Defense Science Board
1996 Summer Study Task Force
on
Tactics and Technology for 21st Century Military Superiority

Volume 2
Part 1
Supporting Materials

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SUMMARY

Unless the U.S. is able to enhance the effectiveness of the military forces that it can very rapidly bring to bear in overseas crises it will have diminishing ability to influence events and protect its interests and commitments in the 21st century.

The reasons are spelled out in the 1995 DSB Summer Study which posited 21st century regional adversaries with the motives to accomplish their military goals quickly and the means to disrupt and delay U.S. Desert Shield-type military deployments to their neighborhood. Rapid and effective application of U.S. military force can prevent bad situations from becoming much worse and a demonstrated capability may help dissuade aggression in the first place. This 1996 DSB Summer Study on Tactics and Technology for 21st Century Military Superiority was tasked to identify how to make rapidly deployable forces more potent.

Based on its analysis, this Task Force believes that substantial, possibly revolutionary, enhancements of the effectiveness of rapidly deployable military forces are feasible. We believe that the concepts we explored in this study can be refined, tested, modified, shaped and evolved into fielded capabilities over the next 10-20 years. The Task Force believes that the technology can be brought to necessary maturity to enable new CONOPS and tactics during this time within reasonable resource expenditures.

Air- and sea-based firepower alone may well be sufficient to deal with certain military challenges confronting the U.S. in the 21st century. However, for both military and geopolitical reasons, many potential future military contingencies will offer critical early roles for U.S. ground forces in theater. These roles include integrating with coalition forces, complementing remote sensors by filling in gaps and resolving ambiguities, identifying noncombatants, securing points of debarkation for follow-on forces, temporarily controlling territory, locating and neutralizing weapons of mass destruction (WMD) capabilities, and preparing to make more permanent the gains achieved by long range precision strike. Thus, the conceptual approach outlined in this report provides for the rapid insertion of ground forces as well as for air- and sea-based firepower.

This expeditionary force concept will not deal with all future military contingencies. It would serve as a precursor force to help deter aggression, halt attacks, secure critical areas and in general prepare the way for the later arrival of more extensive forces. It could accomplish other missions, particularly those on the lower end of the conflict scale, on its own: getting in, doing the job and getting out quickly. It clearly is not intended for major offensive ground campaigns although the sort of rapidly deployable military capability we envision would contribute to avoiding the need to conduct such campaigns. The concept borrows features associated with Special Operations Forces (SOF) but its operations would in general be of a larger scale than the SOF's and be overt rather than covert.

The Task Force's concept exploits the enormous and barely scratched potential of emerging capabilities to provide theater wide situation understanding, effective remote fires and a robust interconnected information infrastructure. We use the term "situation understanding" throughout this report to represent the higher order knowledge obtained when situation awareness is combined with appropriate context and training.

We envision the integration of these capabilities with a ground force redesigned from the bottom up, starting with-the "combat cell," the smallest warfighting unit. The resultant ground force would be comprised of 10-20+ man light, agile combat cells and, depending on the operational environment, a helibome armed reconnaissance capability. Such combat cells would operate in highly dispersed postures, presenting few concentrated targets for the enemy. The combat cells could also coalesce into larger units when necessary. Initial analysis suggests that equipping the cells with organic vehicles significantly enhances their effectiveness and survivability. Stealth, situation understanding and information warfare will be vital ingredients in their survival kit. The concepts also call for extensive use of unmanned vehicles and robotics, and rely on a substantially reduced logistical footprint.

The Task Force believes considerably more attention to these ground combat cells is warranted. Light infantry, getting relatively little notice and resources from the Pentagon, has not changed much in capability over many decades but has great potential for enhancement if enabled by new tactics and technology.

A joint and distributed expeditionary task force — comprised of light and agile ground and air combat cells coupled to remote suites of sensors, weapons and information processors — can be a potent military force, able to take on missions (at least for limited duration) now requiring much larger and heavier forces on the ground:

- **New levels of situation understanding are necessary to enable effective remote fires and ground operations in widely dispersed postures.** It can be provided by sensor and information management suites able to do for the ground war what the Cooperative Engagement Capability (CEC), is beginning to do for the fleet air defense. The goal is to provide a comprehensive, shared, fire control (and combat identification) quality picture of the ground environment. The picture is derived by fusing the data (high resolution, multispectral, geometrically diverse) from multiple sensors on a variety of platforms from satellites, aircraft and unmanned aerial vehicles (UAVs) to unattended ground sensors and micro air vehicles. Management of this-diverse sensor suite and the information it produces will become a critical task for future theater and battlefield commanders. Traditional distinctions between intelligence and tactical surveillance will disappear.

- **This new expeditionary force will be dependent on remote fires that are effective against a variety of targets.** It will not be sufficient to merely rebase historical weights and rates of fire. The fire must be made much more efficient and the demand for emergency fire must be reduced. The keys to accomplishing these are affordable precision weapons and greatly enhanced situation understanding which will turn today's fleeting observations into tomorrow's tracked targets. With the appropriate ensemble of weapons, this will permit us to attack the enemy when he is most valuable and most vulnerable. Shortening the time of flight of the remote weapons will not, by itself, provide the requisite responsiveness and, thus, there will be important roles for loitering weapons and in-flight updates to incoming weapons. The remote fires could be delivered by land-based tactical aircraft if the bases are available and more generally by bombers and sea-based aircraft, missiles and long range guns. We envision an important role for armed UAVs as well.

- **A necessary foundation for this concept is a robust information infrastructure.** It must not only provide secure communication among the distributed participants but also geographical location, precise time, telemedicine and other functions. The multitiered communication network makes use of geosynchronous and low earth orbit satellites, aircraft and UAVs. The ground combatants' portal into this infrastructure will be a personal information ensemble based on commercial cellular technologies, able to provide paging, conferencing and even imaging services. Intelligent software agents will help manage both the operation of the network and the applications of the information that flows through it.

- **The robust wide band communication networks and enhanced situation understanding offer the potential for both more centralized control (the CINC can see "everything") and more decentralized empowerment (the combat cell commander can see what the CINC sees).** These capabilities can present future commanders both opportunities to exploit and tensions to resolve. A major challenge will be the exploration of the command relationships that best take advantage of these additional degrees of freedom. We will not be able to eliminate the fog of war. We can, however, provide the tools and training to help the combatants, from Joint Task Force commander to combat cell member, better deal with the uncertainty and chaos that will remain intrinsic to combat.

The Task Force explored and analyzed the concept in several environments — halting combined arms attacks, controlling territory in the presence of hostile militia and conducting operations in urban terrain. The results are discussed in the report and more detail is provided in Volume 2. While we do not expect that we got all or even most of the details right, they provide a starting point for further development and experimentation. The report also provides more detail on the systems and associated concepts of operation needed to provide the situation understanding, remote fires, information infrastructure and force insertion, extraction, sustainment and survivability. The substantial implications for training these expeditionary and dispersed force concepts are also discussed.

Several necessary conditions for the sort of revolutionary changes we envisage are already in place:

- **There is a compelling strategic rationale,**
- **The enabling technologies are maturing rapidly and,**
- **There are efforts now underway within the Services to explore such new warfighting concepts.**

What is missing are the organizations and processes necessary to test and evolve joint warfighting architectures for new concepts such as the distributed, expeditionary force concept proposed here: agile ground combat cells, coupled to

ensembles of distributed remote sensors and precision weapons, all interconnected by a robust information infrastructure and supported by smart logistics techniques.

The Task Force offers three sets of recommendations. The most important is to establish a joint effort and a "try before buy" environment to pursue these concepts. The joint effort, sponsored by the Secretary of Defense and the Chairman, JCS, would develop, test, analyze, and evolve these concepts through a series of experiments (to learn, not prove), supported by refocused simulation and analysis capabilities. Our adversaries will surely work hard and creatively to expose potential vulnerabilities in the distributed force concept. Furthermore, they will have access to much of the same technology that enables the concept. Their countermeasures will call for counter-countermeasures. Some of their responses may limit the applicability of the concept, others could prove to be more damaging to its basic viability. An energetic Red Team must be an integral part of the process to explore and develop these new warfighting concepts.

The second set of recommendations calls for support of critical enabling systems and mechanisms — many already ongoing, others new. These include making the USD(A&T) and the ASD (C^3I) the enforcers of the joint technical information architecture and providing funds to equip some of our light infantry forces with modern communication, navigation and targeting technology. The third set of recommendations calls for the establishment by 1998 of a joint operational task force to be the primary recipient of the products — tactics and technology — that evolve from the above efforts.

