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WARFIGHTING WITH EMERGING TECHNOLOGIES

Report on the

Tech Base Seminar War Game

Held at

Waterways Experiment Station
Vicksburg, Mississippi

March 28-31, 1988

U.S. Army Laboratory Command
Directorate for Technology Planning and Management
2800 Powder Mill Road
Adelphi, Maryland 20783-1197

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1988

3. REPORT TYPE AND DATES COVERED
Final Report March 28-31, 1988

4. TITLE AND SUBTITLE
Warfighting with Emerging Technologies
Report on the Tech Base Seminar War Game

5. FUNDING NUMBERS
Produced on site

6. AUTHOR(S)
Sally VanNostrand

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Military Personnel
Training and Doctrine Command

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Laboratory Command
2800 Powder Mill Road
Adelphi, MD 20783-1145

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
None

12a. DISTRIBUTION/AVAILABILITY STATEMENT
[redacted]

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Tech Base Seminar War Game, was held on March 28-31, 1988 at the Waterways Experiment Station in Vicksburg, Mississippi to strengthen the dialogue between the technologists and the users and to evaluate the warfighting utility of our technology achievements. The main insights were: robotics to engage the enemy; remotely operated high power microwave systems; use of long range precision fire systems; integrated intelligence (found to be indispensable to use of new technologies); operational and tactical deception; increased operational mobility; use of high capabilty sensors; and a fragmented battlefield developed. Emerging technologies and the resulting future systems are becoming a central element of the evolving strategy and doctrine of the US.

14. SUBJECT TERMS
Tech Base Seminar War Game

15. NUMBER OF PAGES
40

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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Block 14. Subject Terms. Keywords or phrases identifying major subjects in the report.

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Block 16. Price Code. Enter appropriate price code *(NTIS only)*.

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

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DEPARTMENT OF THE ARMY
HEADQUARTERS, U. S. ARMY MATERIEL COMMAND
5001 EISENHOWER AVENUE, ALEXANDRIA, VA 22333-0001

20 June 1988

To the Army Research, Development, and Acquisition Community,

In recent months, we have introduced into the Army technology base management process several innovations which have been designed to better articulate our objectives, strengthen the dialogue between the technologists and the users, and evaluate the warfighting utility of our technology achievements. The first of these innovations was the formulation of a comprehensive Technology Base Investment Strategy (TBIS) which provides a framework wherein program investment decisions can be made.

The second innovation was the conduct of a Tech Base Investment Strategy Conference at the Johns Hopkins University Applied Physics Laboratory between 22 February and 4 March, 1988. This conference provided researchers, tacticians and policy makers the opportunity to have an in-depth exchange of information and opinion about the state of the art and the role of the emerging technologies in the long term national security and warfighting strategy of the United States.

The third and most recent innovation was the introduction of war gaming as a means of gaining insights into the utility of our technical innovations, and of providing a concurrent experience for users and technologists in the application of technical innovations to a possible future war fighting situation. This mutual experience thus continues and deepens the dialogue between developer and user.

I am pleased to provide you this report on the third of these innovations -- the first Army tech base war game. This report provides a summary of the major insights gained during the war game conducted by the Army tech base community at the Waterways Experiment Station, Vicksburg, Mississippi during the period March 28 to 31, 1988. I encourage all to study the insights gained during the game and to reflect how our tech base endeavors can be enhanced to further the Army's success in battle.

There is no doubt that this war game experience fully met, and exceeded, our original goals for conducting it. This success was directly dependent upon the generous cooperation of the Training and Doctrine Command in making available the highly qualified and motivated officers who served as operations experts at the various levels of command played in the game. Another major contributing factor was the cooperation and support from the Office of Net Assessment, Office of the Secretary of Defense, who made available the models and contractor support so necessary in the running and control of a credible wargame. Thirdly, the support and hospitality of the Corps of Engineers Waterways Experiment Station made it possible to run the game without complications or difficulties for the game planners and participants. To these three organizations, I extend my personal appreciation.

Malcolm R. O'Neill

Malcolm R. O'Neill
Brigadier General, USA
Deputy Chief of Staff for
Technology Planning and Management

Main Insights

In a conventional land war in Europe, conducted in the year 2015:

- The use of robots to engage the enemy at the FEBA, with the first concentration of troops massed as a strike force behind the FEBA, appeared to be an effective concept of operations.
  - This reduced the number of troops on portions of the battlefield where vulnerability is usually the highest.
  - To be more than just smart mines, robots had to be capable of both offensive and defensive application.
- Remotely operated High Power Microwave systems appeared to offer the potential of significantly suppressing enemy C^3I in the combat area.
- Very long range precision fire systems provided significant increases in flexibility at the operational level through better use of distributed assets, substitution of fires for maneuver of units, and reduced forward logistics. Significant leverage was gained by munitions capable of being targeted across corps boundaries as well as deep attack of enemy rear areas.
- Robust and survivable C^3, and multi-source, integrated intelligence were indispensable to the effective use of the new technologies.
  - Connectivity had to be maintained to execute doctrine and tactics.
  - Remote on/off control and/or IFF of smart mines was critical.
- Operational and tactical deception played a major role in the conduct of the game.
- Increased operational mobility was critical on a battlefield where strike forces were located predominantly in reserve positions.
- High capability sensors made movement, emission and firing very risky and amplified the impact of deception, low observables, and anti-sensor weapons.
- A fragmented battlefield developed through use of barriers and counter-attacks, eroding the concept of frontlines, as the battle progressed.

Several assumptions, not explicitly played in the game but which appeared significant to the eventual outcome were:

- Space assets, although drawn down during the course of the game, were available throughout the game.
- Soldiers and units were capable of twenty-four hour per day operations, even while in a state of chemical attack readiness.
- Adequate logistics support was available in the theater for the duration of the game.
- Complete interoperability of NATO C^3I, fire support, and logistics support existed throughout the theater of operations.

Caveat

For all its educational and analytical value, one game by itself cannot provide definite answers or detailed conclusions. At best, a quality wargame can test assumptions and produce insights that might not otherwise come to light in a less dynamic analysis. These insights, in turn, can suggest areas in which further analysis may be useful.

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I. Introduction

For over a quarter of a century the United States has relied upon a qualitative edge in military technology as a means of counterbalancing the numerical advantage of the Warsaw Pact in the European theater. Often this qualitative advantage has been implemented on a case by case basis in individual weapon systems imbedded in an overall force structure built upon older tactics and doctrine.

Economics and demographics indicate that the United States will need to continue to depend upon a qualitative edge in militarily significant technologies to counterbalance the numerical superiority projected for the European theater, as well as threats in the Third World and the Pacific Basin. Recently the Secretary of Defense commissioned a review of the United States strategy with the objective of ascertaining the elements of an integrated perspective. In January 1988, the Commission on Integrated Long-Term Strategy presented its final report. Among the main points of the Commission's report is the conclusion:

> *"Our strategy must also be integrated. We should not decide in isolation questions about new technology, force structure, mobility and bases, conventional and nuclear arms, extreme threats and Third World conflicts..."*
>
> (Reference 1)

Thus, there is emerging within the national security community a concerted effort to consider technology, force structure, and scenario of application as an integral problem.

