. First, it lets you know what you are moving towards as your long term vision. Second, it gives you a template by which to organize all of the Just-In-Time and other data you collect in the meantime so it will all be usable in the future. It makes today's data much more valuable for the future! It's simply a matter of optimizing our return on investment.

Proposing Project MOADB (The Mother Of All Databases) -- A Human Genome Project for ALL Geospatially relevant information.

I would like to take a moment to say that I believe the following concept of a universal Geo-Spatial Database to be a potentially critical enabling technology to both the Army and the entire DOD at large. I am convinced that it isn't a detail or subset of BV, but rather should be a key strategic thrust for the United States. Its importance goes far *beyond providing an organizing principle for all future BV data collection and logging (which it would, in fact, do). Its scope and relevance might even warrant the creation of a new Agency to conceptualize, build and maintain it. Trust me, this could be a BIG win and a true RMA (Revolution in Military Affairs).*

The vision here is very simple. Let's build <u>one</u> master geo-spatially organized, multi-media database of the entire world. Period. While this is a daunting task, it is achievable and could provide us with an absolutely unique advantage as a world power. Think about it. What if you had every point on earth measured and identified with a multimedia-based, object-oriented, time correlated, geo-spatially accurate location. Every bit of elevation data, reconnaissance images, Sigint data, weather, target track, political movement, historical map or anything else one considers relevant (even scribbles on a paper napkin) would be fused into it. It would be in a state of continuous updating based upon whatever relevant data is being collected.

How does one decide what to include in such a MOADB? Simple. If anyone <u>ever</u> thought it was relevant, we label it (time, how collected, confidence level, security classification, etc.) and include it. The idea is that if any one ever requested it, at least they thought it was valuable, and it could be valuable again. That's reason enough to put it into the database. How and if it's used in the future then becomes a matter of choice. Even data known to be wrong is kept for possible future use (just labeled as being inaccurate - and why, if known.). This bad data could end up being a valuable tool to identify what went wrong in a post-action analysis, for example.

Sure it's big (so is the earth and the Army's mission). But making it *Really Big* (and always current) will eventually reduce the amount of stored information and reduce what will need to be collected by others in the future. Why? Take elevation data, for example. Once you actually know the elevation of any given point on earth, you REALLY KNOW it. Meaning that every time in the future you happen to collect the same data, you can confirm it (often by sparse statistical sampling) and then ignore it (aside from updating the time of last confirmation). When elements of the MOADB become compact enough to load onto an airborne surveillance platform, for example, it would mean that only the Deltas would need to be down linked (just like the way we humans would process things). This would radically reduce the necessary communications and storage bandwidth and dramatically reduce the time required to update the master database.

There are of course a significant number of conceptual, technical and operational challenges to accomplishing this. Some of the more significant are discussed below, briefly and in no particular order.

Database Systems Object Structure. No one has ever built a database of remotely this size and complexity. It is not clear that any existing DB architecture is appropriate (or even close). It would need to incorporate an open, modular, and completely scaleable structure. We are near to figuring this out for supercomputers (initially the CM5 architecture), perhaps the DB is resident in a massively parallel supercomputing architecture, perhaps it is comprised of a PC hyper-network.

Data Collection/Distribution Infrastructure. It doesn't matter how slick the DB or its structure is, if you can't pump the required data into and out of it in a timely manner - it's of limited use. This might require a whole new (satellite/terrestrial based) distribution system, and also be able to load share across existing nets and pipes.

Storage Media And Server Architecture. Probably some holographic (tape?) linear media combined with rotating optical (or hybrid like MO) raid arrays.

Loss-Less Geo-Spatial Data Reduction. Complexity management would surely be an issue. However, I believe we can solve this in much the same manner that we deal with the complexity of the real world. Simply stated, don't keep storing what you already know (just note when it was updated). Once we develop this (or some other) mature understanding of the data structure and complexity management of such a database, the total amount of stored information will actually go down.

The Maintenance Function. Maintaining a database of this scope is an enormous job. Obviously an attribute of a continuously updated database is that it's a good thing to update it correctly!

Multimedia Data Types. The organization of this type of database must be content agnostic -- except for the principle that data are always organized based upon the coordinates of where they were collected. Known data types include: elevation, images, radar (SAR, IFASR, etc.), spectral data, EMR, velocity vectors, density, emissivity, graphics, BDA labels, and every object descriptor imaginable.

Infinitely Extensible Architectures (Hardware And Software). The systems must be arranged so as to permit near infinite expansion. Let's try to avoid the geo-spatial equivalent of the "Year 2000 Problem".

Networked Distribution (the mini-MOADB Network). The notion of the MOADB feeding (and being fed by) N number of smaller Mini-MOADBs is essential to the BV field utilization program. Each database user would have a subset of the MOADB resident in their computing infrastructure. Not only would they have the use of this subset, but they would have the ability to provide updates and revisions that would be uploaded to the MOADB (through an authentication and verification process). I would envision that a unique fault tolerant MOADB wide-band digital network would be developed to support these activities.

Security Aspects. Obviously INFOSEC/CRYPTO needs to be integral to the construction and utilization of this sort of system. It presents a further technological challenge.

Conversion of Raw Datapoints towards "Objects" and "Deltas". Ultimately we need to develop the philosophy and technology to convert collected data points into correlated object representation. This is "indexing" in its most advanced form. It works for people and it ought to be employed in the machines that serve people. I am convinced that the whole premise of DTEDs (digital terrain elevation data) is fundamentally flawed. While it is perhaps a sensible way to acquire terrain data, it doesn't seem to make any sense as a method to store, process or use it. We need to evolve to an object-oriented model (like the way we process this room) that gives you what you need to know to get the job done. This means having object representation of the family of objects that comprises our world, paying attention to the differences, and knowing where all of this is located in RELATIVE space well enough to execute the mission at hand, or any other mission in the future. Humans don't use a DTEDesque brute force method to record and function in our world and neither should the machines that serve humans. We need to get past clumsy models based upon arrays of points in space. The concept of stored deltas just means that you don't keep storing what you already know - just what changed from your starting model.

