INFANTRY SITUATION AWARENESS

PAPERS FROM THE 1998 INFANTRY SITUATION AWARENESS WORKSHOP

EDITED BY SCOTT E. GRAHAM & MICHAEL D. MATTHEWS

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy)	2. REPORT TYPE	3. DATES COVERED (from. . . to)
November 1999	Final	1 JUL 98 to 31 DEC 98

4. TITLE AND SUBTITLE	5a. CONTRACT OR GRANT NUMBER
Infantry Situation Awareness: Papers from the 1998 Infantry Situation Awareness Workshop	5b. PROGRAM ELEMENT NUMBER 62785
6. AUTHOR(S) Scott E. Graham & Michael D. Matthews, Editors	5c. PROJECT NUMBER A790
	5d. TASK NUMBER 212C
	5e. WORK UNIT NUMBER C05
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences Fort Benning Field Unit (TAPC-ARI-IJ) P.O. Box 52086 Fort Benning, GA 31995-2086	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600	10. MONITOR ACRONYM ARI
	11. MONITOR REPORT NUMBER

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 words)*:

This volume contains papers developed from the Infantry Situation Awareness Workshop, held at Fort Benning, Georgia, 29-30 September 1998. It consists of 16 chapters representing the views of key program participants on Infantry situation awareness (SA) issues. Specifically, five questions were addressed: (1) What the most critical Infantry SA requirements; (2) what new training techniques and requirements are needed; (3) what pitfalls should the Army try to avoid in its drive to enhance SA; (4) how can SA be measured in Infantry soldiers and teams; and (5) what the most critical Training, Leader, and Soldier SA research issues that the Army should address in the next five years. These questions were addressed at four levels of echelon: individual combatants and squads; platoons, companies, and battalions; Infantry brigades; and future Infantry teams. Implications for future Infantry SA research and development are discussed.

15. SUBJECT TERMS

Situation awareness situational dominance digitization infantry cognition command and control

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON (Name and Telephone Number)
16. REPORT	17. ABSTRACT	18. THIS PAGE			
Unclassified	Unclassified	Unclassified	Unlimited	206	Dr. Michael Matthews 706-545-2198

PAPERS FROM THE 1998 INFANTRY SITUATION AWARENESS WORKSHOP

EDITED BY SCOTT E. GRAHAM & MICHAEL D. MATTHEWS

November 1999

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

Table of Contents

FOREWORD

Enhanced situation awareness is one of the primary goals of Force XXI and beyond. It is a critical axis of advance of the revolution in military affairs. The key concepts are, however, sometimes misunderstood. The focus of situation awareness is upon the warfighter, not on the digital architectures. Technologies to enhance situation awareness must be designed to aid leaders and soldiers in doing their jobs on the battlefield, i.e., enhancing their battle command, decision-making, and soldiering skills.

Toward that end, the U.S. Army Research Institute hosted the Infantry Situation Awareness Workshop at Fort Benning, GA, in September 1998. The objectives of the workshop were to capture Infantry situation awareness requirements, relate these requirements to digital and human technologies, and identify improved ways of measuring situation awareness. The focus was on the Infantry soldier and his unit, especially on training and leader development requirements.

This volume contains summaries of the workshop discussion groups and articles written by program participants. The participants included the very best from academia, business and industry, and government, in terms of knowledge and expertise of Infantry situation awareness. Achieving real progress in addressing the myriad of warfighter situation awareness challenges requires establishing and maintaining an open dialogue between behavioral researchers and Infantry warfighters. The workshop and this book are a great start.

EDGAR M. JOHNSON
Director

Executive Summary

Requirement

Situation awareness (SA) refers to the ability of a person to develop an adaptive internal model of his or her environment. Good SA also implies that the person can use that information to solve problems or otherwise interact effectively with the environment. As the Army continues to integrate advanced technologies into its force, SA is increasingly being recognized as a determining factor in battle outcome. Most of the focus in digitization has been on materiel, e.g., hardware, communications protocols, and bandwidth, as well as on doctrine and organizational structures. Digitization, however, also implies a host of far-reaching human dimension concerns, including training, leader development, and soldier issues.

Recently, the Army has begun to develop digital systems for the Infantry force. While it behooves the Army to build on the successes and lessons learned from its efforts to digitize the heavy force, light force requirements may be quite different. Many questions still exist as to specific Infantry SA requirements and as to how the new systems can best be employed and trained.

To address these many questions, the U.S. Army Research Institute sponsored the Infantry Situation Awareness Workshop on 29-30 September 1998, at Fort Benning, Georgia. The objectives of the workshop were to develop SA requirements and performance measures for Infantry combatants and teams, to establish a dialogue between cognitive and behavioral researchers and Infantry warfighters, and to identify requirements for future training, leader development, and soldier research.

The purpose of this book is to present the systematic views of key participants and to serve as an archival resource for future work in Infantry SA issues. The work reported here represents a fundamental and significant step toward enhancing the combat effectiveness of the Infantry warfighter of the future.

Approach

The workshop consisted of a series of invited addresses that defined the history and scope of SA research and application in Army systems. Following these presentations, the attendees were divided into four working groups. Each group was co-led by a retired general officer and an established SA researcher. The groups focused on (1) individual combatants and squads, (2) platoons, companies, and battalions, (3) Infantry brigades, or (4) future Infantry teams. Each group was asked to explore five key questions. These were:

1. What are the most critical Infantry SA requirements? How are these linked to combat effectiveness and operational readiness?
2. What new training techniques and approaches are needed?
3. What pitfalls should the Army try to avoid in its drive to enhance SA?
4 How can we assess SA in Infantry soldiers and teams?
5. What are the most critical training, leader development, and soldier SA research issues that the Army should address in the next five years?

Findings

The main findings of the workshop are summarized for each of the five questions addressed by the working groups. The issues raised have significant implications for future research and development in Infantry SA.

1. What are the most critical Infantry SA requirements? How are these linked to combat effectiveness and operational readiness?

The groups discussed how light SA requirements differed from heavy SA requirements and ways in which the light force can leverage technologies and lessons learned from the heavy force. In general, light Infantry lacks an integrated command, control, communications, and intelligence (C3I) system that can be used to transmit and receive reports and orders. Such a system should provide known locations of friendly and enemy forces, permit near

instantaneous calls for fire, and display thermal images, digital maps, and graphics. It should also provide easier, consolidated reporting and combat identification warnings.

A key SA system requirement is that it must allow Infantry teams to excel in night and limited visibility operations, particularly in restricted and urban terrain. Other SA requirements include: better communication of commander's intent—two echelons up and down, capability for en route updates, and tools for coordinating combined arms actions. At higher echelons, enhanced SA is needed to reduce risk, promote initiative, develop economy of force, and project logistics.

2. What new training techniques and approaches are needed?

The Army must develop and/or modify training environments to specifically train situational dominance. This may require development of SA tasks, conditions, and standards for individuals, small teams, leaders, and battle staffs. As with other effective training, SA training should provide repeated practice, performance feedback, and increasingly difficult, complex situations.

New training methods are needed to train and sustain individuals, teams, and staffs for digital battlefield tasks. Soldiers and leaders must be trained in the basics, as well as in how to use the technology-based SA systems. Soldiers must, for example, be able to navigate with a map and compass as well as with a global positioning system (GPS). The training goal should not be task proficiency, but "hyper-proficient" individuals and teams who can fully exploit available SA technologies.

3. What pitfalls should the Army try to avoid in its drive to enhance SA?

There was clear agreement that leaders and soldiers must learn to avoid over-reliance on SA system support. During Rapid Force Projection Initiative (RFPI), for example, there was a tendency to focus on Joint Surveillance Targeting Attack Radar System (JSTARS) information to the exclusion of other sources and forms of information. Also, leaders must be specifically trained how to use the new SA information to make better decisions. They must avoid deferring decisions until they have "perfect" SA.

Other threats include: information overload and its resultant fatigue, over-control of subordinates, vulnerability to countermeasures, unequal/incompatible technology among coalition forces, and failure to adapt organizational structure to new doctrine and procedures.

4. How can we assess SA in Infantry soldiers and teams?

One measurement framework discussed includes three levels of SA with corresponding measurement approaches for each. The first is "Perception" of elements in the current situation. This would include knowing the location of oneself, buddies and enemy, as well as knowing the terrain and obstacles, mission details, and commander's intent. The second is "Comprehension" of current situation, which would include understanding friendly and enemy strengths and weaknesses, status of mission, deviations from the expected, and timeliness/confidence in information. The third level is "Projection" of the future, which would include projection of friendly and enemy activities.

The groups discussed how process indices, direct measurement of SA, measures of decision-making, and performance measures can be combined to obtain a complete picture of SA. Other SA measurement issues/approaches discussed include: capturing the interrelationships among performance, workload, SA, and soldier acceptance; assessing/maximizing unit effectiveness when attachments have diverse technologies; comparing ground truth maps to separate staff solutions; assessing proactive information seeking; and a concern for shifting baselines as technology changes.

5. What are the most critical Training, Leader Development, and Soldier SA research issues that the Army should address in the next five years?

The overarching issues are ways to develop and train leaders and soldiers to take full advantage of emerging SA systems. For example:

- What are the best methods for using live, virtual, and constructive environments and training support packages to train situational dominance?
- How do we create and sustain "hyper-proficient" individuals and teams?

- How do we develop "leadership" and "cohesion" in increasingly digital environments?
- How can we best train adaptable decision-makers?
- What SA information is needed at each echelon for optimal decision-making; what are the training implications for such a decision?
- How can we develop better-distributed training capabilities, for example, to train hybrid teams?
- How can we best improve information display capabilities (e.g., for 3D terrain visualization) which are tailorable to decision-maker preferences and have information grouping strategies for different echelons?

Organization

Section 1 consists of three chapters. Chapter 1 offers a detailed overview of the purpose and scope of the workshop. The next two chapters are based on addresses given by two retired general officers. In Chapter 2, GEN (R) Edwin Burba relates his observations of recent warfighting exercises involving the 4th Infantry Division, which is the Army's first digital division. The effects of digitization are viewed as dramatic in enhancing combat success, but were also found to require new ways of thinking and tactics. A model of SA, based on cognitive theory and Army operational considerations, is described in Chapter 3. MG (R) Bert Maggart and Dr. Robert Hubal developed this model.

The next four sections of the book report findings from each of the four working groups. Each section begins with a chapter summarizing the group's discussions. This is followed by two chapters, one written by the group's retired general officer, and the other by the group's SA researcher. Thus, Chapters 4-6 deal with SA needs at the individual combatant level, Chapters 7-9 with platoons, companies, and battalions, Chapters 10-12 with Infantry brigades, and Chapters 13-15 with future Infantry teams.

The book concludes with Section 6, Chapter 16, which offers a retrospective analysis of the workshop. It summarizes the key findings and brings together common themes in Infantry SA.

Contributors

THE EDITORS

Scott E. Graham, Ph.D., is the Chief, U.S. Army Research Institute Infantry Forces Research Unit, at Fort Benning, Georgia. He was responsible for planning and organizing the Infantry Situation Awareness Workshop. Dr. Graham wrote Chapter 1 and was the principal author of Chapter 16.

Michael D. Matthews, Ph.D., is a research psychologist, U.S. Army Research Institute Infantry Forces Research Unit, at Fort Benning, Georgia. Dr. Matthews authored the synopsis of GEN (R) Burba's address, and was co-author of Chapter 16.

CHAPTER AUTHORS AS THEY APPEAR IN THIS VOLUME

Chapter 1: Infantry Situation Awareness: Introductory Thoughts

Scott E. Graham, Ph.D.

Chapter 2: Keynote Address: Army XXI Insights

Edwin H. Burba, Jr., GEN (R), serves as Chairman of the Georgia Military Affairs Committee, and consults with the U.S. Army.

Chapter 3: A Situation Awareness Model

Lon E. (Bert) Maggart, MG (R), is Program Director, Advanced Learning Environments, Research Triangle Institute, Research Triangle Park, North Carolina.

Robert Hubal, Ph.D., is a consultant with Research Triangle Institute, Research Triangle Park, North Carolina.

Chapter 4: Group 1 Summary: Situation Awareness for Individual Combatants and Squads

Jean L. Dyer, Ph.D., is a research psychologist, U.S. Army Research Institute Infantry Forces Research Unit, Fort Benning, Georgia.

Chapter 5: Situation Awareness Requirements for Individual Combatants and Squads

William R. (Bill) Richardson, GEN (R), is a consultant with Burdeshaw and Associates, Bethesda, Maryland.

Chapter 6: Situation Awareness for the Individual Soldier

Mica R. Endsley, Ph.D., is President of SA Technologies, Marietta, Georgia.

Chapter 7: Group 2 Summary: Situation Awareness Requirements for Platoons, Companies, and Battalions

Kenneth L. Evans, Ph.D., is a research psychologist, U.S. Army Research Institute Infantry Forces Research Unit, Fort Benning, Georgia.

Chapter 8: Situational Awareness in Infantry Battalions

Leonard (Don) Holder, LTG (R), is a principal staff member with the TRW Systems and Information Technology Group, Killeen, Texas.

Chapter 9: Infantry Situation Awareness Workshop - The Gawron Perspective

Valerie J. Gawron, Ph.D., is a principal human factors engineer with Veridian, Buffalo, New York.

Chapter 10: Group 3 Summary: Situation Awareness

Margaret S. (Marnie) Salter, M.A., is a research psychologist, U.S. Army Research Institute Infantry Forces Research Unit, Fort Benning, Georgia.

Chapter 11: Developing Digitized Light Formations

Frederic J. (Rick) Brown, LTG (R), consults with the Institute for Defense Analyses, Alexandria, Virginia.

Chapter 12: Infantry Situation Awareness Workshop: Observations from a Participant

Richard W. Pew, Ph.D., is a principal scientist at

BBN Technologies, Cambridge, Massachusetts.

Chapter 13: Group 4 Summary: Situation Awareness Requirements for Future Infantry Teams

Patrick J. Ford, M.A., is a Senior Staff Scientist with HumRRO, Monterey, California.

Chapter 14: Situation Awareness

Paul F. Gorman, GEN (R), is President of Cardinal Point, Inc., Afton, Virginia.

Chapter 15: Model-Based Measurement of Situation Awareness in Dynamic Tactical Environments

Daniel Serfaty, Ph.D., is Chief Scientist, Aptima, Inc., Woburn, Massachusetts.

Chapter 16: Concluding Thoughts and Observations

Scott E. Graham, Ph.D., and Michael D. Matthews, Ph.D.

Chapter 1

Infantry Situation Awareness: Introductory Thoughts

Scott E. Graham, Ph.D.
U.S. Army Research Institute
Fort Benning, GA

The U.S. Army is working to build an Infantry force that will be capable of full spectrum dominance in the 21st century. One of the key capabilities being sought for the modernized Infantry leader and soldier is enhanced situation awareness (SA). Toward this end, the U.S. Army Research Institute (ARI) is involved in several research and development programs which have goals aimed at enhancing situation awareness. These include Land Warrior, the Military Operations in Urban Terrain Advanced Concept Technology Demonstration (MOUT ACTD), and an ARI work package on Training Modernization for Infantry Forces.

Demonstrating enhanced SA may be easier said than done. Certain senior program reviewers, including the former Deputy Commanding General, U.S. Army Training and Doctrine Command and the DoD Human Systems Technical Area Review and Assessment Panel, have raised doubts as to whether these programs can actually demonstrate enhanced SA, in part because of difficulties in operationally defining and measuring SA. Part of the challenge is in even establishing the level of baseline SA for system comparisons. ARI, along with behavioral scientists from the Natick Research and Development Center and the Army Research Laboratory Human Research and Engineering Directorate are, however, working to address these SA definition and measurement questions.

In support of these SA issues and the general need to develop leaders and soldiers for a modernized Infantry force, ARI brought together a select group of military and civilian leaders for an Infantry Situation Awareness Workshop. The workshop was held 29-30 September 1998 at Fort Benning, GA. The objectives of the workshop were:

1. To develop SA requirements and performance measures for Infantry combatants and teams;

2. To establish a dialogue between cognitive and behavioral researchers and Infantry warfighters;

3. To identify requirements for future training, leader development, and soldier research. That is for the T, L, and S of the DTLOMS force development domains (Doctrine, Training, Leader Development, Organizations, Materiel, and Soldiers).

Definitions of Situation(al) Awareness

The Army formally defines SA in TRADOC Pam 525-5, Force XXI Operations, as "the ability to have accurate real-time information of friendly, enemy, neutral, and non-combatant locations; a common, relevant picture of the battlefield scaled to specific levels of interest and special needs." From this definition, the Army generally speaks of SA as knowing "where I am, where my buddies are, where the enemy is, where non-combatants are." Much of the focus has, however, tended to be on the requirements for digital architectures and processes for capturing and presenting SA information. By contrast, the focus of the workshop was on the requirements for how leaders and soldiers can be trained to exploit this information and on how SA can be measured.

Measuring SA has been troublesome. Dr. Dick Pew, one of our group leaders, has noted that there has been "...great difficulty in achieving operational definitions [of SA] that are neither vacuous or circular." The general notion that SA relates to performance is appealing. That is, the more individuals are aware of their surroundings, the better their decisions and performance. This, however, leads to the circularity. How do you know you had good SA? Because there was good performance. Why was the performance good? Because there was good SA. If you cannot isolate and measure the specific contribution of SA, the practical value of the concept is greatly diminished.

The SA measurement problems become even greater when you are trying to assess higher levels of SA. For example, it is easier to assess whether a platoon leader knows the location of

friendly and enemy units (e.g., you can have him plot them on a map), than it is to assess a leader's capability to predict future states and actions. Also, most SA measurement work has focused on individuals, and in particular, on aircraft pilots. By contrast, much of the interest by the Army and indeed at this workshop was on the collective SA within teams, be they Infantry squads or brigade battle staffs.

The workshop generally addressed SA in the way currently being forwarded by the Commanding General, 4th Infantry Division, the Army's First Digital Division. Situation awareness is not seen as the end state, but as the foundation for situational understanding, i.e., understanding what the SA information means; and for situational dominance, i.e., taking/directing actions based on good decisions from the SA information. That is:

Situation Awareness ➡ Situational Understanding ➡ Situational Dominance

The workshop objective of developing SA requirements for Infantry combatants and teams was not focused on information capturing, processing, and presentation technologies, but on more fundamental questions about leadership and decision-making. For example, for various echelons, leader positions, missions, and environments, what information do Infantry leaders and soldiers need? And from that, how can we better train and develop our leaders and soldiers to make full use of that information? Again, the emphasis is on training, leader development, and soldiers.

Balanced Development of DTLOMS

Recently, Army leadership and the combat developments community have underscored the need for a balanced development of DTLOMS in the draft "Army Experimentation Campaign Plan." This is formal recognition of the fact that building digital architectures, improved sensor-shooter links, and new battle command systems are, in themselves, not sufficient for 21st century full spectrum dominance. There also need to be complementary improvements in training, leader development, and soldier abilities and skills. At times, it appears there is a near frantic urgency by

technologists to build digital architectures without full appreciation of operational requirements. This urgency, in part, is a function of budgetary opportunities. The focus should, nevertheless, be on developing tools and systems that support warfighters and their decision-making, not on the digital architectures per se.

Training

How do we train situational dominance? If the Army and the Infantry force are truly going to make a half evolutionary/half revolutionary change toward enhanced SA, they will have to take a serious look at the training system. As new systems are introduced, e.g. Land Warrior, the Army Battle Command System (ABCS), it will not be sufficient to squeeze new system training into existing programs of instruction and unit training plans. There should be a comprehensive re-examination of the full range of knowledge and skills needed in the information age and for ways to effectively train them. New training environments and systems will need to be developed for both institutional and unit training that specifically develop SA decision-making skills. In part this will require the redesign of tactical engagement simulations (TES) including live, virtual, and constructive, with appropriate training support packages for each echelon.

A new training strategy will be needed for individual/collective and institutional/unit. The strategy should specify the "best practices" for training and sustaining SA basic, digital, and hyper-proficient skills in soldiers, leaders, and units. To a large extent, training for enhanced SA can be effectively addressed by extending current training methodologies. These include:

- Training in a realistic, functional context - "Train as you will fight;"
- Frequent, task-specific feedback;
- Repeated practice in increasingly difficult contexts; and
- Effective use of part-task trainers, low cost simulators, and distributed learning capabilities.

Leader Development

How do we develop leaders who can fully exploit the emerging digital and SA systems and at the same time demonstrate the full range of skills known to be necessary for good Army

leadership? Future leaders will have accurate, near real-time pictures of the battlefield and the ability to communicate readily with all echelons. The challenge may well become how to be a good leader despite overwhelming digital capability. Leaders will have to learn that sitting in front of SA workstation displays "controlling" the battle is not good leadership. Consider the leadership skills laid out in Draft FM 22-100, "Army Leadership" and some questions concerning the potential impact of SA technologies on leadership skills and processes.

- Interpersonal skills - including communication and team building. How can leaders demonstrate "follow me" leadership skills using digital communications? How can SA technologies be used to quickly build effective, cohesive teams? How can leaders facilitate the building of ad hoc teams or a more effective integration of active and reserve component units?

- Conceptual skills - including critical reasoning and critical thinking. How do we train leaders "how to think" and not just "what to think?" How do we train leaders to use the digital SA information to make better decisions? How do we develop innovation, adaptability, and the ability to handle and reduce uncertainty? How do we develop "disciplined intuition?"

- Technical and tactical skills - including knowing how to operate and apply SA technology systems to warfighting tasks. How do we develop balance between technology and leadership skills? How do we develop Army leaders to function better in non-linear, decision-making environments?

The basic point is that as we move toward greater digitization, there are likely a number of second and third order leadership effects that the Army has just begun to consider. For example, we may doctrinally claim that there will be decentralized, non-linear decisionmaking. Getting NCO and officer leaders to truly delegate (or conversely fully assume) decision-making responsibilities does, however, represent a significant cultural change in the Army and may be difficult to effect.

Soldiers

What soldier attributes are needed for full spectrum dominance? Force XXI Operations (TRADOC PAM 525-5 (August

1994)) says: "Individual soldiers will be empowered for independent action because of enhanced situational awareness, digital control, and a common view of what needs to be done." "Increased flexibility and adaptability will be required at all levels." And, "Individuals will be equipped with personal protection systems and communications and weapon systems that will allow them to respond instantly to the chain of command and rapidly changing situations." Some believe that to meet these requirements the personnel system will need to attract and retain a different population of soldiers than is in the force today. An alternative, and perhaps more realistic, position is that we have about as high a quality of force as we can expect. The changes that will need to occur will have to come from improved training, placement, command environment, and a careful design of SA systems.

Concerning the SA systems, there are many unresolved questions as to how much and what type of information soldiers and leaders need at each level. Just because we may have the capability to give the small unit leader large amounts of real-time battlefield information does not mean that we should. A combination of growing technological capability and a downsized Army is leading some to project that small units and individuals will be "empowered for independent action." If this is to happen, there will need to be detailed changes in doctrine and a clear articulation of the role of the future individual soldier and small unit. Such change could come as part of a "revolutionary" redefinition of the role of the Infantry force.

It is also important that SA systems are designed with the soldier in mind. In the past, much of the emphasis regarding human factors has been on the physical fit between the soldier and a piece of equipment or crew station. In the future, human factors issues will also be focused on the fit between the soldier and information, i.e., is the information presented in such a way that the soldier makes good decisions based on that information? This will require the development of interfaces that are intuitively reasonable to the soldier and/or ones that can be tailored to the preference and needs of the soldier or leader. In many cases, tactics, techniques, and procedures (TTPs) will need to be re-examined to take the greatest advantage of new SA technologies. Too often existing analog procedures are simply converted into a

digital procedures, e.g., the use of analog report formats in digital reports.

Need for Improved SA Measurement Techniques

Useable, psychometrically sound SA measurement techniques are becoming increasingly important. Foremost, there is the need to assess the effectiveness of new systems. The future of certain modernization efforts will increasingly hinge on their ability to demonstrate enhanced SA. In addition, decision-makers are increasingly calling for hard metrics as evidence. Demonstrating enhanced SA is a difficult task which is made even more difficult by the lack of acceptable baseline measures. In other instances, SA measures are needed to validate the effectiveness of new training approaches and TTPs.

One of the axioms from the behavioral sciences is, "That which gets measured, gets done." If the Army and other services are seriously looking to improve situational measurement, then individual and/or unit SA should be specifically assessed. One approach is to focus feedback on leader situation awareness during after action reviews. Such an approach was recently used in the Digital Leader Reaction Course (DLRC) in support of Army Experiment 5. As noted by Dr. Jim Lussier in an evaluation of the DLRC, "During the execution of the exercise, the mentors posed questions designed to direct the learners' way of thinking, for example, to broaden the perspective in terms of enemy intent so that the learners considered the overall enemy divisional intent rather than just that of the regiment in front of them."

One possibility would be to establish something equivalent to "tasks, conditions, and standards" for SA. In such a framework, success in training or in a tactical engagement simulation exercise would, in part, require a leader to demonstrate a specified level of SA. Such an approach would require significant research and development to devise an acceptable task and measurement structure. It is possible that such a research and development effort could follow from the recommendations made during this workshop.

Workgroups

The crux of the workshop was the discussion and presentations of four working groups. Each group was co-led by a retired general officer and an established SA researcher. The groups and leaders were:

Group 1 - SA requirements for individual combatants and squads
Co-leaders: GEN (R) Bill Richardson and Dr. Mica Endsley

Group 2 - SA requirements for platoons, companies and battalions
Co-leaders: LTG (R) Don Holder and Dr. Valerie Gawron

Group 3 - SA requirements for Infantry brigades
Co-leaders: LTG (R) Rick Brown and Dr. Dick Pew

Group 4 - SA requirements for future Infantry teams
Co-leaders: GEN (R) Paul Gorman and Dr. Daniel Serfaty

Each working group was comprised of approximately 20 knowledgeable military and civilian personnel. These included participants from recent and ongoing Army experiments, to include the Rapid Force Projection Initiative (RFPI), Task Force XXI, the MOUT ACTD, and Land Warrior. The groups also included leaders from the Joint Readiness Training Center, 75th Ranger Regiment, 82nd Airborne Division, the Infantry Center and School, and scientists from Army laboratories and other services. The working groups each addressed five basic issues.

1. What are the most critical Infantry SA requirements? How are these linked to combat effectiveness and operational readiness?

   The groups discussed how light SA requirements differed from heavy SA requirements and ways in which the light force can leverage technologies and lessons learned from the heavy force.

2. What new training techniques and approaches are needed?

   The groups discussed ways to develop and/or modify training environments to specifically train situational dominance. They

also discussed how light SA training requirements differed from heavy SA training requirements, and what training issues should be addressed in the Army Experimentation Campaign Plan.

3. What pitfalls should the Army try to avoid in its drive to enhance SA?

   The groups discussed ways to specifically avoid the mistakes that were made in planning and executing the Army Warfighting Experiments (AWEs) and the Advanced Concepts Technology Demonstrations (ACTDs). They also discussed lessons learned from the observations of individuals and units at the combat training centers.

4. How can we assess SA in Infantry soldiers and teams?

   The groups proposed approaches for developing SA measurement techniques and frameworks for organizing the measures. To the extent possible, the discussions were in the context of upcoming experiments and tests.

5. What are the most critical Training, Leader Development, and Soldier SA research issues that the Army should address in the next five years?

   The groups identified the top T, L, and S research and development issues needed to support Infantry SA requirements. The overarching issues addressed research approaches to develop and train leaders and soldiers to take full advantage of emerging SA systems.

Overview of This Volume

The thoughts and insights on SA of the military leaders and professional experts who participated in the workshop are documented in this book. This collection of writings represents a unique set of perspectives on SA requirements, training issues, and operational/technical considerations within the context of Infantry warfighting. As General (R) Paul Gorman illustrates in Chapter 15, SA requirements for Infantry soldiers and leaders are many orders of magnitude more complex than similar require-

ments for other forces. The contents of this book represent a beginning effort to comprehend these complexities and build the groundwork for useable SA systems that will provide future Infantry forces the capability to rapidly and overwhelmingly dominate the battlefield.

The keynote address of General (R) Edwin Burba is summarized in Chapter 2. General Burba observed several recent Army exercises and experiments which tested SA technology. He offers his insights on the tactical and strategic implications of this technology on Infantry warfighting. This is followed by a particularly thought-provoking chapter on a SA model by Major General (R) Bert Maggart and Dr. Robert Hubal. The remainder of the chapters are from the four working groups. For each group, there is a group summary followed by commissioned chapters from each group co-leader. The final chapter contains some concluding thoughts and observations.

Chapter 2

Keynote Address: Army XXI Insights

GEN (R) Edwin H. Burba, Jr.

The following is a summary of the address made by General (R) Edwin Burba. The focus of this presentation was on insights on situation awareness gained from Army XXI exercises. This synopsis was prepared by Dr. Michael D. Matthews, research psychologist, U.S. Army Research Institute, Infantry Forces Research Unit.

Situation awareness is a key concept which is receiving much attention in the Army. While this attention has generated useful discussions and applications, there is a need to (1) keep situation awareness research and development in balance; (2) avoid inefficient or irrelevant research, development, and application; and (3) develop and maintain the right focus in situation awareness research in order to maximize payoff to the soldiers in the field. To that end, insights gained from Army XXI exercises are discussed.

Army 21 Exercise Insights

1. Situational Awareness: Overriding to Combat Outcomes

When a force equipped and trained with situation awareness technology faces one that is not so equipped, the initial outcome is an overriding defeat of the opposing force. However, it is unreasonable to think that the enemy will not quickly learn to alter his tactics when faced with a force of this type. The specific tactics that the enemy may turn to will be influenced by a variety of factors and will be discussed in more detail later.

It then follows that research must be conducted to allow friendly forces to successfully react to changes in enemy tactics. The situation awareness hardware must be designed to resist electronic countermeasures. Moreover, the tactics that friendly forces employ must also help react to adjustments the enemy

may make. For example, if the enemy is thought to be reading the electronic signals of the friendly forces, then this could be turned against him by deploying false signals to confuse enemy commanders.

> *Clearly, situational awareness has overriding combat aspects. It's decisive when used properly. . . it isn't a modest enhancement, it's a decisive enhancement!*

In short, a major lesson learned from Army XXI exercises is that, properly used, situation awareness produces a decisive enhancement of combat outcomes. Nevertheless, the enemy will quickly adapt to this technology. It is imperative that the commanders and battle planners of the friendly forces remain flexible and anticipate these changes in enemy tactics. It is friendly counter-action to an uncooperative enemy's reaction to initial friendly actions that is the ultimate arbiter of success. Situation awareness provides a decisive edge in these battlefield dynamics.

2. Sensor to Shooter Times Make a Big Difference

A second major lesson learned from Army XXI exercises is that the time delay between sensing data and feedback to combatants is crucial. Given the speed with which modern forces can move, data that are only a few minutes old may be of little use. That is, if the enemy moves out of the munition footprint, then the ability to effectively engage him is compromised and a military edge lost. Terrain will impact the flow of information by interfering with sensor acquisition, signal transmission, and precision munitions target honing. Or, there may be some delay between sensing intelligence data and integrating those data into the system.

Weapons systems with implicit sensor/shooter capability, such as the Apache-Longbow and Comanche helicopters, minimize the sensor/shooter delay. These systems are extremely lethal. Also, weapons systems with large shooting footprints can be lethal and decisive, because they allow for somewhat more error in shooting accuracy and delays in sensor to shooter times. Thus, artillery special munitions are one of the most effective killers where they can be used.

One way to enhance the utility of situation awareness sensors is to employ multi-source cueing of these single source sensors. That is, while situation awareness input from a single sensor may vary in validity or reliability, a threat detected by multiple sources would be more likely to be real. Getting this information to appropriate levels of command in a timely manner allows effective command and control and subsequent maneuver and synchronization of friendly forces and targeting of specific enemy systems.

3. Branch Contributions Vary With Enemy Standoff

The issue of branch contributions varying with enemy standoff is an overriding concern. Observations of Force XXI exercises demonstrated that when situation awareness information is provided in a timely and accurate way (i.e., enemy at long range) the blue force dominated the fight. As the standoff moves from deep, to medium, to close, maneuver forces contributions increasingly emerge as crucial to battle success. With close standoff, the ability to maneuver and to buy time for sensing is key. More accurate simulation modeling is needed for close standoff battles, as well as additional consideration to enemy technical and tactical countermeasures to situation awareness.

> *During the initial phases of the first exercise . . . the OPFOR decisively defeated the blue forces. They just ran over them. And in that particular scenario, the blue forces were introduced to the enemy at very close ranges. Before they could get the sensors to find the enemy, process the information, and get it to the shooters, they had been overrun by the enemy.*

4. Infantry Contributions Vary With Situation Awareness

A striking observation taken from Army XXI exercises is the degree of enhanced outcome of digitized over analog forces. The perspective presented here is mostly from that of battalion or brigade level. At those levels, good situation awareness allows for sound risk-taking and bolder, more decisive moves. It also provides time to react to tactical emergencies and to exploit tactical opportunities. Moreover, good situation awareness allows simultaneous fighting in depth against close-in artillery and armor

reserves. Other advantages that accrue are better optimization of combined arms mass and accelerating the tempo of battle. Observations of the exercises showed that units that were not equipped with digital systems were at a distinct disadvantage. In a word, good situation awareness determines sufficient enemy locations, dispositions, compositions, and weaknesses to provide an edge to the friendly force.

> During Army XXI experiments, we had one brigade that did not have all of the "gee-whiz" situational awareness that the other two brigades had, and it was the difference between night and day. When the analogue brigade received the situation awareness equipment it performed exponentially better. So it does present a big, big payoff from battalion level and above.

Another key point in this context is that situation awareness of friendly forces is as crucial as situation awareness of the enemy. Furthermore, the surface has barely been scratched in exploiting situation awareness sensors. The critical question is what systems, at what levels, give Infantry the greatest return on investment with these technologies. Affordability is a reality. These systems provide an enormous contribution to the synchronization of the entire combined arms team effort but some are expensive.

5. ABCS Contributions Signal Wave of the Future

The Army Battle Command System (ABCS) will play a key role in future Army operations. Its utility is compelling for medium and near stand off fights. The Maneuver Control System (MCS) allows good integration of information, a large user-friendly screen, and good visualization of the battle. Critical considerations in these systems are good intelligence and horizontal integration of ABCS, which will maximize situation awareness of Combined Arms Training (CAT) outcomes. ABCS at brigade allows vertical as well as horizontal situation awareness. Effective training of soldiers in the use of these systems is extremely crucial. We have not invested enough in training, so this should be a focus for the future.

6. The Enemy has a Vote—Countermeasures

It is worth highlighting that the enemy will not react passively to the tactics of the digitized Army. This is sometimes not given the attention it warrants. Enemy adjustments may be technical and/or tactical. Examples of technical countermeasures include imitative deception, partial electronic disclosure, and jamming. Even technologically less sophisticated enemies may employ tactical countermeasures. Examples here include long range dispersion, moving quickly in order to beat sensor/shooter lag times, quick dispersion of resources following an attack, avoiding Joint Surveillance Targeting Attack Radar System (JSTARS) detection by moving slowly (< 3 km per hour), and other innovative approaches depending on the setting. During exercises, the OPFOR quickly adjusts to the threat posed by the digitized force. Thus, a major lesson learned from Army XXI exercises is to plan for these countermeasures in order to preserve the effectiveness of the micro-chip sensor and shooter systems.

There are a lot of different things that the enemy can do to obviate or diminish situational awareness technologies. However, the BLUFOR, once it's introduced to these, comes up with counter-counter measures that are relatively effective. This is a very important point to recognize.

7. Terrain, Weather, and Smoke Make a Difference

Another factor that was made very clear from observations of Army XXI exercises was that environmental factors, broadly defined, make a tremendous difference in the application of situation awareness technology and tactics. It has always been true that terrain and weather are crucial factors to battle success, and it should be emphasized that this will not change. Terrain intervenes on detection. If detection is interrupted, situation awareness is degraded. It is vital that terrain and weather influences on detection be modeled into the development of detectors and situation awareness systems.

8. Some Tactical and Technical Realities are Immutable

While the introduction of digitization to the Army has widespread ramifications for how force is optimally employed, there

are several factors in warfare which remain unchanged. A major point is that soldiers will still engage the enemy in close combat, and thus basic combat skills are absolutely fundamental to combat success. The notion of a battle captain hunched over a computer terminal, killing the enemy with a mere keystroke (the "Pac Man" approach) is simply not accurate.

Other immutable factors are the importance of movement and maneuver - you can't kill a moving target; the importance of synchronization; the sustainment and affordability of systems; the need for tight operations security; awareness of and the ability to anticipate enemy countermeasures; and the role of terrain and weather in combat operations.

Situation Awareness: For What Purpose and What Level?

Numerous factors must be considered in applying situation awareness procedures to Infantry operations. While the basic situation awareness system must have certain common features across different situations, it must also be sufficiently adaptable to allow for different missions in different environments. The situation awareness needs will vary with type of mission. Is the setting strategic, operational, or tactical? What role (targeting, shooting, detecting) for what task (recon, over-watch, infiltration) is operable? It is very important to develop systems that can be applied to a variety of combat scenarios. We must not assume, for example, that combat will usually be similar to that encountered in Desert Storm.

> The awareness of our own force is as important as that of the enemy force . . . far more important than we thought it would be.

Another factor that should be considered in situation awareness is at what level is the information being processed? The situation awareness needs at the brigade level may often be quite different from the needs of personnel operating at the platoon level or below. The platoon leader probably wants to know specifically where each of his individual assets are located, for example, while the brigade may be more interested in locations of companies and platoons, but not individuals. The optimal situa-

tion awareness system will allow variable resolution, allowing decision makers at different levels of command to tune in or out various levels and types of information. The division must be fully aware of the situation of its brigades, providing deep artillery support, reserves and reinforcements, preparing battlefield intelligence, and being able to sustain 1st and 2nd echelon fights. Thus, situation awareness needs vary with level.