At the very least, pursuit of these concepts will yield potent multipliers for "standard" forces and tactics. There is a good chance that we can achieve dramatic increases in the effectiveness of rapidly deployable forces if redesigning the ground forces around the enhanced combat cell proves to be robust in many environments. There is some chance that all this will amount to a true revolution in military affairs by "eliminating the reliance of our forces on the logistics head as Blitzkrieg freed the offense after World War I from its then decades old reliance on the railhead." *

* From a presentation to the DSB Task Force by MG Robert H. Scales, USA, entitled "Modern Land Warfare Follows Technology Driven Cycles."

Forward

This report of the Defense Science Board Summer Study on Tactics and Technology for 21st Century Military Superiority includes three volumes. Volume 1 provides a summary of the principal findings and recommendations of this Task Force. This volume represents the consensus view of the Task Force along with supporting analytical results.

Volume 2 contains a set of supporting materials prepared by Task Force panels, or provided as inputs to this Task Force. Each section of Volume 2 is shown with its author(s).

Volume 3 is a collection of papers on relevant technologies. Some papers were prepared by Task Force members. Most were contributed by other experts in response to requests by the DSB Task Force. The author(s) for each paper is shown.

Table of Contents

Volume 1 - Final Report

(Under Separate Cover)

Volume 2 - Supporting Materials

Part 1 (Unclassified)

Table of Contents

Volume 2 - Supporting Materials

Part 2 (Classified) (Under Separate Cover)

Volume 3 - Technology White Papers
(Under Separate Cover)

I. DISTRIBUTED INFORMATION INFRASTRUCTURE

II. RECONNAISSANCE / SURVEILLANCE

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Volume 2, Part 1,
Conops 1 — Leading Edge Strike Force

Team 1 Report

LEADING EDGE STRIKE FORCE (LESTFOR)

LTG Jerry Granrud (Ret), Team Leader

TABLE OF CONTENTS

1. GENERAL CONCEPT

GENERAL CONCEPT

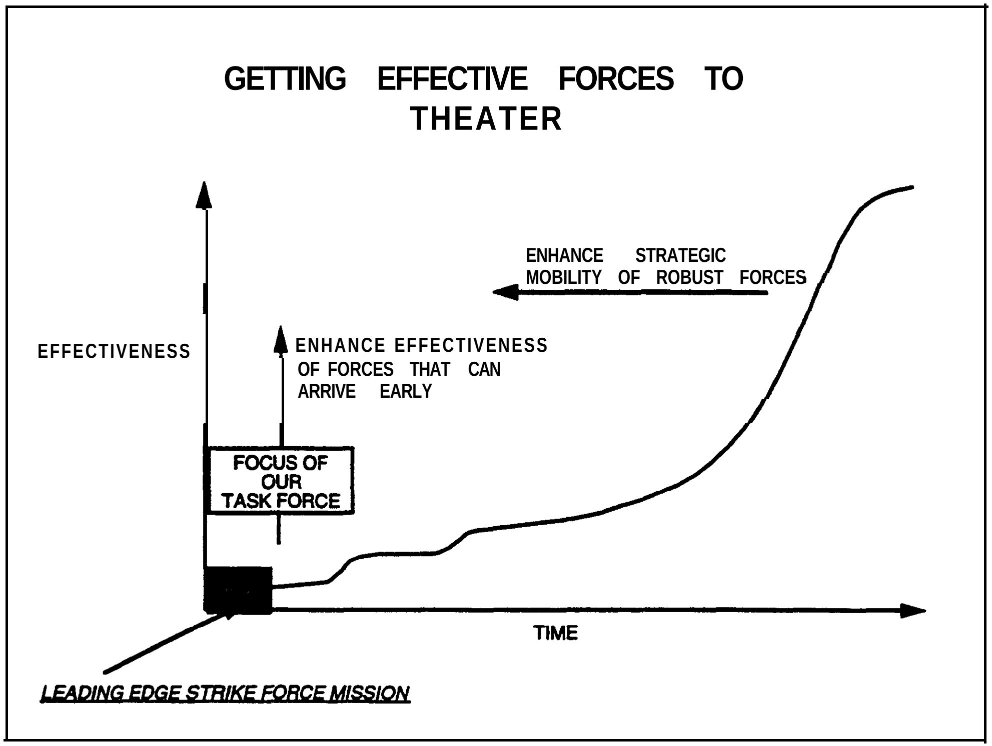
The US will employ limited but more effective ground forces in combat operations across the spectrum of conflict to implement its national military strategy. These enhanced units represent forces other than specialized reconnaissance forces or SOF. They are drawn from the general purpose forces and tailored into specific force packages as determined by mission, enemy, terrain, time and troops. They use standard service systems, not tools which are specially designed for specific missions. These units can then be reintegrated into the general purpose forces when the mission is concluded.

In a high intensity operational environment, units will not be expected to defeat in isolation a numerically superior and determined adversary. They will empower the larger, general purpose forces to which they belong to be more effective and efficient in prosecuting land warfare. These smaller forces will be employed to achieve the following operational objectives:

- Increase the nation's ability to project power
- Break up massed enemy forces, attack lines of communications, degrade C4I nodes, and destroy targeting capabilities.
- Establish the preconditions for gaining and maintaining control of the optempo
- Shape the battlefield so that our general purpose forces can be employed more effectively
- Supplement efforts to gain, maintain, and exploit information dominance
- Expand the dimensions of the battlespace so that the enemy must disperse his efforts in response
- Delay, disrupt and deceive the opposing forces
- Synergize our psychological warfare efforts
- Support conservation of our main forces by reducing exposure of our soldiers to casualties and by reducing the logistics requirements to sustain forces

OUR VISION FOR HIGHLY EFFECTIVE, RAPIDLY DEPLOYABLE FORCES IN THE 21st CENTURY

- A distributed force, only a part of which need be on the ground in theater, consisting of:
  - suite of sensors -- space, air, sea and ground-based — complementary processing to provide unprecedented situation awareness
  - suite of remote weapons effective against all targets
    - a capablllty to handle "leakers" with organic fires
  - a rapidly insertable ground force organized around "empowered" combat cells
  - a comprehensive & secure communications network linking the distributed forces to each other and to remote sensors, shooters and other resources
  - the means to achieve reaional air and sea dominance
  - A command structure able to manage all the above
- This distributed force is the initial JTF



The foundation of the types of forces and their requisite capabilities envisioned in this concept begins with this figure. Introducing the forces quickly and efficiently into the theater, with the requisite combat power to survive and accompanying logistics to sustain, is absolutely critical. In the future, the historical precedent of phasing forces, building stockpiles, and building sufficient combat power to engage a potential enemy force will no longer be adequate. Accordingly, the future force will have to arrive capable of fighting with what they bring. light enough to maneuver. strong enough to survive. and deep enough to sustain. Concepts of deployment will have to transcend notions of simply staging to being able to provide a near seamless transition from strategic, to operational, to tactical means of mobility. The following scenario provides a framework for illustrating how a Leading Edge Strike Force (LESTFOR) could be commissioned, organized, deployed, and fought in the 2015 time frame.