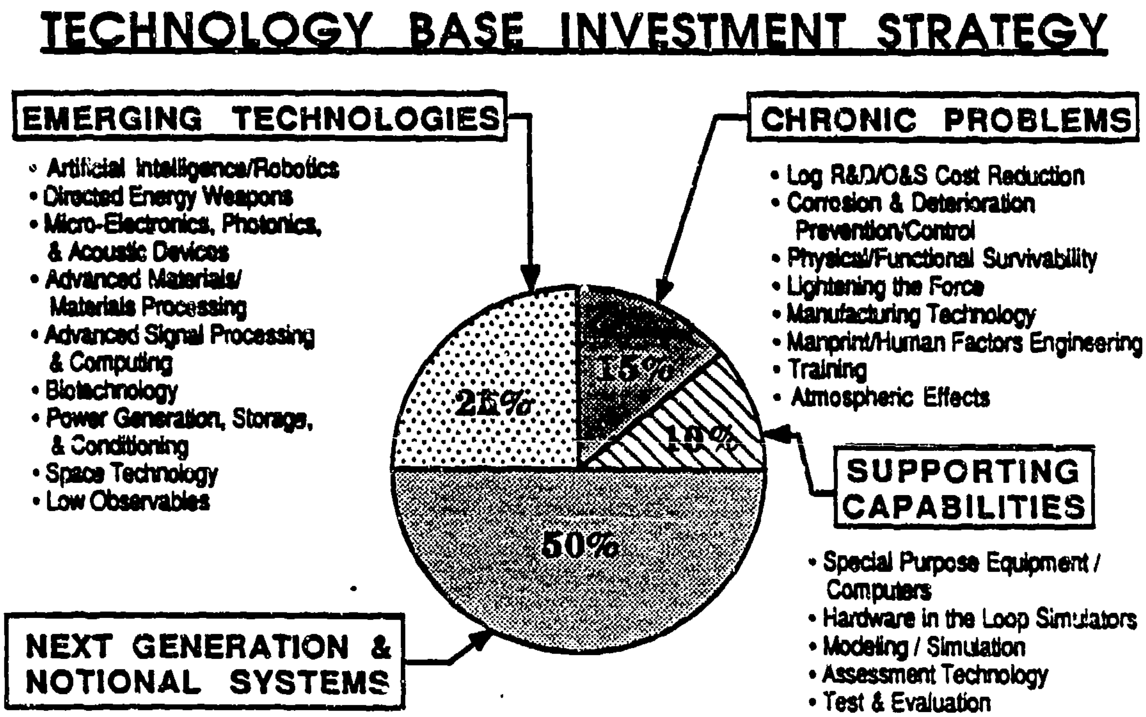
While the Commission was doing its work, efforts have been underway independently within the Army community to broaden and deepen the dialogue and information exchange between the developers of Army tactics and doctrine and the developers of the technology and hardware needed to implement the evolving concepts of operation. To this end, there has been much interchange between the Training and Doctrine Command's Airland Battle Future and Army 21 projects with the technology base community of the Army Materiel Command. This has resulted in sharper focus on both the feasibility and desirability of new concepts and new technology.

In recent years, the Army technology base program has been funded at a level of about one billion dollars per year. This tech base program, spanning research in academia to demonstrations with troops, contains efforts in many scientific disciplines and has applications to virtually all aspects of land combat operations. To both provide a common basis for discussion of the tech base program with the user, and to provide a means of targeting and pacing investments in technological areas considered crucial to the future of the Army, the tech base community has developed and articulated a Tech Base Investment Strategy (TBIS). This investment strategy has as its central goal the timely transition of technology developments in synchronization with the evolving tactics and force structures.

II. Background

The Tech Base Investment Strategy is graphically presented in Figure 1. In the TBIS, there are four main areas of investment: Emerging Technologies, Next Generation/Notional Systems, Chronic Problems, and Supporting Capabilities. An Emerging Technology is one in which the state of the art is rapidly changing and is projected to have a significant impact in both the military and commercial arenas. These technologies, listed in Figure 1, are further described in the Appendix 1 and Reference 2. Next Generation/Notional Systems (NG/NS) are those system concepts which are synthesized from available and projected technology to satisfy an identified military need or provide a new military capability. Within the TBIS, the NG/NS provide the systems perspective for tech base resource allocation. The Chronic Problem portion of the TBIS provides the focus needed in dealing with problems that over time have continuously limited the useful life or raised the life cycle cost of military hardware. Finally, the Supporting Capability category provides the investment focus for the unique facilities and instrumentation needed by the Army laboratories and RD&E centers to conduct military technology and systems development.

Figure 1



As the Army makes investments in technology development, there is a need to be able to project if, how, and when the emerging technology developments can be transformed and integrated into militarily useful systems. To address this need, the Army tech base community conducted an in-depth review of the emerging technologies during a two week conference held between February 22 to March 4, 1988. This Tech Base Investment Strategy Conference brought together government, industry, and academia subject matter experts to assess the state of the art of each of the emerging technologies and to synthesize in an unconstrained way, how these technologies might be integrated into notional systems to satisfy a future need or provide a new capability. A detailed description of the state of the art assessments and the notional systems conceptualized during the two week TBIS Conference are contained in the conference proceedings, Reference 3.

While a conference on the emerging technologies was seen as a necessary component of the process to sharpen the understanding of the state of the art in various technical areas, it was understood that it was insufficient for gaining insight to how these technologies could or would affect military operations on a future battlefield. Needed was a component in the investment process which allowed both technologists and doctrine developers to project and evaluate how the technological advances, and the embodying notional systems would contribute to war fighting capability. It was decided that this need could be satisfied through the "play" of a tech base war game tailored to explore the impact of the emerging technological capabilities in a future war situation.

III. The Tech Base War Game

SEMINAR WARGAMING

In general, wargames consist of a series of human decisions whose consequences are evaluated using some adjudication process. The adjudication process can be made highly deterministic by having the outcome determined by models and data bases designed before the game is started. On the other hand, the adjudication process can be made more interactive with the players themselves. This is the case of a seminar wargame.

Although using models and data bases to support analysis of outcomes, seminar wargames use the informed judgement of the players, from both sides of the game and/or the control element, to discuss and decide the possible outcomes of a decision. The discussion and decision take place within the context of a seminar where opposing sides describe why certain moves were made and what results were expected. After discussion, the umpire makes a decision and the next round of play takes place.

The purpose of the seminar type wargame is to gain insight into the issues at hand, with emphasis on learning the impact of various capabilities and decisions in the context of a typical scenario.

OBJECTIVES

The Tech Base War Game played at the Waterways Experiment Station was formulated to achieve three objectives:

1. Gain insights into the effectiveness and military utility of notional systems embodying emerging technologies;

2. Educate tech base managers on the interaction between war fighting scenarios, technology, strategy, and tactics; and

3. Expose military personnel to the potential of advanced technology.

The first objective was approached by embedding the notional systems in various parts and levels of the models used to calculate the results of operational moves on the part of the players. Thus, notional systems which were conceived as having a role in close combat were made part of the infantry or armor units that would be employed in a close combat operation. Where a notional system had no obvious precursor in the current force structure, units were created to accommodate them in a new force design. The war game models were reconfigured then to the projected notional systems. However, there were manpower and logistic constraints imposed on the total force structure so that the resulting total force did not exceed current levels and was representative of what was expected in the year 2015.