Conclusions

Integration of situation awareness technology into the digitized Army may provide an overwhelming advantage if properly employed. The underlying concern is to build a system that focuses efforts on killing enemy units, while protecting friendly forces against enemy actions and fratricide. Situation awareness is constantly in transition, a fact made more relevant by the speed with which modern units may move and maneuver. Care must be taken to ensure that the technical systems used are sustainable, affordable, and have multiple applications.

Many wildcards exist with situation awareness. Enemy countermeasures must be anticipated and dealt with. The enemy will mature with experience in fighting a digitized force. It cannot be assumed that combat will always be against technologically challenged forces. We must be prepared to fight an opponent who also possesses digital resources. The situation awareness systems must be practical, useable, sustainable, and cost-effective.

> *I think we are in some kind of transitional situation right now. We need to be able to fight the Desert Storms at the same time we are executing missions in the Bosnia's and Haiti's of the world. Situation awareness systems that transcend the requirements of this transitional period are those with the most contemporary relevance.*

If the enemy is at long range, military intelligence, artillery, and aviation systems will dominate battlefield success. As the enemy closes, maneuver forces supported by other members of the combined arms teams will play an increasingly important role. They will execute security zone and main battle area operations to provide time for sensors to target then shoot enemy forces before

those forces can close and destroy our key systems (sensors and long range precision shooters). It is still a combined arms fight but with situation awareness for all forces it is an exponentially faster and more lethal fight. This quantum leap will change organizations, equipment, doctrine and training, and some aspects of leader/soldier qualities, but the robust requirements for maneuver forces and certain tactical and human dimension immutables will persevere as they have for generations.

Synchronization of the combined arms team in the deep, close and near battle remains the cornerstone of success. Because situation awareness provides overwhelming leverage to synchronization and because synchronization is most operative at battalion/brigade level, that is the level of highest situation awareness payoff for the maneuver forces, particularly the Infantry. This will be true regardless of strategic setting or what dimension of war is being addressed.

Chapter 3

A Situation Awareness Model

MG (R) Lon E. (Bert) Maggart
and
Robert Hubal, Ph.D.
Research Triangle Institute

General

Situational awareness (SA) has been defined in a number of ways, but for the purpose of this paper, we describe it as knowledge of a specific situation that enables a commander to:

- Place current battlefield events into context;
- Readily share a portrayal of the situation with staff and subordinates; and
- Predict, expect, and prepare for future states and actions.

Traditional discussions of SA tend to focus on either technology or on measurement techniques. Our effort however, is on the mental or intellectual processes that result in situational awareness. Our model closely resembles the SA Model proposed by Endsley, but we distinguish more finely her individual factors. We view SA as having five interrelated components.

- Battle skills
- A continually revised mental representation used consciously in decision-making
- Automatic processes used in decision-making, including pattern analysis, proceduralized knowledge, and an analogical engine
- Spontaneous input
- Technological support

Based on the interactions among the five components, we also maintain that situational awareness exists on four distinctly different levels in our framework: past, present, near term and

future. The past supports trending predictions, while in the present, SA results from the ability to derive expected outcomes from conscious and automatic processes, for example, "intuition." In the near term, the interaction among components allows the user to rapidly and efficiently update and adapt mental representations using inputs from supporting technology and visual, auditory, and other sensory cues from the actual environment, yielding more easily recognizable near term consequences.

In the future, because the user has acquired present and near term SA, the application of a sixth component, native skills, which underlie most of the first five components, allows for an intelligent way to modify existing mental representations to account for future possibilities. We view native skills as a collection of abilities inherent and perhaps innate to a commander that directly affect how the commander establishes SA (i.e., intuitive processes ordinarily not under conscious direction).

Battle Skills

As part of our SA model, we decompose battle skills into experience-based habits of thought, knowledge of effective and ineffective rules, and refined intuition; skills based on global preparation; and knowledge from episodic preparation or mission specific information.

Experience is the accumulation of knowledge gained through participation in events or activities real or simulated. Experience is in large part the basis for analogical reasoning and may well be the basis for much of what we describe as native skills. Experience enables learning and shaping of effective mental or cognitive rules, both conscious and unconscious.

Global preparation skills are those commonly taught in Army classrooms and during training exercises, the National Training Center, Battle Command Training Program and other simulations. Both the educational and training processes are relatively standardized throughout the Army so that officers of any given rank, branch and position have roughly equivalent backgrounds.

Episodic or mission-specific information is acquired through typical communication within the command post. Some

of the important knowledge that is acquired for a given situation includes spatial knowledge of the battlefield, temporal knowledge of the battle, logistic and readiness of the command, and enemy positions and fighting capacity. Episodic information is that which is needed to deal with the current and related future tactical situations.

Mental Representation and Conscious Decision Making

A central component of our SA model is a mental representation that is both a dynamic, imagistic visualization of a tactical situation and a collection of general and specific associated knowledge. We purposefully do not describe this structure in detail, for mental representations differ between individuals and in fact change rapidly as new information arrives and battle command skills dictate.

Further, we do not wish to take away from the intense cognitive processing that a commander must perform while making battlefield decisions. We do, however, propose that commanders must have the ability to imagine and intuit. It is not clear to us if all commanders possess these capabilities, nor is it clear if they are learned skills or innate. Given that imagination and intuition are present, commanders use at least two cognitive constructs in deriving relevant information for efficient, effective decision-making from their mental representation of the warfighting situation:

- When the mental representation reflects aspects of the environment such as terrain, friendly and enemy force locations, synchronization points, and distinctive features, the commander can use visual and spatial imagery in conjuring a picture of the battlefield. The picture can assist in choosing among numerous tactical alternatives including formations, unit locations, support by fire positions, breach areas and objectives. Similarly, memories of sound (e.g., radio traffic, wheeled and track noises, rotor flappings and gunfire) enable retrieval using auditory knowledge. The commander can also use tactile, olfactory, and other forms of imagery.

- When the mental representation involves prepared displays of information, such as charts, tables, and graphs, the commander can use cues inherent in the displays for retrieving impor-

tant information. For instance, charts enable row and column retrieval of information using spatial knowledge, whereas written instructions support primarily sequential retrieval. Computers can generate adaptive displays of information that depict unit arrays over time (amoebas) as a form of temporal knowledge.

In sum, at any point in time the mental representation is a snapshot of the environment, not necessarily literally accurate but comprehensive enough to enable successful decision-making using knowledge of tactics, logistics, readiness, the terrain and the enemy. Initial mental representations may be largely formed through intuition, with SA data and information used to discipline the intuition. "Disciplined intuition" may be trained.

Automatic Processing

Decisions are made not only through conscious processing but also through automatic processing. We propose three forms of automatic processing: pattern analysis, procedural skills, and analogical reasoning.

Pattern analysis occurs at a very low level, such as the level of recognizing friendly and enemy tanks or identifying common battlefield conditions on a display screen. Pattern analysis is the automated process that transforms much combat information into intelligence.

Procedural skills are those perceptual and motor skills that automatically feed into a decision. Scanning the horizon for identifiable patterns, swerving to avoid an obstacle, even reacting to calls of distress, can all be considered procedural. Procedural skills are learned, preset, immediate responses to specific stimuli.

The analogical engine also provides automated, immediate responses to stimuli. We term this component analogical because the process involves more than simply pattern recognition or proceduralized response. A commander with broad experience and focused expectations will quickly and intuitively understand a plan of action based on recognized patterns, and will begin mapping structural and surface similarities between the situation and the recalled pattern. In addition, a commander can consequently

update his/her mental representation to reflect differences between the situation and those previously encountered. The results of this human analogical engine are typically called "intuition."

Simultaneously, the commander will process the information to determine how present or near term events relate to future operations. This information may be recalled later and used to directly impact on the decision-making process or become input into a future mental representation. In either case, this processed information may become critical in future battlefield decisions.

Technological Input

Technology is integral to obtaining and transmitting the information necessary in forming an initial mental representation of the situation and in updating the representation with new information. We believe that technology applies to situational awareness in two distinctly different ways. First, it provides the means to transmit new or updated visual, auditory, and other cues from various electronic and human sources.

Second, technology assists in the decision-making process by presenting information in ways that lead to a clearer understanding of present and future situations. Adaptive representations assist the user in gaining knowledge, either in accordance with a format established by the user or automatically, based on an internal analysis of trends in the flow of information. In this fashion, the state of the situation controls how and what information is used, allowing the commander to focus on temporarily critical information while effectively ignoring other information.

We believe that presentation of information using technology should adapt rapidly and automatically to the user as situational contexts dictate. For instance, if the commander is already fully "loaded" in his/her visual capacity, important information must then be presented using an auditory channel. Similarly, at different points in time, presentation of enemy knowledge might involve location alone, enemy positions plus estimates of strength, or only those enemy forces that are immediately dangerous. The technology must scale and adapt to the situation.

Spontaneous Input

We believe that apart from the normal decision processes, there exists the possibility of input from a variety of sources, which is so important that it causes an immediate change in both on-going and planned operations. These inputs feed primarily into the automatic processing component, since it is relatively automatic for a commander to realize how important the information is and how it affects operations.

Native Skills

Native skills account for the existence and contribution of critical but abstract mental processes such as imagination, innovation, creativity, the ability to visualize and the ability to battle command. Native skills are the heart of situational awareness but the most difficult aspect to define. These skills refer to what Americans describe as an "intuitive feel for the battlefield" or what the Germans call "Fingerspitzengefuehl" and the French call "coup d'oeil". Clausewitz noted this phenomenon in his writings:

> *Things are perceived, of course, partly by the naked eye and partly by the mind, which fills the gaps with guesswork based on learning and experience, and thus constructs a whole out of the fragments that the eye can see; but if the whole is to be vividly present to the mind, imprinted like a picture, like a map upon the brain without fading or blurring in detail, it can only be achieved by the mental gift we call imagination.*
>
> **-Clausewitz**

We know these skills impact on analogical reasoning, ability to visualize, expected outcome, commander's intent and concept of the operation and the decision. However, we don't know to what extent. We know, at least anecdotally, that some commanders are more gifted in these skills than others. Native skills are rarely taught in Army schools, probably because we have been unable to define them accurately enough to study and understand, much less teach. In fact, Clausewitz suggests that it is impossible to teach such skills. We believe that native skills are the major distinction between great commanders and those less

accomplished, but that significant additional study is necessary to finalize a conclusion on the issue.

Decision-Making Process

The decision-making process is the sum total of all the tools--those derived from conscious and automatic processing and from the adaptive display of information that technology provides--that the commander and staff use to arrive at a decision about present, near term or future operations.

Outcomes

Outcomes resulting from the model are consistent with the notion of past, present, near term and future situational awareness levels. An operations order is a present outcome, an operations plan is a near term outcome and a future outcome may be a request for specific information. While it is possible that a present tactical outcome may result from an unexpected, random event, generally it is the product of executing the operations order. It is usually verification that the visualization, planning and execution were successful or not. The variance between expected and actual outcomes provides valuable information to update battle skills, experience, and the technology databases that display present information and provide the basis for future operations.

The product of the model is sufficient understanding of the situation to begin the decision-making process to produce present, near term or future outcomes and to provide input for collective process which result in shared situational awareness.

Collective Process

The situational awareness model presented suggests an individual adaptive process that results in decisions that drive specific outcomes. This is important because the commander must understand the situation before conceiving a concept for the entire unit.

We learned during the Gulf War that even a small advance in situational awareness technology (such as global positioning

system equipment) can have enormous impact on the outcome of battle. We know that individual situational awareness technology is important for building confidence and for freeing leaders from mundane, time-consuming tasks, so that they can instead spend their limited mental resources thinking, planning and commanding.

Given basic competence in battle skills, combat outcomes would be better if commanders were able to spend more time thinking about present and future operations. Shared situational awareness begins as a mental construct, and therefore improvements in the thought process will generate improvements in this area as well.

We believe that the model describes a more rational basis for most collective activities, including the orders process, command and staff actions and troop leading procedures, among others. It is the commander's concept of the operation that initiates staff and subordinate command planning. To the extent that the commander's concept of the operation is illustrative of his intent or vision, it provides to all participants a common understanding of the battlefield. More importantly, it is the basis for establishing a common view of the battlefield.

The current lack of situational awareness technology in all but a few tactical units suggests that shared situational awareness will remain, at least into the near future, mostly a mental rather than technological process. The mind is our only existing system for recording battlefield input, rapidly processing it, and providing useful output once the operation is underway. There just is no way to achieve and sustain shared situational awareness using maps, stickies and grease pencils. This is not necessarily bad, however, because we need to learn more about the mental processes in order to develop technologies that are complementary.

The problem for the commander today and in the future is to first create in every mind in the unit common or mutually consistent "pictures" of the battlefield, then achieve understanding of what the common picture means. Technology can create the common graphic, but not understanding. Situational awareness is achieved using the mental processes described in the model to

convert information provided by technology into meaningful analyses leading to desired outcomes. If we can improve these mental processes in the present manual environment, expected future outcomes using technology should be exponentially better. We believe that huge future payoffs in both individual and shared situational awareness are possible if we can better understand "native skills" and their relationship to analogical reasoning and the formulation of mental representations described in the model.

Conclusion

If the preparation of commanders, particularly those at battalion and brigade levels, is generally identical in terms of education and training, then the difference between those who are successful in combat and those who are not clearly results from other factors, experience for example. However, we believe the difference primarily to be native skills. Specifically, we believe that commanders who have imagination and intuition, who are innovative and creative and have the ability to battle command will be successful under all circumstances, especially during combat operations. Significant anecdotal evidence from the National Training Center and assertions by noted military theorists like Clausewitz suggests that not every leader possesses such skills, but that the skills are clearly a causative factor in battlefield success.

The Army needs to investigate and verify or reject this contention. If the Army determines that the native skills we have described here are essential for battlefield success, then we must set about determining if these skills are innate (and if so, how genetically distributed throughout the population), or are skills that can be learned. We need to discover ways to teach leaders how to use their skills more effectively, and we must find ways to use technology either as a surrogate or as an adaptive mentor.

Technology does not guarantee perfect situational awareness and perfect situational awareness does not equal battlefield success. We believe that unless one has the native skills of imagination, the ability to visualize and the ability to battle command, complete situational awareness is not possible to achieve. Even if technology makes available every possible piece of relevant information about the battlefield to the commander, situational awareness will never be achieved without the native intellectual skills to put the information into context.

Battlefield success depends on having the necessary information about the situation. However, information alone does not guarantee battlefield success. To be successful, the commander must have the battle command skills to visualize information so that it can be used effectively, the ability to motivate soldiers and to use force of character to impose his/her will over the enemy. Without question the Army needs to understand why some commanders appear to have a natural feel for battle command and others have no clue.

Acknowledgments

We especially want to thank the following individuals who took the time to review our work and make comments that resulted in a far better product than we alone could have produced.

Col (R) John Burlingame
Col Greg Fontenot
Col Jeanette James
Dr. Jack Hiller
Dr. Kathy Quinkert

Chapter 4

Group 1 Summary: Situation Awareness for Individual Combatants and Squads

Jean L. Dyer, Ph.D.
U.S. Army Research Institute
Fort Benning, Georgia

A full appreciation for the situation awareness (SA) issues raised by the group on individual combatants and squads can only be achieved by establishing the framework in which the group's discussion occurred. First, the conference speakers who spoke prior to the discussion group focused on SA in terms of battalion and brigade levels for heavy/mechanized units (Army XXI) and for Infantry units (Rapid Force Projection Initiative - RFPI). Consequently, group members often made essential distinctions in SA between light Infantry and heavy/mechanized units as well as between individual/squad and battalion/brigade operations. Second, most group participants were currently involved in one of two Army initiatives where SA is of critical importance. These initiatives are the Land Warrior system for the individual soldier and the MOUT ACTD (Military Operations in Urban Terrain Advanced Concepts Technology Demonstration). Inherent in both programs are SA system design, training, and measurement issues.

The Concept of SA

Often SA is equated with simply knowing more about your surroundings. But in the group discussion, situation awareness was defined more broadly, as knowledge itself is not sufficient on the battlefield. Knowing what is going on does not mean knowing what to do. There is a difference between situation awareness, narrowly defined, and situation understanding. Simply providing more data or information to the soldier, team leader, or squad leader does not necessarily mean that better decisions will be made or that performance will be enhanced. The distinction between situation awareness and situation understanding is critical to how systems are designed, how the effectiveness of sys-

tems is determined, how SA is measured, and what soldiers are trained on and how they are trained.

With new systems capable of providing large volumes of information to soldiers and small-unit leaders, it is critical to ask what information they need as well as what they will do with this information. Three levels of SA were defined. At level I is knowledge: for example, location of self, buddies, non-combatants, friendly units, the enemy, and aircraft; knowledge of the terrain and operations orders. At level II is comprehension or understanding of this information: for example, what does it say about enemy activity, weakness, and composition; the capabilities of friendly forces; location of self in relation to other units on the battlefield; the status of the mission; time to prepare for the next mission; and deviations from the original plan. At level III, the actions of enemy and friendly forces are projected.

Designing systems to enhance SA must consider these three levels. In system design, a good cognitive task analysis is needed first. The primary goal is identified (e.g., destroy X), followed by definition of the subgoals (e.g., acquire, identify and shoot), and lastly determination of the decisions associated with each of the subgoals. This analytic approach translates into identifying what you need to know and what you need to project. In designing systems for SA, more data does not necessarily mean more information. Filters are often proposed to reduce the information received by soldiers at different levels. But if a filter is inserted in a system, the customer must know beforehand what is important. There is a need to move toward designs that do more than provide level I SA data to systems that integrate data or at least assist the user to integrate and comprehend it.

Although level I SA is defined as what you know through information from the real world, what you "really know" is influenced by many things:

- where you direct your attention
- whether you trust the information
- whether you trust one sensor or source more than another
- whether there is independent confirmation of information
- the certainty of the information
- the timeliness of the information

Thus the quality of the information provided by systems influences SA as does the user's trust in it. An individual's past experience, training, ability, and long-term memory moderate SA, as well as external factors such as the system's capabilities, workload placed on the user, and complexity of the automation.

The group's discussion of SA technical requirements typically corresponded to level I SA; that is, improving the ability of soldiers and squads to know what is going on. On the other hand, the group's discussion of functional needs and the advantages of SA typically corresponded to levels II and III SA; that is, the application of SA information to better accomplish the mission.

The Light Battle and SA

The nature of the light battle as it affects SA and how it differs from the heavy battle was discussed. The light force has fought a non-linear battle for a substantial period of time and will continue to do so. Despite statements by conference speakers regarding the importance of destroying the enemy at distance, the group stressed that the close battle will always occur. There will be no cold battle for light forces, it will always be hot and it will always be in close depth. Because the enemy is a thinking enemy, it will adapt to our operations and tactics, and discover ways to reduce our effectiveness despite enhanced SA.

A critical distinction drawn between the heavy and the light force was that the battlefield communication network is quite different, as the light force communication capability is more limited. Light Infantry lacks an integrated command, control, communication and intelligence (C3I) system. Eventually, C3I information will improve for ground commanders, and they will have substantially more information available to them than ever before. How to manage and prioritize this information are critical issues. Is there a technical solution? Is there a training solution? Is the solution a combination of technology and training?

With systems that enhance SA, the success of operations will no longer depend solely on physical capability (steel on target and speed), but also on who can obtain and use battlefield information of the maximum amount at the fastest speed and in the

most accurate way. Knowledge, speed, and lethality are now interlocked. More knowledge faster will allow the Infantry to maneuver weapons and forces with maximum capability of achieving the mission. Continuous operations will be the norm.

The group agreed that good SA should give the commander what he needs to know versus what he wants to know. Good SA should produce accurate knowledge of locations (friendlies, the enemy, noncombatants), plus the right information delivered to the right person at the right time. The Army's Advanced Warfighting Experiments (AWEs) have shown the potential for information dominance, to remove information uncertainty or at least reduce it, and to reduce the potential for fratricide. One of the challenges with digitization is to integrate information from different sensors and sources into a common and intelligible picture of the battlefield.

SA Functional Needs for Individual Combatants and Squads

The group examined the following proposition regarding functional requirements of a system that provides enhanced SA for Infantry squads:

> *Small, dismounted teams should have technologies that enable them to fight with great efficiency by communicating continuously and covertly, navigating continuously, sensing the enemy over the hill, delivering alerts and tailored pictures to the warrior, and planning and executing continuously.*

Except for the concept that enhanced SA should allow squads to plan and execute continuously, all agreed with this proposition. Some felt the demands placed on squad leaders during execution were so great that it was not possible for them to plan at the same time. The capability to "sense the enemy" was expanded to include being able to assess civilian activities and their meaning.

The capability to "sense the enemy over the hill" was viewed as critical in determining courses of action. Will the

enemy do what the leader predicts or expects? What if he does not? Will improved SA allow the leader to in fact "sense the enemy over the hill" and therefore to rescue a plan, and/or execute contingency plans faster and better? Can systems be designed to depict intervisibility in the terrain? Can they be designed to capture subtle changes in the environment that indicate enemy presence?

It was noted that in many rotations at the Joint Readiness Training Center (JRTC), the Blue Force does not put on a "red hat" - does not think like the Red Force or visualize how the Blue Force appears to the Red Force. On the other hand, the JRTC opposing force reads the Blue Force well. Will enhanced SA improve the leader's ability to conceptualize the battle from the adversary's perspective?

A question was raised whether it was more important to focus on the enemy or the friendly force in designing systems or in attending to system displays. Is there a danger in becoming too focused on blue forces when using SA displays of troop locations? The consensus was absolutely not, when it comes to having a soldier know where his buddy is. Knowing your buddy's location is crucial, as demonstrated repeatedly in combat, and this knowledge builds soldier confidence. In balancing the SA information about friendly and enemy forces, the group acknowledged that leaders must recognize that enemy information is always partial and not as complete as friendly information.

The consensus was that soldier systems that provide information on friendly soldier locations will allow the Infantry squad to spread out over a greater piece of terrain. This will probably lead to greater squad autonomy and require more squad initiative. However, the greater dispersion will not obviate the need for mutual support; nor will it change the basic way the Infantry fights.

For the dismounted soldier, digitized maps of the terrain must be high resolution. Displays need to reflect terrain changes in three- or ten-meter increments to be of value for terrain analysis purposes. Yet, this degree of resolution has not been achieved to any degree of satisfaction to date. In addition to digital maps, architectural plans of buildings or pictures of buildings would be valuable additions to the terrain database.

An information-dominant battlefield should mean a better C3I system, including the capability for better communication with close support aviation. In addition, it will result in better fire distribution, squad execution, and more efficient planning, fires and logistics. An early Land Warrior test showed that the Land Warrior system with its enhanced communication capabilities significantly reduced the time to process and send information. A better C3I system, where information flows relatively freely up and down the chain of command, means that more decisions will now be made at lower levels, particularly the squad leader level. However, at this point in time, no one knows whether an enhanced C3I system will result in too much information flow at the small-unit level and overwhelm those soldiers and leaders or whether, in fact, better decisions will be made.

Assuming soldiers and squad-sized units have the capability to transmit information, questions were raised regarding what decisions should "go up" and what decisions should "go down." At what level should fire reports and spot reports be made? The group decided that decision rules must be established, preferably by leaders, not by the system. Thus the system software should have an open architecture where a commander can set the information/display filters he desires for a mission, and then provide guidance to his subordinate commanders. The open architecture should allow a commander to easily and quickly change the filters as well. And, the architecture must allow for input of the commander's intent into the information flow. The group recommended that the system default for information distribution should be automatic transmission two levels up and two levels down, with a higher command having a zoom capability to any lower level desired.

The group felt that the complexity of Infantry demands is often underplayed. With enhanced SA systems, these demands will be even greater at the lowest echelons. The SA information critical to individual soldiers and rifle squads differs both quantitatively and qualitatively from the information presented to staff members in a TOC (tactical operations center) or to aircraft crews (which have been the focus of much SA research). In a TOC, the environment is defined by the medium or the equipment. In recent AWEs using digital equipment, visual displays have dominated as well as audio (radio) input. With the Land Warrior sys-

tem, the soldier will also have a visual display (digitized terrain, text information providing orders and spot reports, etc.) and radio input. But the soldier will also be confronted with the real world (ground truth as opposed to only a visual representation of it), where he must attend to and interpret real-world, real-time images, smells, and sounds. Because of this diversity of information, all shown historically as critical to combat success, the demands on a soldier's SA skills are extremely challenging.

Lastly, the group stressed that the presence of high resolution SA (maps, better communication, etc.) does not eliminate the need for higher commanders to be forward in the fight. Command should not be by remote control.

SA Technical Requirements

With these general functions in mind, the group agreed on a specific list of SA system requirements for the individual combatant and squad. The requirements should result in an overwhelming advantage against potential adversaries, not just a slight edge or equal capability. These requirements are listed below. Capabilities that are a part of the Land Warrior system are marked with an asterisk.

Navigation/Location Features
- Position location*
- Inertial navigation
- Digital compass*
- Laser range finding*
- Laser designation
- Terrain analysis and visualization capabilities

Sensors
- Enhanced night observation*
- Still video recording of images*
- Local remote sensing of enemy locations and movement
- Sensor fusing

Combat Identification
- Discrimination of friend, foe and non-combatants
- Combat ID warnings to tanks and helicopters

Communications
- Non line of sight communications in close and urban terrain

Firepower
- Precision weaponry and munitions

Digital Capabilities
- Manual data entry devices*
- Voice controlled computers
- Link to the tactical internet
- Common architecture with heavy forces

Software Capabilities
- Orders and overlays*
- Decision aids
- Fully embedded training systems
- Ability to incorporate the system in simulations

A caution was made about including decision aids in a system, as there is tendency to rely on these, even if they are wrong.

Training Issues

The training issues related to SA were both global and specific. The global questions were: can you train a soldier/leader to have SA; once a level of SA is achieved, how do you train the soldier/leader to leverage that SA knowledge; and how can you train people to know when they have insufficient SA? To date, there is relatively little research that addresses these SA global questions. Specific soldier, leader, and squad training issues and needs were based on the system-unique features designed to enhance SA. Training research and development are also needed to address these issues.

The group concurred that before a soldier or leader can possess SA or achieve a higher level of SA, he must have technical expertise. For example, a point man must master his basic skills and achieve a certain level of technical competence before he can have SA. Otherwise his attention, of necessity, is directed "inward" rather than "outward." There is no cognitive processing capability left if individual skills, whether leader or soldier, are lacking. And the degree to which technical or basic skills must be mastered varies with the situation. Night operations are more difficult than day. Combat also makes SA harder to achieve, given the tremendous stress on individuals and units. We know that in combat, soldiers resort to the basics, to habit, to well-trained behaviors. Is it possible to make SA a "basic" or a habitual way of processing and thinking about sensory input? What is the payoff

from making training more demanding? New tasks and standards may be required for soldiers and leaders; more may be demanded of junior leaders.

Is personnel selection a partial answer to training SA? Do we need to change our criteria for recruiting soldiers? Although some in the group thought SA may be innate, not all agreed with that position. Hence, the underlying question regarding what makes some individuals more "situationally aware" than others remained. Do high SA individuals have better spatial ability or different spatial abilities? Are they better at attention sharing or pattern matching? Do they have mental models or schemas that allow them to be more aware? Do they have the ability to discern patterns that others find difficult?

We know that experience is critical to SA, so from a training perspective how can we short-circuit this process? Often simulations are used in training. But the group stressed that, to date, no simulations, not even virtual simulations, have come close to approximating the environment of the individual soldier. There are too many aspects of the soldier's environment and contingencies within that environment that have not been replicated and are extremely difficult to replicate. For instance, we have not simulated sounds well (except for some weapons fire), touch, and smell. How do we simulate the dynamics of the close fight such as that in Northern Ireland? The group also felt there was a danger in assuming that simulations are adequate for training SA. The group was concerned that policy and decision-makers may become too complacent about the initial level of technical competence that is required for SA, the need to train back-up skills for contingencies when technology goes down or is captured, and the extent to which simulations can actually train leaders and soldiers to the required level of proficiency.

One proposal was to design SA exercises to train leaders to adapt to various unpredicted actions on part of the enemy, and to train them to examine their plans from the adversary's perspective. SA exercises could also be developed to train leaders on how to use such information in the planning process - making it more efficient, and to avoid the pitfall of focusing too much on information per se rather than applying that information to the development of the plan.

As decision-making will be more rapid, involving both more information and a greater variety of information, leaders must now be trained to process an expanded base of information as well as to make decisions under stress. Leaders must be trained to make quick estimates of the situation, outline different courses of action, and decide on one.

With respect to tactics, techniques and procedures (TTPs), there was a general consensus that systems with enhanced SA will require new TTPs as well as a change in existing TTPs. For example, dispersed operations will become the norm, with revised TTPs needed for independent fire team movement and synchronizing fire team fire and movement, all with minimal voice communications. TTPs may need to change to take advantage of the increased amount of position location information. Squads may have to learn to function as scouts do now. Leaders must learn how to connect to the tactical internet; do battle planning digitally; record, send, and receive orders in digital format; call for fires digitally; and plan and integrate fire engagement sectors digitally. New procedures for communicating with fire support and aviation will emerge. Given a more timely flow of information, frequent estimates of the situation and quick responses will be required. At night, TTPs for employment of laser pointers will be needed. Revised TTPs for signals and operations security may be required. Even TTPs for system power management may emerge.

With more demands placed on soldiers and leaders by new soldier systems, generic questions were raised about institutional and unit training. How will these systems impact home station training, combat training center training, institutional courses, tasks and standards for leaders and soldiers, and NCO qualification? We must train squad and fire team leaders to develop initiative, and train squads to be more autonomous and more cohesive. We must re-examine how specific skills such as marksmanship, navigation, and communication, are affected. Should unique SA tasks and conditions be developed; what should they be? What computer training and skills are required? Performance standards with new systems must be rigorously enforced as soldiers with the weakest skills are the first lost in combat.

Measuring SA

Measuring SA ranges from assessing what the soldier knows to assessing what he does. These behaviors require different measurement techniques and provide different pictures of the status of SA. Four measurement approaches need to be considered when evaluating alternative system designs, training effectiveness, and the level of SA within an individual or squad. These four approaches are complementary; they do not duplicate each other. And there are many factors that can moderate or influence the resulting assessment. The four approaches discussed by the group were:

- Process indices
- SA state of knowledge
- Decision-making behaviors
- Performance

Process indices assess such factors as eye movements, verbalization, communication, button pushes, and information acquired. A limitation of process indices is that they do not tell you what an individual does with this information; they do not assess a state of knowledge. The point was made that what soldiers do not do should also be measured (e.g., not use a digital map, not use a particular sensor, not push a button). Although nonverbal measures may be obtained their meaning is particularly hard to assess.

The individual's state of knowledge, his SA, can be assessed through questionnaires, posttest, on-line probes, techniques where a simulation is frozen at random intervals and then each individual is asked what is happening and what he knows, and subjective measures regarding the individual's self-estimate of his SA. Asking a soldier what he knows, either after or during the mission, is considered an objective technique. Obviously obtaining such measures during field exercises is very difficult. Asking an individual to rate how good his SA is on a 10-point scale, to subjectively assess his state of knowledge or to separate things he knows from those he thinks he does not know, are considered subjective measures. Subjective SA can be task specific or global in nature. One problem with subjective measures is that individuals do not know what they do not know. Simulations have been

used frequently in SA assessments. But the group stressed that dismounted Infantry is very hard to model and simulate. Physical/hardware models are much better than cognitive models. We do not model information flow well, nor how people think and interact with equipment. Therefore, when simulations are used to assess SA knowledge of soldiers, we should interpret the results in light of the limitations of the simulation.

Assessing SA per se, the individual's state of knowledge, is not sufficient. The Army will not buy a system on enhanced SA alone. Therefore, SA must be linked to decision-making and then to performance. Yet having data does not guarantee good decisions nor good performance. And good decisions do not guarantee good outcomes. In terms of SA measurement, an unequivocal measure of performance that directly reflects SA is good, that is, a direct measure of SA that translates into performance - if your state of knowledge is X, then Y should happen. But such measures are very difficult to find.

Another critical factor in SA measurement is the scenarios in which you test performance. You need a variety of performance measures (e.g., time, speed) over a variety of tasks and scenarios, including degraded modes, to reach valid conclusions. Consider, for example, whether the scenario requires simple or high-speed tactics. If only simple tactics, then the new system may not show a SA advantage. If high-speed, then the new system may shine.

The SA assessment should provide as much sensitivity as possible. For example, can you tell whether SA is leading to wasting rounds or to the soldier having more opportunities to fire? What are possible data gaps? What are possible negative outcomes? To develop sensitive measures, the tester must think "out of the box." With simulations, sometimes an effective technique is to throw in bad data and determine when individuals become aware of it and what they do with it. Another issue that needs to be addressed is how system software can be enhanced to provide "automatic" measures of SA, whether they be process indices or performance measures.

Measurement plans and techniques must consider where SA is measured and who is critical within the chain of command.

At the squad level, it is important to tailor SA measurement techniques to soldiers in different duty positions. Not only do these individuals vary in prior experience that may affect their SA, but they also have different roles on the battlefield. To treat them the same or to aggregate them in the measurement process could be misleading. Factors that can moderate the level of SA and what is done with SA information, particularly individual differences in SA (intuition, pattern matching, etc.) and prior experience, should be incorporated in the overall measurement plan and assessment. Within squads, the extent to which members have a common SA is critical, i.e., team SA measurement.

In most Army tests of new systems, testers focus on performance. Data on why the performance occurred are typically not obtained. Only infrequently does the measurement process address SA process indices, state of knowledge, or decision-making. Yet it is these other measures that usually provide the explanations for performance; the diagnostics; the understanding of not only how the soldier performed but why he acted as he did. There is a need to work with the test community to obtain a broader spectrum of SA data.

To date, research has typically shown the following relationships between objective, subjective, and performance measures. Experts' ratings of SA correlate with experts' ratings of performance. Self-ratings of SA correlate with self-ratings of performance. Objective measures of performance correlate with objective measures of SA. But subjective SA measures do not correlate with objective SA measures. What does this lack of relationship between objective and subjective mean? Broadly speaking there could be four outcomes:

Subjective-Objective SA Agreement	Individual's SA Status
Good objective and good subjective SA	Individual is okay
Poor objective and poor subjective SA	Individual is okay
Good objective but poor subjective SA	Individual is ineffective
Poor objective but good subjective SA	Individual is overconfident

As indicated above, the lack of relationship between objective and subjective measures should not be viewed as bad, but simply as providing a more complete picture of SA.

Lastly, the group examined one system to determine what types of SA measures could be generated by using the multi-tiered SA measurement approach. The group cited various measures for addressing the SA associated with alternative system designs for a global positioning system (GPS). The specific question was "What is the value of knowing your position and location on the battlefield?". Table 1 lists a variety of measures that could be used for each SA measurement approach.

Table 1.

Application of SA measurement approaches to identifying differences in Global Positioning Systems.

SA Measurement Approaches			
Process Indices	**SA State of Knowledge**	**Decision making**	**Performance**
How often look at display	Do you know where you are on the map?	Time to act on information	Time to reach point X
Can you look at the display while moving? While stationary?	Way points, check points?		Accuracy of getting to point X - use of planned route
What information is used in the display?	Where are your buddies?		Recovery time with loss of GPS
Process/steps required to get at information	Where is the enemy?		Mission performance
Readability	Attend more to friendly or enemy?		Tasks GPS works for and does not work for
Time in viewing information	Terrain knowledge		Desirable route taken? Exposure to enemy, cross water 10 times?
	Confidence in information		Mean dispersion among soldiers
	Shared SA		Follow planned route

The group achieved a better appreciation for the value of this multi-tiered approach when they considered how they might distinguish between a soldier who is dependent on the GPS versus one who uses it primarily to confirm his location. Two measures were identified to help make this discrimination: a SA state of knowledge measure - do you know where you are on the map, and a performance measure - time to recover when the system goes down. The soldier who is highly dependent on the GPS would know immediately and precisely where he was, but would have difficulty recovering with loss of the GPS because he relies so heavily on it for knowing his location. On the other hand, a soldier who uses the GPS to confirm his location might not respond as quickly or as accurately regarding his location, but would provide the better answer when the GPS goes down as he uses other sources of information for knowing his location. A tester could identify system differences by comparing these two

measures. If the decision-maker wanted a system that did not make the soldiers dependent on the GPS, these two data points could help in system selection.

The value of this multi-tiered approach is not restricted to system assessment. It can be applied to other SA assessments, such as assessing individual differences and the success of alternative training programs.

The two articles that follow are by the co-leaders of the group for Individual Combatants and Squads. GEN (R) Bill Richardson speaks to the broad spectrum of SA requirements facing soldiers and squads in the future, and how that impacts their combat role and their training. Dr. Mica Endsley focuses in depth on the meaning of SA, the importance of designing and testing Army systems for the type of SA they provide, and the pros and cons of different measurement techniques.

Group 1 participants included:

LTC Keith Antonia
Ms. Cindy Blackwell
SMA (R) Bill Gates
COL (R) Ray Kauffman
COL Hank Kinnison
Dr. Herb Meiselman
Mr. Warren Morimoto
Mr. Jim Owens
Dr. Bob Pleban
COL David Prewitt
CSM (R) Sam Spears

Chapter 5

Situation Awareness Requirements for Individual Combatants and Squads

GEN (R) William R. (Bill) Richardson
Burdeshaw and Associates

This report is in the form of a briefing which is self-explanatory. In this report is some up-front material that introduces the subject of situation awareness (SA) as it applies to individual combatants and squads. For those who pursue SA from a combat developer's or a training developer's point of view, the charts on Environment, Considerations, Technology Need, and Hypotheses lay a foundation for assessing the Operational Requirements for Future Systems, the Desired Capabilities for Individual Combatants and Squad/Team Leaders, TTPs (tactics, techniques, and procedures) for doctrine writers, and Training needs. Pitfalls, High Payoff Considerations, and What Enhanced SA Provides are then identified.