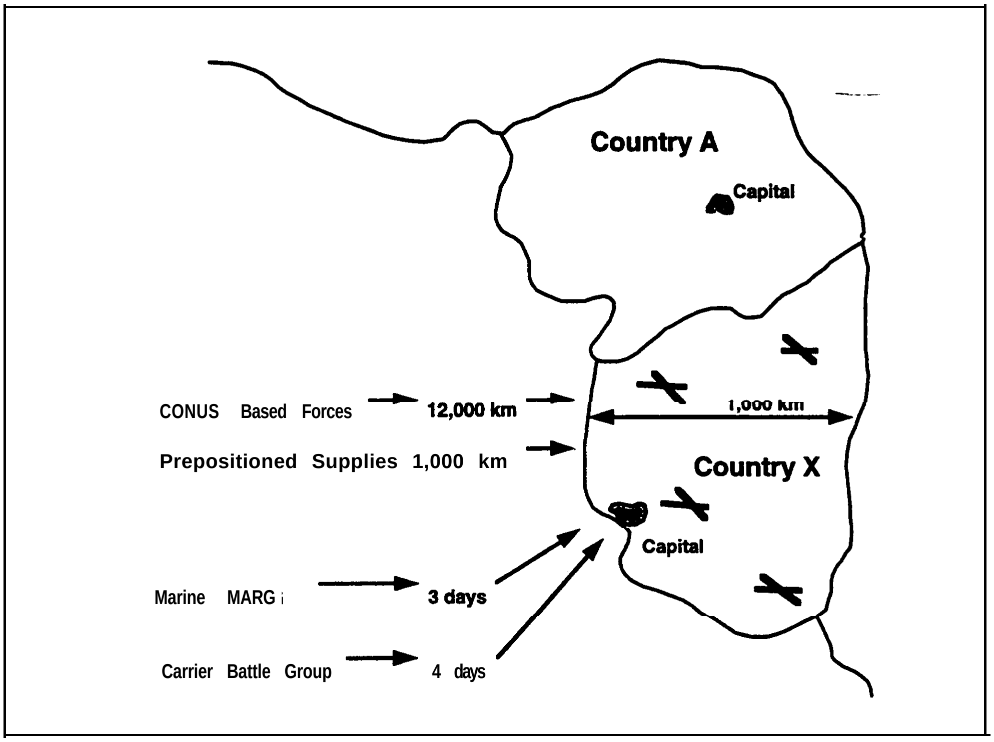
1.1 LESTFOR CONOPS Example

LESTFOR STRATEGIC REQUIREMENT

Following a series of incidents between Country A and Country X, the United States receives information that Country A is preparing to attack its neighbor within the next few days. The President determines that an immediate response by the U.S. to assist Country X is in the national interest and directs the Secretary of Defense to deploy ground combat power to protect air and sea entry ports and to deter an attack by Country A. Upon arrival in Country X, the deployed force must be immediately capable of conducting combat operations against a significant combined arms attack by Country A across the length of the common border between the two nations.

The estimate of-the situation by DoD determines that Country X will not be able to defend itself against the large armored force, supported by missiles and aircraft, which Country A possesses. The disparity in combat capability between the two nations indicates that Country A could achieve its objectives within 48 hours after launching an attack.

The U.S. has no prepositioned forces or equipment on the ground in the region. Country X has a littoral area approachable from the sea, but the nearest Maritime Amphibious Readiness Group (MARG) is 3 days from the theater and is currently engaged in a major peacekeeping effort. The closest carrier battle group is located to support the MARG peacekeeping action and is about 4 days from Country X. Air Force capability, both combat and support, is immediately available from CONUS, Europe, and Japan.



Note: See Annex A for a detailed description of the capabilities of the adversary nation — Country A

LESTFOR CONCEPT

To deploy an infantry brigade* by air from CONUS to Country X within 48 hours of notification.

LESTFOR MISSION

The mission of the brigade assigned as a leading edge strike force is to deploy about 5000 soldiers by air 12,000 km from the United States in order to establish an initial defense designed to act as a deterrent to imminent aggression by Country A. A key requirement is to prevent the seizure of theater strategic air and sea ports to enable the swift introduction of follow-on forces by air and sea. In concert with local forces and other joint forces as they arrive in theater, the LESTFOR will initiate combat operations to engage and delay enemy forces if deterrence fails. In summary

- Upon notification, deploy brigade with attachments to Country X
- Prepare defense to delay aggressor mechanized force if required
- In concert with indigenous forces, deter aggressor offensive operations
- If deterrence fails, initiate operations to engage and delay enemy forces
- Prevent seizure of theater strategic air and sea ports of debarkation (APOD/SPOD)

SCENARIO ASSUMPTIONS

ASSUMPTIONS

- **Accessible, relatively secure air and sea points of debarkation (APOD / SPOD)**
- **Air and sea superiority can be achieved**
- **Coalition warfare**
- **Indications and warning**
- **Deter by rapidly deploying**
- **Limit initial advance**
- **Exploit prepositioned forces and supplies**
- **Phased campaign**

The scenario is based upon a set of assumptions. It is assumed that the host nation (or a proximate friendly nation) will provide an accessible, relatively secure APOD/SPOD. It is also assumed that air and sea superiority can be achieved and that a political environment conducive to coalition warfare is in place. An indication and warning system (global and national) is assumed to provide a minimum of 48 hours preparation prior to the commencement of hostilities on the part of Country A. Finally, there is assumed a capability to exploit prepositioned armament, equipment and supplies, not in the

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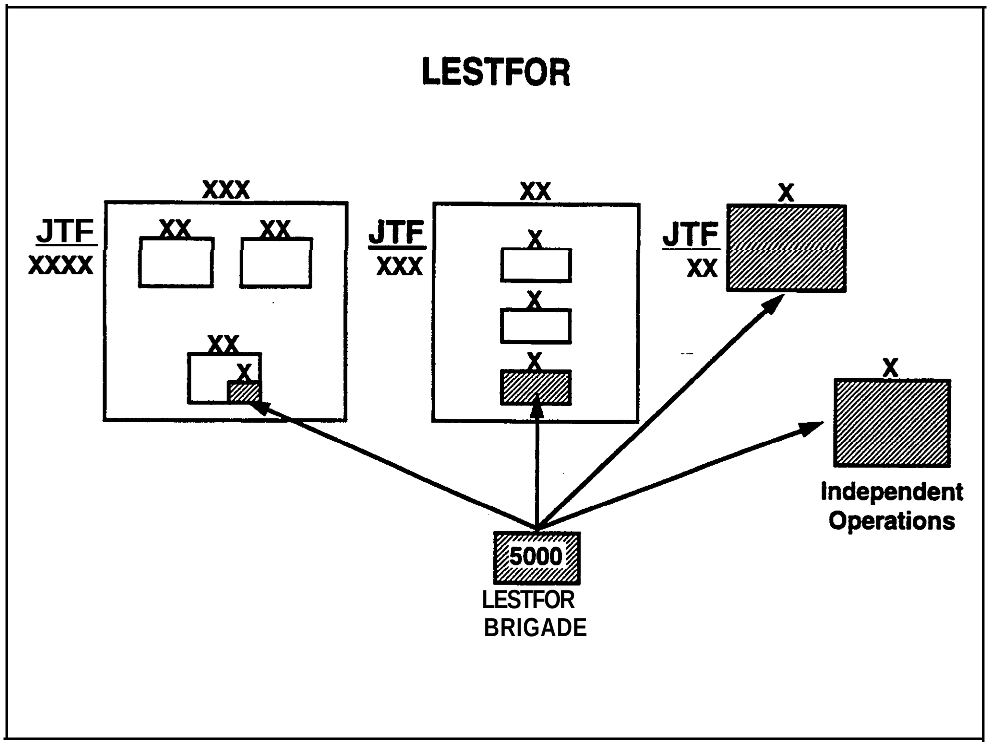
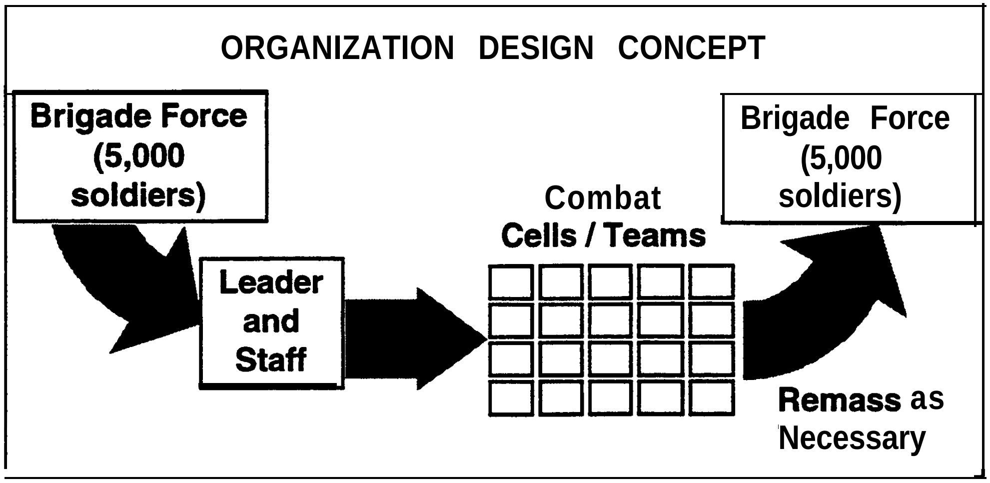
* BRIGADE--(DoD definition)-A unit usually smaller than a division to which are attached groups and/or battalions and smaller units to meet anticipated requirements.

immediate theater, but close enough to allow for their introduction once the LESTFOR is inserted.