STAFFING

The second and third objectives were approached by having the tech base managers be the players in the game and having the military personnel from the Training and Doctrine Command serve as the advisors to the tech base managers during the play of the game.

Many of the emerging technologies can be applied to the activities of the various echelons of the military. Communications and sensor technologies pervade throughout the whole command and control architecture from the President down to the individual soldier. C^3I determines what and when the various command echelons know and do in the course of hostilities. It is also true that the use of some weapon systems, including where and when they are used, is limited by unilateral and multi-lateral political considerations. To accurately exercise both the span of technologies involved, as well as be sensitive to the limitations on their use, the game staffing was organized to play echelons from the National Command Authority down to brigade commanders. Table 1 provides a listing of the various Blue decision makers played in the game. Each of the indicated positions was staffed by a senior technology manager from the Army tech base community. Also, each of these positions was supported by a military advisor from TRADOC.

Table 1

Command Positions Played in Game

- National Command Authority
- Supreme Allied Command Europe
- Director, Central Intelligence
- 4th ATAF
- Central Army Group
- Corps Commander and Staff
- Division Commander and Staff
- Brigade Commander and Staff
- Space Advisor to the President

COMPUTER MODELS USED

While the primary output of this game was to be the seminar discussions among the players, to bound the pace and inject realism into the outcome of players decisions, the game play was supported through the use of two computer models. These models were the Strategic Analysis Simulation (SAS) and the Theater Analysis Model (TAM), References 4 and 5. SAS is both an educational tool and an analytical tool, which provides game players hands-on experience at global and theater level strategic planning across the spectrum from military operations to logistics. In the Tech Base Wargame, SAS was used to set the global context of the theater war in Europe, thereby putting limits on the resources-materiel, intelligence support, soldiers, and supplies that could be made available to the European conflict.

TAM was used to model the execution of operational orders that were developed as part of the play of the game. TAM uses maps of the area of conflict for planning purposes and for determining the occurrence of engagements between opposing forces. Based upon input data characterizing force structures and equipment in the opposing units, TAM calculates the outcome for each engagement. It is in this model that the characteristics of the notional systems were placed to modify the capabilities of Blue and Red equipments.

SAS and TAM were selected for this seminar war game for three reasons. First, each model has an established credibility within the DoD analysis community, especially as tools for evaluating the impact of new technologies and utilization strategies. Second, each model can be run with a minimum of computer hardware, making the logistic planning for a seminar wargame quite simple. Third, these models support easy modifications to the data used in the models so that "what if" exercises can be played during the course of the seminar game, making the play of the game very responsive to the creativity of the technologists and tacticians participating in the game.

SCENARIO

The play of the game was set in the year 2015, with the combat taking place in Europe between NATO and Soviet forces. Explicit assumptions about the adversaries, which set some of the parameters for the play of the game, are given in Table 2.

Table 2

Assumptions About the Adversaries in 2015

UNITED STATES (Blue Forces)	SOVIET UNION (Red Forces)
• Increased Reliance on High-Tech Weapons	• Economic and Industrial Improvements
• Limited SDI Deployed	• Widening Technology Gap
• Troops down by 25% in NATO	
• Military Budget Still Declining	

BOTH SIDES
• Low Intensity Conflict in Third World
• No Further Arms Control After 1988

The forces of the United States were assumed to have been modified and upgraded according to the set of Notional systems which were synthesized at the TBIS Conference. Those notional systems which were explicitly included in the Army force structure are listed in Appendix 2, along with an indication of what aspect of the system was entered into the models supporting the play of the game.* The forces of the Soviet Union were also assumed to have been improved over the course of time and the areas in which improvements were played are listed in Table 3.

Table 3

Soviet Force Enhancements Anticipated By 2015

GROUND	AIR	SPACE
Improved Combat Vehicles	Advanced Helicopters	Multi-tier ASAT
Advanced Engineering, Bridging, & Barriers	Enhanced Airborne Assault	Hourly Satellite Revisit Times
Improved Precision Deep Strike	Improved Active & Passive Sensors	Constellation of Multi-spectral Sensors
Increased Deception, Decoys	Advanced VSTOL	
Improved Troop Control/C^3I		

* More detailed descriptions of the Blue notional systems, their assumed performance parameters, and their impact on the TAM model are available from Headquarters, U. S. Laboratory Command, Attn: AMSLC-TP-PI.

BLUE FORCE CONCEPT OF OPERATIONS

With such overall qualitative changes in forces in mind, the Blue team developed a war fighting plan which employed elements of the notional system capabilities. Using the robotic combat systems, the long range weapons, and deception equipments, Blue's plan provided for conservation of troops in the forward combat areas and reserving the commitment of reserve forces till the objectives and success of Red attacks were known. The major points of the Blue war fighting plan are listed in Table 4.

Table 4

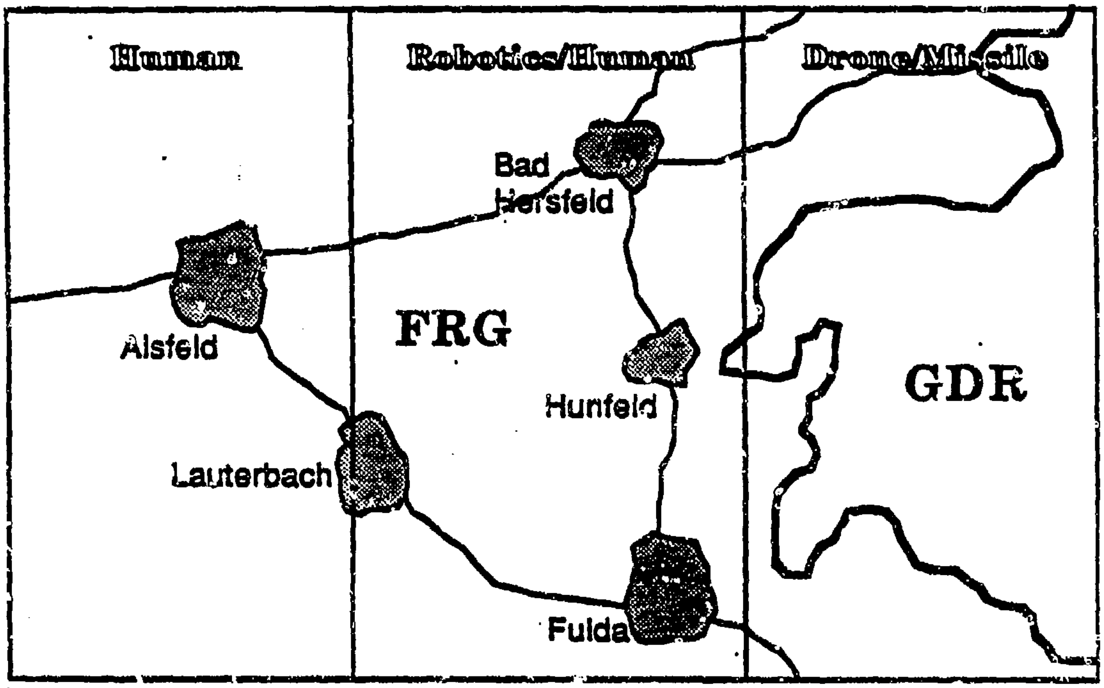
Major Elements Of Blue War Fighting Plan

- Barriers and forward deployed robots would be used to slow any major Red attack.
- A strategic reserve force would be retained for counterattacks in the CENTAG sector.
- Deception would be used to confuse Red as to real intentions for the use of the reserve.
- Long range fires and drone attacks would be directed at both the rear of the first echelon as well as the second echelon of Red forces.
- Critical Red C^3I and logistics points would be interdicted by long range fires and cavalry-type units.