The highest priority for the individual combatant and small unit leader is competence, which means being trained to be tactically and technically proficient. Once this is acquired, the soldier and leader must then gain the second priority, namely, confidence. Soldiers and junior leaders must have confidence in their leaders, their equipment, and themselves to be able to perform the tasks which the average soldier would be incapable of performing. The light Infantry soldier must be better than the rest.

Given the above two ingredients, which come directly from training, the next two priorities are equipment oriented. The first of these is to see as far as a soldier can possibly see, day and night. The second equipment need is a reliable means of communicating information on what he sees up the chain of command. What the Army is putting in the Land Warrior program today will provide these two important needs for the soldier. Then, the Infantry soldier will be more lethal, survivable, and effective than ever before.

OUTLINE

- Information Dominance
- Situation Awareness
- Environment
- Considerations
- Technology Need
- Hypotheses
- Operational Requirements

INFORMATION DOMINANCE

- Army XXI is organized around information
  - rapid target identification
  - faster maneuver
  - effective massed fires
- Information dominance enables decisive operations
  - provides situation awareness
  - improves synchronization of combat power
  - facilitates command and control

SITUATION AWARENESS

- That information the higher level commander needs to know vs. what information he wants to know
- The ability to have accurate knowledge of your own and other friendly element locations, enemy locations and neutral and non-combatant locations
- Effective SA exists when the right information is delivered to the right person at the right time
- A SA system accepts data from all relevant sensors, both organic and external, accepts C2 information from applicable C2 systems and handles operator/commander inputs. This requires:
  - storing, interpreting and managing data
  - filtering or fusing it to build the situation information required

- identifying the right information
- providing a reliable and timely delivery of the results

ENVIRONMENT

- U.S. style of war is becoming more technologically complex and dependent on distributed and interconnected systems
- Combat in the 21st century

  - technological superiority theory
  - mental agility theory
  - the premium on tactics will become even greater
  - we will need an "old-fashioned" soldier with fighting skills, toughness, discipline and lots of field training

- Army XXI operations prompt:

  - faster decision making and operations
  - more information available
  - dispersed operations
  - greater mobility and increased lethality
  - continuous 24 hour operations

- The leader needs to:

  - quickly visualize the present situation
  - imagine possible future situations
  - decide on a course of action

- Knowledge and speed will become crucial
- Night operations will predominate
- Operations in built up areas will increase
- Increased stress will be expected

CONSIDERATIONS

- Army Warfighting Experiments (AWEs) have shown the potential of information dominance and situation awareness
- With information dominance we remove much of the uncertainty associated with operations
- Accurate reporting of friendly and enemy locations reduces the potential for fratricide
- Digitization is critical to providing information dominance. It

will enable the Army to apply information-based technologies throughout the battlespace to acquire, exchange and utilize timely information

- Digitization integrates existing C2 capabilities with sensors and platforms to provide integrated and timely sharing of battle space information and accurate reporting of friendly and enemy locations
- Digitization provides shared situation awareness that translates to a clear, accurate and common picture of the battlespace through a fully integrated capability
- The light Infantry lacks an integrated C3I system to:

  - transmit and receive secure reports and orders, position locations, and calls for fire
  - transmit and receive pictures of the battlefield
  - receive external sensor information on enemy activity
  - display and transmit thermal images, digital maps and graphics
  - receive combat identification warnings

- The failure of an operation will no longer depend solely on the comparison of physical capabilities, such as steel on target, but will primarily depend on who can obtain and utilize battle-field information of the maximum amount, at the fastest speed and in the most accurate way
- Non-linear operations will be the norm
- The doctrine for the Army After Next (AAN) calls for knowledge, speed and lethality
- The light Infantry will be in the close fight from the outset

TECHNOLOGY NEED

- Small, dismounted teams should be able to fight with great efficiency by use of technologies to:

  - continuously, covertly communicate
  - continuously navigate
  - sense the enemy over the hill and interpret his intentions
  - deliver alerts and tailored pictures to the soldier
  - continuously plan and execute

HYPOTHESES

- The number 1 priority for the soldier in the field is to know where his teammates are, quickly, reliably and without having to reveal his own location to unintended listeners
- Reduced visibility limits soldier movement
- SA significantly reduces uncertainty and thus risk
- Navigation errors reduce the leader's ability to maneuver, call for accurate fires, position weapons, and perform logistics missions
- SA will enhance the concentration of combat power

  - the leader can see his unit when it is outside visual contact
  - soldiers will always see their buddies
  - leaders and soldiers will know where they are and where they are going
  - leader and soldier SA will reduce confusion on contact with the enemy
  - knowledge of enemy and friendly situations will open opportunities to seize the initiative
  - SA simplifies reorganization and consolidation

- Decision making at lower levels will be required on the information-dominated battlefield
- The battle commander needs to quickly visualize the present situation, imagine possible future situations and decide on a course of action to get to the future
- Placing the information to support battlefield decision-making in the hands of individuals means decisions could be made and weapons delivered immediately, saving valuable seconds that can mean the difference between victory and defeat
- Individual soldiers using sensors would have up to 15 minutes warning of oncoming enemy forces and could call in Unmanned Aerial Vehicles, missiles, fighters or other assets
- An individual system in the form of a very small computer can provide the soldier with a simple display, message routing, reporting and receiving of location, orders, calls for fire and voice communications
- Too much information, too fast, can create information overload. When faced with information overload, most of the information will be ignored, which can cause major errors

- A key to overcoming information overload is to present fused information as images of clusters of related information, tailored to the leader at each level. If he wants more detail, he will ask for it
- Dominating one's battlespace requires a keen eye on terrain, an understanding of friendly individual soldier's abilities and capabilities, an understanding of the enemy, and an ability to assemble an array of capabilities resulting in combat power
- Dismounted battlespace uses terrain, including natural and man-made obstacles, to the best advantage
- Operations in built-up areas will increase. This means maximizing small team operations in which teams and individual soldiers must know each other's location and be able to readily communicate with each other during the battle
- Jungle operations will require much better SA than we experienced in Vietnam
- SA will facilitate a continuous decision loop of observe, orient, decide and act (OODA)
- For the AAN, mental agility (making rapid changes and decisions) is critical and translates directly to physical agility
- SA permits better planning and execution at various levels
- Leaders must still be well forward in the fight

OPERATIONAL REQUIREMENTS FOR FUTURE SYSTEMS

- Position location
- Enhanced night observation with and without weapons
- Sensor fusing
- Daylight laser range finding and designation
- Still video recording of images
- Non Line of Sight (NLOS) communications in close terrain
- NLOS communication in urban terrain
- Digital connectivity
- Precision weaponry and munitions
- Local remote sensing of enemy locations/movements
- Combat identification warnings and discrimination of friend, foe and non-combatant
- Link to the tactical internet
- Inertial navigation
- Common architecture with heavy forces
- Manual data entry devices
- Embedded training systems

SA Requirements for Individual Combatants and Squads

- ❑ Voice control computers
- ❑ Terrain analysis and visualization
- ❑ Orders and overlays

SA REQUIREMENTS: DESIRED CAPABILITIES FOR INDIVIDUAL COMBATANTS

- ❑ Master skills
- ❑ Know own location
- ❑ See squad members at all times
- ❑ Observe enemy positions and recognize patterns
- ❑ Communicate within the squad
- ❑ Move readily
- ❑ Identify friend, foe and non-combatant
- ❑ Issue spot report
- ❑ Increase dispersion
- ❑ Improve the use of night sensing devices
- ❑ Gain improved fire and movement
- ❑ Acquire filtered information
- ❑ Provide/receive protection from surprise
- ❑ Receive warnings/advisories Chemical/Biological
- ❑ Improve use of night/limited visibility (obscurants)
- ❑ Acquire confidence
- ❑ Possess requisite physical and cognitive skills
- ❑ See, Shoot And Kill The Enemy First

DESIRED CAPABILITIES FOR SQUAD LEADER AND TEAM LEADER

- ❑ Know location of friendly forces
- ❑ Know location of enemy forces
- ❑ See own members at all times
- ❑ Communicate effectively within the squad
- ❑ Control squad movements
- ❑ Move readily without loss of position location
- ❑ Call for fires instantaneously
- ❑ Observe enemy positions
- ❑ Promptly identify friend, foe and non-combatant
- ❑ Have tactical options
- ❑ Issue spot reports

- ❑ Enhance surprise
- ❑ Give early warning by video/voice
- ❑ Excel in night and limited visibility operations, restricted terrain and MOUT
- ❑ Provide/receive warning/protection from surprise
- ❑ Know the enemy's intentions
- ❑ Conduct mission planning and rehearsal
- ❑ Be able to think as you go

TACTICS, TECHNIQUES AND PROCEDURES (TTPs)

- ❑ Dispersed operations as the norm
- ❑ Synchronized fire team and movement
- ❑ Independent fire team movement
- ❑ Minimal voice communications
- ❑ Communications to fire support, air and aviation
- ❑ Quick fire channels
- ❑ Link to the tactical internet
- ❑ Frequent estimate of the situation
- ❑ Quick response to observations
- ❑ Orders format in computer radio system
- ❑ Digital battle planning
- ❑ Manual data entry
- ❑ Frequent use of combat ID
- ❑ Periodic precise position location
- ❑ Engagement sectors planned and integrated
- ❑ Calls for fire
- ❑ Silence and security
- ❑ A system of signals
- ❑ Coordinating movements of small cells of soldiers in MOUT
- ❑ Communications to fire support, air and aviation
- ❑ Power management

TRAINING ISSUES

- ❑ Full strength squads
- ❑ Non Commissioned Officer qualification and train-up
- ❑ Squad and team cohesion
- ❑ Home station training
- ❑ CTC training
- ❑ Sensor availability

SA Requirements for Individual Combatants and Squads

- ❑ Communications training
- ❑ Computer training
- ❑ Potential for initiative
- ❑ Marksmanship
- ❑ Mission planning and rehearsal
- ❑ Maneuver live fire exercises
- ❑ Smell
- ❑ Night training
- ❑ Ambush and mine avoidance
- ❑ Confidence building
- ❑ Skill sustainment
- ❑ Training aids, devices, simulators and simulations (TADSS)
- ❑ Getting the big picture
- ❑ Unique SA tasks and conditions
- ❑ Higher training standards for soldiers

POTENTIAL PITFALLS

- ❑ Untrained soldiers
- ❑ Untrained leaders
- ❑ Untrained squads
- ❑ Hollowness in the squad
- ❑ Equipment shortages
- ❑ Excessive reporting
- ❑ Battery power problems
- ❑ Urban combat
- ❑ Information overload

HIGH PAYOFF CONSIDERATIONS

- ❑ Confidence markedly increased
- ❑ Skilled in night operations
- ❑ Improved rifle marksmanship
- ❑ Reduced casualties from engagements and fratricide
- ❑ Better precision engagement
- ❑ More squad autonomy
- ❑ More shooters per engagement
- ❑ More engagements at longer ranges
- ❑ Enhanced maneuver on the battlefield
- ❑ Emphasis on the offensive
- ❑ Overmatch

WHAT WILL ENHANCED SA PROVIDE?

- Knowledge → competence → confidence
- Better small picture yields a good big picture
- Better fix on the enemy
- Better fire and movement
- Better direct fire distribution
- Prompter and more accurate fire support
- Better protection from fratricide
- Larger squad area of operations
- More lethal, survivable and effective soldier

Chapter 6

Situation Awareness for the Individual Soldier

Mica R. Endsley, Ph.D.
SA Technologies

The U. S. Army is rapidly coming to a recognition of the need to conquer and command information as a tool in its quest for battlefield domination. With far reaching consequences this thrust incorporates not only the distribution, management and utilization of information about friendly forces and their dispositions, but also similar command of information on enemy forces and dispositions. "This post-technological age has been defined as one in which only those who have the right information, the strategic knowledge, and the handy facts can make it" (Bennis, 1977). Insuring that the soldiers of the future will be on the winning side of this struggle requires that the Army come to grips with its situation awareness needs and with a process for insuring that the systems it procures and the training it provides do everything possible to maximize soldier situation awareness, as it can be assured that enemy forces will be doing everything possible to maximize their own.

Do We Need SA?

In general terms, having a high level of understanding of what is going on in the battlefield (or pre-battle scenario) is called Situation Awareness (SA). Situation awareness is what allows the soldier, the platoon leader or the company commander to make the best decisions possible to carry out mission objectives. Just which aspects of the situation are important, however, depends on which role within the organization the individual occupies and the specific mission objectives. As shown in Figure 1, SA is the foundation for all decision making and all actions.

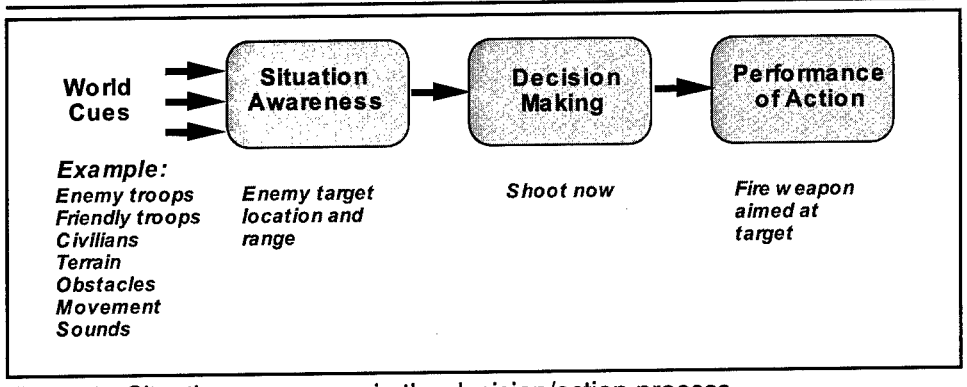

Figure 1. Situation awareness in the decision/action process.

To be without SA is to be like a blindfolded deaf man shooting a gun. He may hit his target by luck, but the odds are fairly low. Our objective, in design and training, is to provide the soldier with the best information and tools possible (e.g., an illuminated target, positive enemy identification and a laser sight) so that he has the information needed to hit the right target at the right time. How close we come to providing the soldier with the "ideal" perfect knowledge is one measure of how good a particular system design is.

Even if he has good SA of course, the soldier still has to choose to shoot at the right time (affected by a host of training and psychological factors) and has to know how to shoot a weapon well (also a function of training and expertise) in order for the end result to be satisfactory. Situation awareness is therefore the foundation for good performance - necessary but not by itself sufficient. As in the example of the blindfolded man, however, without SA, even a well trained soldier and expert marksman is at a significant disadvantage.

What is SA?

A formal definition of SA states that it encompasses Perception (Level 1 SA), Comprehension (Level 2 SA) and Projection (Level 3 SA), shown in Figure 2 (Endsley, 1988). The individual soldier has to perceive the important information (hear the twig snap, see the tracks on the ground). Based on this he has to comprehend what it means (enemy troops nearby) and with very high levels of SA will be able to project what this means for the future (a sneak attack from the north is likely).

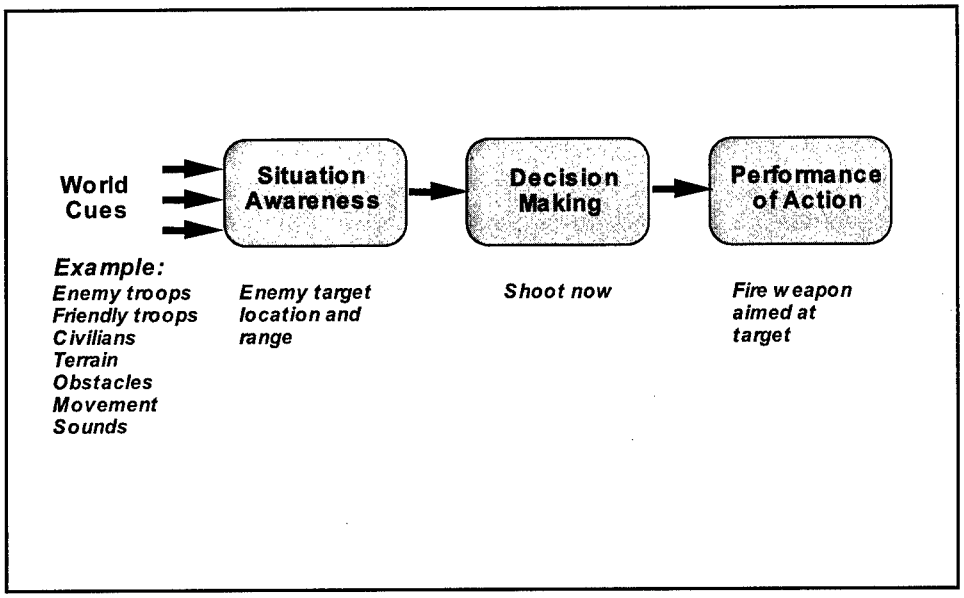

Figure 2. Definition of situation awareness.

While this process sounds relatively straightforward, we find that SA failure frequently occurs at the first level, perception, even when all the cues are present. This is because most environments have so much information to attend to, we may fail at attending to the "right' bits. The fog of war is a significant factor hindering SA. In many cases the needed information may not be present, or significant overload (e.g., thousands of incoming calls) can make it difficult to find the needed information. SA is also much more than perception, however. It requires comprehension - understanding the significance of information that is perceived, and what it means for the future. These aspects of SA are heavily dependent on training and experience.

SA requirements for a particular mission are essentially the set of which things need to be perceived, comprehended and projected. While this will vary, some general requirements can be listed as in Table 1. The soldier's SA requirements will encompass everything from knowing where he and his unit are to information about enemy troops and non-combatants. He will need to be able to form higher level SA to include an understanding of the relative strengths and weaknesses of an opponent, and an understanding of how events and information impact on the stated mission. The ability to develop an appropriate level of confidence in information is identified as particularly important. In some cases the source of information (a traditional source of confidence in

information) may not be known or may be more indirect with information technologies. Finding ways to provide the individual with some idea of the reliability of information provided by new systems is an important consideration.

Table 1.
SA requirements for the individual soldier.

Level 1 - Perception	Level 2 - Comprehension	Level 3 - Projection
■ Identification ■ Location ▪ self ▪ buddies ▪ friendly units ▪ enemy ▪ non-combatants ▪ aircraft ■ Terrain/obstacles ■ Orders from HQ	■ Enemy ▪ activities ▪ weaknesses ▪ composition ■ Friendly ▪ abilities ▪ capabilities ■ Status of mission ■ Time until ready for next mission ■ Deviation from planned ■ Deviation from expected ■ Best path over terrain ■ Confidence in information ■ Timeliness of information	■ Projected enemy actions ■ Projected friendly actions

How Do We Get SA?

Improving SA will not occur strictly through the provision of new information technologies. In fact, some of these technologies may actually inadvertently interfere with SA. To better depict this, view Figure 3. Situation awareness is a function of all of the information that is taken in, either directly through the soldier's own senses, via communications (verbal or non-verbal) with squad members, and from any new technological system that is provided.

In today's world, most soldier SA is acquired either directly though the environment or from others. As we add new technologies to the soldier's resources, one of two things may happen. This new technology may add to his SA by giving him more and better information that is needed, or it may actually detract from his SA by shifting his attention away from the direct environment to focus on the technology. "Getting lost" in the system is a frequent phenomenon and one which can have critical consequences unless these systems are designed carefully. In reality both more and less SA may result from some new technologies, as we may inadvertently increase SA for some information (e.g., own location on a digital terrain map) but decrease SA for other information (e.g., where one's buddy has gone). As attention is a

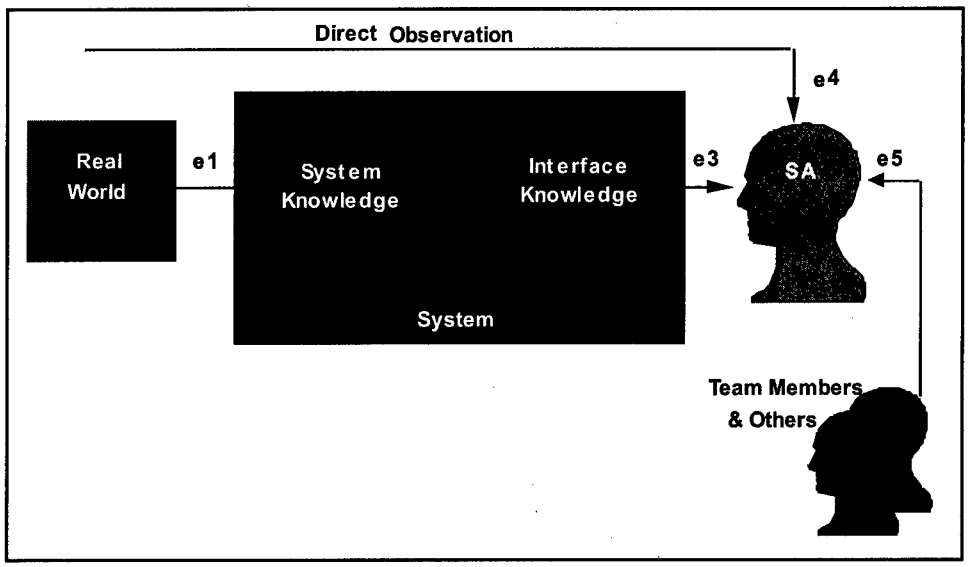

Figure 3. Sources of situation awareness system is not enough.

limited commodity (more paid to one thing can mean less available for other things), this possibility needs to be very carefully monitored with the introduction of new technologies into the battlefield.

In addition, it must be pointed out that just getting needed information to the system is not enough. It also must be presented through the interface in a form that allows it to be quickly read (or heard) and comprehended. If the system requires the soldier to dig through menus and hunt for needed information, he may not achieve the situation awareness required, particularly under stressful and time pressured battlefield conditions. For this reason, the SA that the soldier possesses, not that the system possesses, must be evaluated as the measure of merit of the system. SA only exists in the mind of the individual.

A Process for Achieving the Army's SA Requirements

The major challenge facing the Army today is the need to change the process by which it procures and evaluates new systems. The Army has long been forced to do the best job possible with often very limited equipment and systems. As such, it has met this admirable aim head on, and focused its efforts on training. It had to devise ways to make systems work, sometimes in spite of their inherent design limitations. While the Army will always need to focus on training, both for its missions and the

operation of its new technologies, a fundamental shift in this thought process needs to occur as it faces a mounting barrage of high technology equipment. Only after the best possible system design has been procured should the focus shift to training. A reliance on training to overcome poor design will always result in a suboptimal situation. No matter how well trained, soldiers will be unable to fulfill their best potential with poorly designed information systems. The best way to leverage information technologies depends on successfully designing them to provide the best throughput to the human operator. Once that has been achieved (and only then), we should shift the focus to training.

The leveraging of information technologies requires a structured process of analysis, design and evaluation in order to avoid the costly mistakes of the past. While this process has certainly formed the basis for system procurement in the past, the successful infusion of information technologies will require that each step be performed far more carefully than before. A structured approach is required to incorporate SA considerations into the design process, including a determination of SA requirements, designing for SA enhancement, and measurement of SA in design evaluation.

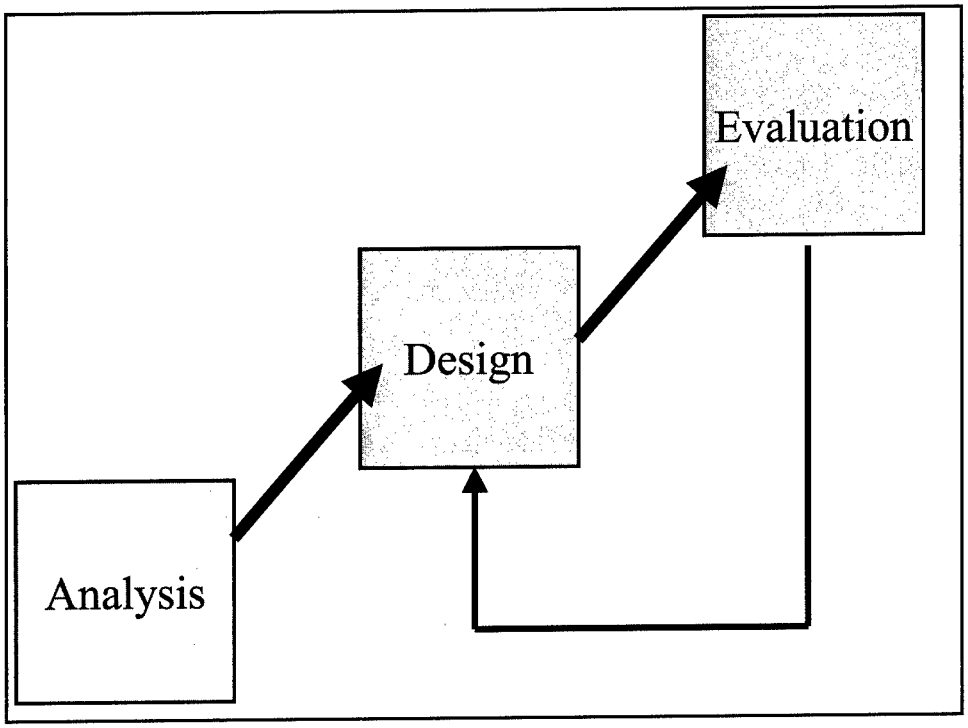

Figure 4. System development.

SA Requirements Analysis

Designing interfaces that provide SA depends on domain specifics that determine the critical features of the situation that are relevant to a given individual, such as the soldier. A goal-directed task analysis methodology (Endsley, 1993) has been used successfully for determining SA requirements in several different domains. This methodology focuses on the basic goals (which may change dynamically) of a soldier for a particular mission type, the major decisions he needs to make relevant to these goals, and the SA requirements for each decision. SA requirements are established in terms of the basic data that is needed (Level 1 SA), required integration of the data for a comprehension of system state in light of goals (Level 2 SA), and projection of future trends and events (Level 3 SA).

The method is significantly different than traditional task analyses in that: 1) it is not pinned to a fixed timeline, a feature which is not compatible with the work flow in dynamic environments like combat, 2) it is technology independent, not tied to how tasks are done with a given system, but to what information is really, ideally needed, and 3) the focus is not just on what data is needed, but on how that data needs to be combined and integrated to support decision making and goal attainment. This last feature, defining comprehension and projection needs, is critical for creating designs that support SA instead of overloading the solider with data. The first step therefore must be to carefully determine just what SA factors a given individual needs to be aware of. Not just what is available, but what does he really want to know? This analysis provides the most important foundation for successfully creating systems that support situation awareness.

SA-Oriented Design

Second, the development of a system design for successfully providing the many SA requirements that exist in complex systems is a significant challenge. A set of design principles has been developed based on a theoretical model of the mechanisms and processes involved in acquiring and maintaining SA in dynamic complex systems (Endsley, 1995b). These guidelines include: 1) Direct presentation of higher level SA needs (comprehension and projection) instead of just low level data which can

be quickly overloading, 2) Goal-oriented information display in which the data and information are organized around the soldier's goals, rather than the technologies, 3) Support for global SA, providing an overview of the situation across the individual's goals at all times (with detailed information for goals of current interest), enabling efficient and timely goal switching and projection, 4) Use of salient features to trigger goal switching, 5) Reduction of extraneous information not related to SA needs, and 6) Support for parallel processing. To date, an SA-oriented design has been successfully applied as a design philosophy for a number of systems. These principles help to display information in a way that can be managed in a highly dynamic environment, avoiding the pitfalls of information overload and attention narrowing.

SA Design Evaluation

Finally there are many concepts and technologies that are currently being developed and touted as enhancing SA. Prototyping and simulation of new technologies, new displays and new automation concepts are extremely important for evaluating the actual effects of proposed concepts within the context of the combat environment with actual soldiers. If SA is to be a design objective, then it is critical that it be specifically evaluated during the design process. Without this it will be impossible to tell if a proposed concept actually helps SA, does not affect it, or inadvertently compromises it in some way.

Figure 5 provides an overview of the various methods that are available for measuring situation awareness. (For a complete review see Endsley (1996).) Most methods involve the creation of a simulation of the system under consideration. Measurement approaches can be broken down into a consideration of SA processes, direct measurement of SA as a state of knowledge and measures which infer SA from behaviors and performance. Each approach has some advantages and disadvantages. In practice, a variety of techniques may be needed to obtain a complete assessment of the system.

Behavior and Performance Measures

In general, performance measures provide the advantage of being objective and are usually non-intrusive. Computers for

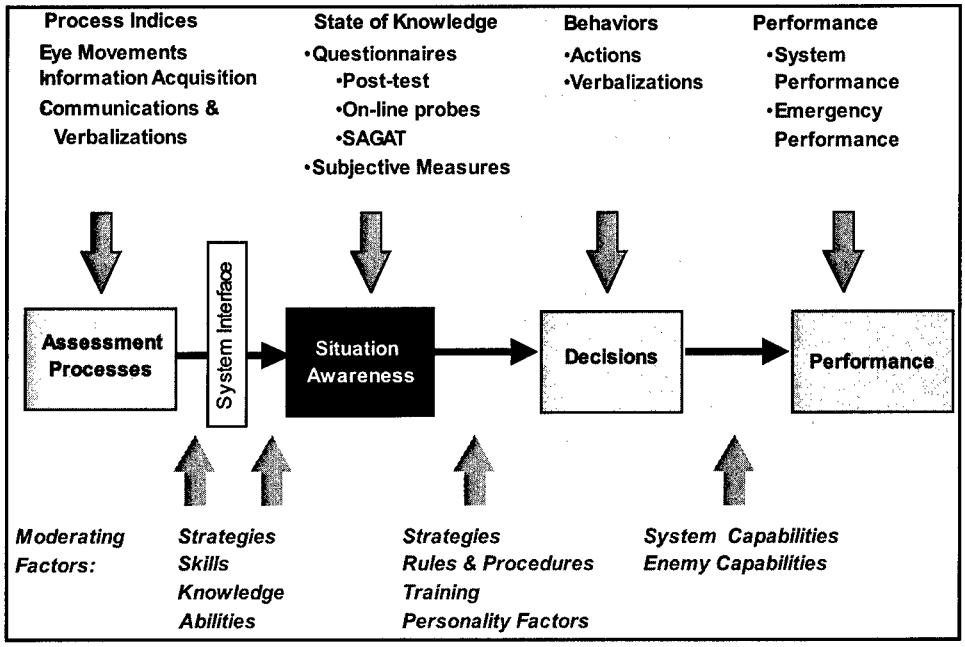

Figure 5. Approaches for measuring SA in system evaluation.

conducting man-in-the-loop simulations can be programmed to record specified performance data automatically, making the required data relatively easy to collect, and these measures can be collected in more realistic field evaluations. Several limitations exist in using performance data to infer SA, however.

Global measures

Global measures of performance suffer from problems of diagnosticity and sensitivity. While global measures of performance (success in achieving mission objectives) are most important, as measures of SA, they are somewhat limited. Many other factors that can act to influence performance, such as decision making, workload impacts on actions or individual strategy differences, may occlude an accurate assessment of SA. For example, a system may provide better SA, but unless strategies and decision processes change to use it properly, these benefits may go undetected. Therefore, insufficient sensitivity may exist to reveal some of the subtle problems (or benefits) a system may provide, during the limited amount of testing that can be conducted.

Imbedded task measures

Some information about SA can be determined from examining performance on specific soldier subtasks that are of interest, for example, time required to determine the occurrence of a specific event. Such measures will be more meaningful than global performance measures.

While finite task measures may readily present themselves for evaluating certain kinds of systems, for others determining appropriate measures may be more difficult. An expert system, for instance, may influence many factors in a global, not readily predicted manner. The major limitation of this approach stems from the interactive nature of situation awareness sub-components. A new system to provide SA on one factor may simultaneously reduce SA on another, not measured, factor. In addition, it is quite easy for individuals to bias their attention to a single issue which is under evaluation in a particular study if they figure out the purpose of the study. Overall, as improved SA in one area may easily result in decreased SA in others, relying exclusively on the measurement of performance on specific parameters can yield misleading results.

In general, where good objective measures of performance are available they should always be collected. In some cases, measures which provide a clear, unambiguous indication of specific types of SA may be available. As a system can affect SA in unpredicted ways that a particular set of performance measures or test-scenarios may not reveal, however, it is highly recommended that direct measures of SA also be assessed.

Direct Measurement of SA

Objective Measures

The most commonly used means of objectively evaluating a design concept's impact on situation awareness involves directly questioning people as to their perceptions of critical aspects of the system they are operating. The Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 1988; Endsley, 1995a) is a procedure wherein a mission simulation is frozen at randomly selected times, the system displays blanked and the simulation

suspended while participants quickly answer questions about their current perceptions of the situation. Participant perceptions are then compared to the real situation to provide an objective measure of situation awareness.

SAGAT includes queries about all of an individual's situation awareness requirements, including Level 1 (perception of data), Level 2 (comprehension of meaning) and Level 3 (projection of the near future) components. This includes a consideration of system functioning and status as well as relevant features of the external environment. This approach minimizes possible biasing of attention, as people cannot prepare for the queries in advance since they could be queried over almost every aspect of the situation to which they would normally attend.

SAGAT provides an objective, unbiased assessment of situation awareness that overcomes memory problems incurred when collecting data after the fact, yet minimizes biasing of situation awareness. Empirical, predictive and content validity have been demonstrated for this technique (Endsley, 1995a). The advantage of SAGAT is that it provides an indication of SA across a wide range of the individual's SA requirements. It therefore provides better sensitivity and diagnosticity than performance measures often do. It usually requires a man-in-the-loop simulation, however, and has not been used as often in field evaluations.

Subjective Measures

Subjective measures of situation awareness are easier and less expensive to administer than objective measures, but may lack the same degree of accuracy and diagnosticity. The most commonly used method is to have operators provide ratings of their situation awareness with system concepts along a designated scale. Taylor (1990) developed the Situational Awareness Rating Technique (SART) which has individuals rate system designs on the amount of demand on attentional resources, supply of attentional resources and understanding of the situation provided. As such, it considers perceived workload (supply and demand on attentional resources) in addition to perceived understanding of the situation. While SART has been shown to be correlated with performance measures (Selcon & Taylor, 1990), it is unclear whether this is due to the workload or the understanding

components. It has also been found that SART and SAGAT do not correlate well, suggesting that objective and subjective measures of SA may be measuring very different things (Endsley, Selcon, Hariman, & Croft, 1998).

Process Modeling Methods

Several process tracing tools may be applicable to the study of SA processes. Eye-trackers and methods for assessing information acquisition (such as covering information so that overt actions are required for observation) may provide useful assessments of how attention is deployed (or not deployed) in the process of acquiring SA, typical scan patterns, and relations between elements. This information may provide useful insights into the process of acquiring SA or into the types of mental models directing this process. Studying the communications process between soldiers, or between soldiers and commanders, may also provide useful information on the types of SA which are lacking from displays, verbal techniques used for acquiring SA and differences in SA strategies between individuals.

Verbal protocols may provide some useful information on not only what is attended to, but also may provide a certain degree of insight into how that information is integrated and used in the process. Significant difficulties in processing and using the data provided by verbal protocols must be dealt with by the evaluator, however, if this technique is to be used successfully.

Each of these techniques can be viewed as providing useful partial information on SA processes from which some inferences may be possible. Because verbal communications and verbal protocols take place in a very limited time frame, however, they cannot be regarded as complete representations of what controllers attend to or process. Eye-trackers and information acquisition methods are more likely to capture the SA acquisition process, but will not provide any information on how that information is used or combined to form higher level SA. Approaches that measure SA processes can generally be thought of as ways of augmenting our understanding of how a technology influences SA in the combat setting, but because they provide only a partial picture they cannot be relied upon as the sole measure of soldier SA when evaluating new technologies.

Example of SA Measurement for System Evaluation

As an example, Figure 6 shows how one might evaluate a Global Positioning System (GPS) device for impact on situation awareness. While it is expected that GPS in general may have a very positive impact on soldier SA (as compared to traditional way finding techniques), there may be considerable variability in how different GPS systems and display approaches affect SA. Careful testing should reveal the effects of the particular GPS display implementation on SA, so that the best display approach can be selected. Evaluations that focus on soldier assessment processes

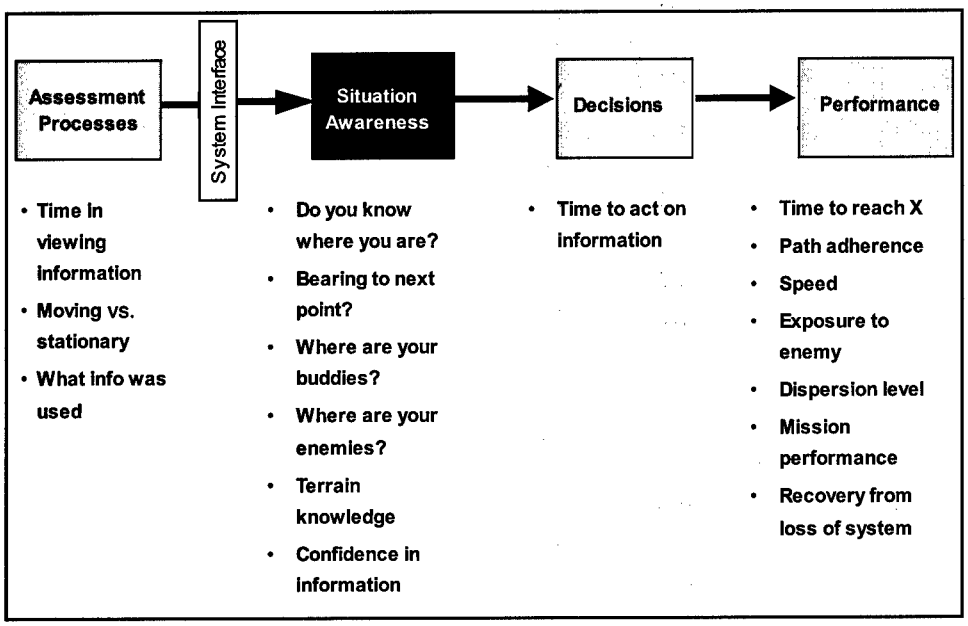

Figure 6. Measurement of SA for evaluation of GPS.

may measure how much time they spend in studying the display, whether it is used while stationary or can be used while moving and can assess which information in the display is used (or not used). Direct assessments of SA would focus on the degree to which soldiers are able to accurately locate themselves, their squad members and enemy locations, know the correct bearing to the marker point on their path, and degree to which they can indicate the advantage and vulnerability of their path with respect to terrain features. Their degree of confidence in the information can also be directly assessed (e.g., are they aware when the GPS is providing poor quality information?).