ORGANIZATION

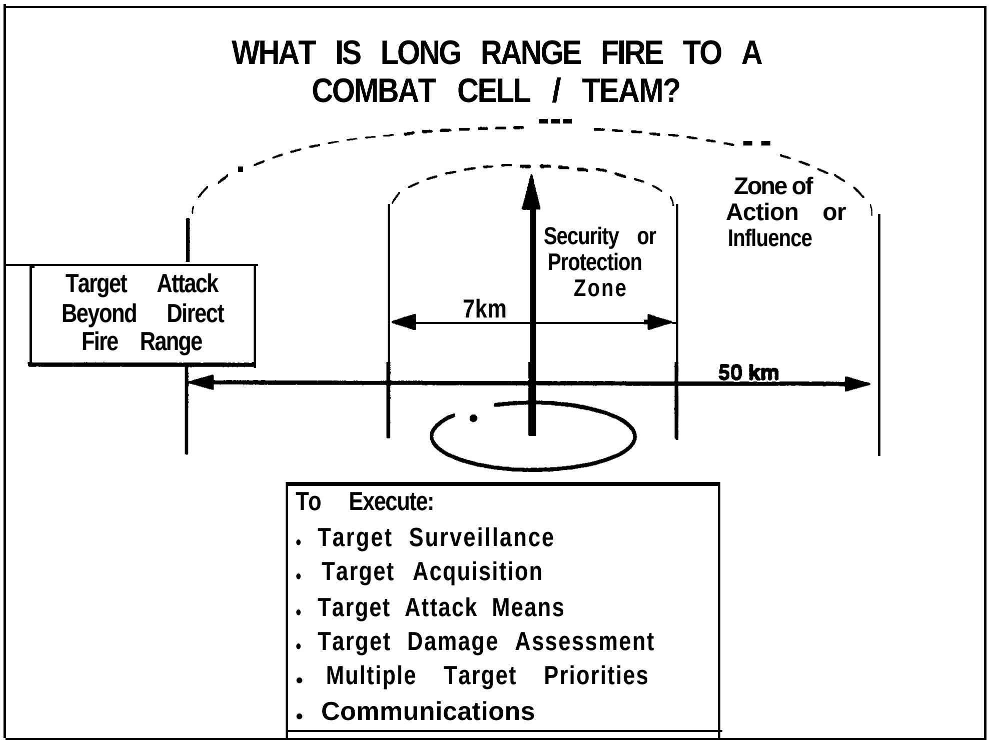


Forces available in the Continental United States (CONUS) are of two types — heavy and light. Because of the very rapid force projection time lines required in this scenario, the light force is initially selected because it can be transported more quickly as a coherent combat entity. This light Brigade LESTFOR is a component of a standard general purpose division — it is not specifically configured, equipped, or trained as a habitual leading edge task force. The capability of the Brigade to conduct this mission is the result of technology enhancements and doctrine and techniques which are widely available in the general purpose force structure. The two most important external resources are Advanced Reconnaissance, Surveillance, and Target Acquisition (RSTA) and non-organic long range fire support. However, it is both possible and likely that additional force capability, such as Psychological Operations and Civic Action units and rotary wing combat platforms will be added. Because of training techniques and technology, it will be possible to very quickly provide specific area and enemy operational information to the Brigade before, during, and after completion of the deployment to Country X. When the larger follow-on force is deployed in numbers capable of conducting dominant maneuver, the LESTFOR Brigade will return to its parent division.



By 2015, a LESTFOR brigade will be organized, equipped, and trained to fight as a highly dispersed force broken into a large number of combat cells/teams, coordinated and supported by battalion and brigade C^2 to enable the total force to extend its reach and combat power throughout an extended battle space. If required by enemy action as the battle develops, the teams can be reunited quickly into larger fighting formations to create sufficient combat power against major, concentrated enemy combined arms attacks. Force attributes include:

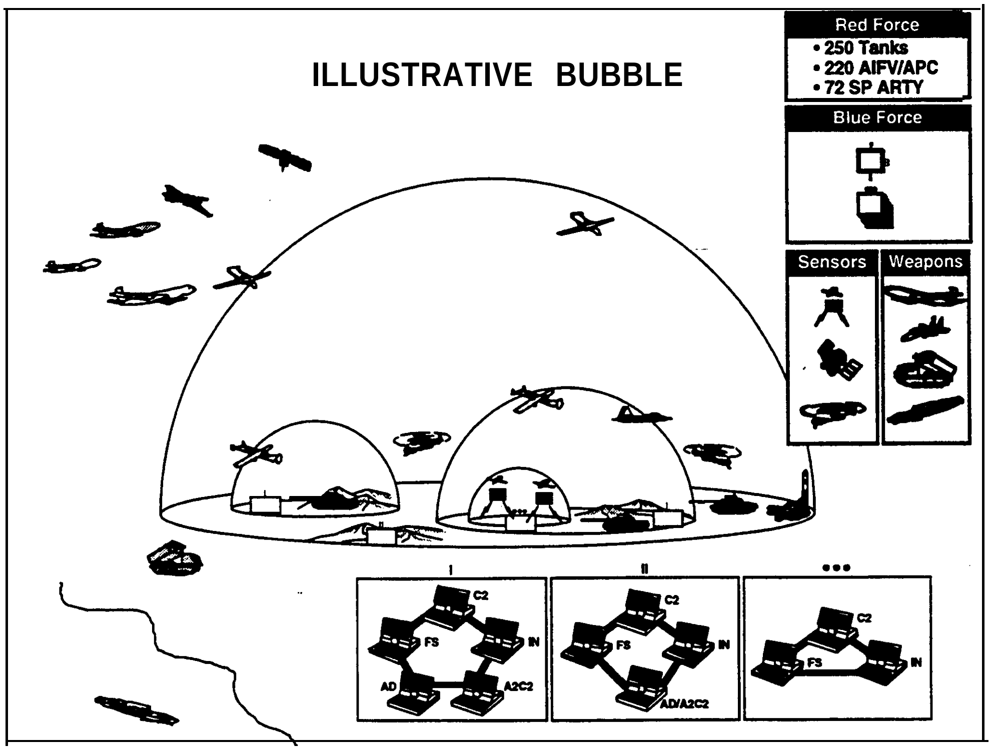
- combined arms synchronization capable at all levels
- all elements (team/cell to brigade) connected to the situational awareness infrastructure
- access to remote precision and massed fires from all joint platforms within range, down to the smallest team level
- flexible combat support tailoring and delivery
- reduced layers of command and control
- tactical mobility down to team level
- organic anti-armor direct fire capabilities
- medical support and evacuation not organic
- combat service support not part of deployed force



A 2015 combat cell or team could occupy an area of 7 km diameter. Within that security or protective zone the unit takes action(s) to protect and sustain itself. The unit uses precision resupply, direct fires, and appropriate security measures and mobility to achieve protection and security.

The team's zone of action or influence will extend to 50 km diameter. In this zone the team attacks beyond its direct fire capability. The team's responsibilities include RSTA and attack of targets in this zone. The team is enabled by a robust "tactical operational internet" (providing comprehensive situational awareness, communications, and intelligence) and long range precision fires.

The diagram below depicts the distribution of teams/cells against an armored force on the move. It provides a conceptual view of numbers of targets, sensors, weapons and command and control to execute such a concept. However, these systems rely on many steps to operate effectively--acquiring targets, passing information, assigning weapons, dispensing munitions, performing BDA, and many others. Each of these steps must function reliably for the concept to succeed.