The application of these planning guidelines resulted in a redefinition of the combat area as depicted in Figure 2. Essentially, the battle area was divided into three zones, each of which had unique characteristics as noted in the figure. The net result was that at the beginning of hostilities the forward edge of the battle area (FEBA) and the forward line of troops (FLOT) were widely separated. Essentially, the highest density of troops was in the area of the counterattack forces, while robots and a minimum of troops were used to establish a zone of "area denial" instead of an "area of occupation."

Figure 2

CONCEPT OF OPERATIONS



IV. Insights From Play Of The Game

INITIAL ENGAGEMENT

The play of ground combat operations began with a Soviet attack in the southern part of the sector defended by the United States Vth Corps forces, an area just north of Fulda. In this area, U.S. forces had deployed a complete complement of robotic weapons, smart barriers, and remotely operated high power microwave weapons. The barriers included anti-helicopter mines which, in coordination with other air defense systems prevented a simple overflight of the defended area. The robotic weapons, smart barriers, and long range precision fires succeeded in extracting heavy losses against the attacking Soviet divisions. Because the Blue war fighting plan called for a low density of troops forward, Red personnel losses were significantly higher than for Blue forces. The Red losses of men and equipment in the robot defended zone was sufficient to attrite and slow the attack in the southern area.

High power microwave weapons were targeted to produce at least soft kills against forward area C^3 and unshielded vehicles of the attacking force. This had the result that the attacking force had reduced ability to locate the robots, was unable to maintain reliable communications between attacking units, and lost effective artillery fire control to locate and service targets developed as the attack progressed. Red forces lost cohesion between units and between maneuver elements and supporting artillery.

Four characteristics of the robot/barrier defense were essential to its success. First, the robots and smart barrier systems needed a degree of HPM hardness that well exceeded that of the attacking force. This hardness was required to prevent fratricide against Blue equipments. Robots needed a capability to relocate during the course of an engagement so that the barrier could be re-established as losses were taken, and to respond to the specific points of attack by Red forces. Thirdly, to avoid losses to initial and supporting Red artillery attacks, Blue force elements needed a high degree of deception capability. Robots, barriers, and soldiers needed the ability to deceive Soviet sensor systems as to the real location of Blue force elements. Fourthly, to allow the passage of friendly forces through defended areas, robots and smart barriers needed to have either remote on/off control or very high confidence Identification-Friend or Foe (IFF) capabilities. Without such an on/off or IFF capability, timely withdrawal or counterattack would have been impossible.

COUNTER-ATTACK IN THE SOUTH

Red forces finally succeeded in breaching the area defended by robots and barriers and pushed westward. However, part of the Blue plan was to allow a penetration and then to use a deep strike brigade to counterattack the second echelon of the Red force. The deep strike brigade was committed to a flanking attack against the second echelon forces. This deep strike brigade was characterized by combat vehicles which were directly linked to reconnaissance systems, thus creating reconnaissance-strike complexes which were able to attack targets with very little delay after their identification. Contributing to the success of these reconnaissance-strike complexes was the ability of the combat vehicles to deliver indirect fires.

The force characteristics that led to the success of the counter-attack were high on-line personnel strength, and dispersed but netted command and control. High availability of the equipments of the counter-attack force depended on low maintenance and logistics requirements. The high availability of personnel for the counter-attack was achieved by having the robots and smart mines absorb the losses inflicted by the Red first echelon attack. In order to move the counter-attacking forces quickly and deceive the Red forces as to the point of the counter-attack, Blue forces needed a small battlefield signature. Reduction of logistic elements in the force as well as use of advanced low observable technology made such deception possible. Essential to the counter-attack operation was a C^3 architecture which provided no targetable nodes, which provided multiple path information distribution, and direct linkage between combat vehicles and reconnaissance assets.

THE OPERATIONAL COUNTER-ATTACK

As play of the game proceeded, it became evident that the 8th Mechanized Division of the US Vth Corps was able to contain the Red advances in the Fulda area, but a major breakthrough was about to occur in the area further north, defended by the Belgian Corps. The Red force penetration in this sector created an opportunity for Allied forces to conduct a counter-attack between the rear of the first echelon and the head of the second echelon of attacking Red forces. Fortunately, at the beginning of the game, SACEUR and CENTAG commander had held a two-division-plus force as theater reserve for just such an eventuality. A Blue two division counter-attack was launched into the flank of the Red attack.

To create the favorable conditions for a counterattack, SACEUR adjusted the corps boundaries so that VIIth Corps acquired the 8th Mechanized Division and responsibility for some of Vth Corps frontage near Fulda. This permitted using the division held in reserve near Frankfort to be used in the counterattack force in the area of Hanover. This, however, necessitated a road march of over 250 kilometers for this division. Using dedicated, on-call satellite surveillance of the Red force movements, CENTAG commander was able to ascertain the location and pace of the gap between the Red first and second echelons. This provided the timing of the Blue counterattack for maximum effectiveness and lowest vulnerability.

In conducting this counter-attack into the gap between Red first and second echelons, Blue forces had to make full use of the advanced technology characteristics of the Blue force. Long range precision fires, which had been held as an operational level reserve were committed against second echelon forces to both attrite and slow the second echelon. These fires came from throughout the theater rear area. (These long range systems were constrained from firing previously to prevent their detection by Red intelligence and their being attacked by Red air or long range fires.) This bought time for the counter-attacking forces to conduct a rapid road march from their positions well to the south of where the Red penetration had occurred. These long range fires had to be coordinated and delivered across corps areas, which relied upon distributed and responsive C^3I.

The movement of division size forces in sufficient time to attack the gap between the first and second echelons required a high rate of road march. This capability was provided by the fuel efficiencies expected in the force, by the availability of quickly deployable bridges, rapid pavement repair, and soil stabilization methods. However, all these advanced technologies were not sufficient to reduce the logistic load for a fast march. Division commanders eventually had to elect to leave non-combat logistic support behind and depend upon corps and theater to provide logistic support once the divisions were committed in the counter-attack.

Success of the counter-attack was dependent upon denying the Red forces an accurate knowledge of the whereabouts of the counter-attacking force. Blue utilized deception and camouflage to cause Red to think that the counter-attacking force was moving toward the northwest rather than preparing for an attack against the Red flank. The leaving behind by Blue of logistic support elements may have contributed to that deception.

STATUS AT THE END OF PLAY

The play of the game was halted on the eighth day of the war. At that point, the brigade size counter-attack in the south near Fulda, and the operational counter-attack in the north near Hanover had resulted in both Blue and Red forces existing in pockets. In both cases, the first echelon of Red forces were separated from their second echelons by Blue forces. But these Blue forces were also separated from their rear area support by the Red first echelons. This raised the question (at the end of the game play) of how such isolated units would be resupplied and sustained.