Behavior and performance measures could include things such as how long soldiers take to act on directions to move to new point and how long they take to get to that point. Error in veering from the assigned path, speed in moving along the path, degree of enemy exposure, the dispersion level of the team, and success in mission performance also provide measures that may be indicative of changes in soldier SA associated with the use of the system. Most importantly, assessments of such systems should include a measure of how long it takes soldiers to recover from a system failure (either due to degradation or inoperability/ damage). As reliance on any form of automation can render a person "out-of-the-loop", the ability of the solider to figure out where he is at and resume way finding using traditional manual techniques at any time should be carefully considered.

This is just an example of how SA measurement can be used within the system evaluation process to insure that the best system design is selected for any new technology. A similar strategy can be employed for soldier system evaluations based on an understanding of what tasks and activities the system may be expected to positively impact and those for which the system's design may cause problems. It is important that both potentially positive and negative affects be considered in this process so that design modifications can be carried out as appropriate.

General Measurement Considerations

Several general points need to be discussed that are relevant to the conduct of SA evaluations for soldier systems. First, the scenarios used to test the system are probably as important as the measures used. It is important that a variety of terrain, missions and mission tasks be included in the analysis so that the limitations of the system might be revealed. It is very possible that a given system may be good for certain tasks or conditions, but not for others. Testing should also include a representative range of individuals using the equipment (not just the best and brightest), and should examine its use for different mission roles. Realistic conditions, such as jamming or poor data, should be included in the scenarios. If systems are tested only under ideal conditions, some of the very real problems that may exist with information technologies will not be revealed. It is important to find these problems during early testing so that design solutions can be developed.

Secondly, it is unlikely that most new information technologies will impact SA at only one level in the organization. Information technologies are likely to make the linkages between the individual soldier, the squad, and the battalion even more tightly coupled. The impact of a particular system will therefore likely need to consider different levels in the organization. While a particular technology may improve the SA of the commander, for example, it might simultaneously lower the SA of the soldier if it takes his attention away from his immediate surroundings. Evaluations will need to be performed carefully in order to detect these potential problems.

Finally, the evaluation of complex information technologies increases the range of testing situations that the Army will need to consider. Operational testing in realistic environmental conditions has formed the backbone of the Army's testing approach and it is likely that this will continue to be the case. This level of testing will need to be augmented with more controlled "man-in-the-loop" simulation testing, however, in order to provide the sensitivity needed to make detailed design trade-off comparisons and to detect many of the subtle but significant problems that may be present in such systems. Without such careful testing, real problems with a system's design may not be detected in time to affect the design process. This will leave the Army with expensive systems that cause significant problems for soldiers during their use.

Conclusions

In conclusion, the Army faces a major crossroads in its development and use of technology as an aid to the soldier and its mission as a ground-based fighting force. Significant changes in the type of terrain and missions assigned to the Army are being accompanied by large scale changes in the capabilities that new technologies provide. These technologies provide a major opportunity for overcoming (or at least diminishing) the fog of war which has accompanied battle from time immemorial. Realizing the potential of these technologies for improving soldier SA, however, requires that the Army step up its approach to the design and evaluation of such systems. Information technologies have created significant challenges in every domain they have been introduced into. Repeating the costly mistakes of others is not in the Army's best interest. Instead, the Army has the opportunity to

side-step these mistakes by taking advantage of the lessons learned. A careful analysis, design and testing process is the key to developing information technologies that will meet the needs of soldiers, squad leaders, and battle commanders.

References

Bennis, W. (1977). Thoughts from a victim of info-overload anxiety. Yellow Springs, OH: Antioch Review.

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. In Proceedings of the Human Factors Society 32nd Annual Meeting (pp. 97-101). Santa Monica, CA: Human Factors Society.

Endsley, M. R. (1993). A survey of situation awareness requirements in air-to-air combat fighters. International Journal of Aviation Psychology, 3(2), 157-168.

Endsley, M. R. (1995a). Measurement of situation awareness in dynamic systems. Human Factors, 37(1), 65-84.

Endsley, M. R. (1995b). Toward a theory of situation awareness. Human Factors, 37(1), 32-64.

Endsley, M. R. (1996). Situation awareness measurement in test and evaluation. In T. G. O'Brien & S. G. Charlton (Eds.), Handbook of Human Factors Testing & Evaluation (pp. 159-180). Mahwah, NJ: Lawrence Erlbaum.

Endsley, M. R., Selcon, S. J., Hariman, T. D., & Croft, D. G. (1998). A comparitive evaluation of SAGAT and SART for evaluations of situation awareness. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting . Santa Monica,CA: Human Factors and Ergonomics Society.

Selcon, S. J., & Taylor, R. M. (1990). Evaluation of the situational awareness rating technique (SART) as a tool for air-crew systems design. In Situational Awareness in Aerospace Operations (AGARD-CP-478) (pp. 5/1 -5/8). Neuilly Sur Seine, France: NATO - AGARD.

Taylor, R. M. (1990). Situational awareness rating technique (SART): The development of a tool for aircrew systems design. In Situational Awareness in Aerospace Operations (AGARD-CP-478) (pp. 3/1 - 3/17). Neuilly Sur Seine, France: NATO - AGARD

Chapter 7

Group 2 Summary: Situation Awareness Requirements for Platoons, Companies, and Battalions

Kenneth L. Evans, Ph.D.
U.S. Army Research Institute
Fort Benning, Georgia

General Requirements

General SA requirements have applicability across platoons, companies, and battalions (i.e., are echelon non-specific). These requirements also will, in many cases, overlap with the general requirements identified by the other three groups at the workshop. Prior to initiating group discussion on general SA requirements, the two Group 2 leaders provided an introductory framework to guide the overall group effort. Definitions of SA were presented, recognizing that SA requires knowledge of internal states (though soldiers may not always recognize their own internal state and may need reminders), external states, the environment, and the relationship between digital SA systems (machine or man-machine) and the environment. However, it was noted that digitization has not yet had a substantial impact at the battalion level and below. The concept of three SA levels was also presented and discussed. These levels are environmental perception (situational awareness), comprehension of the current situation (situational understanding), and projection of future status (to develop situational dominance).

Foremost among general SA requirements identified was the need to know one's location, in relation to the location of both friendly and enemy troops. This requirement was soon expanded to include the need for visual location information on interservice, reserve, and coalition forces, in addition to information on area civilians (non-combatants and the media). A wide variety of other METT-T (Mission, Enemy, Terrain, Troops, and Time) planning factors were also identified, including:

Mission

- ❑ understanding of commander's intent (two levels up and down for leaders at every echelon); plan for succession of command
- ❑ need for enroute mission planning updates
- ❑ enroute mission rehearsal needs of units (often while dispersed)
- ❑ recognizing and understanding the significance of threshold events identified by the commander
- ❑ level of unit SA is often mission dependent
- ❑ degrading enemy SA is an important part of the mission

Enemy

- ❑ strength
- ❑ condition
- ❑ status of key weapons and equipment
- ❑ levels of supply
- ❑ SA capability
- ❑ significant changes in enemy activities or strength
- ❑ attitudes among enemy and non-combatant populations

Terrain

- ❑ condition of routes, bridges, and avenues of approach
- ❑ location of minefields and obstacles (enemy and friendly)
- ❑ potential for channelization of friendly or enemy units
- ❑ environmental data (e.g., weather and battlefield damage)
- ❑ consider impact of terrain on communications and subsequent SA

Troops

- ❑ monitor individual soldier status (i.e., internal psychological and physical states)
- ❑ collective information on strength, condition, weapons, equipment, and supply
- ❑ evaluate threats to effective teamwork, coordination, cohesion, and morale
- ❑ accurate information on adjacent units

Time

- planning time horizons and SA capabilities can directly influence each other
- timely warning of immediate threats is always needed
- consider potential variation in all planning factors over time

One final general SA requirement dealt with the relative needs for digital systems information and voice communications over time. During planning and battle preparation, as well as during recovery and continuation, the relative needs for digital SA information are highest. In contrast, information needs in the "red zone" are largely met through voice communication.

Tactical Requirements

Tactical requirements are concerned with how previously identified general SA requirements are linked to combat. Chief among these tactical requirements was the need for accurate and timely battle tracking of locations, strengths, leaders, and key systems (e.g., what's over the next hill or what's the condition of my troops). Another critical concern was the need for effective and timely distribution of SA information to critical points that are often widely dispersed. For example, written orders may become less important in the future, as long as the essence of the planning process can be captured and distributed across battlefield locations.

Tactically, enhanced SA should lead to improved soldier perception, understanding of potential consequences, and anticipation of future events. It should also reduce uncertainty, so that critical situations are clearly seen and the effects of distracting events (e.g., enemy deception, battlefield confusion, and unknown intentions of non-combatants) are minimized. Enhanced SA should also aid in bringing all available combat power to bear upon the enemy, permitting leaders to sustain and extend their tactical advantage, while minimizing risk to friendly elements. In particular, SA enhancement should lead to greater speed in decision making, allowing soldiers and their leaders to

recognize the opportunities and liabilities inherent in a given situation while there is still sufficient time to act. One group member noted "with SA systems we can focus on the enemy rather than on building structure (i.e., pursue the enemy instead of clear a building)."

Although the promise of improved SA is great, it was widely recognized that current strength in Infantry fundamentals needs to be sustained and maintained as future digitization efforts proceed. Conventional back-up systems need to be maintained and training in their use needs to be continued, even after automated digital systems come online.

Unique Platoon Requirements

Identification of unique platoon SA requirements was prefaced by a discussion of the inherent differences in the missions and capabilities of platoons, companies, and battalions. For example, of the three echelons considered it was acknowledged that platoons have the greatest likelihood of losing key leaders during battle. Early in its deliberations of platoon requirements, the group dealt with a variety of issues related to squad leaders, team leaders, and individual squad members. One participant remarked that "if a light Infantry squad leader is looking at a screen (i.e., a visual display), he's looking at the wrong thing." Another noted "a squad leader needs to focus on one thing - the immediate fight; (because) we fight in close proximity (to the enemy and to one another)." Later, the group decided it would be more fruitful to focus its efforts on leader requirements at each of the three echelons for which it was responsible. At this point discussion became centered on platoon leader requirements.

What does a platoon leader need to know? That was the question the group first tried to answer. The consensus was that platoon leaders don't need to know where every soldier is, though they do need to know the location of each squad leader. Further discussion led to refinements in this position. For instance, one group member noted a platoon leader "needs to know where soldiers are generally, because squad leaders can become casualties." It was then acknowledged that at certain times (i.e., recovery and consolidation) knowing the location and status of every soldier would be beneficial.

Group 2 Summary

Some participants thought giving a platoon leader too much information could lead to information overload, while others strongly believed a platoon leader "wouldn't allow himself to have information overload; he'll focus on what's important and will sort it out." The latter faction wanted all possible information to be given to the platoon leader. A compromise was reached when one participant noted a platoon leader had "on-demand needs for information" and described an ideal situation in which a platoon leader could "click on a squad leader icon to see all members of his squad." This compromise eventually led to the group's final position that a platoon leader usually needs to be able to see his squad leaders, though he also needs to be able to see individual soldiers in certain situations (e.g., for fire planning, consolidation, and accountability).

The group generally believed a platoon leader's visual and spatial template should be smaller and more detailed than that of a company or battalion commander, with a shorter temporal horizon. As one person noted, "UAVs (unmanned aerial vehicles) are a joke for guys like us." It was widely recognized a platoon leader needs awareness of the most immediate threats to his platoon, though it was also noted that his visual and spatial template should have "the capability of being scaled out" in order to envision the next threat. However, information that can be gleaned from merely turning one's head to the left and right (e.g., a platoon leader noting the positions of adjacent platoons in the company area) is not needed as part of a digital SA system.

Rather than being routine, it was thought that reports to the platoon leader from subordinates should be by exception only (e.g., when danger areas are identified or when deviations from the plan are needed). Of course, this assumes individual soldiers will always recognize what is important to the platoon leader and his superiors. In instances where this assumption is unrealistic, a digital SA system could be used to filter incoming reports to the platoon leader, assuring that only relevant informational cues are passed through. One participant noted that "you need redundancy built into the system, in order to confirm or deny what an initial report saw." Of greatest importance to platoon leaders is information that can assist in:

- seeing the enemy's flanks, obstacles, and heavy

weapons
- ❑ direct fire planning, fire control, and personnel identification (i.e., friend, foe, and non-combatants)
- ❑ monitoring critical supply levels

Knowing some platoon leaders are relatively inexperienced, group members identified a variety of specific technological requirements to help overcome this experience deficit. For example, it was thought that situational understanding could be improved by providing platoon leaders with a refined system of combat cues to assist in rapidly assimilating SA data in order to make more effective decisions under severe time constraints. Such a system might even aid in mission planning, through augmenting or reinforcing knowledge about the capabilities and support requirements of various weapons systems (particularly those in the platoon), as well as through providing guidance about "what needs to be carried to the next fight." Also mentioned was the need for a precision mapping capability, especially geared to the location and scale of platoon and enemy weapon systems. Finally, a need for an "image capturing and transfer system" was envisioned, whereby a platoon (or subordinate element) could capture a digital image, transmit it to an external expert source, and receive timely information about the nature of the image and its meaning from that external source. However, some thought this latter idea might conflict with the need for an immediate and automatic response (i.e., battle drill).

Unique Company Requirements

Relative to platoons and battalions, the leadership within companies was considered to generally have more depth. Companies were seen as the lowest echelon having a combined arms coordination function, an indirect fire control function, and a substantial information management function. In particular, the company executive officer (XO) must anticipate and forecast future requirements, while managing a heavy load of information coming in and going out, both from above and below. The XO, and often the company first sergeant, are squarely in the middle of company operations and the persons most likely to interface with digital SA systems. Clearly the XO has a need for assistance in receiving, logging, assimilating, and filtering raw SA data (e.g.,

through identifying trends or analyzing patterns) into a format most conducive to the decision-making needs of the company commander. The company commander must first collaborate with the battalion commander in planning and must then coordinate combined arms actions in teams within the "red zone." As one group member stated, "we need to distinguish between what a (SA) system tells us about the battlefield and what the company commander needs to know." Another pointed out that "the company commander's most important thing is planning combat ratios, to ensure he has what he needs to do the job." However, commanders at every level "want to know who's in contact with the enemy."

Fortunately, the XO will likely be a prime customer of any enhanced SA capabilities at the platoon level. Improved information filtering and management at both the platoon and company levels should result in enhanced consolidation of platoon and company reports to the battalion. One participant thought company-to-company coordination, which is different than platoon-to-platoon coordination, could also be improved with better SA. Many thought digital SA systems should support the company's execution matrix, and most thought the primary benefits of improved SA at the company level would likely be seen in improved precision and speed of movement (with speed being an important difference between mechanized and light Infantry forces, as are their varying resupply needs).

Unique Battalion Requirements

Compared with platoons and companies, battalions are seen as having a relatively junior and unevenly trained staff, creating a tremendous training burden on the battalion commander. The primary focus of battalions is on the planning and execution of combined arms operations, sometimes independently and with other assets attached. Against this backdrop the group members identified a number of areas in which battalions have unique SA requirements.

First, the group noted that if all supporting fires could be more quickly and accurately cleared, movement would be greatly facilitated. Second, the battalion needs to be able to "see deep"

(both spatially and temporally) to effectively employ its reserves and plan for the next fight. At the same time the planning function of the battalion staff needs to be supported 24 hours into the future. Third, digital SA systems should facilitate use of the battalion's decision support matrix, while eliminating unnecessary duplication in reporting. It was recognized that "you can get a false picture due to the redundancy and duplication of reports." Lastly, SA systems should support scouts in developing battlefield intelligence and should allow battalion tactics to be quickly altered as SA improves. Yet as one participant warned, "don't let technology drive where the battalion commander goes . . . right now most information is in the TOC (tactical operation center), but that's not where the battalion commander needs to be."

Some group members highlighted apparent differences in typical decision making processes at the battalion level. Perhaps because battalions have somewhat more tactical freedom, more contingent or "if/then" thinking occurs as alternative courses of action and potential changes to the mission are considered. A myriad of cues must be interpreted (e.g., the level of enemy motivation and training) in order to identify leverage points having a high probability of success. One participant stated, "the Battalion Commander can sense a turning point in battle, and act accordingly." Nevertheless, most group members thought improved SA in battalions would reduce risk (e.g., fratricide), promote initiative, and lead to the development of an "economy of force" and better logistical projection.

Threats to SA

At all echelons exist a variety of threats to improved SA. Some are technological, some are procedural, and others deal with human resource issues. Among the technological threats are computer viruses, electronic jamming, spectral interference, electromagnetic pulse systems, and anti-satellite technologies. These threats, particularly in the absence of an electronic screening capability by friendly forces, can be used by a well equipped enemy to degrade the level of our own SA.

There are also a number of enemy procedural strengths and friendly procedural shortcomings that threaten SA. For example, the enemy may employ deception strategies tailored to their

own strengths, or they may choose to operate asymmetrically over both space and time, running counter to preconceived notions and conventional expectations (e.g., the red force travels so slowly that a surveillance radar system cannot detect its movement). Further, friendly units may fall into the misguided habit of only seeking evidence confirming initial expectations, while avoiding all but the strongest kinds of disconfirming evidence. One group participant related an amusing account of a large training exercise in which a battalion only became aware of true enemy strength and location at the moment its TOC was being overrun by an armada of mechanized vehicles.

A lack of quality personnel, particularly those who are well-trained and have depth of experience, can also weaken a unit's SA position. As one group member remarked, "you've got to realize the red (force) SA picture you get with these (SA) systems is (based on) input by somebody." Soldiers who do not fully know their roles within the unit and soldiers who fail to report what they sense can lead to inaccurate or inconsistent reporting of SA information to leaders. Leaders themselves may not understand the significance of the information, nor what they should do with it when received. One participant stated, "we don't train leaders to use the information from the new (SA) systems." Improved training at all levels was generally regarded to be the only remedy for these kinds of human resource threats to SA.

Potentially Negative Results of Enhanced SA

The participants identified a number of potentially negative results associated with enhanced Army and Infantry SA. In particular, it was widely acknowledged that soldiers and their leaders could grow to rely too much on external SA information and support. Some thought being overly dependent on SA technology might deter the use of critical thinking and questioning skills, which would be called into play whenever SA systems are compromised. One participant noted that "the more realistic the display, the greater the chance for misperception." Enhanced SA also could result in hesitant or delayed decision making, while one waits for the perfect SA picture to develop. Another participant believed the Army should avoid the pitfall of "adopting tactics that depend on unrealistically detailed and accurate SA" or "training soldiers to expect continuous, high resolution SA."

Other group members mentioned that coalition forces may have unequal or incompatible technologies, resulting in a dangerous unevenness of SA across forces. Further, there exists the high likelihood that at least some soldiers will be unfamiliar with external or joint terminology, hindering effective communication. Still others cautioned against information overload and the resultant fatigue it causes. As one put it, "soldiers become more fatigued in the digital world than in the analog world, because they have to filter so much information." Finally, there were those who thought enhanced SA would led to much higher speeds of action in combat, especially at the battalion level. Higher speeds could have a number of unintended consequences, such as units being caught unprepared for the resultant increase in fatigue and stress among soldiers operating at an unusually rapid pace.

Training Requirements

The group chose to focus their discussion more on how SA should be trained (i.e., process), rather than on what should be trained (i.e., content). Most acknowledged the Army does a generally good job of training and drilling procedural tasks, though it tends to do less well in areas that require more imagination and creativity. Nevertheless, due to its long history of success within the Army, most thought instructional systems design (i.e., based on defining individual and collective tasks, conditions, and standards) was the best training approach to use as a starting point. It was recognized that conditions would likely change as the battlefield becomes more digitized and that standards could change as higher levels of SA are achieved. However, basic combat tasks themselves (e.g., move and shoot) were not viewed as being in need of change. One participant suggested the use of an event-based collective training strategy, wherein a team or unit is presented with a highly challenging mission, weaknesses are identified in an exercise of that mission, and identified weaknesses are targeted for increased emphasis during subsequent exercises.

With regards to SA-specific training techniques, group members suggested various pre-mortem, in situ, or snapshot critique methods to provide an immediacy of instructional feedback that generally cannot be obtained from a conventional After Action Review (AAR) subsequent to a lengthy tactical exercise. Although AARs can be used to ascertain aspects of SA retrospec-

tively, one military participant noted "AARs are becoming more of an in-process event rather than a culminating event." Another participant thought we should attempt to "calibrate" the SA of soldiers by using "during the action" reviews instead of AARs.

Although basic combat tasks are not likely to change in the future, new tactics will undoubtedly arise from the fielding of new hardware and software designed to enhance unit SA. New system-induced tactics, techniques, and procedures will somehow need to be taught. At least for unit leaders, most in the group thought some rigorous institutional training would be required, perhaps as a formal upgrade to current leader education and development programs. The use of new equipment training teams to introduce a new SA system to a unit would help those soldiers who must learn to operate and maintain the equipment, but it would be insufficient for the needs of leaders faced with a rapidly evolving battlefield having an array of new digital systems coming online.

Realistic conditions associated with digitized battlefields should become a part of all training and development programs to the greatest extent possible, not just in large field training exercises. Group members mentioned a wide variety of conditions they thought should be included in training for enhanced SA, including:

- brigade and division inputs for battalions
- a full, or at least wider, field of view
- more information on air operations, civil affairs, and non-military factors
- simulate systems compromise and failure, by varying the quality of SA information
- insert false information to provide alternating periods of uncertainty and clarity, with better portrayal of enemy interference and counters
- force individuals, crews, and units to cope with large quantities of information

Group members thought all soldiers should be encouraged to seek greater SA. Leaders should recognize all soldiers need developmental opportunities and experience to improve their SA (e.g., don't just assign one particular soldier to a task because

you already know he or she will be successful at it; allow others the opportunity to fail and grow as well; put people in situations where they are weak).

Especially cited as a training requirement for leaders at all echelons was training in the area of decision making. One participant cited his desire for decision-making training that included "the needs to identify key information requirements, to recognize significant developments, to gain critical information, and to act in a timely manner." He further envisioned the need for "repetitious, fully-critiqued decision exercises that promote sound troop leading procedures, deliberate arrangements to maintain SA during operations, and the ability to act with incomplete or conflicting information."

Perhaps the liveliest debate occurred during the consideration of the critical information requirements of leaders on the battlefield, a topic with huge implications for both training development and system design. There were two opposing camps. One camp, composed primarily of those with a scientific or system design background, saw advantages in reducing, structuring, or filtering the information provided to leaders. The second camp, composed primarily of those with a military background, were strongly opposed to any reduction in the amount of information made available to leaders. Those in the second camp thought the leaders themselves should filter the information, while having access to the widest possible number of options. Ironically, both camps used the same analogy, the Windows 95 user interface, to support their respective positions. The first camp saw Windows 95 as the worst possible example of a user interface for SA systems. They envisioned soldiers, particularly under severe time constraints or in an emergency situation, getting lost in a maze of meaningless icons and multi-layered menu screens, 90% of which they will never use. In contrast, the second camp saw Windows 95 as an ideal user interface for SA systems, because many soldiers have already developed facility with that type of interface and because additional information can always be obtained when needed (i.e., by clicking on an icon). The debate was not fully resolved in the amount of time available for discussion, though I think it was an extremely important one that should be revisited.

Evaluation and Measurement Issues

After a presentation on currently available SA measurement techniques, Group 2 participants discussed the relative merits of these techniques and then tackled a variety of other evaluation and measurement issues. Most participants expressed a preference for methods based on field testing conducted in the most realistic conditions possible. As one stated, "whatever means is selected to assess SA, it cannot be in a controlled laboratory environment which does not reflect the reality of (operational) units... the current AWE (advanced warfighting experiment) process appears to be the most realistic measure of what can be expected when a unit is digitally equipped." Yet most recognized that "SA and performance are two different things" and that "good SA may not lead to better performance."

Some participants thought SA evaluation should be concerned with "whether or not the soldier has the right mental picture." Most adhered to the notion that there are at least three distinct SA perspectives, including the Blue Force, Red Force, and Observer/Controller points of view. These differing perspectives should all be considered in measuring the total SA picture. However, others pointed out that we can neither train nor measure a mental state like SA. Instead, we should try to train and measure how soldiers go about getting "the information needed to reach a state of SA and to make good decisions."

As in training (see previous section), most participants expressed a preference for snapshot assessment techniques in measuring SA. Participants, particularly those from the military user community, were attuned to the workload burdens some measurement methods, particularly questionnaires, impose on soldier respondents. Perhaps the general preference for and user acceptance of snapshot methodology is influenced by the fact that it is generally less time-consuming for soldiers than most other methods (though it's not completely unobtrusive) and that it appears to be a useful training technique as well. In evaluating SA system design, participants from the military community thought it important that designers get detailed feedback from soldiers by observing SA system performance in a realistic user setting for an extended period of time.

The group participants offered several warnings about SA evaluation and measurement. First, they thought it important that highly diverse groups of soldiers be used in evaluating SA systems, to insure the results obtained generalize to the entire Army. Second, they cautioned against overemphasizing the importance of physical SA factors (e.g., number of weapons or troops) to the detriment of more intangible SA factors (e.g., element of surprise, moral dominance, level of training, leadership effectiveness), just because the former are more easily measured than the latter. Lastly, they were cognizant of the complexity and situational constraints inherent in the SA measurement. As one participant summarized, "Assessing SA is like trying to measure the goodness of a simulation. Every unit and leader is different and the level of training, professional development, unit turbulence, and so forth are considerations when trying to measure the effectiveness of increased SA."

Potential Research Topics

There does not appear to be a dearth of potential SA research topics, as the group came up with a fairly lengthy list in a relatively short period of time. Although the proposed topics were too numerous to mention each one individually, two stood out by the amount of discussion they engendered. At the top of the list was a widely recognized need for research to determine the best way to scale SA information at different Army echelons (i.e., how much information is needed and how much is too much at each echelon). One participant characterized this research topic as finding the "balance between useful information and distraction." A very close second was the related need to investigate the best ways to provide structure in an SA system's user interface, while simultaneously providing maximum soldier flexibility (i.e., immediate access to additional information when needed). As one participant stated, "sometimes I don't want more information (because) I don't want to be distracted; but sometimes I can't get enough." See the last paragraph of the Training Requirements section for a summary of the latter discussion.

Though not related solely to SA concepts, an interesting observation and potential research topic was offered by one of the group's senior members. Specifically, he noted that all soldiers could be classified into one of three groups: the Killers, the

Followers, and the Fodder. He further observed that a soldier tends to remain in the same group from battle to battle and from training exercise to training exercise. Due to their central warfighting import, he suggested that in-depth research be conducted with soldiers identified as being in the Killers group to determine what is unique about their mental processing that distinguishes them from soldiers in the other two groups. Such comparative research might yield insights into aspects of thought processing and decision making associated with exceptional combat effectiveness, and perhaps enhanced situational understanding, at the individual soldier level.

Finally, the group appeared to have a generally optimistic view of a digitally enhanced future Army, though they noted the need for research related to a variety of SA implementation issues as well. For example, they recognized the need to investigate the ways in which decision making processes will be positively and negatively affected at each echelon by the introduction of SA systems in the digital Army. One participant viewed "battle staff effectiveness (as) the crux of winning the information war," with a critical research issue being "how, how much, and how often we train battle staffs (battalion through corps levels)." Additionally, the group believed some analog skills might transfer negatively to the digital Army, and pondered the need for training research to counter the effects of negative transference (e.g., how to teach soldiers currently in analog units to use new digital equipment as it is introduced incrementally). In contrast, others mentioned the need for research-based design guidelines to help SA system developers accurately portray the complexity of Infantry operations without masking the analog SA cues that soldiers have been using for many years.

The next two chapters represent the thoughts and views of the co-leaders of this group. Lieutenant General (R) Don Holder provides his views on SA for Infantry ranging from platoon to battalion level in Chapter 8. Dr. Valerie Gawron then summarizes her observations of the workshop, and SA issues in the Army, in Chapter 9.

Group 2 participants included:

LTC Joe Anderson
Mr. Scott Bamonte
Ms. Leslie Bulger
Mr. Chris Christenson
GEN (R) Wayne Downing
Mr. Marc Dudley
Ms. Carol Fitzgerald
Mr. Andrew Fowles
MAJ Rick Gordon
Dr. Ed Johnson
CSM Gary Kalinofski
Mr. Bart Kuhn
Dr. Carl Lickteig
COL Stan McChrystall
Ms. Beth Redden
Mr. Buzz Reed
Dr. Renee Stout

Chapter 8

Situational Awareness in Infantry Battalions

LTG (R) Leonard (Don) Holder
Systems & Information Technology Group, TRW Incorporated

General

This paper addresses the doctrinal, training, and technical requirements for situational awareness (SA) in Infantry battalions and proposes research areas for the U.S. Army Research Institute (ARI) in the area. It contains my own views of the subject and incorporates observations made by a discussion group at the Situational Awareness Workshop at Fort Benning in September 1998. The divisions of the paper correspond to study objectives identified by ARI before the conference.

The chief conclusions of the paper are:

- "Implicit" SA—the learned and trained preparation of leaders—is as important as the information provided to Infantry battal ions during operations.
- Automated SA promises great advantages in using time and forces to near-optimal effectiveness.
- "Red zone" SA requirements of battalions, companies and pla-toons are limited, highly specific and cannot be allowed to dis tract leaders from direct observation.
- Battalions will need to retain back-up information and decision aids even after Land Warrior and Army Battle Control System (ABCS) means are in use.
- Battalion-level SA equipment must possess the flexibility to display varying levels of detail and to accommodate changes in leadership positions during combat.
- Battalion-level leaders need repetitive, realistic perception and decision exercises to develop their SA skills. This is especially important for platoon leaders and officers of the battalion staffs because of their inexperience.
- Trainers need training aides, devices, simulators, and simula-

tions (TADSS) that realistically activate the battalion's SA equipment in even the simplest range and training lane events. Battalion-level training will have to portray the full division zone or sector and provide access to division level data bases to replicate the nature of "digitized" combat accurately.

- ❑ Trainers face considerable difficulty in using the current simulations to portray SA accurately and in avoiding simulations-induced stereotyping of enemy actions.
- ❑ Military educators in the officer and non-commissioned officer education systems (OES/NCOES) have a major responsibility for teaching combat dynamics as a means of improving "implicit" SA.

Infantry Battalions

Infantry battalions are the basic fighting elements of Army divisions and brigades. There are currently five different types of Infantry battalions (light, mechanized, airborne, air assault and ranger). All have the same missions of closing with and destroying the enemy and holding ground. All consist of a headquarters, three or four Infantry companies, a scout platoon, and a mortar platoon or heavy weapons platoon (mortars and anti-tank weapons). Mechanized Infantry habitually works with armor units, fights mounted and dismounted, and has special responsibilities for facilitating mobility in heavy divisions. The other Infantry battalions normally fight dismounted.

The addendum at the end of this chapter offers a broad discussion of the characteristics of Infantry battalions. The versatility of Infantry battalions is of special note. Infantry can perform any of the ground tactical missions of the Army in any kind of terrain. Battalions may fight as "pure" Infantry formations or as combined arms task forces. As task forces, Infantry battalions can employ armor, cavalry, engineer, military police, Infantry companies from other battalions and direct the supporting actions of air defense artillery, engineer, military police, combat arms or psychological operations units. They employ their own scouts, mortars and anti-tank weapons and are routinely supported by field artillery and close air support.

The leaders of Infantry battalions vary in experience from highly qualified field grade officers and senior NCOs to staff officers, platoon leaders and squad leaders who are usually serving in their first leadership positions. This mixture of experience affects SA in battalions and creates needs for training, education and systems support that differ from larger unit headquarters

Situational Awareness and Infantry Battalions

The Army is still resolving its doctrinal approach to situational awareness. Its most current definition is equivocal and grammatically tough: "knowledge and information of the relationship between forces which identify opportunities, threats and gaps in information. [Situational awareness] is derived from the application of judgement (resulting from training, education, experience and intuition) to ensure decision-making" (FM 100-5, draft). Tortured as that formulation may be, its direction is fairly clear.

Two other concepts—the Common Operational Picture (COP) and Battlefield Visualization (BV)—overlap SA. The COP is "the aggregate of shared data on the disposition of friendly and enemy forces and neutrals" (FM 100-5, draft). It is generally interpreted as the shared, up-to-date view of a particular tactical situation distributed by a single headquarters.

"Battlefield Visualization" is a more general term that suggests broad orientation and appreciation of current and future states. BV discussions incline toward technical questions about how conditions may be graphically portrayed and how those representations may be distributed. They generally assume a need for situational awareness of a particular type and typically come down to the idea of commanders discussing options on interactive whiteboards and the like.

Situational Awareness overarches these narrower related concepts. For battalions, companies and platoons, the original, folksy TRADOC definition of SA works well enough to allow broad discussion of the subject. That definition holds that commanders need to know:

- ❑ Where am I? Where are my buddies? Where is the enemy?
- ❑ Implied information requirements include:

- What is my condition now and how will it change in the near term? What are my options now and in the near future?
- What is the enemy's condition? What are his present and near term options?
- How will environmental conditions affect me and the enemy?
- How will basic conditions change during the course of this operation?

Knowing the answers to those questions entails much more than circulating graphics or equipping Infantry units with advanced decision aids. Where friendly forces are concerned, SA clearly involves knowing the unit's position, dispositions and strength. It also requires understanding Infantry doctrine (to anticipate the likely actions of friends), the implications of the assigned mission (to know what others expect), the unit's state of training, the qualifications and abilities of individual leaders, and the unit's experience and attitudes.

Likewise, SA concerning the enemy includes more than the basics of knowing his location and organization. For a battalion, it will be valuable to know the enemy's precise dispositions, the placement of his heavy weapons, his mission and intentions, his freshness or fatigue, his recent experience, the quality of his leaders, his doctrinal norms and actual past behavior, and the options open to him. Battalion commanders will also want to know what enemy reserves can reinforce forward elements and when those reserves become committed either against the battalion or elsewhere. The most important element of situational awareness for the battalion may be knowing specific enemy strengths and weaknesses that the tactical plan must account for.

Gaining a full understanding of the battalion's physical surroundings poses special challenges. Unlike the air and sea environments where much of the pioneering SA work has been done, the ground environment is irregular and almost endlessly varied. Minor irregularities in the ground and otherwise insignificant vegetation or features that protect soldiers from observation or fire have often been key to success at battalion, company and platoon levels. Equipping Infantry units with highly accurate representations of the ground would therefore confer a real advantage on them.

Changes in weather, light conditions or obscuration have also changed the character of battalion engagements decisively. Weather or enemy actions that interfere with laser designators, thermal sensors, or helicopter operations can pose problems for a battalion. Likewise, fire or rubble in a town or the recent destruction of a bridge can be highly significant to a battalion's movements. As the Israelis learned in the intifada and the Americans found in Vietnam, the signals that a population sends—behavior of the civilian population, absence and attitudes of civilian police, changes in field and market routines—may also suggest imminence of enemy action. Even changes in plant health or animal behavior may be significant when an enemy uses chemical or biological weapons.

Finding these things out and keeping key elements of information current poses special problems in the face of enemy deception, concealment and misrepresentations. There is literally a fight for perception, a race for comprehension and a great advantage to accurate forecasting of tactical conditions in the Infantry fight. Passive concealment and active deception measures accompany all small unit actions and external support in penetrating these ruses will be of great value to battalion commanders and their subordinates.

The payoff for good SA comes in seeing the potential for effective action inherent in the tactical situation and in making accurate, timely judgments. Both of these skills depend more on experience and learning than on simple perception of the facts.

To help clarify these issues, researchers may consider SA to have explicit and particular aspects and implicit and general aspects. The explicit and particular dimensions concern information about the dispositions and condition of the battalion, the location and condition of the enemy and tactically significant features of the environment including the actions of third parties (friendly forces, neutrals, civilians, other agencies) at a particular time. Implicit and general considerations include intangible but relevant factors such as the larger tactical context (the division's and brigade's missions and concepts), morale factors and what these imply for the battalion. This general understanding is of major importance to the battalion leadership's ability to recognize the meaning of battlefield information and to anticipate the course of events.

Range of interest

It is important for soldiers and researchers to understand the limits to which situational awareness must be extended. In practice, the answer to this will depend on the specifics of each case.