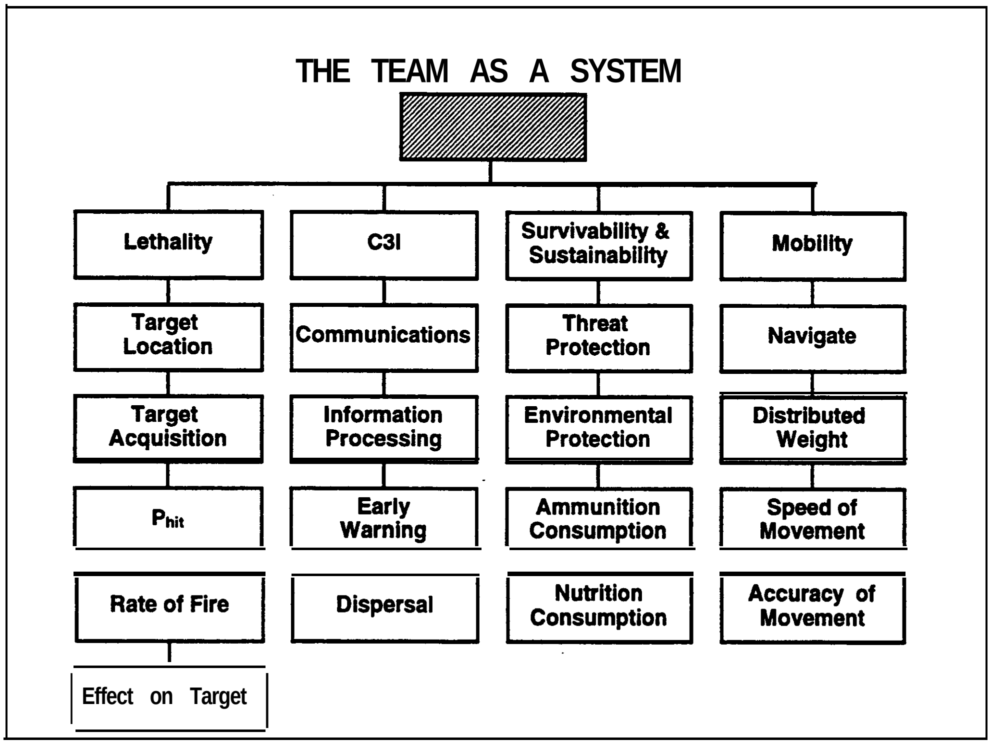


Operational capability at the team/cell level will be enabled by technology to reduce unknowns and build confidence. Teams will:

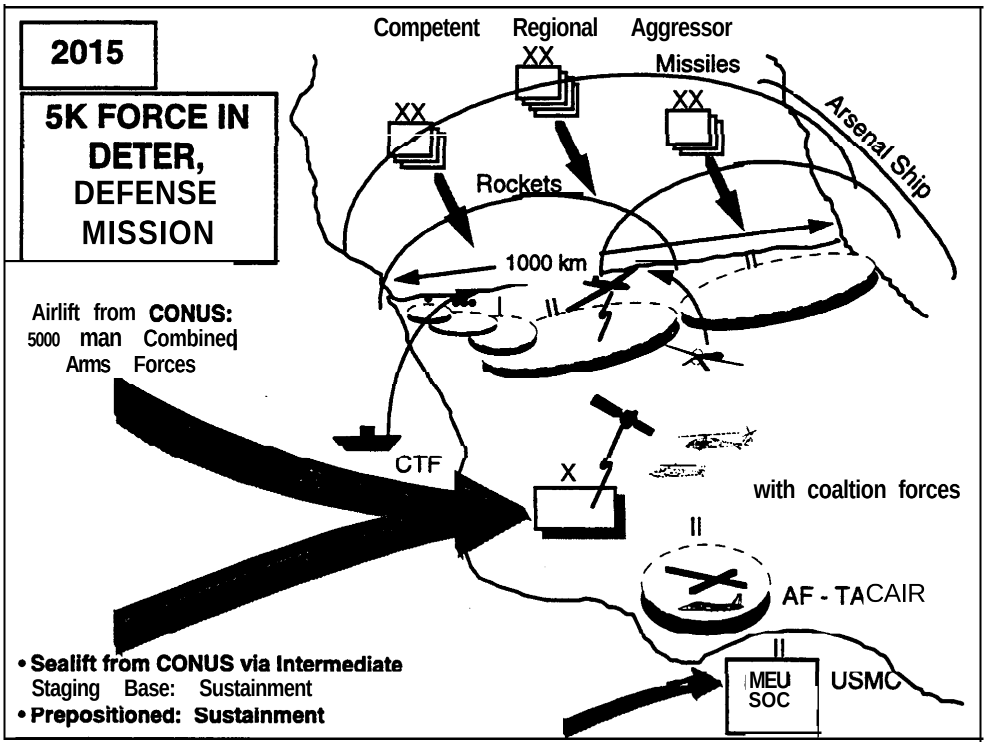
- Rehearse missions on virtual reality simulations of actual terrain
- Study real time video of the objective area
- Plan for and rehearse precision resupply enroute to objectives to reduce soldier load
- Use real time local language speech translators with HUMINT contacts and coalition partners
- Rehearse with remote precision fire systems
- "Fly" insertion/extraction missions with helo crews on virtual terrain simulators
- Have continuous link with friend/foe identification systems
- Have real time sensor input enroute to an objective and continuous update for "over the hill" terrain and enemy situation information
- Integrate with commander's real time mission tracking system

While the envisioned dispersal and disposition of small team forces brings an inherent degree of survivability, these factors also carry a significant vulnerability should those forces come under direct attack. For that reason, we must provide the future force with enhanced organic fires; enough to allow them to protect themselves during direct encounters with enemy forces, or to assist another small team in similar straits in close proximity. "Full force protection" must begin within the force. In addition to this, we must guarantee our teams a reliable means of exfiltration or tactical repositioning once contact with the enemy has been broken off.

Even with a sophisticated command and control infrastructure, and accurate and responsive fire support capability, the light infantry team, of whatever size, remains one of the most complex entities on the battlefield. The chart below helps to characterize this complexity and provides a model for analysis.



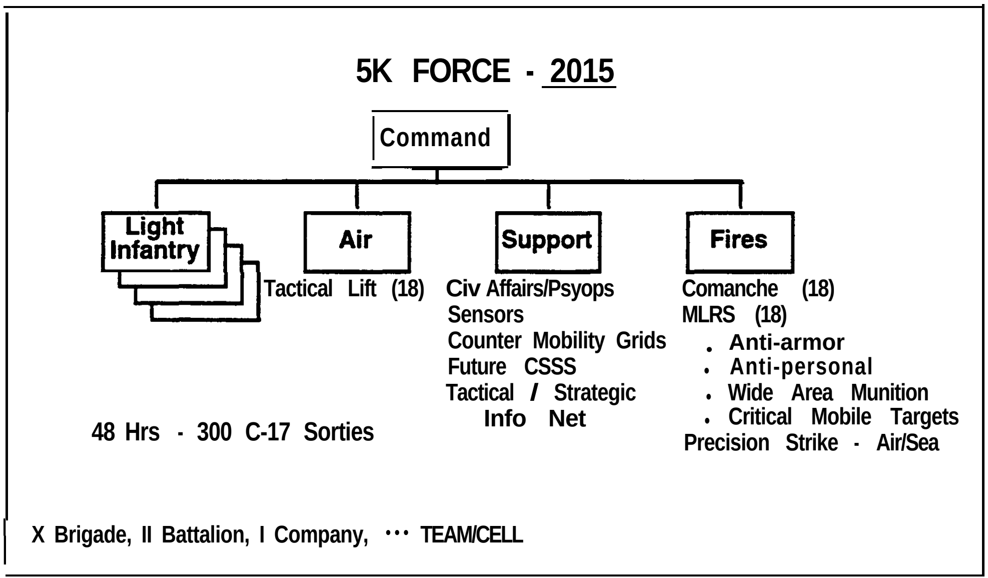
2. LESTFOR CONOPS



2015 — Brigade Type Force.

Examination of the conditions for dismounted "light" soldiers to defend against mobile armored formations has been the basis of our efforts in describing the array of technologies and tactics that will enable a 2015 force of 5,000 to achieve on that future battlefield what the 2d Brigade (Bde), 82nd Airborne (Abn) Division, was prepared to attempt with existing resources and support on 9 Aug. 1990.

The chart above depicts a notional deployment, in 48 hours, of our 2015 "Bde" size force (5,000), at the invitation of an ally, to defend against a "competent regional aggressor". It is opposed by an enemy force of potentially ten divisions across a front of 1,000 km. In terms of today's organizations, one squad of this future force will be expected to control/ deny to an advancing enemy at least 7-8 km of this front.



We have structured this 2015 force as shown above.