The situation at the end of game play also raised the question of C^3I support for the units which were isolated. In this game, maximum use was made of space C^3I support which was assumed to be available to every echelon. At the end of game play, it was assumed the actions of these forces would still be coordinated with the rest of the theater with such a C^3I net.

INSIGHTS FROM THE PLAY OF THE GAME

The use of robots to engage the enemy at the FEBA, with the first concentration of troops massed as a strike force behind the FEBA, appeared to be an effective concept of operations.

- **This reduced the number of troops on portions of the battlefield where vulnerability is usually the highest.**
- **To be more than just smart mines, robots had to be capable of both offensive and defensive application.**

The events of the game, the results of force-on-force calculations, and the adjustments to operational concepts and system characteristics that had to be assumed along the way, yield the insights and lessons learned from the game. The Blue concept of operations, that is the three zones of figure 2, proved to be an effective concept of operations if certain aspects of the robots and smart mine barriers could be achieved. Going into the game, certain lethality characteristics had been assumed, and these characteristics were needed to obtain the high attrition rates against the Red forces. But not foreseen before the play of the game were the necessary repair, rearm, replacement and mobility needed to allow both offensive and defensive application. As the counterattack in the Fulda area was planned, it became evident that the mines and robots had to have positive control to permit friendly passage of lines and avoid fratricide.

Remotely operated High Power Microwave systems appeared to offer the potential of significantly suppressing enemy C^3I in the combat area.

In the game, high power microwave systems appeared to provide significant leverage by disrupting the forward area C^3I of Red forces. But to make this effectiveness useful, Blue forces had to have a high degree of HPM protection, again to avoid fratricide.

Very long range precision fire systems provided significant increases in flexibility at the operational level through better use of distributed assets, substitution of fires for maneuver of units, and reduced forward logistics. Significant leverage was gained by munitions capable of being targeted across corps boundaries as well as deep attack of enemy rear areas.

Long range precision fire capability was found to be a decisive factor in several ways. First, long range precision fires were used to reduce the Red chemical attack capability by attacking the Red launch sites. This resulted in continued operation of Blue airfields. Second, long range fires were used to attrite second echelon forces as they moved behind the first echelon. Third, long range fires, fired across corps boundaries, were effective as a time responsive alternative to maneuver forces.

Robust, survivable C^3 and multi-source, integrated intelligence were indispensable to the effective use of the new technologies.

- **Connectivity had to be maintained to execute doctrine and tactics.**
- **Remote on/off control and/or IFF of smart mines was critical.**

To carry out the Blue concept of operations, and to prepare and conduct the counterattack operations near Fulda and Hanover, robust, survivable, and responsive C^3I was absolutely essential. The control of the robots and smart mines during the defensive phase of the war was necessary to assure their positioning and control as the Red force moved into the area. As the battle continued this robotic force had to be made part of the counterattack plans being executed by a brigade. Thus connectivity between echelons and laterally was an essential characteristic of C^3.

Accurate understanding of the situation on the battlefield and of the Red force intentions was dependent upon a multi-source, integrated intelligence capability. No one sensor system was capable of providing the data required to locate and track the enemy before and during the battle. To accomplish timely maneuvers and fire missions, executing units had to be directly connected to the intelligence production assets.

Operational and tactical deception played a major role in the conduct of the game.

Before hostilities began, Red forces successfully used deception and camouflage to mask their deployments prior to their attack. Blue forces depended upon low observable technology to mask the location of their forward defense zone and robotic systems. The operational counterattack depended on successfully denying knowledge of the movement of division size units through corps areas.

Increased operational mobility was critical on a battlefield where strike forces were located predominantly in reserve positions.

Tactical and operational mobility were critical to the Blue force successes. Robots needed cross country tactical mobility to be effective in brigade level defensive and offensive operations. High speed road march capability, provided by high efficiency engines, quickly deployable bridges, soil stabilization technology, and overall reduced consumption by the force, was needed to accomplish the operational counterattack at Hanover.

High capability sensors made movement, emission and firing very risky and amplified the impact of deception, low observables, and anti-sensor weapons.

The performance of sensor systems impacted both operational and tactical level plans and operations. The sensor system capabilities were such that operational and tactical plans had to take account of the likelihood that some sensor system would detect moving, shooting, or communicating units. Thus, for instance, Blue long range fire support systems were held till absolutely needed for the counter-attack. The success of Blue sensors in locating and tracking Red second echelon forces was a necessary condition for success of Blue operational and tactical counter-attacks.

A fragmented battlefield developed through use of barriers and counter-attacks, eroding the concept of frontlines, as the battle progressed.

The disposition of the forces at the end of the game highlighted both the potential and liability associated with highly mobile forces. Flank attacks into penetrating forces can result in loss of contact between elements. Pockets of major forces can be created, and these forces must be resupplied, controlled and supported with intelligence. Such battle outcomes emphasizes the need for logistic support systems not tied to a ground based line of communications, and the need for a C^3I system not dependent upon ground based facilities for continued connectivity.

A detailed review of the scenario, the tactical and operational maneuvers, and results in terms of movements of the forces and the FEBA and exchange ratios may be found in the final report of the Tech Base Seminar Wargame, Reference 6, prepared by Booz-Allen & Hamilton.

V. Implicit Assumptions

SPACE ASSETS IN THE PLAY OF THE GAME

The existence and use of space-based communications, reconnaissance, and anti-satellite capabilities, were assumed to be available to both sides. Early in the game hostilities, loss of a U.S. satellite due to unknown causes was the source of heightened state of defense readiness. However, active play of space assets, that is, the choosing of the deployments, scheduling and control of space asset missions, and the choosing of targets in space, were not an element of the game play for either Red or Blue forces. Instead, game control provided changes to the available space assets and defined what the space assets were or were not capable of doing during the course of the game. Game control provides, as part of the overall strategic scenario, a situation in which Red and Blue forces had a continuing degradation of space capabilities as the result of attacks by respective Red and Blue ASAT systems. In the game, Blue forces did have available the capability to launch on demand "CheapSats" which were responsive to the needs within a corps area of interest. Thus, even though some assets were taken out of play by control, there was an assumed ability to replace at least some for specific needs.

The play of the game by both the Red and Blue sides was predicated on each using their own space assets to develop operational alternatives, or on degrading the impact of the other side's space-based intelligence systems. Spoofing of space based reconnaissance was key to the success of the Blue strike brigade counter-attack in the south, as well as, for the operational level counter-attack in response to the Red penetration in the NORTHAG area. Thus, the mere presence of space based assets influenced the decisions on how to execute the ground combat plans.

Space communications assets were also assumed to be available to provide the C^3I connectivity required for the command and control of maneuver forces, as well as, for the timely operation of reconnaissance-strike systems against time sensitive targets. Not only was space based reconnaissance used in the development of targets, but space assets were used to provide parts of the communications network required to get target data to strike elements.

TWENTY-FOUR HOUR OPERATIONS

Notional systems to allow soldiers and units to work and fight in continuous operations were not explicitly played in the game. However, the counter-attacks and Red deployments of large units to achieve surprise assumed that technologies were available to enhance the performance and endurance of soldiers during continuous operations. The overall scenario opening the play of the game called for a reduced force structure in the theater by about 25%. None the less, the game called for defending fronts, and executing operations over the same distances as the 1988 force structure faces. To make this possible, soldier support systems, such as, feeding, clothing, and hygiene technology, must be available which will allow soldiers to work extended hours. Further, systems must be available which allow the individual soldier to do more. Robotic assisted logistics were assumed available in the rear areas to provide this capability. Similar soldier and unit performance enhancing techniques were required for the forces in contact.