As a general rule it makes sense to parallel the command and control rule of seeing the fight "two levels up and two levels down". Battalions generally need to see where their companies and platoons are and know what the brigade and division commanders intend. "One up-one down" has much more immediate meaning and may suffice for most of the time, but the battalion commander can only anticipate developments fully and fight most effectively when he understands the situation of the division. Knowing the division commander's intention and the activities of surrounding battalions is essential for constructive exercise of initiative in seizing opportunities in combat. Similarly, knowing what constitutes disaster for the overall effort has guided battalion commanders in knowing when to depart from the plan to prevent loss of critical terrain or resources.

Another way of scoping situational awareness is through the dimensions of time and space. If a battalion commander in the attack estimates that it will take four hours to reach, seize and secure his objective, he would logically define areas of interest to reflect his assessment. These would include all the enemy units that might support opposing forces on his objective with fires and all those that might maneuver to reinforce the objective area in the four hours at issue. As the attack progresses, this area of interest would contract with the time remaining. (That is, when the objective is within an hour of being taken, the number of possible enemy counteractions is reduced to those that can take place in that time.)

If the commander understands success in terms of controlling a key terrain feature or complex, he will set his information objectives differently. In that case, understanding the conditions necessary to seize or retain ground will assume special importance in his situational awareness. (This kind of general understanding of key terrain led separated battalion and company commanders along the Elsenborn Ridge to act independently to hold that feature early in the Battle of the Bulge thus decisively shaping the course of the action.)

In any case, the battalion's leaders will want to know in advance as much as is possible about the enemy they face and the conditions in which they will fight. In defense, any notice of an attack is helpful and detailed information about the enemy's strength and armament is desirable. In attack, advance notice of the enemy's organization of the defense, location of major weapons, assailable flanks, obstacles, and positions of reserves all help shape the operation. In any operation, knowing about the activity of enemy's artillery, special weapons, and aviation assets assists in protecting the battalion. Knowing about the movement of enemy reserves enables the battalion commander to concentrate his force at the most advantageous time and place.

Stability and Support Operations (SASO) open up a different range of interests for Infantry commanders. These are too numerous to review, but gaining an understanding of them adds to the training load of battalions slated for SASO missions. Junior leader failures to appreciate the sensitivities and abilities of civilian authorities, leaders of non-governmental organizations, other government agents, coalition partners or adversaries in the population can create real problems for the larger force. Recounting his experience as a division commander in NATO's Bosnian peacekeeping mission, MG (R) William Nash noted that his battalion commanders had to have a sensitivity to the overall situation that would only be expected of division commanders in combat.

Opportunities

Better understanding of conditions and opportunities promises great tactical advantages to battalions, companies and platoons. By removing some of the uncertainty from their operations, improved SA fosters more precision in planning, greater efficiency in operations, and, sometimes, reduced stress on soldiers. It also enhances the use of time, an advantage that has commonly provided a tactical edge of great value.

Better knowledge of the situation eliminates errors and reduces the need to hedge or "safe-side" in tactical planning. If the battalion commander knows the time and place of an enemy attack or the design of his defense, his own actions will be more effective. If he understands the enemy's true situation, he may free himself from the need to withhold forces from the fight to

cover contingencies such as exposed flanks or the possibility of counterattack from a particular direction. Moreover, he gains the advantages of being able to decide and act faster if he understands his situation earlier and can brief his subordinate leaders and soldiers faster and in greater detail.

A clearer view of circumstances also improves economy of force—the full use of all available resources. Full visibility of the battalion's platoons facilitates coordinated maneuver and more effective application of force. It also gives the battalion commander the ability to detect and correct errors in maneuver or positioning and thus avoid some of the penalties of poorly coordinated operations.

Knowing where the enemy is and is not or what maneuver the ground will support greatly enhances the effectiveness of battalion operations. If the battalion commander knows such things as exact enemy dispositions, the location of enemy obstacles, the availability of supporting artillery and the true location of his platoons he will enjoy considerable fighting advantages. As a result, he will be able to "push the envelope" of possibilities to the limit, employing every supporting weapon or system as it becomes available. He will also have a better, earlier appreciation of the results of supporting fires, electronic warfare, or engineer effort that can be translated into better exploitation of tactical advantages.

Knowing when to break off an attack or understanding that persisting can lead to significant gains are also major advantages of advanced SA.

The effects of uncertainty, the unknown, and surprise create enormous stress in combat. To the extent that improved SA reduces uncertainty, fills information gaps, and prevents surprise, it may relieve some of the anxiety of fighting, diminish the number of stress casualties, and therefore prolong a battalion's effectiveness. On the other hand, when a battalion, company or platoon finds itself in exceptional danger, seeing that clearly and well in advance may add to the stress of an already bad situation.

Pitfalls

ARI asked conference participants to consider possible pit-

falls that may accompany enhanced situational awareness. In discussions of battalion-level SA, these fell into the categories of over-reliance on high levels of understanding and susceptibility to deliberate countermeasures.

Creating the expectation of consistently complete and accurate information and of a high degree of situational awareness in training and doctrine could lead to disappointment and disorientation in actual operations. If Infantrymen in battalions come to expect nearly full knowledge of themselves, their enemy and their surroundings at all times, interruptions in that level of information may reduce their effectiveness. Commanders accustomed to high-resolution knowledge of their situations may, in its absence, defer decisions to await near-perfect SA and thereby lose advantages that come with acting promptly with less information.

A related pitfall lies in adopting tactics, techniques and procedures (TTPs) that rely on consistently or unrealistically detailed and accurate SA. Standards for "degraded information" conditions should remain in Mission Training Plans to facilitate training at various levels of SA.

There is also some danger of creating predictable enemies in training and intelligence databases whose visibility and actions will not match those of actual foes. If training and planning are based on false assumptions about enemy actions, dangerous conditions may arise without being noticed by soldiers who have been trained to expect a single pattern of enemy behavior or a clear view of enemy forces. If Infantry leaders train with a single set of assumptions about the nature of combat, they may fight the first engagements of a future conflict at a great disadvantage.

The classic historical example of an officer corps trained to the wrong image of combat is that of the French Army of 1940. Convinced by a deliberately inculcated set of expectations, leaders throughout the army simply couldn't respond to the actual tempo of combat achieved by the Germans. Japan's inability to anticipate Russian actions in Manchuria (1945) and the US failure to visualize the conditions of Chinese entry into the Korean War (1950) offer further examples of this sort of pitfall.

Asymmetric threats are of particular concern here. Enemies who know how to conceal their true strengths and intentions and who employ unfamiliar tactics may frustrate even highly sophisticated intelligence operations. For American Infantry battalions, the greatest danger appears to be in unconventional operations that an enemy may pursue either as the main mode of fighting or as an accompaniment to conventional action. By declining force-on-force fights or supplementing conventional tactics with harassment, terrorist action or surreptitious use of chemicals and biological agents, an enemy may resist us without presenting a clear target.

Technical countermeasures to U.S. information collectors also represent pitfalls. Disrupting communications of the battalion at critical junctures, blinding optical sensors, jamming or spoofing electronic collectors, closing airspace to important theater systems and interfering with space operations would all impose some cost on battalion SA.

Perhaps the greatest technical vulnerabilities of Infantry battalions are their high-density internal communications, their dependence on night vision devices, and their reliance on the Global Positioning System, which now affects everything from navigation to fire support to precision munitions. Systems and force designers must take special care in protecting those assets. Infantrymen must train to do without them.

Complications

Maintaining situational awareness in Infantry battalions poses unique problems. The short reaction times for Infantry battalions, companies and platoons in close combat will not generally allow for effectively transferring large volumes of information. Overburdening them with information in the middle of a fight is, in fact, likely to reduce their combat effectiveness.

In close combat, the situation develops so fast that tracking it from outside the battalion is not possible. While it is feasible and useful to warn fighting Infantry units of incoming enemy artillery or air and the shifting of enemy reserves, it is far harder to provide Infantrymen in contact with useful information on the enemy

across the street or behind the next hill. Until the enemy loses freedom of action (the ability to move or shift his position), his close-in adjustments and changes of direction or activity will be impossible to predict or report promptly to soldiers in contact. In the "Red Zone" where forces commit to decisive engagement, the battalion will continue to rely on its scouts and Infantrymen for necessary information. In platoons, the concentration required to fight reduces the time leaders have to render reports, listen to those of others or refer to displays. They will benefit most from systems in their own hands that locate enemy heavy weapons, warn them of immediate danger, and facilitate their coordination with friendly units in their immediate vicinity.

Enemy movements normally create some confusion. This can be multiplied by duplicative or inaccurate reporting. Assuring that multiple sensings of moving enemy forces do not result in posting multiple symbols on the fighting unit's displays is an important requirement. The first digitized heavy brigade at Fort Hood has found it necessary to assign responsibility for posting every enemy unit to the common display ("icon management") either to the S2 or to a unit in contact. That brigade considers information on an attacking enemy to be "stale" after five minutes and "old" after only ten minutes.

Fast insertion of Infantry units into a battle area also complicates situational awareness and will continue to do so until the Army develops means of updating units in transit. To be complete, this capability will have to support collaboration between commanders of moving units and briefing of troops about to be committed as they move in different vehicles or aircraft. The Infantrymen on the panel rejected suggestions that this extend to updates to paratroopers during their actual descent as impractical, dangerous and too late to matter.

Urban combat, a topic of increasing concern, also comes with its own set of complications. Tracking maneuvering platoons above and below ground level is beyond the current capabilities of Land Warrior prototypes or Force XXI Battle Command, Brigade and Below (FBCB2) terminals. More simply, the challenges of terrain appreciation, communications, understanding masking effects of buildings, following the movements of civilians and accounting for the fires and rubble that always accompany

fighting in cities raise considerable problems to situational awareness for Infantrymen.

Interference with communications and C2 equipment must also be taken into account. The inadvertent electronic interference that accompanies the mere presence of an enemy force on the battlefield will itself cause problems. Added to that incidental interference will be active electronic warfare and counter-sensor actions. These will range from false signals and the installation of dummy equipment in the area to deliberately aimed attacks at vulnerable or exceptionally important sensors, communications links and the Global Positioning System.

Finally, dismounted Infantry units commonly suffer leader casualties. They will need a very flexible supporting SA system that transfers information and capabilities to new leaders in the middle of a fight. When a platoon leader replaces his company commander, for instance, there must be a means of enlarging his situational field of view and changing his information and decision aids without delay.

Implications

Some clear implications emerge from all this. To sustain their operations, Infantry battalions must be able to repair or replace SA equipment quickly. To counter electronic interference, the battalions' equipment should be designed to shift automatically to alternate frequencies or signal modes. Further, it seems that manual back-up means will remain necessary for some time. Important areas for back up include alternative navigation aids, communications devices, and maps. Voice communications and information paths will have to supplement digital and visual signals in battalions for some time and will occasionally be the only means of coordinating the actions of companies and platoons and informing their leaders of critical developments.

To offset the effects of leader casualties and changes in organization during combat, battalion-level SA equipment and practices must support unanticipated changes. Battalion information and decision aids must quickly accept and display attachments, transfer data on detachments to gaining commanders, and allow any leader to assume the position of his superior.

Because Infantry battalions and their sub-units may move into action over considerable distances with minimal time for troop leading procedures and mission orientation, their SA equipment and their transports need means of communicating on the move. Airborne Infantry, air assault battalions, light Infantry, and mechanized Infantry all need means of updating themselves and refining plans as they travel. Gaining this ability will require equipping Air Force transports, helicopters, Bradley Fighting Vehicles, trucks and some watercraft with SA packages to support Infantrymen.

Because of increasing urbanization and the desire of potential enemies to fight us in conditions that reduce American advantages, Infantrymen must improve their SA capabilities in cities and other close terrain. The Infantry School has successfully encouraged greater attention to military operations in urban terrain (MOUT) issues; it must follow through in the coming experiments and modify its Land Warrior system and other SA tools for urban combat.

Because so much of SA is inherent in the mission and dependent on standardized TTP, Infantry leaders in battalions must prepare for combat by learning the implied tasks that come with every mission and must understand the processes by which the battalion, company or platoon obtain support and information. The inexperience of the lieutenants who lead platoons and the captains and lieutenants who serve as battalion staff officers suggests that intensive, repetitive training at both individual and unit levels is necessary underpinning for SA. Tactical training, decision exercises and individual professional development must be frequent and good if junior officers are to develop the judgement necessary to interpret information on the battlefield.

Requirements

SA requirements, as battalion panel members saw them, fell into tactical, technical and training categories.

Tactical Requirements

- ❑ Tracking location and movement of the organic and attached elements of the battalion and monitoring positions of leaders,

strength and condition of platoons, location and condition of key weapons and systems.

- ❑ "Flagging" threshold events or the approach of decision points to accelerate decision-making and thereby gain advantages of tempo and momentum.
- ❑ Recognizing opportunities and vulnerabilities in time to react.
- ❑ Gaining visibility of support nodes (unit maintenance collection point, casualty collection point, ambulance exchange point) and their capabilities to support (stock levels, presence of recovery vehicles, or ambulances).
- ❑ Distinguishing the civilian population, friendly forces and non-military entities from enemy.
- ❑ Displaying coalition, non-government organizations, civilian groups and objects of tactical significance on battalion SA equipment.
- ❑ Creating the ability to cooperate with "un-digitized" units or agencies.
- ❑ Defining enemy dispositions, flanks, obstacles and heavy weapons.
- ❑ Distributing information to critical leaders routinely and as casualties cause leadership changes.
- ❑ Making relevant databases of brigades and divisions accessible to Infantry battalions and delivering important information to critical points.
- ❑ "Seeing" chemical, biological and mine hazards and the exact paths around them.
- ❑ Warning battalions of fratricide dangers of direct and indirect fire weapons, air weapons, and friendly obstacles.
- ❑ Warning battalions of incoming enemy fire.
- ❑ Maintaining soldier accountability during sensitive operations such as passages of lines, infiltration/exfiltration, and aerial extraction.
- ❑ Eventually monitoring and distributing vital signs of individual soldiers.

Technical Requirements

- ❑ Ability to accommodate changes in organization or status (attachments, detachment, casualty and strength tracking)
- ❑ High quality, detailed terrain analysis for mounted and dismounted Infantry.
- ❑ Dependable linkage between the Land Warrior and FBCB2

systems.

- ❑ Precise navigation under all conditions (MOUT, close terrain, damaged infrastructure represent the greatest challenges).
- ❑ Fast, accurate distribution of control measures and changes to control measures and prompting when Infantry approaches areas affected by restrictive control measures.
- ❑ Variable resolution that permits views of individuals to unit aggregations as conditions require.
- ❑ Automatic status tracking of heavy weapons' condition and ammunition stocks.
- ❑ Variable marking equipment that makes analog military and non-military groups visible to the battalion or task force.
- ❑ Identification Friend or Foe (IFF) systems effective for variously equipped forces.
- ❑ Digital cameras with image links to platoon level.
- ❑ Artificial intelligence aids built into decision aids.
- ❑ Recognition of flank units (U.S. or coalition), other friendly forces in the sector or zone and transiting friendly aircraft.

Training Requirements

- ❑ Clear doctrine and TTPs for SA-related tasks organized to support training in units with all or only some of the most current SA aids.
- ❑ Complete representation of the surrounding environment of operations in individual, crew, collective training programs. For battalion exercises, this means providing a full depiction of the division's activities with realistic levels of ABCS information reaching the battalion staff, the companies and the platoons.
- ❑ SA modification of ranges, training areas and the combat training centers that permit digitized orders, reports, and force tracking of actual and simulated forces.
- ❑ Embedded individual/crew sustainment training routines for SA equipment and decision aids.
- ❑ Leader and battalion staff training that improves perception and understanding of significant information and the anticipation of tactical developments at battalion, company and platoon levels.
- ❑ Structured and repetitive leader training in decision making that creates and sustains the ability to identify tactically important information, recognize significant developments and act in a timely, tactically advantageous manner.

- Institutional education that parallels field training and builds Infantry SA through advanced understanding of requirements and characteristics of battalion operations.
- Periodic evaluation of Infantry fundamentals associated with SA; specifically, these include formations and movement techniques, organization and conduct of defense, reaction to contact, distributing direct fire, and employing indirect fires.
- Collective training exercises that test the unit's and staff's abilities to recognize opportunities and liabilities in time to act.
- After action review (AAR) tools that detail effectiveness in creating high levels of SA and in bringing all available combat power to bear as a result.
- Sustaining or extending tactical advantages; minimizing risk.

Research Issues

Finally, conference directors asked panel leaders to assist them in identifying issues that ARI might profitably consider. The battalion, company, and platoon panel offers the following:

- How combat performance varies in units that face real tactical disadvantages with and without good situational awareness.
- How to tailor information to the needs of battalions, companies and platoons.
- Most effective balance of flexibility and structure in SA programs and TTPs.
- How decision and execution techniques change with the addition of enhanced SA.
- How to train and educate adaptable battalion leaders.
- How to identify and remove negative transfer from simulation-based training.
- How to improve SA expertise, experience and specialization.
- Effects of incremental fielding of SA technologies.

Addendum: General Characteristics of Infantry Battalions

As pointed out previously, Infantry battalions form the basis for combined arms task forces. They can accept attachment of companies or platoons from tank, cavalry, engineer, air defense, chemical defense, military police and other special purpose units to augment their basic capabilities for operations of certain types.

Infantry companies also have the training and organization to permit their detachment to other Infantry battalions or to armor battalions or cavalry squadrons. Infantry battalions are routinely supported by aviation units and by field artillery but not trained or expected to accept attachment of those organizations.

Uniquely versatile, Infantry battalions or task forces can be employed in any combat mission and in any environment. That is, they can be used to attack, defend, delay, reconnoiter and perform security tasks in any kind of weather, climate or terrain. Normally, battalions operate as part of a coordinated brigade effort. Brigade commanders direct their general positioning and maneuver in conjunction with a plan that involves one to three other battalions. The progress and movement of neighboring units affect battalion security, rate of movement and freedom of action.

Infantry battalions can be transported by air or ground means at considerable speed. In the extreme case, airborne units may enter combat after flying from bases in the United States. Air assault and truck-delivered Infantry may also cover a lot of ground in moving from assembly areas to forward positions. This mobility changes abruptly to the speed of the foot soldier once the battalion is committed. Where situational awareness is concerned, this means that the battalion should be able to follow developments and alter its plans while it is in transit just as it does when it arrives in the operational area.

In combat, battalions fight by combining the effects of fire and maneuver. They maneuver prior to contact using formations to secure their movement and to accelerate their transition to active combat. Once in contact, they maneuver in order to bring fire on the enemy from the most advantageous positions, to pass through defended areas, or to reach positions from which they can launch assaults (close combat). They support maneuver and reduce enemy strength with indirect fire and direct fire. Battalions use direct fires (rifles, cannons, machineguns) and indirect fires (mortars, field artillery, close air support) about equally. In defense, they will magnify the effect of these fires by using obstacles (mines, ditches, wire).

The tempo of Infantry action has implications for situational awareness. It is desirable and feasible to feed considerable

amounts of information into the battalion before and after periods of actual combat, but the battalion can only absorb smaller amounts while it is fighting. Further, the tempo of action for committed forces—especially for mechanized Infantry while mounted—is so great that externally obtained information cannot reliably follow the movements of enemy units in the battalion's immediate area. While cues on future enemy actions and the movement of enemy reserves into the area will be useful, the battalion itself will have to follow enemy actions in its vicinity with the help of others who can see the enemy directly. Those will be scout helicopters, neighboring units, and the battalion's own scouts.

Battalion commanders typically bring twelve to fifteen years previous experience to their positions. Their principal assistants, two majors and about twenty senior non-commissioned officers (NCOs), possess eight to fifteen years of experience each though the majors usually will be on the short end of that scale and will have spent just over half of their past service in battalions. Company commanders will have four to six years of Army experience including service as platoon leaders and company executive officers.

Battalion is the first level of Army organization that possesses a staff. The staff is a group of specialist sections that assists the commander in coordinating and supporting the battalion's actions. Principal staff leaders oversee personnel and administration, intelligence, operations, and logistics. Special staff officers attend to communications, medical support, maintenance, fire support, engineering support, air defense; nuclear, biological, and chemical (NBC) defense; legal affairs and spiritual support.

Battalion staffs represent a real addition to combat power through their contributions to situational awareness and overall coordination, but they are notoriously inexperienced and require special attention. All the staff officers of the battalion except the two majors—the executive officer and the operations officer—tend to be captains awaiting company command and senior lieutenants in their first staff positions.

Companies coordinate the fighting of the Infantry platoons and afford command and control over assigned areas or mission tasks critical to the battalion's operation. Companies use forma-

tions of their own with the battalion's formation or separately and employ fire and maneuver on similar lines as the battalion. They fight with or without attachments and support their own operations with assigned mortars, anti-tank weapons, and supporting artillery fire. As teams, they can control some of the battalion's attached troops (tank or engineer platoons). A company executive officer and first sergeant assist the commander in key operations, support and leadership tasks, freeing him to lead operations from a forward position.

Companies generally take about 150 men into action, organized as three Infantry platoons, a support element and a command group. Once in contact, companies must commit all their resources quickly to generate their full combat power potential. They therefore do not maintain reserves or uncommitted forces for very long and find themselves decisively engaged (in situations where their viability depends on the outcome) quickly. To fight most effectively, companies need clear visibility of their own strength, dispositions and weapons status; the best possible understanding of terrain and other environmental effects on their movements and weapons employment; and the clearest possible view of the enemy forces they must fight immediately and those who are capable of joining the engagement.

Platoons are the direct fire, fighting elements of the battalion that accomplish most of its combat tasks. Composed of about thirty men, platoons fight in teams using fire and movement (the alternation of rushes with direct fire suppression of the target area) to reach their assault positions or to adjust their defenses. Platoons may be assigned short-term independent missions such as patrol or outpost duties.

Platoons depend on drills and other trained responses to stimulus in combat. They learn formations, movement techniques, formatted maneuvers, patterns of fire distribution, and combat shooting techniques to overcome the violence and high tempo of close combat. These standardized actions are trained responses to specific cues or conditions; they depend on general situational awareness and fast, rough estimates of the situation for their effectiveness. Early warning of contact, information on the enemy's precise location with the exact dimensions of his position, the location of his heavy weapons, and cover offered by the

ground are the greatest situational awareness needs of platoons in the crucial early moments of first contact.

Most of the battalion's platoon leaders are novice leaders in their first leadership positions. Assisted by platoon sergeants of about ten years' service and squad and section leaders and generally well prepared by schooling, they must still overcome great inexperience to lead effectively and to gain basic situational understanding. Platoon leaders historically make disproportionately large leadership contributions—and suffer disproportionately large casualties.

Chapter 9

Infantry Situation Awareness Workshop - The Gawron Perspective

Valerie Gawron, Ph.D.
Veridian

I was very impressed with the two-day workshop. The presentations, breakout groups, and social events were well planned and executed. Of special note were the mix of participants, the enthusiasm of both participants and organizers, and the balance of design and training. The best method for identifying actionable requirements is to engage articulate researchers, acquisition specialists, developers, users, and testers in simultaneous, dedicated communication. This was done extremely well. I recommend continuing this mix, but in addition, identifying the roles of each of the participants.

The persons who attended the workshop were very motivated to accomplish the goal of enhancing the situation awareness (SA) of Army soldiers. The retired general officers and the operational personnel present were especially excited, but the latter group voiced concern over maintaining the momentum. I recommend follow-up with these personnel to show progress and to solicit their comments.

I propose that SA requirements must be considered for all three parts of a system: design of hardware and software, selection of users, and training of system users and maintainers. The first and third parts were explicitly addressed in the workshop. The middle part, selection, was not, and yet it was alluded to many times throughout the workgroup discussions. In addition, two other areas concerned me.

First, there was a lack of a common definition of SA. At the beginning of the breakout session, I worked through a standard definition of SA looking at performance in chemical/biological protective gear and in dealing with snakebites (see Figures 1 and 2). I received feedback that these examples were extremely useful in

keeping the group focused. I recommend that a standard definition, consistent with the vast SA literature, be developed and adopted by the Army.

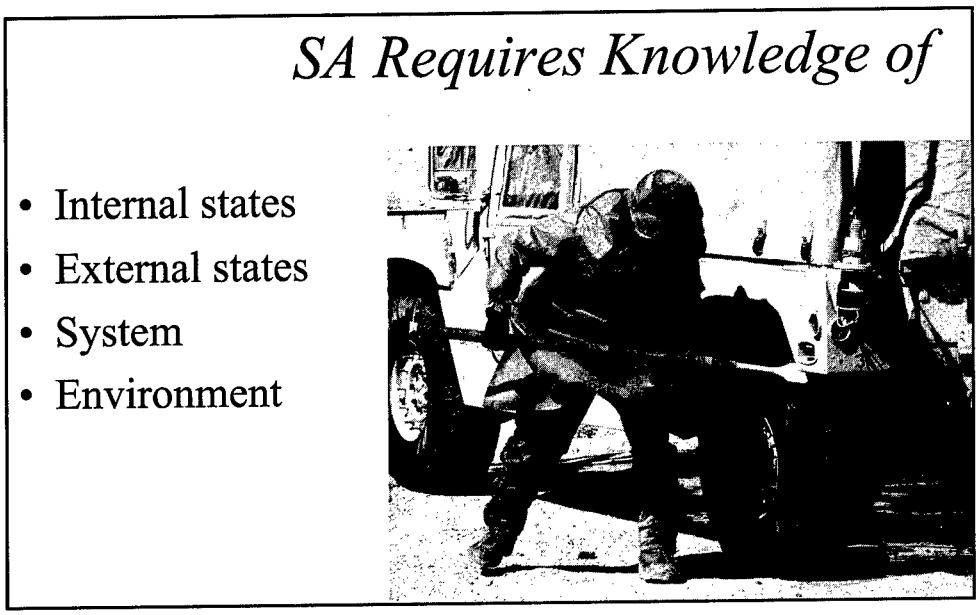

Figure 1. Common definition of SA.

Second, there was no representation from the Reserve Component at the workshop. I recently received a briefing from LTG Frank Campbell, Director for Force Structure, Resources, and Assessment, J-8 of the Joint Staff, indicating the importance of reserve units to support missions of the Air Force, Army, Navy, and Marines. His major concern was interoperability of equipment across the services and across operational and reserve forces. His briefing indicated that the reserves would play a large and continuing role in this nation's defense. I did not see any participants from the Army Reserve Component in my workgroup. I think such participants must be included in developing SA requirements.

SA Requirements

The group generated numerous SA requirements for platoons, companies, and battalions. Many of the primary and more obvious requirements and issues are presented in the two previous chapters. I am including a description of some of the other SA requirements and issues that were discussed.

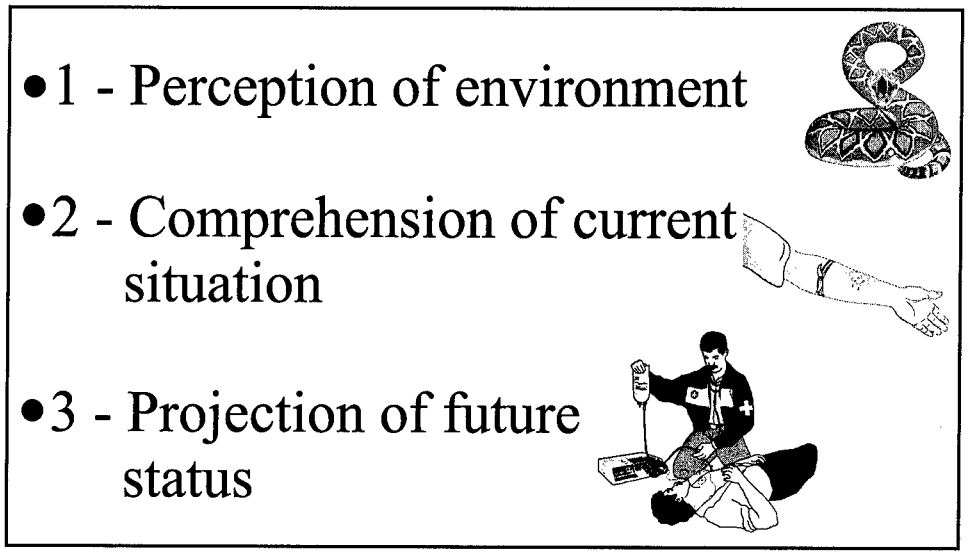

Figure 2. Levels of SA.

For Platoons:

- ❑ Use-initiated data collection mechanisms—Logistics information should automatically be updated so that soldiers always have accurate knowledge of current status;
- ❑ Feedback on targeting—Sensors and digital models should provide the best possible battle damage assessment so that soldiers always have accurate knowledge of enemy status; this is especially important for crew-served weapons and direct fire planning and coordination;
- ❑ Consequence notification—Digital models should identify the effects of decisions and actions made at all levels on soldiers in an individual platoon;
- ❑ Strength feedback—Individual soldiers' strength should be monitored to provide information on internal states, e.g., fatigue, dehydration, exposure to chemical agents;
- ❑ Automatic reporting—Algorithms are needed to provide concise status reports to the company or to prompt for a needed report, e.g., type equipment, type formation seen;
- ❑ Support for additional personnel—Tools that would assist

tailoring information for support detachments and attachments, e.g., coalition medical team;

- ❑ Civilians on the battlefield—Ability to designate these personnel and refer to policy for handling them to include police, allies, Red Cross, etc.; and

- ❑ Decisive terrain—Tools to assist in terrain analysis, e.g., to accurately portray decisive terrain along with the criterion for deeming it decisive (e.g., highest ground, able to support tanks). The system should enable the user to feel like he or she has physically walked the area; identify the character of the ground; provide high resolution of obstacles and antitank weapons; mark checkpoints; and track urban forces.

For Companies:

- ❑ Joint coordination support—Better ways of converting Air Force and Navy interactions into terms meaningful to the Army;

- ❑ Reports on the status and mission of surrounding squads, platoons, companies, battalions, brigades, (two up and two down); also, updated reports on allocatable resources;

- ❑ Obstacle and fire plans automatically updated based on current status of obstacles and targets;

- ❑ Tools to help tailor force packages based on the mission requirements;

- ❑ Models to predict how the enemy (and possibly coalition forces) will respond;

- ❑ Information systems that help prevent mechanized companies from outpacing themselves; and

- ❑ User-oriented information—Information on the pace of operations reflecting differences between mounted (20 km/hour) and dismounted (1 km/hour) Infantry.

For Battalions:

- ❑ Clearance of fire support - to rapidly clear fires while ensuring no fratricide or collateral damage;
- ❑ Status and priority of allocatable assets (including aircraft status and current position), combat power, intelligence, projected use, and reserve; status and mission two up (brigade and division) and two down (platoon and company) to whomever and wherever needed;
- ❑ Tools to help collect, organize, and understand reconnaissance information;
- ❑ Support to assist coordination with sister services and engineering attachments;
- ❑ Preview of planned and predicted events and maneuvers on the battlefield over the next 24 hours to aid in mission rehearsal;
- ❑ Support for tailoring force packages for mission, mission planning, development, and execution of decision matrix;
- ❑ Status of enemy—personnel, equipment, tactics, state of preparedness, likely targets, intent, motivation, and condition;
- ❑ Support for terrain management; and
- ❑ Radio net surveillance to identify important status changes.

What Next?

The next steps are hard to take, especially in a resource-constrained environment. First, there needs to be more participation by the warfighter in determining SA system requirements. It was clearly the perception of the operational personnel present that there has not been enough participation by users in specifying requirements for future Army systems. Army users are ready for participatory requirements definition. I recommend that they also participate in test plan development.

The Army also needs to develop tools that will aid in the development and utilization of SA technologies. Several things are needed to ensure that the SA requirements of Army soldiers are met: a digital model, a data collection and archiving process, SA design guidelines, and capture of lessons learned.

A Digital Model

It is very clear that the Army cannot test every system in every condition in which it will be used. Therefore, a digital model of SA of soldiers in squads, platoons, companies, brigades, battalions, and divisions is needed. Requirements for a digital SA model are listed in an Aerospace Requirements Document developed for the Society of Automotive Engineers. Of critical importance is projecting field test data to combat data. I suggest using an approach developed by Dr. Ted Lovesey from the United Kingdom. He recorded the same measures of mission effectiveness at all stages of system development: static mockup, dynamic mockup, developmental test, operational test, field exercises, and combat. He used z scores to normalize the measures across the various stages. He found he could accurately project how well a system would do at the next higher level of fidelity.

An example of his approach is shown in Figure 3. The bars show the range of system performance under various test conditions (plus and minus one standard deviation). The mean value would be the center of the bar. Note there was a 65% decrement in effectiveness between static laboratory simulations and wartime operations. I have found decrements between 60% and 80%. This approach is extremely useful in identifying if SA will be sufficient for wartime operations. The main implication is that incremental value of a system in wartime operations tends to be much less than is estimated in simulations and field tests.

A Data Collection and Archiving Process

Empirical data are critical to the development and validation of digital models. Literally hundreds of tests are conducted each year throughout the Army that could provide the needed data. Three things stand in the way: 1) a standardized set of measures, 2) a central repository, and 3) requirements to make deposits. The first obstacle can be tackled by cooperation

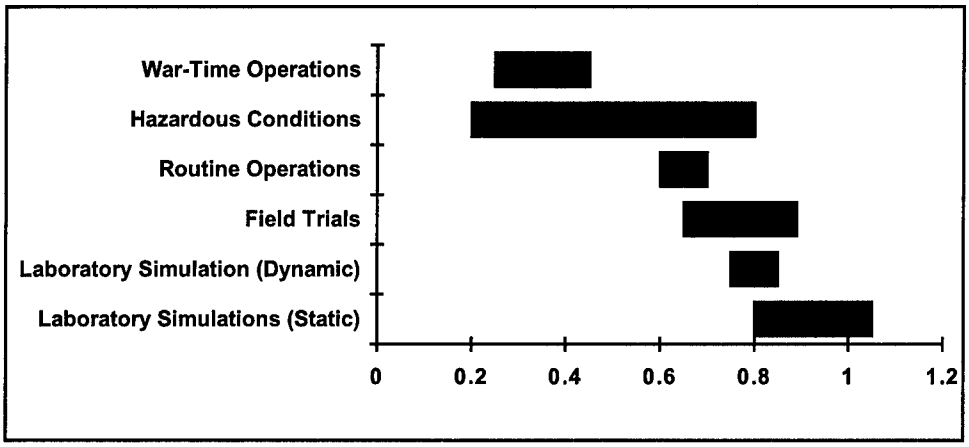

Figure 3. System effectiveness projection model.

among the program managers of the major Infantry R&D programs: Land Warrior, the Military Operations in Urban Terrain Advanced Concept Technology Demonstration (MOUT ACTD), the Rapid Force Projection Initiative (RFPI), and Small Unit Operations. The second obstacle can be overcome by the U.S. Army Research Institute (ARI) at Fort Benning. With web technology, developing and maintaining a central repository is easy and inexpensive. The final obstacle can be overcome by using some of the general officer enthusiasm and imposing a directive to researchers and testers to provide the needed data.

SA Design Guidelines

The Naval Air Warfare Center Aircraft Division has been collecting design guidelines for enhancing SA. There are also guidelines for training SA. I recommend a collaborative effort to expand the current guidelines to cover both Army and Navy needs.

Capture of Lessons Learned

I began a collection of SA lessons learned that has been helpful to test and evaluators. A similar collection would be useful to designers. Here is my list of lessons learned.

1. There may be a dissociation among SA, workload, and performance. The inverted U relationship between workload and performance has been known since the 1920s. Specifically, performance is optimum at moderate levels of workload and degraded at either low or high levels of workload. There seems to be a

similar relationship between SA and workload, i.e., optimum SA occurs at moderate workload. At too little workload, a person minimizes his or her sensory processing. At too high workload, a person focuses on only one stimulation.

2. Operators can have too much SA. For example, I know of a case where a sensor fusion display presented all relevant information on all threats that could destroy the aircraft. Pilots' performance (measured as the distance penetrated past the threats) for this full SA system was degraded compared to a system that showed only a small portion of the threats.

3. All three aspects of SA must be measured during any system evaluation. These aspects are: 1) sense entities, 2) identify entities, and 3) project the actions of the entities. In one instance, a decision aiding system automatically detected and identified all entities. The human operator was expected to project the future actions of the entities. Operators did worse with the system. The reason—the operators felt they did not have the opportunity to assess the behavior of the entity during the identification and therefore could not project its future actions.

4. There are and will continue to be individual differences. This is nothing new. All pilots know who has the best SA in their squadron. Ironically, testers typically expect the best performers to show the greatest increase in SA with the addition of new SA-enhancement systems. This often does not happen because the best baseline performers do not have as much room for improvement.

5. The right intentions but a bad design still result in bad SA. In one case, an adaptive system perfectly compensated for decrements in pilot performance. The pilot was, however, informed of his actions on a low contrast display that washed out in bright sunlight. The information was there in front of the pilot, but was unreadable.

6. Who has responsibility is critical to assessing SA. Persons who do not think they are responsible for being aware of an entity, do not try to maintain SA on that entity.