CONCEPT OF OPERATIONS - INITIAL OPERATIONS

- Brigade LESTFOR flows by C-17 (300± sorties) directly into country X (D - D+2)
- Disburse tailored integrated infantry / intell / engineer / psyop teams throughout country
- Establish sensor grid system
- Set up HUMINT system, begin reporting
- Integrate coalition forces and deploy to defensive positions
- Establish target lists and allocate attack systems
- Conduct battalion level rapid reaction operations (rehearsal / demonstration) with integrated force support
- Prepare on-call pre-emptive strikes
- Command and control elements (team through Brigade TF) will have
  - Early warning (UAV, sensor, HUMINT, national systems)
  - Virtual terrain information for mission preparation
  - Friend/foe identification
  - Subordinate element tracking during all operations
  - Precision tailored resupply to remote locations
  - Access to (pending approval to use) all joint indirect fire systems

The LESTFOR will flow into theater via C-17, directly into Country X. We anticipate this will require approximately 300 sorties. On arrival, tailored integrated "teams" would disperse throughout the country with the mission of establishing a sensor grid (including human sensors) while deploying to defensive positions with "coalition forces." From these positions, the coalition forces will begin to construct target lists and allocate attack-systems. Elements of the force will conduct battalion level rapid reaction operations (rehearsals and demonstrations) with integrated force-support in an effort to maximize their deterrent value against Country A forces. Should deterrence fail, LESTFOR units will have provided for that contingency with preparations for pre-emptive strikes by remote and inorganic fire assets, as they arrive in theater.

To facilitate these functions, C^4I elements, from Company through Brigade Task Force levels, will possess the following capabilities:

- early warning mechanisms (e.g., UAVs, integrated sensor systems, a HUMINT network, NTM);
- "Virtual Terrain Information" for mission analysis, preparation, and rehearsal;
- highly reliable IFF;
- all-weather, day or night subordinate element tracking;
- precision tailored resupply;
- access to (pending approval to use) all joint indirect fire systems.

CONCEPT OF OPERATIONS - FOLLOW-ON OPERATIONS

- **Having established information dominance and ability to move essential information throughout Task Force, combat elements will:**
  - **Deploy well forward**
  - **Engage in active recon / counter-recon**
  - **Improve combat capability and integration of coalition forces**
  - **Demonstrate resolve**

Operations at the soldier team level will be enhanced by technology to reduce unknowns and build confidence. Team leaders will

- Rehearse missions on virtual reality simulations of actual terrain
- Plan for and rehearse precision resupply enroute to objectives (reduce soldier load)
- Study real-time video of the objective
- Plan for use of high-tech translators with HUMINT contacts
- "Fly" insertion/extraction missions with helo crews on virtual terrain simulators
- Link with friend/foe identification systems
- Plan for pulling real-time sensor input enroute to the objective
- Integrate with commander's real-time mission tracking system

GOALS FOR A LEADING EDGE STRIKE FORCE

- The Leading Edge Strike Force, on the ground, is at least an order of magnitude more capable than a 1996 force of equivalent size
- Capable of a wide range of strategic missions including MOUT, control of large areas and halting combined arms attack
- Capable force in place in 48 hours
- Survive and fight for at least 2 weeks
- Reduce logistics load by 2 orders of magnitude by lavish employment of indirect fires and new sustainment concepts
- Generate new capabilities for the large forces as a spin-off
- Affordable
- Evolve over the next 20 years

Plus

- "Virtual" mission planning

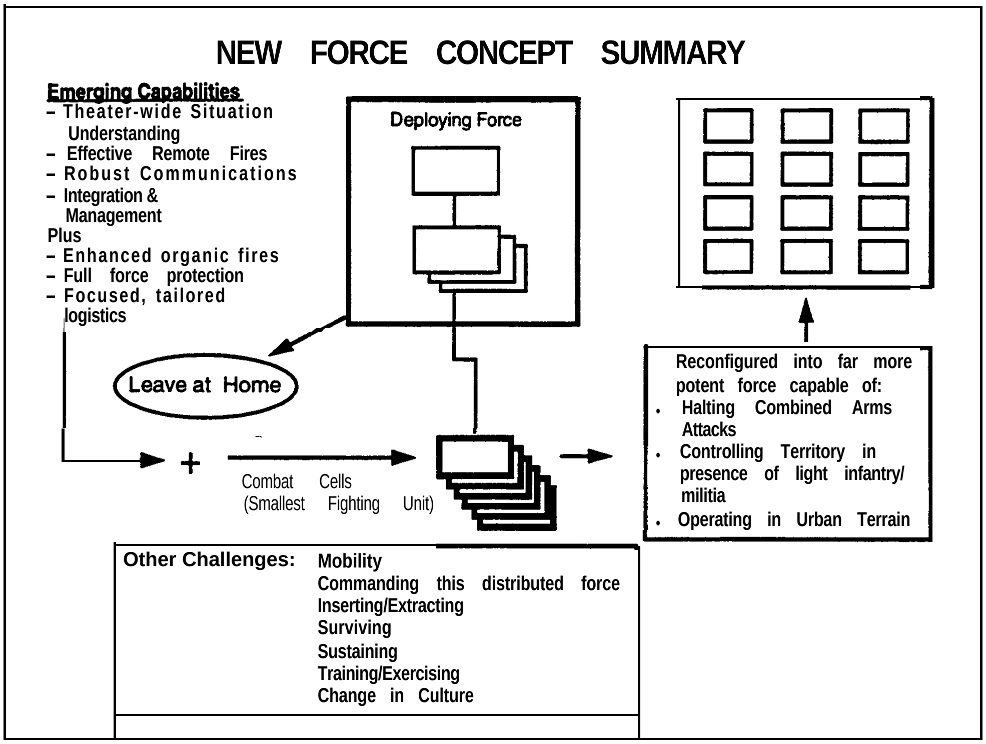
Our concept incorporates the goals envisioned for the LESTFOR as shown above.

CAPABILITY DIFFERENCES BETWEEN TODAY AND 2015 OPERATIONS (BDE THROUGH TEAM LEVEL)

Today	2015
Limited early warning	UAVs, array of netted sensors
Limited small unit comms with tasking commander (limited range FM radios)	Lightweight, long lasting, longer range family of radios
Limited terrain information (maps)	Virtual reality terrain displays
Limited HUMINT	Active HUMINT system with tagging & translation devices
Limited soldier resupply system (movement to contact soldier loads of 60-100 Ibs)	Precision enroute resupply
Limited access to long-range precision munitions	Digital access by teams (when authorized)
Limited commander tracking of multiple subordinate units	Real-time display of all friendly elements
Limited ability to see the objective	Real-time video of the objective

A Brigade LESTFOR today is not capable of conducting the 2015 mission proposed in the scenario. Regardless of the type of the operating elements deployed, improvements in the force are necessary across the spectrum of unit capabilities. For example, this chart provides a partial listing of current limitations followed by potential technology enhancements to overcome them.

Note: A historical example of a LESTFOR of 1990 is provided at Annex B for comparison.



The key to our concept of the deploying force lies in the combat cells/teams previously noted. They will provide for a fundamentally new organization on the future battlefield — capable of providing a distributed force signature from which to direct devastating fires, and able to rejoin as necessary with other cells to form up to a brigade sized unit with its accompanying organic combat capability. The individual team members who will make up these cells will be markedly empowered beyond the capabilities of their present day counterparts; not just in terms of improved systems and equipment, but also in terms of new training capabilities that will harness the potential of "virtual reality" technologies and other means of modeling and simulation. To a very large degree we intend to raise the level of preparedness and readiness of the conventional soldier and marine to a level previously associated with only our Special Operations Forces. The bridge between these will be technology — and particularly, training technologies.

3. SUPPORTING CONCEPTS / TECHNOLOGIES

The concept for deploying a LESTFOR against a competent regional aggressor as outlined in the foregoing sections encompasses every aspect of warfighting from command and control, through weapon employment; to supplying soldiers with food, water and medicine. However, the idea of empowering a very small force to become literally the combat equivalent of a current infantry division requires specific improvements in at least 4 or 5 functional areas. Most of these capabilities will be the product of ongoing modernizing initiatives of the Department of Defense which are not necessarily focused on this concept. However, without attention to specific technology and doctrinal changes which support this concept, the very complex interrelationship of capabilities required may not be developed in balance.

Specifically, the following functional areas must be appropriately understood and developed in order to execute the LESTFOR concept.

- Information Dominance, including
  - Command and Control
  - Combat ID
  - Electronic Warfare
  - Information Warfare
- Effective Remote Fires
  - Weapons/Munitions
  - Target Acquisition
  - Target Selection
  - Battle Image Assessment
- Force Protection
  - Organic Weapons for local protection
  - Counter Air/TBM
  - Protection against chemical and biological agents
- Movement of People, Materiel and Supplies
  - Strategic movement
  - Tactical mobility
- Mission Tailored Logistics
  - Food, Water
  - Munitions
  - Medical
- Training/Readiness
  - Before deployment
  - During movement
  - In combat operations

The following sections examine these functional requirements as they relate to enabling the concept leading edge strike force.