As a result of Red chemical threat, Blue forces were required to operate in chemical protection gear. During the play of the game, it was assumed that there was no penalty in soldier performance or endurance while in chemical protective gear. Since chemical attacks were not on a large scale in the game, and the game ended after the fourteenth day, the real impact of such an assumption was not readily apparent. Generally speaking, chemical attacks were deemed only effective against personnel. Thus, robotic systems suffered no degradation in performance.

LOGISTICS SUPPORT THROUGHOUT THE BATTLE AREA

The play of the game was set in the context of global hostilities, and to that extent the Strategic Analysis Simulation was used to bound the logistic support available to the European theater. Further, the game play extended only over fourteen days of war. This had the effect that the availability of supplies to conduct the operations was never really a problem in the theater. There were always enough supplies in the theater. Further still, was the assumption that combat vehicles, weapon systems, communications, and the like had fuel economies and maintenance features which reduced the demand for logistic support in forward areas. All these factors combined to set a situation where logistics were not a determining factor in the overall game. This observation cannot, however, be applied to the planning of the operational level redeployment to counteract the Red penetration in the NORTHAG. To make that operational move, it was determined that combat units making that move did not have enough organic lift to make the road march if they had to carry enough supplies with them to sustain combat after they made contact with the Red force. This implies that for successful execution of such time sensitive redeployments by brigades and divisions, corps and theater must provide the logistic support to the redeploying units. Where deception and speed are key factors in success, higher echelons will probably be required to assume the burden of sustaining the force in contact.

A further observation should be made about the logistic support of units on a fragmented battlefield. While this did not become a problem during the play of the game itself, at the end of the game, there were large forces, both Red and Blue, which were cut off from logistic support lines. If operational level maneuvers result in such disjoint pockets of forces, there needs to be a resupply concept that sustains forces until "frontlines" are re-established or a truce is declared.

NATO INTEROPERABILITY

Execution of the operational counterattack in the area around Hanover relied upon unconstrained interoperability of communications, fire support, intelligence and logistics. German and U.S. forces attacked from the south, Belgian forces dealt with the Red first echelon attack on the west, and a U.S. division counterattacked from the north. This effort required the ability to share intelligence products, and to net and integrate the reconnaissance assets of one nation to the fire support systems of another nation.

Interoperability of command and control throughout the theater also was essential. This was particularly important where the U.S. counterattack forces from the south had to pass through areas defended by a German corps, and in the north where a U.S. division had to pass through areas defended by a British corps. To accomplish these operations, it had to be assumed that units could be recognized and resupplied as they passed through allied areas. Otherwise, the speed of the maneuvers would not have been fast enough to reach the gap between the Red first and second echelons.

VI. Relationship To Other Efforts

The structure of the Blue forces played in this tech base game was essentially determined by the results of the TBIS Conference where the state of the art was projected and applied to notional systems. When embedded in a war fighting scenario, certain attributes of these systems were exploited on the one hand, and their potential and real limitations were experienced on the other hand. By and large, the synthesis of notional systems out of the tech base and their "play" by technologists was uncoupled from developments in the national policy arena and on-going tactics and doctrine developments of the Training and Doctrine Command. Nonetheless, there appears to have developed a common thread between the insights from the wargame and the conclusions being reached in these other arenas.

The Commission on Integrated Long Term Strategy : es in their report four areas that they deemed "especially urgent":

"1. the integration of 'low observables' (Stealth) systems into our force posture;

2. 'smart' weapons – precision - guided munitions that combine long range and high accuracy;

3. ballistic missile defense; and

4. space capabilities for wartime operations."

(Reference 1, pg. 49)

During the play of the tech base game, each of these was found to be essential for successful land combat operations.

A review of the on-going Airland Battle Future concept development of TRADOC indicates that this effort is also highlighting some specific technical areas as being essential to the success of future land combat. System attributes which are emerging as common requirements of the various concepts being explored are the following (from Reference 7):

"(1) Dynamic (emplaced during battle) barriers, self-defending, on-off control, discriminating friend or foe (especially non-traditional - low sustainment).

(2) Low cost counterfire target acquisition system (active/passive] no less capable than Firefinder.

(3) A target acquisition means to locate 'silent' guns.

(4) *Significant IEW capability able to locate and disrupt threat C^2 - Army to regiment.*

(5) *Robust, redundant C^2 systems - long range.*

(6) *Reliable, lethal man/light vehicle portable antitank systems (mobility firepower kill acceptable).*

(7) *Accompanying air defense systems.*

(8) *Cheap, easily emplaced deception devices."*

The tech base wargame played as notional systems the direct equivalents of items 1, 4, 5, and 8. Capabilities 2 and 3 were assumed as part of the C^3I capability and item 6 was nearly equivalent to the forward area combat robots which had an antitank capability. No new ground based air defense systems were included in the game.

Thus, it may be concluded that the emerging technologies, and the notional systems they engender, are becoming a central element of the evolving strategy and doctrine of the United States.

VII. Next Steps

The insights gained from one wargame are not sufficient justification for making radical changes in doctrine or in development priorities. In the case of this tech base wargame, wherein the performance parameters used in the models were educated predictions of what the state of the art would be 20 years hence, there is a need to examine closely on how dependent successful operations were upon specific parameters. This is especially true with respect to the independence of action and mobility attributed to robotic weapon systems, as well as, the effectiveness of high power microwave systems in defeating enemy C^3I targets. Both of these were key capabilities in the planning and execution of Blue's war fighting plan.

This game also gave only one version of how events might evolve over time, given the specific starting conditions of hostilities. The same force structure and equipments used under different weather and terrain might have performed differently. In this game, robots and smart barriers were combined with terrain features to force enemy penetrations into preselected areas. Such use of barriers might not be possible where terrain and urbanization did not contribute to barrier effectiveness.

There are some next steps indicated. First, the game play and the consequences of decisions should be reviewed to ascertain what technical performance parameters weighed heavily upon the outcome of an action, both for Blue and Red forces. From such a review there can be identified which of the emerging technologies contributed to the outcome. Specific areas to be examined as a result of this game would be:

- Directed energy weaponry and protection therefrom
- Robotic systems,particularly independence of action based upon the utilization of artificial intelligence and cross-country mobility equivalent to that of future manned vehicles
- Establishment and maintenance of C^3I connectivity throughout the force and in particular from surveillance assets to strike assets.

Second, for the purposes of technology base planning and doctrinal development, a number of questions should be explored. These questions derive from the play of the game and the assumptions which were needed to execute the Blue concept of operations. The answers to these questions may be obtained in several ways – additional wargames, specific operations analyses, system feasibility analyses, intelligence studies, computer simulations, and simulations with soldiers such as the DARPA developed SIMNET. Some questions which have been identified to date, relative to key insights of the game, are listed in Table 5. This list is not exhaustive but points to the next level of issues which should be considered as further technology base investments are made in the emerging technologies.