7. Rules are made to be broken. For example, fusing sen-

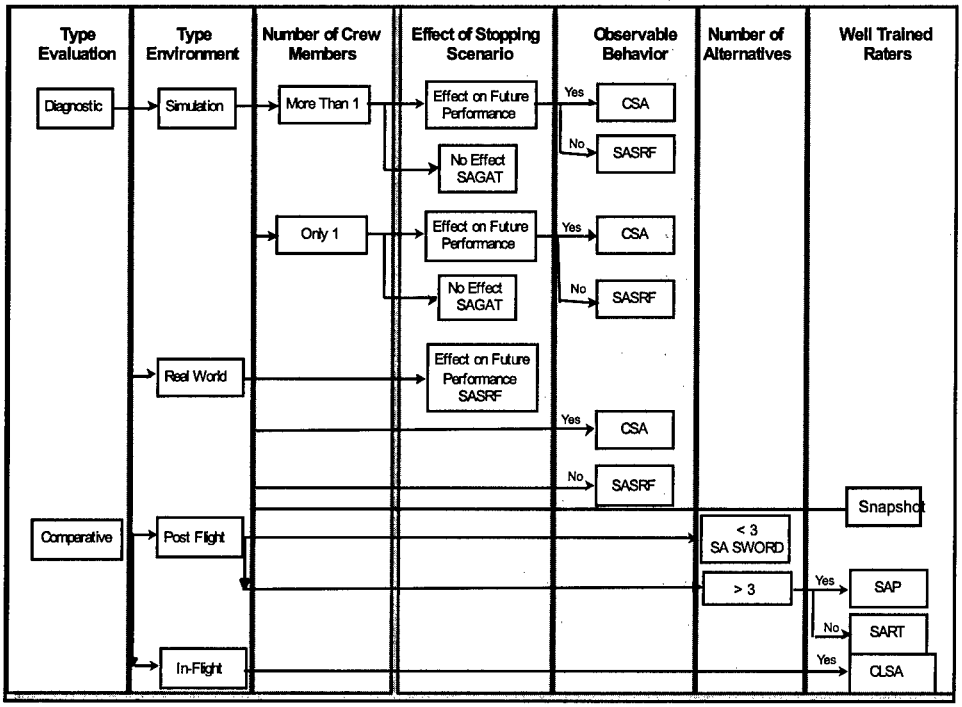

Figure 4. Draft SA verification procedure.

sor images generally makes identification of entities easier. But in one system, operators felt the work of manually fusing the information enhanced SA of these entities.

8. Words are critical in rating SA. Situation awareness rating technique (SART) was developed for British pilots. Americans give different connotations to some SART words.

9. Perceived imminence of death is a SA booster. Firefighters describe the phenomenon of every sense being more intense and all action viewed in slow motion.

10. Building schema is critical to SA for humans and computers. Schema are patterns that help cut through data to the information. More experienced personnel typically have better schema based on experience and therefore spend less time maintaining SA.

11. SA, trust, and workload all must be considered during an evaluation. Emphasizing SA may cause operators to have higher workloads. Further, operator distrust of systems may decrease SA and increase workload as operators focus on the SA

system. They then try to do the systems' work in parallel to their own to make sure it's working right.

SA Verification Procedure

The Tri-Service Flight Symbology Working Group, a sub-panel of the DoD Human Factors Technical Advisory Group (TAG), is updating MIL-STD-1787, Flight Symbology. As part of section 4, verification, an SA verification procedure is being developed. The procedure has been briefed to the group twice and as a result minor modifications have been made. The current version is in Figure 4. I recommend ARI involvement to make this procedure standard across both air and ground vehicles. The group meets twice a year.

Information Management Support for the Warrior

The US Air Force Scientific Advisory Board just completed an ad hoc study entitled, "Information Management Support for the Warrior". Two outputs may be of interest: 1) a conceptual design of a Battlespace InfoSphere and 2) a database of technologies and technology development programs to develop this Battlespace InfoSphere. The report is currently being reviewed. The study will continue for another year. You may wish to participate and provide an Army perspective.

Conclusion

The workshop was an excellent first step. I hope you will continue down the road to providing US Army soldiers an unfair SA advantage.

Chapter 10

Group 3 Summary: Situation Awareness Requirements for Infantry Brigades

Margaret (Marnie) S. Salter
U.S. Army Research Institute
Fort Benning, Georgia

Overview and Scope

The group's first task was to identify what broad echelons of situation awareness (SA) information were of significance or relevance for Infantry brigades. There was overall concurrence that with a focus on brigades and brigade headquarters, the rubric of "2 up and 2 down" generally applies: that is, the level of interest extends two echelons above and below, from corps through platoon. Some discussion ensued over the brigade's need to know platoon level information, as possibly leading to a tendency to micromanage. It was suggested that although a brigade commander can focus down to company level, except under unusual situations a commander does not want to know platoon level information even if he can obtain it. An attempt was made to define a term to cover this contingency and the need for flexibility. The term "granularity" was suggested as perhaps acceptable to define the conceptual level of detail needed, and "granular variability" to suggest that although doctrine says information is needed two levels up and two levels down, this should not be blindly adhered to.

Extension of the discussion on the definition of the level of detail required for SA in brigades treated the familiar concept of the relevant common picture (RCP) or, alternatively, the relevant consistent (or conceptual) picture. Since relevance changes with the fight, everyone changes the RCP as the battle unfolds. Relevance is a function of mission, enemy, troops, terrain, and time (METT-T). Thus, with true SA, a common operating picture may be a more useful term. The outcome of the discussion was to leave the SA "level of granularity" defined as one where SA provides variable resolution appropriate to METT-T.

There was extended discussion as to whether there are lessons to be learned from the digitization already achieved in heavy forces that can also be utilized by light forces. Successful application of lessons learned would save both money and time. Initial reaction, based on the collective experience of group members, was that some common or critical battlefield functions do not cross over from heavy to light and most results, lessons learned, and tactics, techniques and procedures (TTPs) would probably not transfer.

It was suggested that perhaps it is more missions in common, or equipment and systems in common, that share lessons, rather than forces. Although staff processes might be similar for heavy and light units, the heavy brigade tactical operations center (TOC) cannot be put into a light brigade TOC. There are too many differences. Additionally, the tempo of a light unit is different from the tempo of a heavy unit. The military decision-making process (MDMP) as applied at the Joint Readiness Training Center (light forces) is a deliberate 72-hour cycle, but at the National Training Center (heavy forces) the pace is continuous operations. Although the effects of digitization on the light MDMP are largely unknown, the current differences in the planning cycles between light and heavy units may preclude cross training.

Not only does dissimilar technology (actual equipment) make heavy and light units different, but the same technology distributed in varying proportions makes applications different. Different technology leads to different adaptations, as does the same technology in diverse locations. Both heavy and light units want to know where the enemy is and is not, but the way the picture is painted for them is not the same. Group members suggested that light forces need more information and a relatively higher level of fidelity before making a decision. A heavy unit has time to recover from a "bad read," but a light unit does not have so many opportunities to recover. A proposal was made that fratricide for dismounted personnel comes when SA is lost, and it is too late to recover.

Increased SA, especially for lower levels, changes the MDMP. Some light specialty units (e.g., Rangers) have already started changing their procedures to make all planning data accessible on the tactical web (TAC WEB). This provides the

opportunity for true concurrent planning. The traditional 1/3 - 2/3 planning rule no longer applies as the squad leader has most of the same information as the commander does, and in the same time frame. However, there may be unforeseen costs involved in everyone seeing the same thing.

With knowing the enemy location as the bottom line, there is currently not a good interface between heavy and light requirements. Problems occur when developers try to give newly devised products to the light force that have not been tested in the field by the appropriate user, the Infantry soldier. The ideal circumstance would provide capability for self-adapting software and displays based on the individual using them since the interaction between the user and the machine is critical.

A caution was raised that the group discussion had become focused entirely on current technology and applied to the way we are doing things now with existing capabilities. The next question became whether research and development efforts should address SA needs in the near, mid, or far future. It was agreed that although some focus should be on the future, most efforts should focus on current needs and issues. Rapid development of new technology is driving the pace. New equipment must change TTPs or the expenditure of scarce resources (time, people and dollars) will not be an advantageous tradeoff. Private industry has learned that the biggest investment should be in the redesign of the organizational process. Productivity may actually be decreased with digitization unless it is well planned for.

What are the most critical SA requirements? How are these linked to combat effectiveness?

To create high performers, it is important to develop multi-echelon, multifunctional staff training. The group consensus was that the light force should look at the way the heavy force has proceeded, moving very carefully in adoption of training support packages and simulations. Light forces must look at today's SA needs, but also look toward the future. The basic question will still be "where is the enemy, where are the friendlies?"

The critical requirements for Infantry brigade personnel will still be METT-T dependent, providing knowledge of both the friendly and enemy location at every echelon. Additionally, information is required about the environment (including smoke, fog and dust) and the time available to prepare for/conduct operations or react to enemy maneuvers. ("Me, the enemy and the terrain.") There is also a requirement to know the preparedness of friendly forces—"the state of my shooters. It is not just enough to know they are there, but whether they are ready."

However, SA is more than a point in space. You have to know what to do with the information you have, to know where the enemy are, where they were, and where they are going. This requires information plus the ability to project future enemy actions from current SA. These thoughts led to observations on what the commander himself brings to or contributes to SA. SA assumes that brigade and battalion commanders are experienced. Much of what is talked about concerning the requirements of the battle commander is what is in the commander's thoughts. Spending more time on the process helps mitigate the lack of experience, but for a leader, there is no shortcut for basic proficiency. If a commander lacks flexibility and mental agility, the best equipment cannot help him.

A commander has to know the right questions to ask. With digitization, the questions are new and different. Concept of the operation and commander's intent are necessary but not sufficient to produce high SA and battlefield success. Intuition plus timely data lets a commander use experience and insight to adjust the mental image of the battlefield based on all of the information available. The key to success is a combination of training and experience. Commanders will need to have confidence in digital data and learn to trust these alternate sources of information. There is presently a tendency to corroborate the icon independently to develop "icon trust." It would be better strategy in the short term to learn to relook the basic situation instead of trying to validate the icon. Improving performance and taking advantage of the technologies designed to increase SA comes from sequential training. The sequential process starts with mastery of basic skills, followed by practice on utilization of new hardware and software in multiple repetitions and scenarios, tempered by the commander's judgment.

Group 3 Summary

What new training techniques or approaches are needed?

TRADOC has recently published a new training approach known as the Three-Step Learning Process. Step 1 (Learn the Basics) encompasses all of a leader's basic skills. Step 2 (Learn the Hardware and Software) is the phase during which the leader is trained on, and then practices using the new digital equipment in tactically-based scenarios. Step 3 (Practice Execution) is the stage where the leader becomes so proficient as to be at a state of over learning and mastery, also known as "hyper-proficiency". Step 3 mastery provides leaders with the ability to execute tactical scenarios, with flexibility and adaptation to the situation as hallmarks of their performance. The key to optimal performance is not to get committed to specific scenarios in a specific environment, but to get good enough to be able to have this expert performance cross over to all scenarios. The skills demonstrated by leaders will reflect these new levels of experience and competence.

Concerning the role of training simulations in this process, an overall caveat was offered to carefully exploit simulation, and to temper or augment simulation usage with more realistic experiences. Simulations are but one part of training and serve as the basis for more advanced instruction. Hands-on experience in field exercises is critical to task mastery.

Retention of procedures is much harder than retention of motor skills. Digital proficiency is slowly gained but may be rapidly lost. For the digital battlefield, commanders and staff need to be trained in how to use data (Steps 1 and 2), but feedback about actual proficiency becomes an issue to be addressed since a unit cannot evaluate or fully stress itself. An additional question covers measuring individuals versus teams. Individual proficiency does not necessarily equate to team proficiency and individual training is not team training. Soldiers must be trained together as true operational teams, not just individuals arbitrarily combined into teams for training purposes.

Steps 1-3 in the TRADOC model are not specific to digitized training but may have widespread application in that domain. Most frequently failure comes from not knowing the basic skills needed for task performance. With digitization, new equipment training will be required. Eventually there will be some

sort of device comparable to a COFT (conduct of fire trainer). For example, a staff COFT could provide training support packages to enhance after action reviews for staff performance. The procedures for staff competencies are complex because the machineries (hardware and software) are complex. There is a tendency to focus on technology and ignore the practice of warfighting when a simulation is fielded without the required staff training support packages. Step 3 reiterations of complex procedures permit the flexibility to address new situations.

The group also discussed the commander's job and what skills differentiate the novice commander from the experienced commander. Experienced commanders can show better ways to do things, based on intuition and familiarity. There may need to be a list or set of tasks, conditions, and standards for commander proficiency. They could be called MTPs (mission task procedures) specifying leader tasks and the performance measurement parameters of these tasks. A competent commander, with time, can instruct the rest of his unit on these tasks. Workstations for self-evaluation would be useful tools at any level.

Another issue considered was whether there is a need for certification for Step 1 proficiency on the basic staff processes. Staff certification at the institutional level can be a problem if certification is subsequently seen as an instrument for personnel decisions. Certification at unit level, however, assesses whether the staff (as a group of individuals) knows what needs to be done, and can do it as a team. There must also be a distinction between evaluation and the products that enhance training. Systems should support the commander. Besides staff planning, another area that is not taught very well is task execution, although units are graded on execution at the training centers. There is a danger, however, that for the officer, tasks, conditions and standards for leader and staff responsibilities may legislate away initiative.

The overall consensus on training approaches was that light forces are different from heavy, and a lot of planning is needed to maximize the SA enhancements provided by digitization. Although technology will change the way missions are conducted, superior performance will still come from good execution of the tactical processes.

What pitfalls should the Army try to avoid in its drive to enhance SA?

Many pitfalls were identified. Requiring a skill qualification test for Step 1 (basics) may become a problem. If a test is used for providing feedback during training, it may be acceptable, but, as noted previously, it should not be used for certification. With the heavy force, information on friendly forces comes through automatic reporting (e.g., tracking a vehicle through the Force XXI Battle Command Brigade and Below [FBCB2] system). This may be more troublesome for light forces. The complexity and sheer number of platoons, squads, and individuals could over-task the FBCB2 system. Updating the relevant common picture becomes a critical task. If we track the enemy, and add friendly force deception, more requirements are added to the system. SA implies more than just a digital display for light forces. Despite these many requirements and functions, field systems must be not be unwieldy. Weight and vulnerability are items of concern with any piece of equipment that provides SA to light forces.

Another potential pitfall, noted earlier, is the potential for succumbing to the temptation to over-control or micromanage at brigade level. Team building must occur in small units, with staffs working together. The commander must let the staff do its job. The leader who does not want to over-rely on digitization or micromanage can monitor voice communications on the net and intercede only when necessary.

The Army will need to change both force structure and TTPs to meet future requirements. Increased communication across echelons tends to flatten the organization. As noted, this changes the decision-making process and the commander's control of information throughout the process. There is currently no standardization of requirements for leaders. For the short term there must be definition of both basic and advanced skills. Units and staffs must be taught how to execute, especially for staff proficiency. Execution-based training rather than planning-based training is currently very difficult for light units.

There was also discussion as to whether there should be evaluations of hardware and software knowledge, or evaluation of who trained together, and how well. The need is to test the mini-

mum level of competence necessary for mission accomplishment and have training products there to help support this requirement. Again, as noted earlier, these assessments should not be used to make personnel decisions. With new equipment there is a certain basic competency required to operate it successfully. If the staff knows the process, then they can step beyond it as required. However, there tends to be a general problem with basic competency and prerequisites for command and staff positions have not been well defined.

As for the commander's role in management of the staff process, no one knows how it will be impacted, and what benefits new equipment will provide. Perfect intelligence changes the way the commander thinks. The question must then be asked as to whether he has been trained to leverage this technology. Does he know how to think differently or take advantage of the short decision window? The consensus was that the way to perform missions is changing, and there is a need to sustain proficiency even without the digital equipment present. The amount of time it takes to sustain these new skills is as yet undocumented. SA measurement must be addressed in teams to ensure a shared representation of the battlespace.

What are some alternative approaches to assessing SA?

The first and most important comment from the group was the acknowledgement that if you do not or cannot measure something, you tend not to do it. If it is not measured it does not exist. "Good" team SA is subjective. It is different for every unit, every situation, and every mission. SA proficiency evaluations need to be systematically collected. While no standard checklist suitable for all systems may be plausible, it would appear that there are certain classes of information teams ought to have in common. At a minimum, skills in monitoring this information must be measured.

Situation awareness assessment can be seen from three perspectives: from that of research, from training, and from the viewpoint of a practitioner. Research assessment tends to be interfering, and asks for antecedents - what the personnel knew and what led to different behaviors. Looking at SA from the training perspective causes less interference, and has the same end-state as the research perspective - are they learning? A SA practi-

tioner is looking for SA in action; that is, how it impacts on a mission. He asks why some people know what they know, and why others do not know as much.

The overriding measurement question is how to get the data. Stopping the unit or team in the middle of an exercise to ask or probe with mission-specific questions changes the conditions of the exercise. Collecting data in the middle of the fight changes the process. The best way may be to replay an exercise or event immediately after its conclusion to reconstruct the picture of the battlefield - on the map or in a simulation, to see what the overall SA was at the time. SA can be studied in pairs. For example, a participant's view of a situation may be compared with a subject matter expert's evaluation of a situation. This provides an assessment for the entire staff and as such can be addressed in an after action review.

A way to train light force staff processes (and training the trainer) may be contained in the training support packages known as COBRAS (combined arms operations at brigade level, realistically achieved through simulation) training materials where expected behaviors are detailed in advance. Another way would be to examine the effects of enhanced SA on staff and unit performance at the combat training centers. An unanswered question is whether training in specifics of enhanced SA makes a difference, and whether the ability to utilize SA can be increased.

It is important to determine critical digital staff functions in order to assess what is truly important. How SA is measured depends upon what you want to measure and whom you want to interface with. We tend to measure or assess what is easy to quantify, but it is difficult to determine what the right level of measurement might be to allow a look across units. At this time we do not have the means in light Infantry brigades to compare the information that two different companies have. Measurement needs to include not just SA, but what that SA leads to. Interestingly, the indirect results of SA may be more measurable than the SA. Tasks, conditions and standards are acceptable for measurement if you know what to look for. It is possible that one starting point might be that good SA leads to a decision and the decision event can be used as an indirect measure of the awareness, although one must be careful to avoid circularity of reasoning in this approach.

What are the most critical Training, Leader Development, and Soldier SA research issues that the Army should address in the next five years?

The first problem is how to analyze the critical decision points for light forces. Besides decisions on what we are measuring, there is a need for enhancing competence through a comprehensive training strategy for the digitized division. Another of the costs of learning SA includes the cost of commander time - how much time it takes for the commander to learn and what tradeoffs are involved in providing this time. Time needs to be a key variable. The question becomes how to create (gain) and keep (sustain) high proficiency most efficiently and effectively.

Still unknown is the psychological impact of good SA and its overall effect on the social psychology of the battlefield. The Light Infantry cannot go into an unknown situation or environment as easily as a heavy force can. Boundaries are, by definition, limiting. The human, with the flexibility of his mind, will blur the finite distinctions between heavy and light forces. Light forces will use this flexibility to do what they need to do on the battlefield. Light forces, compared to heavy, buy time and surrender space. They need execution-based decision-making tools, and better information throughout the decision process.

What are the high payoff top priority targets?

The final discussion centered on the question "What are the show stoppers?" The answer became an overall summary of the preceding discussions and unanswered questions. The first caveat was a reminder not to do anything without working with the unit, remembering to equip the man, not man the equipment. Tests without train-ups tend to lead to failures, and it takes both time and personnel to execute training solutions. There are people costs and time costs and often a 3-4 year time delay before the payoff is seen. There is a progression from the lab, to the battlelab, to a real unit. SA and the effects of SA will be hard to isolate.

The Infantry School leads the light digitization development and evaluation effort. The right questions must be asked - who

will be the test unit, at what location? Should it be a training organization at Fort Benning or an operational unit from elsewhere? The test unit needs to be stabilized and isolated from other commitments. There is a tendency to put too much stress on everybody to do too much in too short a time. Great commanders know when to go fast and when to go slow. Dealing with computer technology compounds the issue - it is difficult to keep up with the technology. Therefore, commanders cannot afford always to be dependent on better technology. Technological development is necessary, but experienced, well-trained commanders are the key components of success in battle.

LTG (R) Rick Brown, the author of Chapter 11, gives his insights into SA at Brigade level. This is followed by Dr. Dick Pew's Chapter 12 on SA issues including definitions of SA, the importance of team SA, the role of training in SA application to the Army, and future research areas in SA.

Group 3 participants included:

COL Lloyd Austin
LTC (P) Art Bartell
COL (R) Dan Deter
Dr. Jon Fallesen
LTC Kurt Fuller
Mr. Wes Hamm
MAJ (P) Casey Haskins
Mr. Randy Hill
Dr. Jack Hiller
LTC Dave Lawrence
Dr. Denny Leedom
Dr. Mike Matthews
MG (R) Bert Maggart
COL (R) Ward Miller
CPT Todd Reichert
Dr. Zita Simutis
LTC Mark Singleton

Chapter 11

Developing Digitized Light Formations

LTG (R) Frederic J. (Rick) Brown, Ph.D.
Institute for Defense Analyses

These observations were developed in part at the U.S. Army Research Institute's (ARI) Infantry Situation Awareness (SA) Workshop where we discussed brigade echelon SA for light forces. Others come from observation of the various Army Warfighting Experiments (AWE) associated with digitization of mechanized forces. Hopefully they may assist those concerned with important issues of extending SA through digitization to light forces.

I was aided greatly by the thoughts of the exceptionally qualified working group which included a serving Airborne Brigade Commander enroute to his second Joint Readiness Training Center (JRTC) rotation, an executive officer (XO) of the Ranger Regiment, an operations officer (S3) of the 101st Brigade in the Rapid Force Projection Initiative (RFPI), as well as experts, both serving and retired, responsible for developing and assessing the effectiveness of current battle command/staff training for digitized forces.

The following observations are mine. But they clearly draw on careful listening to the insights of others combined with personal experience with digitized units since the early trials of Intervehicular Information System (IVIS) at the Armor Center in 1985 and continuing through all of the AWEs.

General Observations

Development of highly proficient digitized units, designed to seize tactical advantage from great increases in availability of tactical information, suffers from several common myths which are quite dysfunctional. Several of these myths are:

- Digital "overload". This suggests that digitization causes lead

ers to be inundated in data to the degree that their ability to command effectively in warfighting is degraded, to some undefined degree. I have not found this to be the case in the AWEs I have observed. Really well-trained commanders appear to thrive on information. They know what they want, when they need it, and they clearly know how to harness available information sources to suit their combat needs. I have observed this at division through battalion echelons. Conversely, poorly-trained leaders and staffs are rapidly inundated with information—doing poorer, faster. Solid learning (both training and education) of commanders, staff officers and staff teams is the critical path to effective use of digitization in all units, battalion through division, both light and mechanized.

- Situational awareness is the desirable end state of digitization. The Commanding General 4th Infantry Division (CG 4ID), the EXFOR Division, has proposed that there are at least three lev els of application of information. They are situational awareness leading to situational knowledge which, if focused in time and space, produces situational dominance. There may be more or fewer levels. The point is that improved SA leads to other, perhaps more profound, warfighting capabilities, which are yet to be discovered. If there is one appropriate end state, it has yet to be determined. Force XXI is a process of change to an unknown future. Attempts to define precise end states of capability too soon for management purposes may be precisely wrong. "Spirals" of development are naturally untidy as both welcome and unwelcome surprises occur. The manager must shape his or her policy and practices to this reality, and not try to force change into known, confining, management ruts.

- "We" (at Mach .8) know what is "best" for the unit (at Mach 1.2). As leaders and staff teams become increasingly competent, they appear to move to new plateaus of capability. They become hyper-proficient. Competence of both individuals and small teams seems to improve suddenly and geometrically, not arithmetically. I describe this "breakthrough" as analogous to passing the sound barrier (Mach 1.0). Most of us are below Mach 1.0. We have not been "there" in warfighting decision-making. It is a formidable challenge for the great majority of us at Mach .8 to develop requirements for the hyper-proficient Mach 1.2 or higher individuals, small teams and units across Doctrine, Training, Leader, Organization, Materiel and Soldier

(DTLOMS). How do we create then sustain Mach 1.2 level leaders?

- The Army knows how to train digital teams. The Army can train superb small unit teams—fire teams and squads—exceedingly well. However, tactics, techniques, and procedures (TTPs) for staff team learning both by echelon and by function Battlefield Operating System (BOS) have not been defined nor have explicit requirements or performance measures of success been established. This is a formidable obstacle to the preparation and sustainment of warfighting proficiency for hyper-proficient staff teams.

Insights Concerning Creation of Hyper-Proficient Leaders, Teams, and Small Units

Successful use of increased information is absolutely leader dominant. The engine of success is the direction of the leader who knows what he/she wants. I suspect that there will be apparent easing of difficulty in execution of staff processes for the marginally-practiced who can draw on the common formatting in presentation of information provided by the Army Tactical Command and Control System (ATCCS). However, the major tactical payoff of increased information is very likely to be exploitation of very specific, timely information by exceedingly competent, confident commanders. Each commander will have his own particular, unique requirements based on the ultimate diversity of warfighting—Mission, Enemy, Troops, Terrain, and Time (METT-T), and highly individual command styles. This suggests that digitization makes leader preparation even more important in the future than it has been in the past.

There is a very positive precedent concerning leader dominance in light forces. That was light leader training initiated with formation of the Light Infantry Division (LID) in the early 1980s. This approach was very successful largely because leaders were very well trained prior to their subordinates' training and thus could demonstrate desired proficiency (and lead) by example. This appears even more necessary in digitized units!

Digitized leader information requirements are highly idiosyncratic. Information needs of competent commanders seem to

differ considerably. That variation should exist within a common framework of a military decision-making process (MDMP). The MDMP is a common, consistent, thought process - a combat-proven approach. But within that disciplined thought process, the format and detail of presentation of information required can be expected to vary greatly from commander to commander. There is no "cookie cutter" proceduralization. There will be a near term challenge of converging the current MDMP as practiced at the "dirt" Combat Training Centers (CTCs): plan, prepare, execute at JRTC and plan, prepare then monitor, plan, direct in execution at the National Training Center (NTC). Given the different tempo of current tactical operations at the NTC and the JRTC today, both approaches are right, but the latter appears more responsive to the likely tempo of operations in digitized units (light and mechanized). Neither may be sufficiently responsive for highly idiosyncratic future commanders.

There appears to be considerable sharing of thought within a highly proficient digitized command/staff team—a "whole" which is much greater than the "sum of the parts." Team work and genuine bonding within the team seem to be very important particularly as command and staff strive to become increasingly proficient. Commander teams, tactical operation center (TOC) teams, fire support teams, intelligence teams—teams dominate digital decision-making. A poor to fair analog staff can be relative strangers yet remain somewhat competent—guided by the current proceduralization of decision-making (i.e., matrices). Conversely, I suspect that strangers (i.e., a new team) in a digitized staff will be relatively less capable than their peers in an analog command/staff. Ability to communicate as competent, cohesive teams summarizing complex cross-BOS collateral tasks in "audibles" whether in a command and control vehicle or on a "white board" seems likely to be a precondition to command/staff hyper-proficiency. Too much is happening too fast for strangers. Rapid training/bonding of replacements in digitized staffs promises to be a substantial future issue in digitized units. And the virtues of stability in command/staff teams will become increasingly evident for both mechanized and light forces.

There is a serious risk of separating the individual fighter (of all grades) from the environment about him. The physical senses are important for all soldiers, especially the Infantry unit

commander at all command echelons, just as much as the member of the rifle squad. An objective of digitization should be to intensify all senses. Be alert to not encapsulating the fighter and his commander in the combined arms team in a womb of electrons which serves to dull sensing of both the nature of the fight about him and his physical links to his team mates. This is already a demonstrated risk in mechanized forces. So digitization for light forces must be not just user-friendly; it should be designed to positively encourage command forward in the physical environment at all echelons.

Digitization of light forces should be permitted to draw on very substantial precedents in successfully employing human and material technologies by Special Operations light forces, for example accession measurements used to screen volunteers for elite forces, or practical and continuing experience in training teams, repetitively demonstrated in the Ranger Regiment. Digitization should bring greater, more immediate combat returns to elite forces permitted frequent training with stabilized teams than it brings to any other element of warfighting. Scrub Special Operating Forces (SOF) for "best practices" early in light force digitization.

It is only prudent to acknowledge the vulnerability of digitized forces to enemy counter measures. Degraded mode (analog) training should be included in all individual, team or small unit training. That is, degraded mode learning should be built in to the various structured training exercises. One useful "how to" training precedent could be training to certification as it is conducted on the Conduct of Fire Trainer (COFT) for Abrams and Bradley. There, really high levels of personal and small team proficiency must be demonstrated by soldiers employing fully degraded fire control in order to become "certified".

Creating The First Digitized Light Division

Having associated with the Force XXI AWE process applied to mechanized forces for the past several years, I naturally reflect on design issues for AWEs of light forces. I believe that the following insights apply:

- There are two complementary but different training challenges that need to be addressed in AWEs of light forces. They are training from individual rifleman to platoon, then training battalion and above; that is, higher echelons where both command and staff must be trained. I am uncertain where company fits. I suspect it may be with battalion and above rather than platoon and below due to likely expanded sharing of information processing requirements as company echelon exploits digitization (XO, fire support officer, platoon leaders, 1st Sergeant). Platoon and below is clearly the "cutting edge" most important to realization of Infantry combat potential. However, the technology of computing and power generation for that echelon is not yet mature. Therefore, I suggest focus for now on battalion and above. And, there should be some positive pay off from battalion and above mechanized experience in past AWEs. I suggest it is useful to move out quickly on digitization of the light combined arms command and staff team, battalion and above, drawing heavily on mounted experience. Much of this experience seems directly transferable to light forces—at least as an informed "start".

- Digitization learning requirements for the light Brigade Combat Team (BCT) seem generally similar to those of the mechanized BCT. There may be as high as 90% overlap. Actual comparability could be readily observed as light battalions fight with the digitized mechanized BCT at the NTC in 1999 and 2000. In the interim, assume that most mechanized AWE lessons learned will apply to light brigades and battalions—apply them, then scrub for differences. For example, learning requirements of digitization appear to be virtually identical across mechanized and light forces for all officers, major and above (staff captains too?). If confirmed at a mounted AWE, this could be a significant simplifying assumption for digitizing light forces. Once the basic applicability of what is relevant from the mounted AWEs has been determined, the focus could be shifted to probe expected differences in Battle Command Staff Training (BCST) requirements caused by the method of entry to battlefield, be it airborne, air assault, or foot rather than the Bradley Fighting Vehicle.

- Doctrine, Training, Leader, Organization, Materiel and Soldier are the development foci for Force XXI. The experience of

mechanized AWEs has been that assimilation of digitization is really dependent on the Army ensuring that each element of DTLOMS develops in balance with the others. There is a natural emphasis on materiel (M) stimulated by an aggressive, competent acquisition community reinforced by Department of Defense (DoD) and Congressional oversight. Reliable digital capability (M) is certainly enabling of all other elements of DTLOMS. But long-term effectiveness will be determined by genuine balance among and between each element. In fact, if there were one single most important element, I believe that would be leader (L), not any specific M. Leader competence and confidence are exceedingly important. At each step of development of digitization for light forces, there should be a review to ensure balanced DTLOMS reflecting both appropriate research and development where there are holes and Operational Test and Evaluation (OTE) which asks the right questions, that is, the issues most important to the combat readiness of light units.

- Given the need for balance discussed above and lessons learned from the mechanized force, I suggest that the focus for light force digitization be brigade and below rather than division and below. There may be a direct precedent with the 194th Armor Brigade (Sep) at Ft Knox in the 1980s. It played an invaluable role in the fielding of the Army of Excellence (AOE). The brigade was a readily available test bed for all elements of DTLOMS with frequent NTC rotations and which was directly linked to officer and noncommissioned officer students. It provided a proponent "center of gravity" supporting experimentation across DTLOMS. Other resources then at Fort Knox provided a "heat shield" to protect the table of organization and equipment (TOE) Brigade (Panzer Lehr) focus as a practical test bed. Might there be a similar role for a light brigade at Fort Benning?

- "Heat shield" protection from distracting peacetime Army requirements has proven to be essential support for AWE units, consumed in ever-changing DTLOMS characteristic of the Force XXI process. The Corps, Divisional and post resources of III Corps at Fort Hood were very valuable in enabling/protecting the 4ID focus on intensive warfighting. Similar protection may not be feasible from XVIII Corps at Ft

Bragg due to quick response Force Projection requirements at both XVIII Corps and the 82d Airborne Division. Therefore, should we consider the Fort Knox precedent? That is, should Fort Benning conduct the light AWEs up to BCT with the TOE Brigade of 3ID stationed at Benning (reconfigured as a light not a mechanized brigade) with an assumption that division echelon digitization requirements can be determined (experiment for exceptions) by the current First Digitized Division at Ft Hood? There would be clear exceptions related to method of entry to the battlefield (same variation exists if any one Infantry Division is selected - Airborne, Air Assault, Light Infantry Division). The Joint Contingency Force AWE addresses those kinds of issues. In addition, there appears to be a requirement for a continuing supply of highly competent (Mach 1.2) subject matter experts (SMEs) supporting the AWE. That level of hyper-proficiency is quite challenging to sustain. The Infantry proponent, United States Army Infantry School (USAIS), has developed institutional learning capability which could support hyper-proficient SMEs—exceedingly difficult to do given the turbulence in a Division.

- Current planning for AWE assessment makes excellent use of the Army's CTC capability. The NTC trains mechanized forces, and the JRTC trains light forces. I suspect that "proofing" in one CTC alone may not present sufficiently diverse and chal lenging tactical requirements for an Army preparing for global commitment. I suggest a requirement to assess both light and mechanized digitized units in AWEs at both JRTC and NTC . This would provide excellent representation of a broad range of terrain and type missions. Digitized units need to be highly capable in both pure and cross-task organized light-heavy or heavy-light. That is done today routinely for mounted AWE. I suggest that there is a need for a similar policy for light AWEs—for example, a mounted Divisional Cavalry Squadron included in the task organization for the Light Brigade AWE.

- As a practical issue, for very busy units to accept, in fact to accelerate, change through offering "good ideas" to the developer, near-term support to unit readiness (value added) really has to accompany long-term modernization. The press of unit commitments today mandates "bring existent capability to create decisive advantage at every echelon" as digitization pro-

gresses through spirals of development. Progress sufficient to satisfy the DTLOMS developer may not be sufficient to sustain the genuine, proactive, abiding support of the test unit. Genuinely good, useful products must be brought and left, or the "good idea" goodwill essential to accelerated development in the light forces test unit will evaporate.

- There are unsettling parallels between AWE 94-07 Desert Hammer and the recently completed ACTD RFPI. DTLOMS development lessons learned, the hard way, in the mechanized force appear to have to be being learned again in light forces. While M improves steadily, TLS continues to lag seriously. Personnel assigned to the test unit (194 Armor Brigade and 24ID) were reassigned rapidly after the AWE rotation (94-07)—the price for personnel stabilization prior to the AWE. Within two months of the July 1998 ACTD, most digitization expertise (RFPI-based) had been lost to the 101st Air Assault—the entire Brigade staff had already been reassigned.

- The light forces know how to train exceedingly proficient teams. The culture of real proficiency generated by strong teams permitted repetitive, focused training characteristic of elite light forces such as the Rangers was not evident. Training Support Packages (TSP) and Tactical Engagement Systems (TES) were simply not available to permit the test unit to become really proficient in hardware and software prior to the digitization ACTD. Assessment measures of performance and measures of evaluation (MOE) for TLS of DTLOMS were incomplete in 94-07. This continued through RFPI. There were excellent measures in traditional M areas, but incomplete measures concerning training and leader development.

- Forcing functions such as a known timetable for provision of balanced DTLOMS support seems essential to ensure that TES are matched in a timely fashion with proven TSP, and both research and development and OTE of TLS are genuinely supportive. To ensure this, genuine, long term, hyper-proficient, governance across DTLOMS of light digitization seems essential. That governance is sustainable only at a proponent (USAIS) who is charged to maintain overwatch of light forces digitization at both JRTC and NTC, and of execution of the TLS aspects of research and development (R&D) and OTE. This

appears to be precisely the role of Ft Knox (U.S. Army Armor Center) in shepherding development of Strike Forces. Is there a similar role for the proponent applicable for light forces?

More can clearly be done to enhance digitization of light forces, but those needs should not cloud the significant AWE momentum currently present in Force XXI. The glass is more than half full. Hopefully these comments can support acceleration of digitization of light forces.

Chapter 12

Infantry Situation Awareness Workshop: Observations from a Participant

Richard W. Pew, Ph.D.
GTE

Introduction

I appreciated the opportunity to participate in the Infantry Situation Awareness Workshop. It was a unique session because it brought together research specialists and operationally-experienced military officers in an environment that encouraged productive interaction and mutual education. I also appreciated the chance to work with LTG Rick Brown, Marnie Salter and the rest of the members of the Brigade-level team. In this note I will offer some comments and reactions to the deliberations.

Definition of Situation Awareness

The term, Situation Awareness (SA), certainly received its share of attention at the workshop. I heard it used to describe everything from the geographical location of the enemy to the sine qua non of effective fighting forces. We all share the goal of improving the fighting effectiveness of the digitally-supported Infantry forces. We should not be too hung up on purist notions of just how SA should be defined. However, it should be noted that while SA is important, it is not the whole story of effective information management and decision-making for any level of the Infantry. Probably it is important to think of it as the information collection and evaluation phase of operations.

To equate SA with fighting effectiveness, and thereby include decision-making and action within the definition of SA, is to defocus its meaning and weaken whatever usefulness the concept might have. SA should be thought of as an intervening variable in the overall fighting effectiveness equation. It is not an end in itself, but by separating it out, we can draw attention to one very important component of battlefield success and provide a unique focus for selection, training, system design, and technology devel-

opment more generally. When we are looking for ways to improve effectiveness, it is often helpful to take an analytical view and decompose the elements of effectiveness in order to work on them separately. SA is at the right level to be global enough that it can be understood by the using community yet specific enough that one can evaluate alternative ways to improve it, independent of other elements of effectiveness.