Continuous Updates Is The Rule - Always! Every time any geo-spatial data is collected anywhere and for any reason, it should be compared to the MOADB and the database updated as necessary. Even if this is the output of a soldier with a next generation EPLRS in their wristwatch, it all goes towards making the database more current and valuable. Much of this updating and verification would be a completely autonomous process.

CONCLUSIONS AND RECOMMENDATIONS

It is within our grasp to conceive of, and ultimately execute, a Master Geo-spatial Database of the entire planet. This would provide a critical tool to support the Battlefield Visualization needs of our future leaders and warfighters, and provide a unique advantage to the United States of America and it's allies. We need to start laying the groundwork for this NOW so that the strategy of Just In Time data acquisition that we must sensibly pursue in the near term yields us data that will be truly valuable in the future. The notion here is to *pre-purpose* the data via planned formatting, labeling, compression, etc. to make it plug compatible with this future Database vision.

Information Overload within the context of Battlefield Visualization is a Myth. By gaining a better grasp of how human beings acquire and understand complex dynamically changing environments in the Real World, we can build Interactive Presentation Environments (as contrasted to visual displays) that enhance human performance. In the near term the consequences of this requires technology that gives the decision makers <u>radically more information</u> (ideally at the full capacity of human sensory systems) so their brains can better perform the information fusion and correlation tasks. The motivation should be to get the information into the one processor known to be capable of accomplishing this task brilliantly -- the human brain. In order to accomplish this we have to understand how WE work and get the BV systems to adapt to us, rather than the other way around.

In accord with the above, I recommend we do the following:

1) Fund a major program for the creation of a Whole World Database to satisfy the long term needs of Battlefield Visualization and provide a unifying vision for how geo-spatially relevant data should be collected, organized and stored.

2) Fund a serious R&D program to understand what the next generation of integrated multi-sensory Interactive Display Environments should include to transfer information in and out of human beings in the most effective manner. This includes efforts to understand human sensory perception and decision making processes, data organization, and the integrated display environments. This should be a multi-disciplinary effort that includes experts with Command, Army doctrine, Perception Science, Art, Design, and Storytelling skills along with the usual Human Factors and engineering gang. It should also have multi-service and multinational representation in that it appears that we are all going to be fighting the next battles together.

3) Fund a specific investigation into the role of Storytelling Art and Science (from an Army BV requirements perspective). The intended outcome being the development of both tool technology (authoring and presentation), and skills training to enhance the communication of Situation, State, Intent, and COA - throughout the chain of command.

DISCLAIMER! -- OK, OK, so there actually CAN be a problem with information overload.

In my experience when it does occur, it's not usually caused by presenting too much information, but rather by presenting too little, or by just presenting information badly. If you try really hard (or better still, don't try at all) you can make even the simplest data streams overload even the most skilled operator. If you don't believe this (and therefore must be a person who doesn't use computers much) just try a few of these handy tips to help overload people:

1) Make use of unfamiliar or poorly conceived abstractions. -- A nice way to start is to create your own Icons that have one intended meaning for your application, but are "read" as something else by others. For example, say "GO" when you really mean "STOP"… or use the color green, to signify danger… or say, have a set of symbols that the Army is trained on and put them on the BV display of a Navy person.

2) Use colors to obscure rather than to enlighten. -- Imagine doing a BV display for a ground forces commander that puts green camouflage tanks on a green foliage background. Hard to see the little suckers isn't it? The mistake here is thinking that the tanks

should look real, rather than stand out as friendly or foe. Just making the tanks Red and Blue would instantly fix this. Guess which color would represent the enemy?

3) Employ ambiguous multi-modal information display states. -- Like making an electronic moving map display that switches between North Up, Track Up and South Up - and doesn't make the mode immediately obvious. It is seductive to think that it's empowering to give people a lot of choices (after all, it's "only" software...). This is often a trap. I find it's usually better to just pick ONE choice (which may in fact be sub-optimal for certain situations), but becomes accepted and understood by all users. Kind of like the convention set for your car that pressing the pedal on the left stops you, the one on the right makes you go faster, and turning the steering wheel changes your direction. Again, one could argue that there is a superior (even programmable) convention that's better (or one could even make it user selectable), but this sure would make teaching a country to drive safely a whole heck of a lot harder.

4) Label critical functions with Acronyms that are not readily understood by your users. -- At an early briefing on this summer study, I came across the term BVM. No one else at the briefing knew what it meant (other than the BV part, which we just guessed at). So I consulted the American Heritage Dictionary on a secretaries desk outside the briefing room, and found it! That dictionary said that it stands for Blessed Virgin Mary.... In case you're wondering it's a term that came from a NATO conference meaning Battlefield Visualization Methodology (Or perhaps BV Method. The NATO guy wasn't sure - In fact, he thought it was a US Army term. Hmmmm....).

5) use unreadable graphics. -- All you have to do is pick a too small or hard to read font and you can drop reading efficiency to a dangerous level without even realizing it. Often this is a parameter that can be set by the user without the systems author even being aware of it.

These are five examples (out of hundreds) that are making people needlessly drift into information overload. Unfortunately, all of the examples above are presently resident on current, and proposed future DOD BV systems...