In arriving at the answers to these questions, care has to be taken to project to the future and not be constrained by the policies, technology, and doctrine of today. Only then can the wargame insights shape the future.

Table 5

Questions Derived From Wargame

1. Use of Robots and Smart Barriers	• What level of robot survivability can be achieved? • What level of robot survivability is required for the kind of offense / defense operations played? • Are there combat functions that may not be "delegated" to a robot? • How do robots avoid fratricide? • How do robots discriminate between combatants and non-combatants? • What is feasible and useful ratio of soldiers to robots in a force? • Do robots really reduce overall personnel requirements in the force or merely change the mix of occupational specialties? • Do robots and smart mines introduce new interoperability issues? • What is the level of mobility required of a combat robot as compared to a tank, wheeled vehicle or foot soldier? • Are robots expendable or do they need repair, rearm, and resupply services? • How are smart wide area mines emplaced, controlled, and recovered? • What is the appropriate logistics support model for combat robots? • What are the failure modes of robotic units?
2. Use of High Power Microwave Weapons	• What is the effective range of forward area HPM weapons versus their mobility and logistic support requirements? • To what extent can enemy equipments be hardened against achievable HPM levels in a realistic scenario of use? • What effect will friendly and enemy HPM have on U.S. C3I and fire support? • At what echelon should HPM weapons be assigned and controlled? • Can HPM and robots/smart barriers coexist in the same battle area? • What targets are susceptible to HPM effects and under what conditions are HPM weapons effective? • How easily are HPM weapons targeted? • How survivable do HPM weapons need to be to have battlefield utility? • Can HPM weapons be remotely operated? • What are the personnel hazards associated with HPM systems? • Do HPM weapons introduce airspace control problems?

Table 5, Continued

Questions Derived From Wargame

3. Long Range Precision Fire Operations	• What are the targets of long range precision fire systems? • What types of warheads are required to attack the various possible targets? • What must be the range and capability of LRPF systems to be suitable substitutes for maneuver units? • What are the command and control issues associated with long range fires over adjacent commands, particularly non- U.S. commands? Are such systems equivalent to tactical air support? • At what echelon should LRPF units be assigned and controlled? • Can signature of LRPF units be reduced enough to avoid detection and location before firing? • What would enemy response be to Blue LRPF systems? • What must be the end game LRPF performance characteristics to minimize effectiveness of enemy defenses? • For operations in a NATO context, can the theater LRPF capability be provided by hardened, fixed site systems? • To support operations in the European theater, how many LRPF systems would be needed? • Should LRPF systems be considered a new capability, or as the evolving replacement for current artillery and tactical air support systems? • What must be the target acquisition to fire command data flow architecture to effectively use LRPF systems against time sensitive targets? • What are the trade-offs between range, size, effectiveness, survivability, and logistics supportability of LRPF systems? • What is the impact of weather on the use of LRPF systems? • Will long range precision missiles be in conflict with present and evolving arms control treaties?

Table 5, Continued

	Questions Derived From Wargame
4. Mobility at the Operational Level	• Can and should units held in reserve be designed with extra-ordinary battlefield mobility? • For what kind and size units can air mobility be substituted for ground mobility? • In the NATO theater, what factors other than hardware performance limit operational mobility of brigade and division size units? • For operations as played in the game, what are the trade-offs between unit mobility and combat basic loads? • How does unit signature vary with its battlefield mobility? • What are the technological limitations to the mobility of units engaged in operational level redeployments?
5. C^3I Architecture and Survivability	• What is the mix of ground, airborne, and space based communications assets needed to support the kind of operations played in the game? • What are the spectrum requirements of all the systems played or assumed in the play of the game? • What are the spectrum management implications of the capabilities played in the game? • Can and should all units have direct access (connectivity) to airborne and spaced communications? • To what extent can airborne and space based communications assets replace ground based equipments and units? • Given the extended fronts assigned to divisional units, as played in the game, what C^3I data and assets must be made available to such units? • What is the C^3I architecture necessary to support the Blue concept of operations embodying robots, smart barriers, and deep reserve counter-attack forces? • What are the command and control implications of lethal unmanned aerial vehicles? • What are the doctrinal and technological implications of reconnaissance-strike systems as played in the game? • What are the likely enemy responses to greater Blue use of airborne and spaced assets for C^3I? • Does the existent of disjoint forces, as seen at the end of game play, indicate the need for new C^3I concepts and equipments?

Table 5, Continued

	Questions Derived From Wargame
6. Deception and Low Observables	• What level of unit operational autonomy is needed preclude compromising the use of low observable technologies? • Are the operational and tactical deception capabilities feasible in view of Red sensor capabilities? • Will the use of low observable technologies and operational security discipline, by both Red and Blue forces, lead to more frequent, unexpected, and perhaps more violent meeting engagements?
7. Logistic Supportability	• How can large forces isolated from lines of communication be resupplied? • What unique talents are required to man and support robotic systems? • Is the expectation of reduced levels of personnel strength consistent with the logistics support system? • What is the balance between expendable and repairable high technology systems? • How can the civilian infrastructure be used to logistically support high technology systems? • Is the "tooth to tail" ratio in high technology forces an appropriate measure of force combat power? • Can deep reserves also function as part of logistic support resources?
8. Space Operations	• Can CheapSats be launched on order and in time to support Corps and Division level operations? • Can space assets be used to reduce logistic requirements in theater for Intelligence, C^3, RSTA, and weather support? • Is attack of space assets, manned or unmanned, an acceptable policy in a high intensity, but non-nuclear war? • Can control of dedicated theater space assets be accomplished from the CONUS? • Can a war in 2015 be successfully waged without space assets? • Can a war in 2015 be successfully waged without space control? • What is the lowest echelon that needs dedicated space assets?

Table 5, Continued

	Questions Derived From Wargame
9. Twenty-Four Hour Operations	• Is "24 hour" operation feasible in units with reduced personnel strength? • What soldier support will be available to make "24 hour" operations feasible? • How long can soldiers be committed to uninterrupted operations without physical or psychological breakdown? • Is the soldier the "weakest link" in "24 hour" operations? • Is "24 hour" operation possible while in chemical attack protection readiness?
10. NATO Interoperability	• Can the NATO infrastructure be used to supplement personnel strength? • Is interoperability of space assets, including spacecraft control, feasible within NATO? • Do autonomous robots and smart barrier systems introduce new C3 and IFF problems into the NATO theater?

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Appendix I

Description of the Emerging Technologies

ARTIFICIAL INTELLIGENCE / ROBOTICS

Artificial Intelligence (AI) employs computers and other systems to emulate human processes, such as, reasoning, analyzing, and recognizing. AI uses facts, rules of thumb, and past experiences to make inferences about the world or to recommend a course of action. Robotics is the technology of autonomously functioning systams, which sense the outside world, respond through a set of rules or Al, and control an actuator to achieve a desired purpose.

AI is expected to help the Army accelerate its pace of operations on the complex modern battlefield. It can enhance the Army's planning and decision-making process at many levels, leading to significant increases in force survivability, lethality, and agility with reduced manpower levels and overhead costs. AI is expected to significantly reduce decision cycle time when applied to command and control processes. It will make possible new capabilities in many areas. Robotics also has many potential applications, from advanced production facilities to autonomous weapon systems.