Of the many definitions of SA that were tossed around at the workshop, one that particularly bothered me was one that tried to distinguish three levels of "awareness," situational knowledge and situational dominance. This might make sense from an operational standpoint, but it is on an orthogonal dimension from those that we have ever thought of measuring. Awareness and knowledge are part and parcel of the same thing. Awareness is more than simply data or even information. Most of the definitions in the behavioral literature consider that SA is the processed result of bringing data that has bearing on a situation in a context together with the knowledge in the head of the evaluator. We use the term SA to refer to this combination. Situation dominance is certainly an important goal, but, like information dominance, it is something very different than simply having SA. I would interpret it to mean having a militarily superior position in the battlefield. Having good SA might be supportive of obtaining situation dominance, but situation awareness seems to me to involve another whole domain of accomplishment.

Importance of Team SA

At the brigade level the most important aspect of SA is team SA, that is, assuring that all relevant team members share the same information and interpretation of the state of the battlefield. Acknowledging that there is some information that is only relevant at the brigade level, most of the information on which the brigade level picture is created is generated at lower echelons. There should not be a lot of information seeking going on at this level. However, each planning cell, S-1, ...S-N is interpreting data from its own perspective and it is important that those perspectives be shared and coalesced into a common view of the battlefield. At exercises I have seen this being focused on during the preparation of the daily commander's briefing. The commander then puts his own "spin" on it that needs to be reflected to all

those who took part in its preparation. Doctrine and procedures should be reviewed to assure that the opportunities to accomplish this integration are maximized.

Improved Training is the Most Important Implication of SA

While SA potentially has implications for doctrine, procedures, training, system design, and technology development, my conclusion is that the main implications for the operational forces are training implications. Training for SA should be accomplished at two levels, (1) how to actually improve it in the battlefield and (2) at what we call the meta-level, that is, training to understand what SA is and is not and why it is important to think about it as an important sub-component of overall information management, separately from other aspects of battlefield effectiveness. Making the forces aware of it explicitly, even though it is a meta-concept, should help them to understand the importance of bringing to bear all their resources on obtaining the best understanding of "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988).

In addition to a block of training on SA, it will be important formally to put SA discussion into each after-action review and to put SA performance measurement into every evaluation opportunity. As was pointed out by the group, soldiers pay particular attention to the attributes on which they are being evaluated.

Needed Research Activity

Develop a Training Curriculum

A critical research action is to prepare and validate the SA training materials for each echelon and generate the appropriate performance metrics for the various National Training Center (NTC) activities and other relevant exercises. This will provide a challenging task for the U.S. Army Research Institute.

There is a need for such a curriculum across all echelons, but I will focus here on the team SA aspects that are particularly appropriate for brigade level. There is now quite a literature on

team training, but virtually none that I know of concerned specifically with training teams for shared SA. While this should focus on effective shared communication, there should be considerable thought and perhaps even some pilot testing of alternative ways to define and introduce the content that is most important to be shared. This kind of training should be a part of the digital forces curriculum since many of the sources of information out of which SA is to be synthesized will be from the new digital technology, and because some of the sharing techniques will also rely on new technology such as e-mail and electronic publishing. I saw a beautiful application of the web in the Navy—to publish world-wide weather reports updated every 12 hrs. Currently these reports are distributed to all ships at sea by FAX, but no particular ship needs all of them and the source has no way of knowing which ones are needed at any particular time.

Here are a few suggestions for the content that should be in such a curriculum:

Aspects of SA that need to be shared

- Mission/goal awareness
- Common picture of the battlefield suitable to brigade
- System awareness
- Resource awareness—readiness of both physical and human resources

Sources of information on which SA is based

- Sensory information from the environment
- Visual and auditory displays
- Decision aids and decision support systems
- Extra- and intra-crew communication
- Crew/team member background knowledge and experience

Creating audit trails indicating the source, credibility, reliability and revision history of information

Concept of information aging (Different classes of information age at different rates, and need to be updated accordingly, depending on their intrinsic variability and on how rapidly they change.)

An analysis of who needs to know which classes of information

- Via active communication
- Via publication in a known location

System Requirements Research

The group emphasized at several points the importance of the adage, "Equip the man, don't man the equipment!" (with apologies to the women, but any other way it is not an adage). It appears to me that no one really has a handle on how best to display information to enhance its value as an SA facilitator. In fact, at the individual soldier level, I don't think we have solved the problem of how to present a coherent picture of the battlefield at all. There are several initiatives in this direction. Most are technology driven. We need to understand better how to seamlessly aggregate data so that it is useful at various echelons. I do not think this is as simple as summing units or averaging data. Different levels need qualitatively different kinds of information about the same entities. For example, with respect to supplies, the troops simply want to know when they will get there and whether there will be enough. However, at higher levels they may need to know where they are coming from and by what mode of transport. They also want to know whether the rate of delivery will sustain their units. There is a real need for a research project that reviews the information requirements at multiple echelons and determines which requirements are in common and which are different. This kind of information should drive the technology development, not follow it.

Summary

It is clear that the term SA is understandable at a general level to a wide audience, however it means a lot of different things to a lot of different people. While it is serving as an effective stimulus to get military folks thinking seriously about the training and system design implications of the "digitally enabled" forces, we should make sure that it is not being used simply as a synonym for battlefield effectiveness. On the other hand, I do not think those of us in the research community need to be so academically arcane as to insist on operationally precise definitions for train-

ing soldiers to improve their battlefield awareness. The level of definitional precision should suit the purpose for which it is being used.

Reference

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. In Proceedings of the Human Factors Society 32 Annual Meeting (pp 97-101). Santa Monica, CA: Human Factors Society.

Chapter 13

Group 4 Summary: Situation Awareness Requirements for Future Infantry Teams

Mr. Patrick J. Ford
HumRRO

Differences in Future Army Teams

The discussion of anticipated changes to Infantry teams began with excerpts from a briefing in 1971 by GEN William P. DePuy to the faculty and advanced courses in the U.S. Army Infantry School. The briefing included a call for flexibility and individual innovation from GEN George C. Marshall in 1934:

> *The art of war has no traffic with rules, for the infinitely varied circumstance and conditions of warfare never produce the same situation twice. Thus in battle each situation is unique and must be solved on its own merits.*

The immediate application of the quotation was to contrast the emphasis on detailed written orders in the U.S. Army prior to World War II with the German Army's ability to move a corps with verbal orders. The implication for situation awareness for future Infantry teams is that Infantrymen must be capable of more than wielding a bayonet and putting a hole in a target at long range; they must provide human intelligence, senses, and discrimination. Discussion of how the Infantry could provide the human dimension under future conditions concerned the need to avoid dysfunctional concepts, similar to the "need" for control through written orders, and changes to future team operations.

Avoid Dysfunctional Concepts

During the course of the discussion, group members pointed out several beliefs that they felt could mislead combat leaders of the future. Five common misconceptions about future warfare were identified. These were:

The Infantry mission will be the close-combat, direct-fire fight. Much of the DePuy briefing concerned changes in the Infantry role that should have been recognized in 1971, apply today, and are more relevant to future combat. The mission in 1971 was, and remains: "To close with the enemy by means of fire and maneuver to destroy or capture him, or to repel his attack by fire, close combat and counterattack." Table 1 shows estimates to illustrate the declining importance of close combat, as evidenced by the percentage of total casualties attributed to individual weapons, and the increasing importance of finding the enemy, as evidenced by the percentage of Infantry effort devoted to that task. The Infantry mission ought to be expanded to include the purpose of establishing and maintaining control over land and people. This broader context is needed to encompass the range of current deployments and to build the case for including Infantry in the distribution of future sensors and firepower.

Table 1.
Shift in Infantry role by era.

Era	Casualties by Individual Weapon	Effort to Find Enemy
Roman Wars	XC%	V%
Napoleonic Wars	75	10
Civil War	50	20
World War I	30	25
World War II	25	50
Vietnam War	10	80
Future	?	?

Several members of the work group supported the projections. One reason there will be less emphasis on the close battle in future U.S. combat is the political difficulty of committing human bodies. An example of the reluctance to commit to close combat was the recent decision to retaliate to embassy bombings in Africa with missile attacks rather than ground forces. In addition to finding the enemy, Infantry teams must also fix enemy forces by limiting their movement.

Some members of the work group objected to the possible neglect of the close battle on the grounds that an intelligent enemy will force close combat by neutralizing sensors through jamming, shooting them down, or selecting terrain where sensors are ineffective. One of the group members concurred that the close battle would still be relevant--especially in the early stages of a conflict--but the effort should be to preclude the close fight as

much as possible. When close combat is required, it should be viewed as a way to buy time for sensors to be effective.

The U.S. Air Force model of situation awareness transfers to the Infantry. The Air Force model emphasizes heads-up displays for aircrews. The value of such displays for dismounted teams is not apparent, especially considering the large amount of ancillary equipment the displays require.

Dismounted Infantry can operate independently. The term "team" in the title for the work group is fortunate, because it denotes combined arms. There is a tendency to think of Infantry separate from other combat arms, especially in regard to military operations in urban terrain (MOUT). U.S. experience with clearing SS troops from Aachen at the end of World War II illustrates the combined arms nature of MOUT. A large caliber gun was attached to each squad in two light Infantry battalions. Despite the lack of training or doctrine on MOUT, the battalions showed steady progress. Technology that facilitated the use of force multipliers, such as calls for artillery fire, would have been valuable. Today the problem is that commanders think that if Infantry units find and kill enemy forces ("Pac-Manship"), everything else will work out. The result is a loss of synchronization, which limits combat power.

Technology helps us do what we already do better and faster. A person who trained with written materials would implement this dysfunctional concept by developing an automatic page-turner. For warfighting, the application is that units operate a tactical operations center (TOC) supported by digital information as they did before the technology was introduced. Personnel requirements are duplicated, with one person monitoring status digitally and another using non-digital means, and the decision-making process is less effective. In corporate and government settings, the typical result of implementing technology without revising procedures and changing the structure is reduced efficiency.

Discussion concluded that situation awareness technology affects the full range of doctrine, training, leadership, organization, materiel, and soldiers (DTLOMS), with particular emphasis given to organization in order to find ways to do more with less. For

example, the future battalion would be a task force that assumes many of the jobs performed at brigade or higher levels. Similarly, it would be a mistake to try to fit future operations into current doctrine. For example, the impact of implementing digital enhancements is inhibited by the opinion that "there are no new tasks just changes to conditions and standards." Doing more with less probably will require changes to doctrine, such as reduced reliance on control measures.

The commander must be forward to lead. One change in the way that task forces will operate is that the commander may not necessarily be located near forces in contact. One of the challenges under those circumstances will be to recreate the commander's presence. ("How do you get emotional content in an e-mail message?") Several experiments have shown the importance of a commander's knowledge of the status of subordinate units and the emotional and mental state of subordinate commanders. For example, an experiment by the Combat Developments Experimentation Command found that giving commanders in the defense full information about enemy status had little impact on the combat outcome. Experiments typically show that knowledge of the status of friendly units is a better predictor of combat success than knowledge of enemy status.

Discussion of techniques that were effective for situation awareness when elements were dispersed endorsed the benefit of relatively low technology voice communication and maps. Voice communication enables the commander to monitor emotional and mental state. One consensus among senior officers following Task Force 21 Advanced Warfare Experiments (AWE) was that a highly valued capability was for the brigade commander to draw the scheme of maneuver on the map, discuss it with battalion commanders, and work out options over a common graphics display. A former division commander gave an illustration from his experience that the technology for supporting that kind of distributed coordination has been in place since 1979, predating distribution of computers, using simple television transmissions focused on maps. Further, when officers are forced to use screen displays rather than maps during the battle command training program (BCTP), they lose situation awareness. That loss can be attributed to a combination of cultural factors resulting from 30 years of experience with maps and the need to visualize the

enemy in the context of the terrain, especially in hilly, wooded, or built-up areas. The principle is that future technology should build on established skills and support proven techniques.

Changes to Future Team Operations

The key echelon in the future will probably be a battalion organized into a Strike Force that includes light and heavy elements organized into company teams. This is the lowest level that includes both subordinate teams and a staff to provide synchronization. Because it is the echelon that integrates all battlefield operating systems and most force multipliers for immediate battlefield effects, the battalion level is the point where enhancements to situation awareness will have the greatest impact. The work group anticipates that the task force will have many of the attributes of the current brigade and will assume many brigade functions, such as synchronizing sensors, fighting the reserve, and controlling close-in artillery. A colonel might well command the echelon, with company teams commanded by lieutenant colonels.

Several trends since the U.S. Civil War are likely to persist or accelerate over the next 20 years. The trends affect firepower, dispersion, area controlled, and teeth/tail ratio.

Firepower per battalion-sized unit (about 600 people) has increased by two and a half orders of magnitude. Future firepower is likely to be more precise with longer ranges for delivery. The advances are likely to stem from "breaking the tyranny of the 155 tube," and moving toward wire guided, controlled-fragmentation munitions.

Increased firepower has mandated increases in dispersion or, alternatively, decreased density by one order of magnitude. Continuing that trend in dispersion mandates a 75% reduction in the number of tactical operations centers (TOCs). The light TOC takes about 3 hours to assemble, which limits mobility. The profusion of TOCs also increases vulnerability to detection from satellite sensors. The number of fixed nodes might be achieved by changes to the organization of field artillery, intelligence, and logistics functions.

The size of the area controlled has increased by three orders of magnitude. Further increases mandate more effective command and control support at the battalion level and more agile means of maneuver. Command and control support will improve as a function of improved sensor systems with information available at lower echelons.

The teeth-to-tail ratio has declined by three orders of magnitude, meaning that the logistical tail has grown much faster than the combat elements (teeth) it supports. That trend might be reversed by more efficient "just-in-time" logistics. Control of the logistics tail is vital to support strategic deployment at intercontinental distances. The Air Force is currently working toward deploying one third of its resources and being in position to start shooting within 24 hours. The Army should set similar goals.

Continued increases in firepower, dispersion, and area controlled, coupled with a shorter logistics tail, will enable U.S. forces to employ a continuous, 24-hour-a-day, tactic. The goal is to break the enemy's integrity and maintain contact without allowing any chance to reset. Tanks, Bradleys, and dismounted forces currently have the capability to fight at night with clear superiority. Enhanced situation awareness will give future teams enough information about the enemy to make the tactic effective. The major hindrance will be the force structure to support continuous operations.

In addition to the projections for friendly forces, two enemy characteristics were proposed as likely to change how future teams operate. First, enemy forces could be very similar in terms of technology due to the commercial availability of much of the technology. This factor increases the importance of developing expertise in counter-measures and counter-counter-measures. While there was general agreement about the importance of expertise in counter-measures, some members doubted that any enemy force would have the full array of technology, especially related to command and control. Part of the rationale for that superiority is the Situation Awareness Workshop itself. No potential enemy, or friend for that matter, is likely to analyze the implications of situation awareness with anything approaching the rigor shown by experienced warfighters and researchers as this event.

The second enemy factor introduced related to the nature of likely enemies. Because most armies would be reluctant to face U.S. forces in the next 20 years in conventional combat, the most likely future enemy will be criminals or terrorists. The broader range of adversaries requires smaller, lighter, and more agile forces as well as materiel that will support conventional combat as well as alternative missions.

Measurement Approaches for Projected Situation Awareness

The nature of situation awareness and the breadth of the concept complicate measuring situation awareness. Much discussion was devoted to narrowing the scope of the definition of situation awareness. The group then identified measurement and training implications given the definition and the projected operations of future teams. Finally, members proposed research issues in support of the future warfighter.

Definition of Situation Awareness

Situation awareness is a state rather than a process. The difficulty of capturing the full range of expertise in that state becomes clear when a researcher tries to perform a cognitive analysis of decisions an experienced officer makes in a combat scenario. There is no way a researcher can address the scope of analysis that an expert applies to acquire, filter, assimilate, seek, and broadcast information. Although situation awareness is more than the sum of information, it can be deconstructed into data elements that can be the basis for meaningful measurement and can help improve training.

The potential impact of technology on situation awareness is illustrated in Figure 1. Up to a point, data from sensors increases situation awareness by reducing uncertainty. At some point, however, the volume of data might create a new type of uncertainty through data overload. The point of data overload has been reached with the All Source Analysis System (ASAS). Because ASAS receives data from 20 or 30 sources with regularity, the staff is overwhelmed. As a result, the system is not credible and is rarely used. In the national context, about 90% of signal intelligence is not considered.

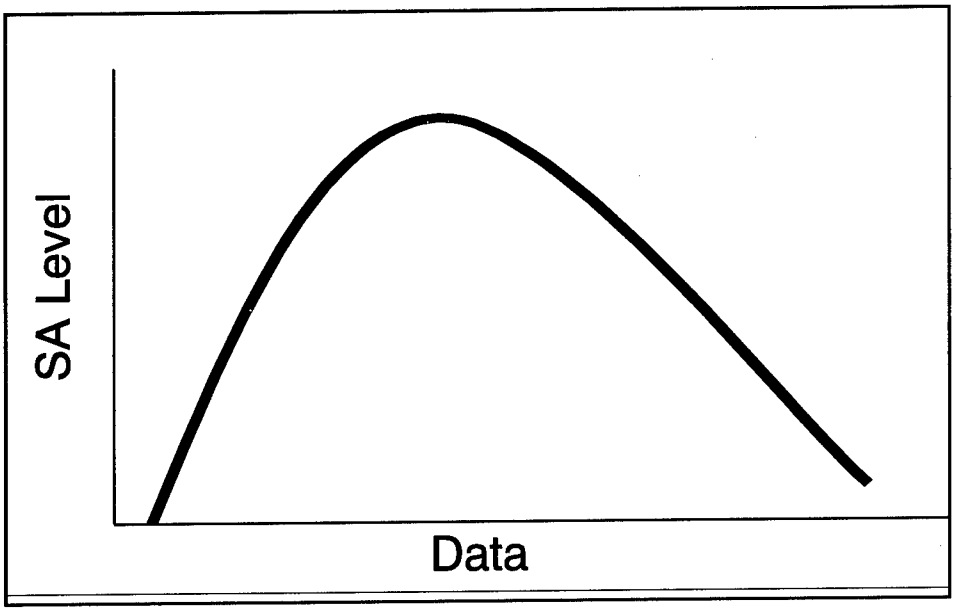

Figure 1. Notational relation between data and situation awareness.

The original version of Figure 1, which was presented during the group discussion, had "Information," rather than "Data," as the label for the horizontal axis. Several members commented that the determining factor for maintaining situation awareness is how well the commander or staff organizes the information rather than the amount of information. In fact, there should be a distinction between data and information; data must be filtered so that the relevance of the information is readily apparent to commanders and staff.

A filtering process should address four characteristics. First, it should determine whether a detected object is a threat, discriminating, for example, between a Scud and a school bus. The Infantryman is a vital source of such human intelligence. Second, the high probability of detection is important. For example, what is the likelihood that a force could reach its present location without being detected earlier? This factor helps assess the credibility of the data. Third, what is the state of the threat? Is it dispersed or massed, covered or exposed? The fourth factor concerns the engagement window, determining whether the target can be engaged given the available resources. For example, because a call for indirect fire requires about 8 minutes per echelon, it is typically an option against a mobile force only if the friendly force can fix the enemy in place.

Group 4 Summary

The paradigm for providing situation awareness for future operations is shown in Figure 2. The micro-AV systems extend Longbow and Apache capability to see accurately and shoot, thus eliminating the middleman between the sensor and the shooter. They also incorporate automated target recognition. Overall, group members felt the system will reduce the amount of filtering of data and greatly enhance the combat power of the task force commander.

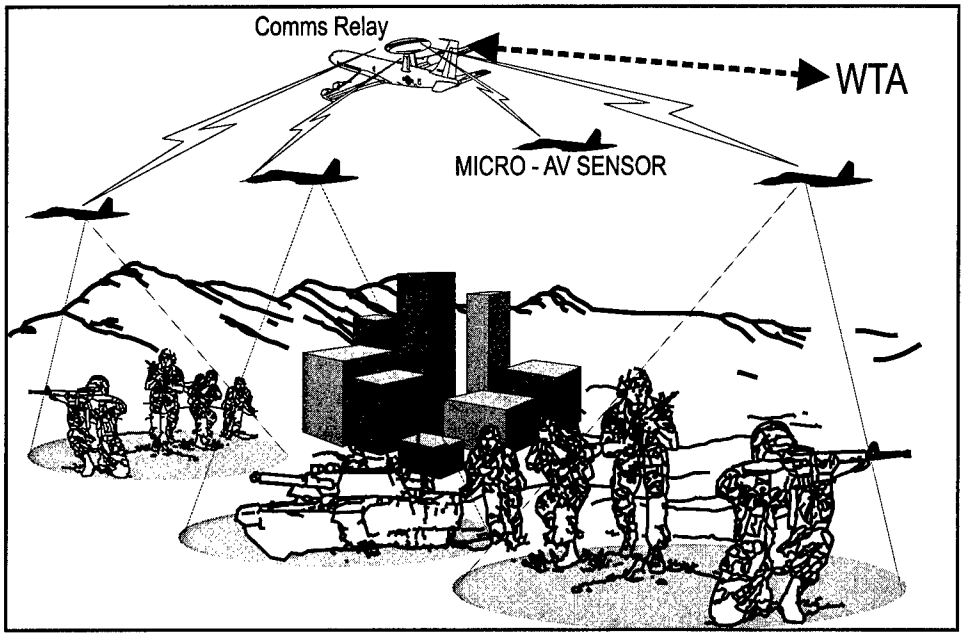

Figure 2. Illustration of constant state capability for situation awareness.

The discussion on filtering data is relevant to a model of situation awareness developed by Endsley (see chapter 6). The model postulates three components: perception, comprehension, and projection. The perception element is similar to the first characteristic of filtering discussed earlier, i.e., identification of objects that may pose a threat.

The group extended the discussion of the nature of situation awareness to include efforts to develop a definition. The definition grew out of concern that other definitions did not relate well to warfighting:

> The common picture of Red and Blue Force location and capabilities with which (within the context of terrain, weather, and time) Blue combat power can be applied to Red combat power to achieve desired outcomes.

The work group endorsed the definition, commenting especially on three components: common picture, context, and achieving desired outcomes.

The Unity of Effort principle of war requires that all echelons from division to company maintain a common picture of friendly and enemy capability. Unity of Effort lets a commander mass force against enemy weaknesses, which is the most efficient use of resources. As one group member stated, "We can defeat the enemy by destroying only 10% of his systems—if they are the right systems."

The context (terrain, weather, and time) might be a useful way for setting objectives for development of situation awareness technology. One member reported recent frustration in trying to convince the services that future sensor suites should monitor weather. For the Army, weather conditions have an impact on the effectiveness of the air scouts and the Longbow. Specifying terrain reinforces the need for a variety of 3-dimensional databases that will help with the comprehension of maps. It would also be desirable for the databases to be able to provide a trace of enemy movement to help project future actions. The specification of time as part of the context highlights the need for sensors that are tailored to the echelon's range of influence. Perhaps the best way to characterize situation awareness for an echelon is a bubble of time, 20-30 minutes, where friendly and enemy forces can have an impact on each other. Currently, the situation of which the commander is aware is rarely the actual situation. That is, brigade lags 10-15 minutes behind the battle and battalion is 5-10 minutes behind the brigade in receiving information. One goal in designing future sensors should be to give commanders more warning time.

The phrase "to achieve desired outcomes" stresses the principle that the relevance of information depends on the tactical purpose at a particular time. Implicit in the phrase is the assumption that the relevance of information can be predicted given a specific echelon and purpose. Some conditions are important to ferret out because they repeat themselves so often on the battlefield—for example, detect, synchronize, target, shoot, screen. Data elements appropriate to the echelon can be identified and given to the commander so he can make decisions such as move

the troops or deploy more sensors. Commanders are eager for such decision loops: "this data, this decision, this tool."

Implications for Measurement and Training

The discussion of the nature of situation awareness and the definition identified three implications:

- ❑ Measures of situation awareness should be considered together with combat outcome.
- ❑ Measures of situation awareness should be decision-driven.
- ❑ The focus in situation awareness should be on warfighters rather than technology.

Early in the work group's deliberations, members were concerned that measurement of situation awareness was hindered by the broadness of the concept. The problem is that discussions of criteria of the impact of situation awareness tend to be circular: "Good situation awareness results in good combat outcomes; therefore if I have good combat outcomes, I can deduce that situation awareness was good."

One perspective within the work group was that relying on battle outcomes was appropriate because defeating the enemy was the ultimate justification for situation awareness developments. Several members countered with the argument that battle outcomes are frequently driven by the stupidity of the enemy as well as by factors that neither side can control. The response was that simulation made it possible for enough repetitions of a scenario to control the effects of such vagaries and show whether units improve regarding outcomes.

Another faction within the group argued that research on situation awareness required measures that were sensitive to skills, tasks, and capabilities relevant to situation awareness. To the extent that the issue was resolved, the conclusion was that measures of battle outcomes as well as measures that allow diagnosis of situation awareness at a microscopic level should be collected. Thus it might be possible to study instances where situation awareness is high but battle outcomes are low, such as the Alamo, as well as cases where situation awareness is low, but the unit is still successful.

The importance of decision-driven situation awareness was first highlighted in a discussion of the scope of the Army mission concerning the need for future commanders to be aware of "the other side of the hill." The importance was reinforced during the discussion of the definition. The specific question in each instance should be what situation awareness is optimal for this decision at this time? The tactical framework for this question, given the layers of enemy forces, is illustrated in Figure 3.

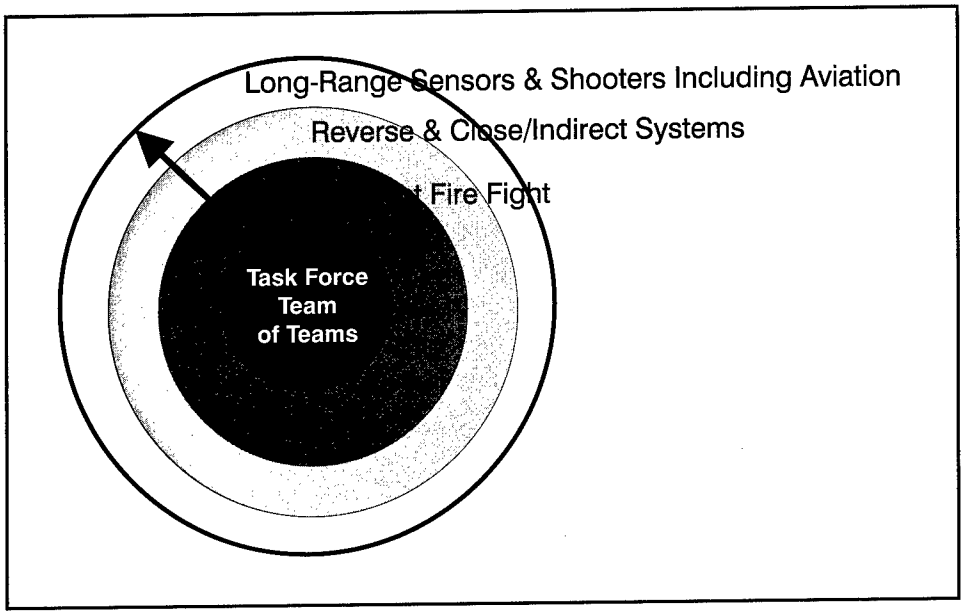

Figure 3. Tactical options that affect situation awareness measures.

Timeliness and friendly force capability apply at all bands of the tactical situation. Timeliness issues concern how the commander manages the time available to get an accurate picture of enemy capability, including deciding that information from current sensors will not be available in time for a decision and deploying other assets to fill the gaps. A relevant measurement question is what is known, and how that information is derived. Answers can then be compared to when relevant information was available. Timeliness is more of a factor in deep battles (the outer ring of Figure 3) than close battles because a commander has more flexibility. Awareness of friendly force capability concerns three questions. What is the capability of subordinate teams in light of attrition? How long can subordinate teams operate given their logistical status? Are target priorities consistent with team capabilities?

Group 4 Summary

Most of the work group's discussion was directed at how measurement approaches related to situation awareness would vary given the time and distance options shown in Figure 3. In all cases the approach is to identify relevant decisions and decompose the decisions into elements that can be measured.

Even though options are limited for the direct-fire fight, situation awareness technology will help the task force commander avoid enemy capabilities and find enemy weaknesses when the commander decides where to attack. The decision will be based on his knowledge of the enemy's tactical integrity as reflected in the location of reconnaissance, obstacles, fortified positions, immediate reserve, indirect fire systems, and command posts. Three compatible measurement approaches are implied. The first is to assess the commander and staff's proactive information seeking and information status. The purpose is to see whether they can identify when they have enough information. The second approach is to design the scenario so some critical information is not included and measure when the unit recognizes it is missing and the steps they take to obtain it. The third approach is to look at the delays between acquiring critical information and implementing it into combat plans.

In the deep battle, the future task force commander and staff will need to find the capabilities of the enemy center of gravity. Relevant situation awareness information will concern the location and status of the enemy's rocket artillery, launch artillery, tank reserves, and the command and control apparatus. Once he has sufficient information, the commander will decide how to respond, for example by bringing artillery forward or utilizing Longbow or Apache systems. In addition to assessing the appropriateness of the decision, measures could assess three situation awareness elements. One approach assumes that the enemy will feed spurious information. It would be useful to measure when the unit identifies that information sources are deceptive. A second suggestion is to periodically compare the task force's "picture" of the location of critical targets with a simulator-generated snap shot of the actual locations. Another idea is to assess whether the task force identifies changes to the state of the critical targets.

The orientation on warfighters rather than technology led to periodic discussions of the training implications of future situation

awareness enhancements. A consistent conclusion was that most collective training would be delivered in a distributed training environment, thus meeting the principle Train as You Expect to Fight. Constructive simulation will support training for large units and virtual simulation will support small units. Training scenarios will be structured to stress measurement approaches. The simulation systems will supply automated after action review (AAR) support. The Army in general, and ARI in particular, have documented experience with distributed training, such as Focused Dispatch, immersive training, and digital applications in the Army Warfighting Experiments.

There was less consensus regarding leader training, depending largely on optimism about how usable situation awareness enhancements will be. One position was that the fundamental decisions will not change even though the amount of data and update speeds accelerate. Even the overload suggested in Figure 1 may be temporary until commanders and staffs become accustomed to the volume of data. The danger might be that commanders become passive compilers of information rather than proactively seeking it.

Other members argued that the requirements to recognize patterns in order to understand the situation and project enemy actions is an art that requires a mentor-apprentice relationship. At least in the immediate future, few senior leaders will have enough experience with the technology to act as mentors. Counter to that concern, experience with BCTP shows that mentors have a steep enough learning curve that any shortage will be short lived, though there is an immediate need to teach senior officers how to deploy sensors.

Research Issues in Support of the Warfighter

In keeping with the focus on the people who will apply situation awareness technology, the work group identified six issues that might be addressed by Army R&D agencies to make warfighters more effective:

- Horizontal integration of situation awareness systems. The specific question is what data are needed at a particular echelon. The intent is to avoid routinely overwhelming

commanders and staffs with data they rarely need.

- Grouping and distribution of information. Once data reaches an echelon, it should be packaged and distributed to the people who need it for a decision. Ultimately this parsing should be automated. The research is to identify the number and content of the packages.
- Identifying effects of terrain on situation awareness. Sensors and guided munitions that are effective in the desert may be ineffective in close terrain. The research would identify the impact of interruptions of energy and provide guidance on how to predict the effects and deploy sensors and weapons to accommodate that impact.
- Identifying implications of enemy standoff. This is a doctrine and organization issue concerned with how to fight the force. At a long standoff, commanders can shape the battlefield with sensors. At short and intermediate standoff, commanders should shape the battlefield with Infantry and Armor. The danger is that planners will focus so much on long standoff conditions that they assume themselves out of a maneuver force.
- Enhancement of distributed training capability. Research on this issue would confirm assumptions about the types of scenarios and feedback that are effective in the constructive and virtual simulations. The issue also includes research on transfer among scenarios and echelons.
- Adapting the presentation of situation awareness information to the characteristics or preferences of users. Research would identify ways to provide flexible orders, formats, and priorities for each data package. The intent is to design machines that adapt to users rather than force users to adapt to a one-size-fits-all machine.

The two chapters that follow were prepared by the co-leaders of Group 4. In Chapter 14, GEN (R) Paul Gorman summarizes his views on SA for future Infantry teams. Chapter 15 was written by Dr. Daniel Serfaty, and examines measurement issues raised during the work group meetings.

Group 4 participants included:

LTC Chuck Allen
Dr. Barbara Black
GEN (R) Ed Burba
Mr. Jan Chervenak
COL (R) Neale Cosby
Dr. Gene Fober
Mr. Chris Kearns
Dr. Bruce Knerr
Dr. Mark McHenry
Mr. Jim Madden
Mr. Dave Miller
LTC Mark Onesi
CSM Charlie Thorpe
LTC Frank Wiercinski

CHAPTER 14

Situation Awareness

Gen (R) Paul F. Gorman
Cardinal Point, Inc.

Abstract: Operational training requirements for future Infantry teams must be derived from mission essential task lists that encompass the entire range of military situations from mid-intensity combat in urban environments to peace keeping and peace enforcement. The first requirement for situational awareness is team cohesion under fire. The second is mission orientation, the ability to act consistent with the commander's intent, and to adjust rapidly to new circumstance.

sit-u-a-tion *n.* **1.** Manner in which a thing is placed in relation to its surroundings; location; position **2.** a place; locality **3.** position or condition with regard to circumstances **4.** *a)* the combination of circumstances at any given time *b)* a difficult or critical state of affairs *c)* any significant combination of circumstances developing in the course of a novel, play, etc. *d) Psychol.* The objective conditions, environment, stimuli, etc. immediately affecting an individual **5.** A position of employment

sit-u-a-tion-al *adj.* **1.** of or resulting from a situation **2.** altered to fit a specific situation

a-ware adj. **1.** Orig., on one's guard, vigilant **2.** Knowing or realizing; conscious; informed - **a-ware'ness** *n.*

WEBSTER'S NEW WORLD DICTIONARY, 1972

Situation: Awareness for What Purpose?

Operational training requirements for future Infantry teams ought to proceed from a thorough understanding of environments in which these must be prepared to operate. Mission essential

task lists (METL) for training can then be derived from that understanding.

Two pitfalls obtrude: the first is propensity to relate future situations solely to Infantry's canonical combat mission - "to close with and to destroy the enemy by means of fire and maneuver, or to repel his attack by fire, close combat and counterattack." The second, a corollary of the first, is presumption that training for Operations Other Than War (OOTW) is a less demanding undertaking, often entailing operational training requirements inconsistent with maintaining Infantry's warrior ethic.

Concerning the first fallacy, Infantry requirements for situation awareness have for decades transcended its functions in close combat. In November 1971, William E. DePuy, then a Lieutenant General and Assistant Vice Chief of Staff of the Army, lectured at the Infantry School on "The Future of Infantry." DePuy cited statistics that showed that enemy casualties caused by the basic Infantry weapon had been declining for centuries, and that the percentage of Infantry effort devoted to finding the enemy, as opposed to fighting him, had been rising over the same period. He averred that technology was changing the Infantry mission as dramatically as that of other arms. Then he shocked students and members of the faculty by pointing out that, while the Infantry's own statement of its mission had remained unchanged since 1941 ["to close with and destroy..."], in practice its mission in Europe during World War II had been "to move the Artillery Forward Observer to the next hill." It should be noted that General George Patton, who headed the board of officers convened for an after action review in 1945, concluded that U.S. artillery had "won the war," and almost certainly would have agreed with DePuy's characterization of the Infantry's role.

Infantry is demonstrably the most versatile arm of our Army. The main advantage of Infantry over other elements of our armed forces is discrimination. Human eyes, and human minds examining any situation on the ground can best judge when that situation requires lethal force, and most surely determine how to apply that force with minimum unintended side effects.

Would that all young Infantrymen could be mentored as was I by General Harold K. Johnson. When he was the Deputy

Chief of Staff for Operations, he taught me a most memorable lesson about operational training requirements. One day in the spring of 1963 I entered his office with a dozen other majors of the Army Staff to brief him on certain matters pertaining to the war in Southeast Asia. I had been sitting on a board considering the adoption of the 5.56mm rifle, and was surprised to find that the General had that weapon on his desk. He handed it to me, and told me to explain to the others the purpose of such a weapon. I started with the mission of the Infantry "to close with and destroy..." He cut me short, and handed the rifle to another officer. The latter reworded my statement, only to lose the weapon to his neighbor. One by one, we tried all sorts of variants on the rifle as an instrument for killing, capturing, or disabling an enemy, but the General kept expressing displeasure, and moving the weapon to the next man. Finally he made this point:

> *Gentlemen, modern wars are not internecine wars, in which the killing of the enemy is the object. The destruction of the enemy in modern war, and indeed, modern war itself, are means to obtain that object of the belligerent which lies beyond the war. The soldier shoots his rifle so that his comrade can advance, and by so moving, rifleman by rifleman, our army asserts control over enemy territory and enemy people. This rifle, and any one of our other weapons, is a means to the end of control.*
>
> *You should know that I have been quoting from General Orders Number 100, and that appraisal is as valid at this moment as when the War Department published that Order in April 1863.*

I would extrapolate from General Johnson's lesson that Infantry is the arm of choice when the objective of any operation is the imposition of U.S. control - as was the case in Panama, Haiti, and Kuwait, and as it would be were our forces to be sent into a Kosovo-like situation. I believe firmly that Infantry's situational awareness must draw upon the full prowess of our intelligence community. Moreover, it constitutes one of the more daunting challenges for our technologists, for over the past century changes in warfare have dramatically raised requirements for Infantry situational awareness. Between 1860 and 1990, per

Infantry unit of about 600 men, area controlled has increased by 3 orders of magnitude, firepower by 2.5 orders of magnitude, and dispersion (lower density) by 1 order of magnitude. In the future, small Infantry teams, their situational awareness enhanced by oncoming technology, will be able to exert decisive control over even larger areas.