3.1 Information Dominance

LESTFOR REQUIREMENT

- **Control and shape the pace of battle**
- **Achieve overwhelming effect at precise time and place**
- **Rapid adaptation to fast changes in situation and environment**
- **Attack high priority targets throughout the battle space**
- **Conform to JTF commander's intent**

The LESTFOR concept depends upon the capability of U.S. forces to maintain a dominant advantage over the opposing force in its ability to know and understand the total battle space environment. Our knowledge of friendly, enemy, and neutral force status, location, capabilities, and intentions must be overwhelmingly superior in timeliness, accuracy, reliability, and accessibility to that of the opposing force. Information dominance will be a prerequisite to enable massive amounts of remote, precision fires to be delivered to a large number of small teams distributed widely across the battle space. Because there will remain a requirement for the JTF commander to formulate an overall plan for the area of operations, the information system must be able to distribute his intent down to all of the small teams for timely and effective team operations within the overall scheme of operations.

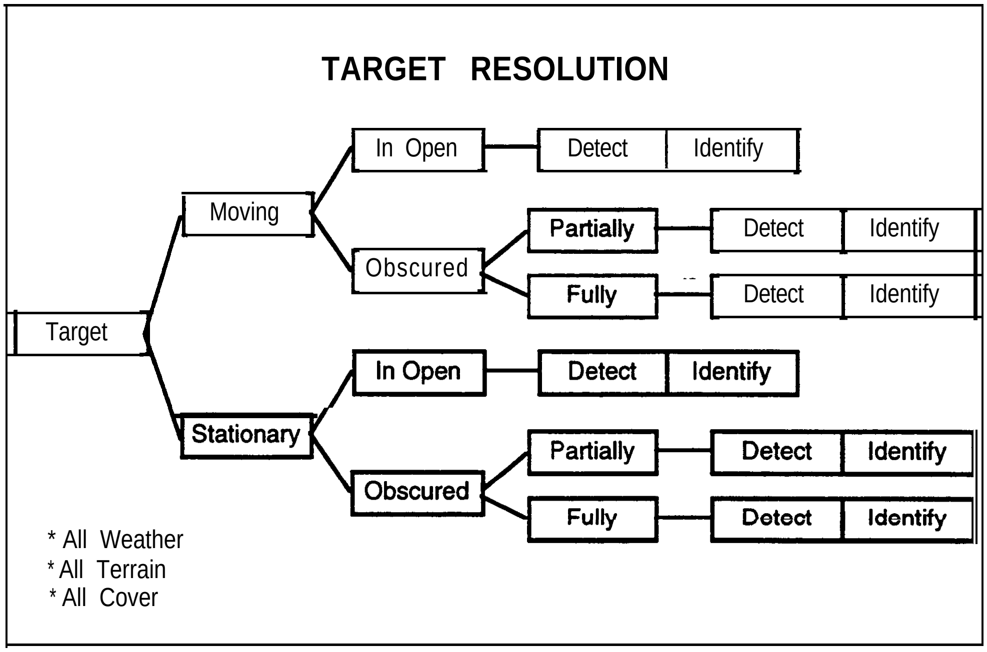
Information dominance in 2015 requires the seamless integration of intelligence, surveillance, reconnaissance (ISR) and command, control, communications (C^3) supported by a communications network which links the smallest team and the JTF command and control structure with the network of national, force level and organic sensors, data bases, and computational resources.

The LESTFOR concept outlined in this scenario will need all of the capabilities previously noted, but at the same time, space and time constraints severely limit what physical means can accompany the LESTFOR into Country X in order to create or use Information Dominance. For that reason alone, the technology enablers for information dominance must exist predominantly outside of the organic structure of the teams and even the Brigade. These organizations must be users rather than operators of the information dominance apparatus. In fact, the majority of the information dominance system will likely be physically located outside of Country X even after the force is deployed in country. Yet the system must be completely responsive to a massive amount of minute by minute individual team requirements which will characterize a distributed set of small teams executing combat tasks currently associated with much larger organizations. Because small teams have very little internal flexibility or robustness, systems provided to them must be continuously available and competent; system reliability in the face of enemy countermeasure, environmental stresses, and frequent changes in mission execution will have to reach levels of near perfection. Some indication of the level of capability required of an information system to support a LESTFOR concept is shown below.

OPERATIONAL CAPABILITIES

- Maps and video feature data transmission
  - Planning: 30 meter resolution, transmitted across all units in country within 20 minutes
  - Tactical targetting and BDA: 10 meter resolution, transmitted to specific units in real time
- Friendly and hostile mover awareness
  - 98 percent accuracy over a 4,000 square km area
  - Estimates of courses of action for designated targets within 5 minutes, 20 minutes for specific movers, and 6 hours for major forces
  - 100 percent identification of hostile and friendly status of any designated target
- Situational picture of part or all of area of operations to entire force, including coalition, within 1 minute

In this environment, target acquisition and assured identification of all targets for precision fires must be accomplished for each team on its timeline regardless of weather, terrain, or cover available to a target. Therefore, targeting systems and sensors must be able to achieve target resolution down to identification level for each target detected. The chart below highlights this requirement.



Target acquisition and resolution to support the concept of dispersed teams will require significant improvements in coverage, timeliness, and fidelity regardless of terrain, weather, or obscurity. The following appear to be very important areas for improvement:

- Foliage penetration with both MTI and SAR
- Near simultaneous multi-spectral coverage
- Passive/multi-static MTI/SAR
- Automatic target recognition
- Fusion and integrated target tracking

3.2 Remote Precision Fires

FIREPOWER

Today

- We use massive firepower and massive forces to deliver it. The use of situational assessment to focus on the most important tactical and operational targets is understood, but the current technology and techniques limit its utility. Firepower is controlled at the highest levels.

Future

- We will rapidly deploy smaller forces with limited organic firepower.
- We need the capability to rapidly understand tactical targets (and the criticality of the targets) on a real time basis to optimize the limited firepower that will be available to the leading edge force.
- We need to maximize the volume of firepower (organic and non-organic) available to small forces. Leading edge force must have the firepower to take out a critical mass of the targets that count using fires from organic sources, arsenal ships, arsenal aircraft, Air Force and Navy TACAIR, etc.
- Fire power must be immediately provided to a large number of small, dispersed combat teams which will conduct target acquisition and assignments, execute fire missions, and conduct Battle Damage Assessment (BDA).

CONCEPT FOR FIRES

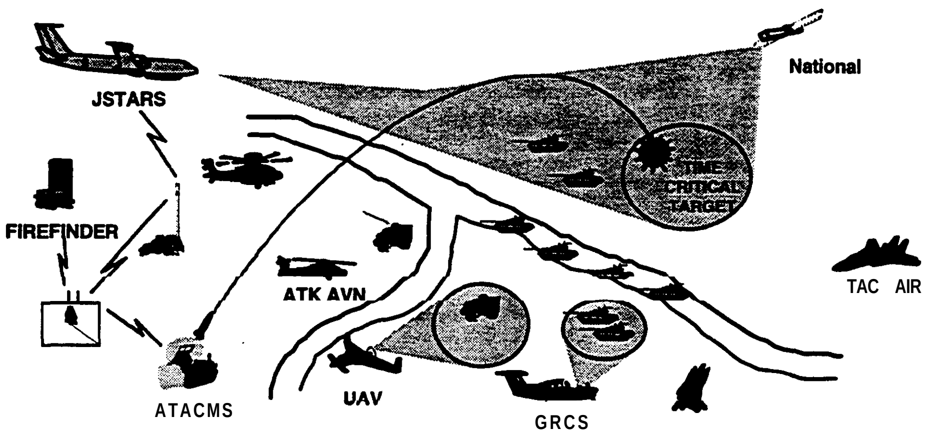
Key principles:

- Long-range precision fires from theater-wide systems - all services
- Theater-wide, integrated battle management and fire control system
  - Information dominance is key
- Discriminatory
  - Target selection
  - Volume of fires
  - Methods
- Limited Use of Direct Fires
- Widely dispersed "shooters"
  - Organic to ground force
  - Off-shore (arsenal ship, NSFS, arsenal aircraft, targetable submunitions, ground attack air)

Precision weapons engagement will require a system of systems that enables our forces to:

- Accurately locate the objective or target,
- Provide responsive command and control,
- Generate a desired effect, accurately assess our level of success,
- Retain the flexibility to re-engage with precision when required.