DIRECTED ENERGY

Directed Energy describes a diverse set of technologies capable of projecting energy in a narrow beam through the atmosphere. Potential military applications include weapons, sensors and communications. Directed Energy Weapons (DEW) use lasers, high-energy microwaves, or beams of charged or neutral particles to cause target damage ranging from temporary blinding of a person or an electronic sensor to instant catastrophic destruction. DEW efforts include both development of weapons and protection of US systems against enemy weapons. Laser communication allows very wide bandwidth transmission using very short bursts and narrow beams, which are extremely difficult to detect, intercept, or jam. Laser radar employs a narrow, focused beam of energy to sense and track objects. DEW offers important potential advantages, such as, speed-of-light attack (which the target cannot avoid by maneuver), multiple rapid shots, and unique terminal effects.

MICROELECTRONICS / PHOTONICS / ACOUSTICS

Microelectronics is the family of technologies which make it possible to put ever-increasing electronic capability in ever-smaller packages. Photonic and acoustic devices support further advances, making possible even more complex operations in small packages. Microelectronics is imbedded in almost all major systems, and advances in this area are particularly important to three other emerging technologies: AI/Robotics, Advanced Signal Processing/Computing, and Space Technology.

Continued research in this area is expected to lead to smaller, less expensive, more maintainable electronic systems with greater capacity; also to provide new capabilities which are impossible or impractical now, especially in the three emerging technologies noted above.

ADVANCED MATERIALS / MATERIALS PROCESSING

Advanced materials offer a number of different approaches to higher performance and/or lower cost weapons and support systems. Advanced materials include superconductors, organic and metal-matrix composites, high-strength fibers, and high-performance ceramics. Advanced processing enables the creation of new material properties (for example, rapid solidification produces glassy metals and alloys of metals which do not normally mix), and means for more rapid or economical fabrication of complex shapes through techniques, such as, vapor deposition, or molecular engineering of materials that can be readily processed. Advanced materials and processing methods can provide major improvements in performance, cost, reliability, and weight, and can replace critical materials available only from abroad.

ADVANCED SIGNAL PROCESSING / COMPUTING

Advanced signal processing is a set of technologies for manipulating electronic signals to extract information of interest which would normally be lost in noise, interference, or jamming. Advanced Computing is a set of technologies for designing and programming exceptionally powerful computers. Both are dependent on advances in Microelectronics/Photonics/Acoustic Technology. Advanced Signal Processing is needed to develop receivers which can intercept, identify, and direction-find advanced enemy communication and radar transmitters in the presence of many other friendly and threat emitters.

BIOTECHNOLOGY

Biotechnology is a diverse set of related technologies which exploit the rapidly advancing understanding of biological processes to control natural processes, and to achieve results which do not occur in nature. By coupling biological processes to electronic or other readouts, one can sense chemical agents or analyze blood chemistry. New vaccines or biologically active compounds can be synthesized.

Biotechnology is expected to provide the capability to develop new chemical agents, toxins, and disease agents, and also the potential capability to defend against all three. Soldier performance may be greatly enhanced by vaccines, protective or energizing compounds, enhanced nutrition, and other advances not yet conceived. Potential battlefield payoffs include increased tolerance for stress, including fatigue and extreme heat and cold, rapid wound repair and improved survivability, and ability to support extended field operations with highly condensed nutrients.

POWER GENERATION / STORAGE / CONDITIONING

Power Generation / Storage / Conditioning technologies enable the generation and delivery of electrical power of the right quality and quantity at the time it is needed. This technology area includes advanced generators, batteries, controls, and pulse power storage and waveform shaping devices.

SPACE TECHNOLOGY

Space technology involves the use of systems beyond the earth's atmosphere, whether temporarily or permanently. The space systems may be used to launch or control weapons; to scan, observe, and report battlefield positions; to transmit or generate signals or power; or to serve as platforms on which materials can be stored or released.

The space environment has not been fully exploited by the Army in terms of concept and use. It drastically enlarges the third dimension above the battlefield, and must be weighed in developing concepts fc·· the future. Whether directly or indirectly controlled, space-borne systems are expected to profoundly affect the outcome of future conflicts. By increased use of space-base communications, many support and staff functions may be transferred from the battlefield to the continental U.S.

LOW OBSERVABLES

Low observables are materials and systems that prevent detection and/or identification by the full range of battlefield sensors. Combinations of design and energy absorbing materials can be used to achieve "invisible" targets. It is foreseen that this technology may have the greatest effect on the Army. With the advent of smart weapons – and the next generation of brilliant weapons – the emphasis required on low observables will increase. The possibility of systems and soldiers that are more difficult to detect will also drastically affect operational concepts and tactics of the future. Low observables translate directly into improved survivability.

Appendix II

Notional Systems Considered for the War Game

COUNTERFORCE

UAMS (Unmanned Air Mobility System)
SEAMS (Special Electronics Air Mobility-System)
SAP (Semi-Autonomous Programmable Platform)
NLOS (Non-Line-of-Sight) Intelligent Mortar System
MAP (Medium Armored Platform)
HAP (Heavy Armored Platform)
Ground Based HPM (High Power Microwave)
Future Aerial Vehicles
DF/IDF (Direct Fire/Indirect Fire) Tank
Anti-Laser Screen
Airborne HPM (High Power Microwave)
AAMS (Attack Air Mobility System)
Arnold (Robotic Combat Vehicle)
L/R (Long Range) Missile System

C^3I

Distribution IEW Fusion System
Wide Area Information Transport System
Information Transport System
Integrated Intercept System
Integrated Sensor System
Local Area Information Transport System
Lower Echelon Information Management/C^2 System
Close-In Mine Detection Along LOC
Pos/Nav (Position/Navigation) System
Range Extension System

COUNTER C^3

Builder Block Decoy System
Camouflage Coatings for Weapon System Platforms
Information Denial System
Integrated Intercept
Integrated Jammer-System
Integrated Self-Protection System
Integrated Deception System
Line of Communication CCD Kits
Multi-Spectral Obscurant Systems
Multi-Spectral Tactical Camouflage Kits
Multi-Spectral Fixed Facility CCD System
SEAMS (Special Electronics-Air Mobility Systems)
Terrain Altering Enhanced Deception Kits
Tunable Dye Laser Generated Deception System
Activity Simulation System

BARRIER SYSTEMS

Aerial Loitering Mine
Airdrop Delivery System
Deadfall Mine System
Explosive Barrier System
Mud Obstacles
Tunnel and Bridge Denial System

COMBAT SUPPORT

Advanced Battlefield Protective Systems
GASP (Ground Automotive Support Platform)
LAMS (Logistics Air Mobility-System)
Logistic Over Shore
Mobile Breakwaters for LOTS Operations
Rapid Assessment Package for LOTS Operations
Soil Stabilization Systems
Structural Component Fabrication System
Survivable Structures
Logistics Over the Shore Throughput Planning Model

COUNTER CBR (Chemical, Biological, Radiological)

NBC Self-Stripping, Self-Decontaminating Coatings
Sorbent NBC Decontamination
Catalytic Emulsion NBC Decontamination System
Combat Vehicle Decontamination System
Semi-Autonomous Robotic CB Reconnaissance System
Close-In CB All Agent Micro Detector
Standoff CB Agent Detector