Situation awareness for close combat should be regarded as a subset of that for control. Let those who suppose that peacekeeping and peace enforcement detracts from the warrior ethic remember that control in any situation is better assured when hostiles, neutrals, and allies alike are convinced that U.S. Infantry can resort to deadly force in an instant, and can do so with telling effect and with minimum collateral damage.

Awareness: Of What?

Many who have glibly addressed requirements for situational awareness have failed to appreciate that there are profound differences in those requirements among the four armed services. For instance, it is important to understand that simple awareness of the location and status of our own forces is far more problematic on the land than on the sea or in the air.

The following table compares typical forces under command of a three-star flag officer of each service. The array, left to right, compares relative ease of gaining and maintaining situational awareness. "Moveable subordinate entities" are numbers of ships, flights of aircraft, armored fighting vehicles, or dismounted elements that maneuver responsive to a single leader; these spread by orders of magnitude across the four services. The problem is most complex in an Army corps. For the reasons depicted on the chart, keeping track of where these entities are, and orchestrating what they are doing, is significantly more difficult than it is in the other services. In the current Army, situational awareness depends upon an extensive, hierarchical command and control apparatus:

	USN	USAF	USMC	USA
	☆ ☆☆	☆☆☆	☆ ☆☆	☆☆☆
MOVEABLE SUBORDINATE ENTITIES	10^1-10^2	10^2-10^3	10^3-10^4	10^4-10^5
RANK OF SUBORDINATE LEADERS	HIGHEST →			LOWEST
COMMUNICATION WITH SUBORDINATES	BEST →			WORST
INFORMATION RE SUBORDINATES	PRECISE →			VAGUE
TACTICAL FLEXIBILITY	GREATEST →			LEAST
COMMAND PRINCIPLE	CENTRALIZE →			DECENTRALIZE

Within a force operating amid the uncertainties and clutter of the surface of the earth, the greatest contribution of improved situational awareness would be to lend purpose and cohesion to its disparate elements as they seek to act on the intent of commanders.

The challenge is greatest for those who fight on foot, where each soldier is dependent on his own physical and spiritual resources, buttressed neither by vehicles, large guns nor other impedimenta. The masterpiece on the Infantry problem remains S.L.A. Marshal, who in his classic Men Against Fire (1947) posited "combat isolation" as a fundamental dysfunctional phenomenon. During training, the Army's ancient forms of regimentation convey a sense of a huge, overpowering, interactive organism capable of advancing inexorably through whatever hostile resistance it may encounter. This misleads the Infantry soldier, leaving him unprepared for the day when his will and his courage may determine whether the Army will move at all. The nearer that soldier approaches battle, the stronger his misapprehension becomes. Activity of aircraft, ships, guns, and other units creates in him the expectation of overpowering strength, and renders the awesome loneliness and emptiness of the battlefield the more debilitating:

> ...The distant sounds of battle... are impersonal ... they produce no dispersion in the force right around him...The unit enters upon the battlefield and moves across ground within range of the enemy's small arms. The enemy fires. The transition of that moment is wholly abnormal. He had expected to see action. He sees nothing. There is nothing to be seen. The fire comes out of nowhere. He knows that

it is fire because the sounds are unmistakable. But that is all he knows for certain...The men scatter as the fire breaks around. When they go to ground, most of them are lost to the sight of each other. Those who can still be seen are for the most part strangely silent. They are shocked by the mystery of their situation. Here is surprise of a kind which no one had taught them to guard against. The design of the enemy has little to do with it; it is the nature of battle which catches them unaware. Where are the targets? How does one engage an enemy who does not seem to be present? How long will it be until the forces opposite begin to expose themselves and one's own forces will rally around the tactical ideas which training had taught them would prove useful?...There is none present to tell this rifleman and his comrades that this is normal and that only his personal reaction to it may change with time. He may go on and on through repeated engagements and never know a situation that is more tangible. In essence it is against this very situation that his unit must find the means to rally if it is to succeed in battle...The enemy fire builds up. Its aim becomes truer. The men spread further from each other, moving individually to whatever cover is nearest or affords the best protection. A few of them fire their pieces. At first they do so timidly...Others do nothing...Such response as the men make to the enemy fire tends mainly to produce greater separation in the elements of the company, thereby intensifying the feeling of isolation and insecurity in its individuals...

One must come to rest on Clausewitz's gloomy warning that: "In war the novice is only met by pitch black night. " On beyond that are to be read the words: "It is of first importance that the soldier, high or low, should not have to encounter in war things which, seen for the first time, set him in terror or perplexity."

That is the desired goal - to shed such a strong light in training that it will dispel much of the darkness of battle's night. We have the word of the nineteenth's great military thinker that it can be done. It remains a hope for those of us who weigh the military problems of the new age...

Marshall wrote before the advent of TRAINFIRE and Tactical Engagement Simulation. In a note for the 1961 edition of Men Against Fire he lauded the former, and there is every reason to believe that had he lived to see training exercises like those at the National Training Center, he would have approved heartily. But with "digitization" it now appears possible to develop in training a wholly new mental construct of battle for each Infantry team, and to provide its members with reliable counters to combat isolation. Situational awareness must, first and foremost, weld together Infantry teams with assured information as to where each soldier is relative to his leader, and to his fellows of the team.

Within that fraction of U.S. Army mounted units that is undergoing "digitization," situation awareness is embodied in a graphic depiction on a screen in each combat vehicle that presents the situation dynamically as an overlay upon a conventional, two-dimension-map. The problem of how to present comparable information to Infantry under fire remains unsolved.

The current approach of "Land Warrior" that relies on a heads-up display and in-the-ear audio seems quite inapt for the circumstance depicted by Marshall - close encounter with a deadly enemy - especially when the desired response includes sensing the location of friend and foe, firing a weapon, and purposeful movement.

I have advocated a display mounted on the weapon-support forearm simply because that area is naturally within the scan of a firing soldier. A simple plot of relative position of self, leader, and team members thereon would do much to evoke a coherent team response.

I have before me a Land Warrior Functionality Design Document approved by the TRADOC Systems Manager, *inter alia*. It describes a communications/computer system that will provide a wide range of information to each Infantryman. Indeed, Land Warrior's stated purpose is to amplify individual performance:

> To improve the fightability of each dismounted soldier in the Army Infantry platoon by integrating him into the evolving digital battlefield. Improved soldier fightability includes enhancements to lethality, command & control, survivability, mobility and sustainment capabilities.

Embedded in the Land Warrior computer are the system operations manual and eight field manuals. There are elegant provisions for preparing and for transmitting formatted messages and orders (warning, operations, or fragment), for navigating (including map displays), and even for video scene capture and transmission. But the document is silent on how Land Warrior should function for situational awareness in a firefight. I believe that some of the documentation and process functionality might usefully be traded for the latter form of "fightability."

Of course leaders of Infantry units require access to the same digitized system of command, control, communications, and intelligence as their mounted counterparts. In fact, their need for powerful, speedy computers with large, facile storage is far greater. Paradoxical as it may seem, dismounted Infantry, commonly regarded as the most primitive form of modern force, demands more of "digitization" than do mounted forces. A moment's reflection will suffice to remind that a fold in the ground that would be inconsequential to an armored fighting vehicle or a helicopter might constitute cover or concealment for an Infantry unit. For example, while the Army's stated requirement for digital terrain elevation data (DTED) to support strategic and operational maneuver is one elevation posting per 30 square meters (DTED 2), its requirement for tactical maneuver is one elevation posting per 1 square meter (DTED 5)—900 times more elements of data to record the accidents of the ground. To this elevation precision there must be added even more complex data on vegetation and the works of man where these affect observation, fields of fire, cover and concealment. Moreover, while a situation can be satisfactorily portrayed for mounted troops by showing vehicles, dismounted Infantry requires plotting individual persons—again multiplying the number of entities that must be managed.

Land Warrior is supposed to facilitate situational awareness for dismounted leaders from battalion down to squad. The limitations of its display, radio, and power supply suggest that a supplemental interface with the Army Battle Command System (ABCS, the "digitized" system) will be necessary to take full advantage of ABCS. For this reason I have proposed a backpack version. In April 1999 ABCS will issue for mounted battalions a set of UNIX-based laptops; one of these computers and associated communications might well be modified for dismounted operations.

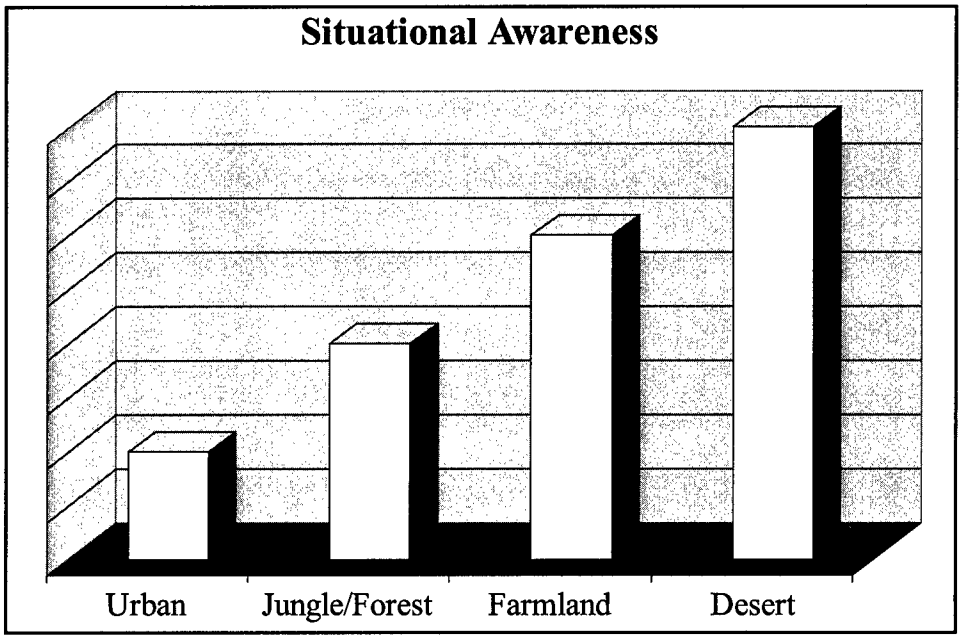

Figure 1. Situational awareness and battle environment.

Figure 1 makes the point that situational awareness is relatively disadvantaged in environments that limit observation and fields of fire, and provide ample cover and concealment. Cover and concealment detract from situational awareness not only because they make it harder to locate the enemy, but also because they have the effect of "fractionalizing" - dividing friendly forces into uncoordinated parts. Men Against Fire has a chapter headed "The Multiples of Information" that describes "informational strength" and "weapon strength" as "the complementary halves of moral strength." In Marshall's view, American Infantry were stronger with weapons than they were with information, and he held that "information is the soul of morale in combat and the balancing force in successful tactics."

> *In combat almost nothing has the appearance of juncture and of hanging together. Viewed from above, an attack would appear not unlike the disparate movements of a colony of water bugs. The first effect of fire is to dissolve all appearance of order. This is the most shocking surprise to troops who are experiencing combat for the first time. They cannot anticipate the speed with which their own forces become fractionalized or the extent to which the fractions will become physically divorced from each other as the movement is extended and enemy resistance stiffens.*

> During Normandy fighting there was much emphasis on the ill effect of the boscage country in compelling a rapid breakdown of the smaller tactical units, thus compounding the difficulties of control. But this was no new problem in tactics. The main difference was that the hedgerows and their effect on a formation were fully visible to the naked eye. It was easy to see what was happening and why.
>
> But a comparable effect is produced in almost any terrain which can serve Infantry forces, including most desert country. It is not the accident of ground which produces the effect but the simple fact that man must take advantage of the accident in order to survive. House-to-house fighting in a town or city (and regardless of what the book says, this is always a catch-as-catch-can business) will split a company apart more quickly than any other kind of action. The hedgerows notwithstanding, in Normandy it was relatively easier for forces to maintain contact among their own elements than in campaigns occurring at the same time in the Central Pacific where troops were advancing across flat, palm-covered islands.

The remedy to "fractionalization" is information: situational awareness. Marshall pointed out that the Army did relatively well with information flowing rearward, but was abjectly clumsy with passing information laterally to the flanks. Arbitrariness and inertia played a role, but few leaders understood that the passing of lateral information at platoon, company, and battalion level is frequently essential for carrying out the commander's intent. Commanders at the lower levels were too often neglectful of the principle that they were not only a channel of information, but also a distribution point.

Perhaps the greatest advantage that will accrue to Infantry teams with advanced situational awareness is the ability to adapt to unforeseen circumstance. One of the key bridgeheads over the Merderet River in Normandy was occupied by four successive small American Infantry units, who, unaware of the strategic importance of the position, moved on to other missions they deemed more important. Eventually, a major attack had to be launched to seize the bridgehead. I have personally interviewed

veterans of the 10th Armored Division, the original occupiers of Bastogne, who were entirely ignorant that they had moved onto center stage in the unfolding drama of the Battle of the Bulge, and behaved as had been their wont in routine attacks across France. Fifty years ago changes to strategic and operational circumstance were communicated by happenstance; with tomorrow's situation awareness, such communications ought to assured for any commander.

Lower echelons will inevitably see any situation with different eyes, and with different brains from that of their higher commander, and there will be rich tactical, operational, and strategic rewards for an army able to refocus to realign its missions to meet un-provided-for situations. Warfare of widened deployments and increased dispersion, with frequent shock use of troops dropped suddenly upon decisive targets, entails combat in which initially there will be little contact among friendly units, and situation awareness will vary widely among them. Hence mission orientation will come to have many times its previous importance in operational training.

> *The need for a clearer concept of [the principle of the objective]... is not greater than the need for junior commanders who will take a keen interest in the larger affairs of war and for higher commanders who make it a practice to get down to their troops. More appropriate to what we will know in the future to what we have experienced in the past is that old truth: It is not always possible to lead from behind. - S.L.A. Marshall, Men Against Fire.*

CHAPTER 15

Model-Based Measurement of Situation Awareness in Dynamic Tactical Environments

Daniel Serfaty, Ph.D.
Aptima, Inc.

This note presents a model of situation awareness (SA) in the context of Infantry missions. We present an operational model of SA that is comprised of knowledge of the critical elements of the situation and the values of these elements as a function of time. Based on this model we discuss the measurement framework we propose to use for identifying the critical elements of SA for this domain and investigating the development of the warfighter's SA over time. We discuss the utility of this method in assessing the value added of SA technology on overall mission performance.

BACKGROUND

Performance in complex military systems is often based on the integration of human observations and judgments with automated information. For example, understanding and using SA technology to locate enemy positions on the ground can be a cognitively complex task. In this context, the warfighter's judgment is based on a combination of visual, contextual, and automated information. The level of technology-aided warfighter performance that can be achieved is a function of the quality of the various sources of information, the trust that the warfighter has in the SA technology, and the user's ability to merge together effectively information and/or decisions from those sources.

A critical advantage of human operators over automated systems is their ability to make use of situational information in performing their tasks. Humans are efficient and robust information processors in that they are able to use what they expect to see or hear to interpret incomplete and uncertain incoming information. On the other hand, humans can commit serious errors

when they make decisions based on their expectations, as has been tragically illustrated by incidents in which soldiers fired at friendly units in locations where they had expected the enemy to be present.

The link between human errors and loss of SA has been documented in several domains relevant to Infantry command and control. For example, in the aviation domain, records suggest that many pilot-caused errors result from a lack of SA. Nagel (1988) notes that breakdowns in SA are one of the most serious problems in aviation operations. Hartel, Smith, and Prince (1991) report that in a Navy and Marine analysis of mishaps, lack of SA was the most frequently cited causal factor. Thornton, Kaempf, Zeller, and McAnulty (1991) found that lack of relevant and timely information was related to Army tactical helicopter crews' poor performance in navigation and threat evasion. Both observational and experimental data support the intuitive assumption that higher levels of SA lead to better task performance, but the quantitative nature of this relationship has yet to be established.

WHAT IS SITUATION AWARENESS?

Although SA is an appealing and widely used term, there is no universally accepted definition of the term, and no standard methodology for defining the elements of SA or assessing an individual's level of SA in the context of a particular task domain. Wellens (1993) suggests that in a military context, SA can be "roughly conceived of as an individual's internal model of the world at any point in time." The most widely referenced definition is one proposed by Endsley (1988) who defines SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future."

As a psychological construct SA has been discussed as both process and product. Like Endsley (1995a), we view situation awareness as a state of knowledge captured at a particular moment in time, and situation assessment as the process of acquiring or maintaining SA. Clearly an individual's level of SA can change over time, and is dependent upon the amount and quality of information that is available—which is independent of the particular individual—and the individual's ability to perceive

and comprehend that information in a timely fashion—which is a function of the individual's prior knowledge about what elements are important, how they are relevant, and how they change over time (Adams, Tenney, and Pew, 1995). Endsley's definition embraces both of these aspects of SA, with "perception" implying information availability and acquisition, and "comprehension and projection" suggesting the individual's ability to use the information.

The assessment of an individual's level of SA has been an equally elusive problem. (See Endsley, 1995b, and Adams et al., 1995, for a general discussion of the measurement of SA.) Because SA is a vaguely-defined concept and the elements of SA are not easy to identify or to quantify, it has sometimes been assessed in terms of task performance. However, as Endsley (1995a) points out, superior performance can result in spite of poor SA, and likewise high levels of SA do not always result in superior performance. In order for the concept to have meaning, SA must be defined and measured independently of performance. For example, we cannot directly infer a commander's level of SA by measuring aspects of his or her tactical performance. Rather, we want to identify and measure those elements in the situation which are predictive of performance.

Although there is no agreed-upon definition for SA, researchers do agree that it must be defined in the context of a particular task. Moreover, for the concept to have meaning, one must be able to specify the elements that comprise SA, with particular sets of elements being relevant for particular system states. Furthermore, although the elements of the situation may change dynamically over time, only some of the changes will be large or severe enough to cause a change in the situation from the point of view of the system operator (Pew, 1994). For some elements, there may be certain ranges in which knowledge of the precise value of the element is not critical for SA, and other ranges in which the precise value is critical.

In order to investigate the relationship between SA and aided decision-making performance, we need an operational definition of SA in tactical domains and a way to measure an individual's level of SA.

MODELING FRAMEWORK

We propose a cognition-based, process-oriented research framework for establishing the elements of SA in the context of mission performance, assessing an individual's level of SA, and investigating quantitatively the relationship between SA and task performance.

Figure 1 depicts a two-stage process by which decision-making performance is carried out. The first process embodies the evolution of SA. Situation assessment is a dynamic process, with input to the process coming from the individual decision-maker's background knowledge and experience, inputs from the command team and the command and control organization, and global and local elements in the situation. The global elements, encompassing such factors as the geopolitical situation, establish

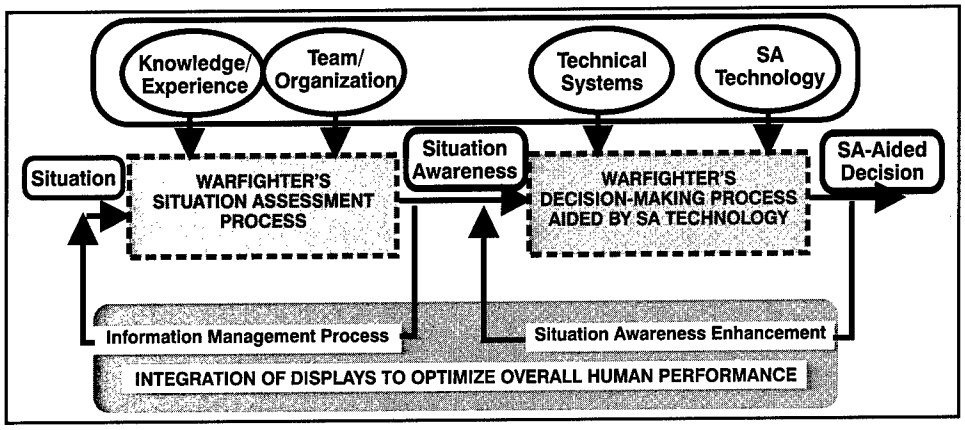

Figure 1. Process model of dynamic situation assessment and SA-aided decision-making.

the general situation and determine the local factors that will comprise the critical elements of SA. The global factors are the "givens" that interact with prior knowledge and experience to provide an individual with an initial mental model of the situation which, in turn, helps determine the information that is critical for SA in this particular situation. The output of situation assessment is a level of SA, which can be measured at any point in time.

The second process in Fig. 1 concerns the decision-making process of interest, e.g., a battle decision process supported by SA technology. This process could be any of several simultaneous decision processes occurring in the command node. One should note that mission objectives will drive, to a great extent,

the nature of the elements of the situation the commander must be aware of. The decision-making process takes as its input the individual's level of SA, information about the tactical environment, and information provided by sensor and SA technology. Due to feedback mechanisms, the output of this process becomes an input to the situation assessment process, and can affect the individual's subsequent level of SA.

MODELING SITUATION AWARENESS

An individual's level of SA is a dynamic variable, evolving over time as the situation changes. Since SA is domain-dependent, what information is perceived and how it is interpreted is a function of the individual's task objectives. We propose that from an operational point of view SA is comprised of knowledge of four aspects of the situation. These four dimensions incorporate the integrated processes of perception, comprehension, and projection over space and time proposed by Endsley (1988), albeit organized in a slightly different order:

1. What are the critical variables in the situation now? (comprehension)
2. What are the current values (or states) of these variables? (perception)
3. What will be the critical variables in the future? (comprehension/projection)
4. What will their values be? (projection)

The complexity inherent in the concept of SA stems in part from the fact that these four aspects are interdependent, and not necessarily sequential. In fact one might argue that one would seek information ("perception") that one needs for the situation/decision at hand ("comprehension"). Moreover, knowledge of the critical variables and of the interrelationships among variables directs information gathering ("perception"), which in turn may influence both comprehension and projection. Projection may direct perception and comprehension in the future.

The attention to the critical elements of the situation (the first and third aspects) suggests that not all the situational elements are of equal importance. For example, air-to-air combat fighters view information about enemy aircraft as more important

than information about friendly aircraft (Endsley,1993). Furthermore, the same informational element may not be equally important over time. For designing an optimal maneuver, knowledge of the location of an enemy vehicle may become more important over time as the warfighter's own vehicle approaches the enemy's location. The task of an individual who is trying to maintain a high level of SA is not to represent the whole state at any time, but only the critical elements, the ones that will affect mission performance.

We represent the relationship between SA and mission performance (P) by a performance sensitivity model:

$$P(t) = P(Si, \text{ other non-SA factors})$$

thus,

$$\Delta P(t) = e1\Delta S1 + e2\Delta S2 \ldots + en\Delta Sn$$

where:

P = mission performance

Δ P = decrement in mission performance due to "less-than-perfect" SA

f = functional relationship

Si = element in the situation vector

ΔSi= decrement in accuracy of estimate of value of si

ei = sensitivity coefficient or criticality factor for si

t = time

This model represents the relationship between elements of the situation and mission performance in terms of the extent to which a decrement in the accuracy of an estimate of particular elements of the situation is related to a decrement in mission performance. The ei values reflect the sensitivity (or criticality) of each element for performance. The magnitudes of these sensitivity coefficients are determined by the mission itself, not by the particular individual who is acting in the situation. They are dynamic in that their level of criticality may change over the course of the mission (for example, the weather may be especially critical during a particular phase of a mission). Knowledge of the critical elements is derived from an individual's past experience and his or her mental model of the situation. Studies of decision making expertise in complex task domains (MacMillan, Entin, and Serfaty, 1993) indicate that, for a given mission, experts tend to agree on which elements are critical and which ones are less so.

The second and fourth aspects of SA concern the perception of the current values of situational elements and projection of their future values. Accuracy in estimating the values of the situational elements is dependent upon the operator's ability to perceive or infer the current values of the elements. Clearly the rate of change of the values of the situational elements is dependent upon the element (e.g., the position of an aircraft will change more rapidly than that of a tank) and the particular scenario as it unfolds (e.g., on some days the weather conditions will change more rapidly than on other days). The rate and extent of change in the values of the situational elements is also determined by actions taken by the individuals involved in that mission.

We represent the relationship between previous and current values of the elements by a dynamic situation model:

$$Si(t) = g[Si(t-1), d(t-1), e(t)]$$

where:

Si(t) represents the values of the situational elements at the current time

g[ ] represents the structure of the commander's dynamic mental model of the situation

Si(t-1) represents the values of the situational elements at the previous point in time

d(t-1) represents actions taken at the previous time (e.g., a change in heading)

e(t) reflects the inherent process uncertainties (e.g., random flux in wind speed)

An individual can obtain the values for the elements of the situation through two mechanisms: direct observation and estimation. For those variables that are observable (for example, vehicle speed or cloud cover), the individual can perceive the information directly. But the values of some elements may not be directly available. For those elements that cannot be observed, the individual must reconstruct or estimate their value based on a mental model of the situation, current observations of other, related ele-

ments, and (if they are known) previous values of those elements. We can think of the function g as in part embodying an individual's dynamic mental model of how, in the absence of external forces, the elements are related to one another and how they change over time. For example, if the location of an enemy aircraft cannot be observed at a particular time, an individual can infer its location based on his knowledge of how fast that type of aircraft travels, atmospheric conditions such as wind speed, and the location of that aircraft at time t-1. This knowledge is embodied in the individual's dynamic mental model of the situation.

In reality it is not possible for an individual to have perfect SA at any time. In part, for information that is directly observable, the shortfall may be attributable to observation error. The individual may, for example, misread the airspeed or misunderstand the location of an enemy unit. The magnitude of the observation error will be related to the quality of the information that is available and the individual's observation skill. In part the shortfall may be due to faults in the individual's mental model of the situation. For example, in estimating the location of an enemy unit that is not directly observable, an individual may use a faulty mental model of the enemy's scheme of maneuvers. For situational elements whose values must be inferred from previous values, the third equation indicates that accuracy in estimating the current values will depend on the accuracy of the previous estimates of the values of those elements. In part the shortfall in SA may be due to information that is not available and cannot be reliably inferred from other information.

The third and fourth aspects of SA involve projection: What will be the critical variables in the future and what will their values be? Knowledge of these aspects must be based on the individual's dynamic model of how the situation will evolve in the future. Just as the individual's comprehension of the current situation directs his search for current situational information, his mental model of the current situation will direct his projection of the future situation, both in terms of what the critical elements will be and what their values will be.

Thus, an individual's level of SA depends upon his or her knowledge of the critical elements and the degree to which he or she is able to correctly perceive or infer the values of the critical

elements of the situation over time. An individual who has accurate estimates of the sensitivity coefficients, who perceives the available information accurately, and who has an accurate dynamic model of the situation (that is, an individual who accurately reconstructs or infers unobservable information at the current time and uses that model to predict future values of critical elements) will have a high level of SA. The second equation indicates that an individual whose estimates of the values of critical elements are perfectly accurate, but whose estimates of the values of non-critical elements are highly inaccurate will suffer little decrement in performance, whereas an individual whose estimates of all elements are only slightly inaccurate may actually suffer a greater decrement in performance. To test the relationships described in the above equations, we must measure SA as it develops over time.

MEASURING THE CRITICAL ELEMENTS OF THE SITUATION

Using the conceptual approach described above, the first goal is to identify the critical elements of SA. A three-step process is used to identify the critical elements of SA for mission performance, or, in a more restrictive case, for a specific task that is part of the mission.

The first step is the identification of a candidate set of situational elements (Si's) that may affect performance at various times (or stages) of the mission. Sources for these data are the various Army Field Manuals. The second stage in this procedure is to obtain estimates of the criticality of these elements at the various stages of the mission—in other words, estimates of the ei values as a function of time. To accomplish this we conduct structured, scenario-based interviews with experienced commanders. The warfighters are asked to rate the criticality of the elements enumerated in Stage 1. They are also asked to specify other elements that they believe are critical to determine mission performance. Assessments of the criticality of various elements are made for each phase of the mission, so that we can capture the criticality of the elements as a function of time. In addition to describing and evaluating the elements, the warfighters are asked to explain how that information is used, and how frequently it is updated. Their responses will provide descriptive information about how experts use projection as an aspect of SA. In a third stage the

criticality ratings obtained from the experienced commanders are integrated to derive a set of criticality weights (sensitivity coefficients) as a function of time.

Once the critical elements of SA have been identified, we use a scenario-based method for assessing an individual's knowledge of the criticality and value of each element at various stages in a mission and empirically relating those measures to aided performance. By comparing the individual's reports of the criticality of individual elements to the values obtained from experts and estimates of the values of the elements to their actual values, we can evaluate the extent to which knowing which elements are critical and knowing what the values of the elements contribute to high levels of SA. Comparison of an individual's projections of the importance and value of elements in the future to the weighting and value he or she actually gives them at that future time will contribute to our understanding of how projection contributes to high levels of SA and to what extent the comprehension of the current situation and projection of the future SA contribute to performance.

In summary, in order to assess how SA affects mission performance, we must first identify the key situational variables that affect performance in this domain. To demonstrate real design value, one must operationalize SA in a quantifiable manner. Therefore, it becomes important to develop theory-based, unambiguous, objective, and quantifiable metrics that can predict the value-added of SA technology as well as the resulting improvements in human-system performance. The approach described in this note is currently being implemented and continuously adapted in a variety of command and control research projects. The evaluation of the reliability and validity of this novel SA measurement method will be communicated in future reports.

REFERENCES

Adams, M., Tenney, E., & Pew, R. (1995). Situation awareness and the cognitive management of complex systems. Journal of the Human Factors and Ergonomics Society, 37 (1), 85-104.

Endsley, M. (1988). Situation awareness global assessment tech nique (SAGAT). In Proceedings of the National Aerospace and Electronics Conference (pp. 789-795). New York: IEEE.

Endsley, M. (1993) A survey of situation awareness requirements in air-to-air combat fighters. International Journal of Aviation Psychology, 3, 157-168.

Endsley, M. (1995a) Toward a theory of situation awareness in dynamic systems. Journal of the Human Factors and Ergonomics Society, 37 (1), pp. 32-64.

Endsley, M. (1995b). Measurement of situation awareness in dynamic systems. Journal of the Human Factors and Ergonomics Society, 37 (1), pp. 65-84.

Entin, E. B., Entin, E. E., and Serfaty, D. (1995). Human-computer interfaces for machine-aided target acquisition (TR-697). Burlington, MA: ALPHATECH, Inc.

Green, D. & Swets, J. A. (1974). Signal detection theory and psychophysics. Huntington, NY: Krieger Publishing Co.

Hartel, C., Smith, K., & Prince, C. (1991). Defining aircrew coordination: searching mishaps for meaning. Paper presented at the Sixth International Symposium on Aviation Psychology, Columbus: The Ohio State University.

Kuperman, G.G., Bryant, M. L., & Clark, L. G. (1991). Man-machine interfaces for automatic target recognition systems. Wright-Patterson AFB, OH: Human Engineering Division, Armstrong Laboratory and Mission Avionics Division, Wright Laboratory.

MacMillan, J., Entin, E. B., & Serfaty, D. (1993). Evaluating expertise in a complex domain-Measures based on theory. In Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting (pp. 1152-1155). Santa Monica: Human Factors and Ergonomics Society.

Nagel, D. C. (1988). Human error in aviation operations. In E. L. Weiner and D. Nagel (Eds.), Human factors in aviation. San Diego, CA: Academic Press.

Pew, R. (1994). An introduction to the concept of situation awareness. In R. D. Gilson, D. J. Garland, and J. M. Koonce. Situational Awareness in Complex Systems. Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Thornton, R. C., Kaempf, G. L., Zeller, J. L. & McAnulty, D. M. (1991). An evaluation of crew coordination and performance during a simulated UH-60 helicopter mission. U. S. Army Research Institute Aviation Research and Development Activity, Fort Rucker, AL.

Wellens, A. R. (1993). Group situation awareness and distributed decision making: From military to civilian applications. In N. J. Castellan, Jr. (Ed.), Individual and group decision making. Hillsdale, NJ: Erlbaum.

Chapter 16

Concluding Thoughts and Observations

Scott E. Graham, Ph.D. & Michael D. Matthews, Ph.D.
U.S. Army Research Institute
Fort Benning, Georgia

For the most part, we were very successful in meeting the workshop objectives. The heterogeneous mix of senior Army leaders, active and retired military, and Department of Defense and private sector researchers generated many high quality ideas about Infantry SA requirements, as well as sound recommendations for improved training, and for Training (T), Leader (L), and Soldier (S) research. Not surprisingly, there was high-spirited discussion in the four working groups about the various Infantry situation awareness (SA) issues. As reported here, the working groups generated numerous thoughtful and thought provoking Infantry SA requirements for individual combatants through Infantry brigades. While there was considerable overlap in the group recommendations, there were also important differences.

The primary focus of each working group was on training, leader development, and soldier issues, and on ways to measure SA proficiency. Much of the discussion addressed the interdependency of the T, L, and S combat development domains. As expected, development of SA performance measures proved to be most difficult. We were successful to the extent that the work groups discussed how established SA measurement approaches could be applied to realistic Infantry scenarios. There were also discussions about measuring the potential SA impact of emerging Infantry systems, e.g., Land Warrior. The workshop discussions and papers represent a good beginning, but clearly much more detailed work needs to be done in the area of SA measurement.

Common Themes

There were a number of common themes that emerged from the presentations and working group discussions. These included:

- Situation awareness is not the goal, but a means to improved decision-making, battle command, and effectiveness in full spectrum operations. The apparent need to proliferate digital communications technologies and SA systems must be kept in perspective. We must consider the overall impact of these high-tech, digital systems on operational readiness.

- SA systems should be designed with the soldier in mind. As one participant stated: "We must equip the man, not man the equipment." Warfighters must play a central role in the SA technologies development process, defining the operational requirement and ensuring that the technology developers stick to that requirement. We must avoid SA technologies that are too heavy, too hard to use, too difficult to maintain, or not inte grated with other systems.

- SA skills must be specifically trained. Leaders and soldiers must be trained how to understand and translate the ever-increasing amounts of SA information into better decisions and battlefield actions. We need to better understand what skills are needed for SA proficiency, e.g., visualization, and develop training procedures for SA skill development and sustainment. This will likely involve repeated practice in increasingly com plex scenarios with feedback.

- Meaningful, reliable SA measures are needed. Measurement of SA proficiency is needed for system development, training, and performance evaluation. Intrusive SA measurement tech niques appropriate for laboratory or simulation studies may not be appropriate for field studies or warfighting exercises.

- Knowledge is power. Enhanced SA or battlefield knowledge seemingly can best be exploited through a shared common picture of the battlefield that is selectively provided to all eche-lons. Again, the focus is on knowledge and understanding, not amount of digital information in the digital pipeline. Maintaining this focus will continue to be a significant challenge for system designers.

- The required level of detail or resolution of SA information will vary by echelon. Platoon leaders need to know with greater specificity the location of their soldiers, other friendlies, and the enemy, than do brigade commander and staffs. Moreover,

the required level of detail for light Infantry forces is greater than that for mechanized forces. SA awareness should gener ally follow the rule of "two levels up, and two levels down." The systems should have the flexibility to adjust the resolution as required.

- SA technologies will sometimes fail. Plus, digitized units will have to interface with non-digitized units, including other U.S. units and those from coalition forces. Soldiers must continue to train and sustain non-digital skills. Simultaneously training digital and non-digital skills, while essential, will place a heavy burden on an already overtaxed training system.

- Despite the growth of information age technologies, certain immutable aspects of combat will remain; for example, the principles of mass and economy of force still apply.

- Specific SA needs will continually vary as a function of mission, enemy, troops, terrain, and time (METT-T). SA systems must be robust and flexible, allowing commanders to "tune in" information critical to mission specifics.

Comments of Keynote Speakers

The workshop also benefited from presentations by retired general officers. In addition to making formal presentations, they participated in the work groups. Some of their key observations included:

- Successful commanders must understand and be proficient with the cognitive skills associated with vision, innovation, imagination, creativity, and inductive reasoning. We must find better ways to develop these leader skills.

- The Army should consider adopting the regimental system, whereby soldiers and leaders would spend most of their careers in the same unit. This would lead to an overall increase in SA.

- Army leaders need more experience. One solution would be to raise the ranks of commanders at various echelons, e.g., having majors be company commanders. This structure is successful in both the British Army and in U.S. Special Forces.

- ❑ Special Operations Forces have developed a battery of tests that identifies soldiers who will not be successful in these units. The Infantry force, with its increasing complexity and impending SA technologies, should consider adopting a similar approach.

- ❑ Digital information displays should be made adaptable or "tunable" to match leadership and decision-making styles. They should be easily adjusted to match rapidly changing operational requirements.

- ❑ Sustainment and affordability of emerging SA systems are and will likely continue to be the long poles in the tent.

- ❑ The greatest impact on enhanced SA in recent Army experiments came from the Joint Surveillance Target Attack Radar System (JSTARS) and Unmanned Aerial Vehicles (UAVs). The Army has, however, barely scratched the surface in exploiting these and similar technologies.

- ❑ Despite what certain technologists and futurists may predict about warfare, there will always be a close fight.

In closing, we would like to thank everyone who participated in the workshop. We were fortunate to be able to attract such a varied, thoughtful, and indeed, wise group. This volume clearly reflects their skills and insights, as well as their dedication to improving the Infantry force. As is most always the case in the training, leader development, and soldier research and development world, there are no final products or answers. Conditions and technologies change, driving the need for revised T, L, and S methods and approaches. This work represents a step along that continuing path.

In part, the role of the human systems R&D community is to provide a sanity check on the formidable forces in the digitization/communications technologies/materiel development community. As one participant said, "Someone has to stand up to the comms guys; they are running the Army." Clearly, this applies to the development of Infantry SA technologies. As the Army prepares to digitize the Infantry force, we must continue to push for sound requirements, solid measurement approaches, and honest dialogue.