PROVIDE DISABLING FIRES TO GROUND FORCES TO ATTACK IN DEPTH

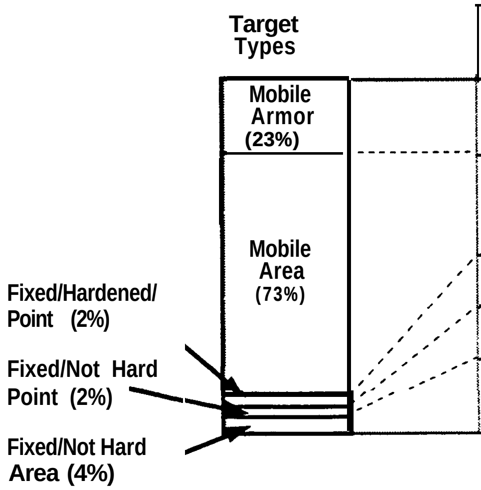


- Force must receive non-organic fires within the same timelines available with organic fire support with equal lethality
  - New C^2 — Joint operating environment — All forces, All systems
  - Enduring overwatch with lethal systems
- Provide large volume of fires to support multiple teams simultaneously — across total area of responsibility — Large, diverse target array
  - Numbers of rounds — inventory limited — can't kill everything
  - Prioritize to most critical need — automated systems response — Kill only the targets that count — when they count
- Provide massed fire on request to team level
  - Concentrate fires from
    - Different locations
    - Different means
- Prioritize target attack
  - Down to lowest echelon

Non-organic fire support from Army, Naval and Air Forces must be provided with the timeliness, volume, and lethality equivalence of organic firepower. Timeliness is a combination of situational awareness, weapon speed and target characteristics.

Augmentation of the teams with non-organic firepower in the concept envisioned will not give us the volume needed to precisely kill all targets. Non-lethal force may be a valuable tool in dealing with this issue. A major challenge will be to identify, categorize and determine which targets need to be the focus of the limited volume of lethal and non-lethal fire. Targets which count will also vary with time.

TARGETS REQUIRE MIX IN WARHEADS, DELIVERY ACCURACY, RESPONSIVENESS



Warhead type	Accuracy (CEP)	Quick Responsiveness
Anti-Armor Smart Submunition	3-50 m	Yes
Area Submunition, Smart Submunition	>10 m 3-50 m	Yes
Unitary Penetrator	<3 m	No
Unitary Blast	3-10 m	No
Unitary, Area Submunition	3-10 m >10 m	No

In the scenario we envision, many of the targets will be mobile, thus complicating the firepower / timeline problem.

The objective is not to kill all the targets (i.e. physical destruction of the force). The object is to defeat the enemy's plan by prioritizing the destruction of the force.

In a selective precision engagement process, high value targets are acquired and attacked early in an effort to disrupt planning and timing of the enemy plan. The entire high value target set is attacked to gain a simultaneous and paralyzing effect. A detailed RSTA plan / execution is required to achieve necessary precision. In addition, precision location terminal guidance and final adjustment is required.

In interactions where mass destruction is desired (e.g., emergency / "stop the force") and "general engagement" is necessary, a less precise RSTA and attack scheme can be followed using smart submunitions, smart bombs / projectiles, and missiles. Generally responsiveness is a function of the operational situation at hand.

COUNTER-MOBILITY

- LESTFOR mobility is enhanced by applying opposing force counter-mobility
- Counter-mobility means must be employed at depth
- Teams must have information about counter-mobility means and locations
- Counter-mobility means emplaced by remote platforms
- Remote sensing and response for team support
  - Provides enduring capability under operator control
  - Rich area for employment of non-lethal technologies

Enhanced mobility is a key element of the empowered team concept and thus achieving maximum mobility asymmetry on the battlefield is critical to the success of the concept. Countering enemy mobility at depth is largely accomplished by application of indirect fires as part of shaping the battlefield and closer-in by a combination of direct and indirect means. Remote (unattended) sensing and response fields can be deployed by these same systems to autonomously (or man-in-the-loop) counter enemy mobility. Once emplaced, these fields are effective for arbitrary periods of time under the control of the network operator.

REMOTE (UNATTENDED) SENSING AND RESPONSE CAPABILITY

- Distributed Unattended Sensor Fields
  - Distributed / emplaced by a variety of standoff and on the ground means — fire support and maneuver systems
  - Radar, IR (imaging / non-imaging), acoustic, aerosol, chem / bio (forensic)
- Effective netting of sensor field
  - RF, fiber
- Distributed Kill / Disablement (Non-lethal) / Response
  - Autonomous (automated sensor net to response)
  - Man-in-the-loop

Operational capabilities to support a concept of massive remote fire delivery to dispersed small teams will require automated recognition of thousands of targets per hour, weapon-target pairing of hundreds of targets per hour and robust multispectral, near ubiquitous, sensor availability. Real time battle damage assessment will be required to determine strike effectiveness because munitions cost will be a major factor in attack and reattack decisions. Operational capabilities available to the deployed force from Brigade level down to individual team level are provided in the chart below.

OPERATIONAL CAPABILITIES

- **Predictive planning system for target prioritization and attack**
- **Target update broadcasts for 2,000 targets per hour**
- **Automatic weaponeering and combat assessment for 500 targets per hour**
- **Critical situation reports and changes provided in less than one minute**
- **Target, force disposition information to teams within a 200 square mile area within 10 seconds**

CONCEPT FOR FIRES
ARMY / MARINE CORPS CONTRIBUTION

- **Rockets - MLRS**
- **ATACMS - BAT**
- **Helo**
  - **Apache Longbow**
  - **Comanche**
  - **AH-7 (4BW)**
- **Cannon**
  GPS / INS / Laser terminal guided rounds
  - **Crusader**
  - **LW 155**
- **UAV Local Area**
  - **MTI / SAR**
  - **FOLPEN**
- **Ground Recon Units**

The Army and Marine Corps provide fires to these units for fires in the security zone or protective zone and in the zone of action. The tactical intemet provides the means to support RSTA and communications requirements. UAVs, ground reconnaissance units and intelligence data links provide information and intelligence for fire support.

There appears to be a significant requirement for attack helicopters in support of small teams.

CONCEPT FOR FIRES
AIR FORCE CONTRIBUTION

- **Supporting Fires**
  - **Close Air Support**
  - **Air Interdiction**
  - **TBM Defense**
    - **BPI capability**
- **Munitions**
  - **with SFW / Area / Penetrator warheads**
  - **JDAM, JSOW, CBU, LGB**
- **Theater Surveillance & Targeting (Tactical)**
  - **JSTARS**
  - **AWACS**
  - **Links strategic and national sources**
  - **UAV - operational & strategic**
- **Comms and connectivity**

The Air Force will deliver air-launched supporting fires down to the team level. Also the Air Force will contribute to battlefield air superiority and operate airborne surveillance and targeting aircraft for deployed fires.

Leading edge teams will also get support from air fires in their security zone and zone of action. These fires are in primary mission areas: close air support, interdiction and TBM defense. Munitions to attack targets include: JDAM, JSOW, CBU and LGB. JSTARS and AWACS systems provide RSTA. Robust communications and computer links integrate air and ground systems — RSTA and delivery systems — into the operational intemet which provides the means to access and control those activities.

UAVs will undoubtedly be central to the target acquisition, attack and BDA processes. The availability of multi spectral sensors from UAVs from remote launch and recovery sites will be the principle source of fire support within the short time lines required for a LESTFOR deployment. UAV development and availability by 2015 could be the pacing item for a remote fire support concept in support of a LESTFOR.

CONCEPT FOR FIRES
NAVY CONTRIBUTION

- Fires support to land forces / TBMD / TAD / Strategic targets
  - T-Hawk / FAST HAWK / ATACMS / Future weapons / Standard Missiles
    - with SFW / BAT / Area / Penetration warheads
    - anti-TBM /air / cruise missile capability
  - Guns
    - 5” extended range 63 nmi / GPS
    - 155 mm vertical gun from arsenal ship / precision
  - Air Power
    - F/A aircraft for ground support / air defense
    - Helos / V-22 / AV-8B / Vertical Joint Strike Fighter
    - E2Cs / UAVs
  - Amphibious Force (ARG) w/ equipment & logistics support
  - SOF teams on submarines
- Targeting
  - Fully capable against fixed targets
  - Ground force / JSTAR / UAV input for tactical targets
  - Naval forces work with JWAC / National systems for TBMD / TAD

Many legacy Naval weapon systems such as Tomahawk and the Standard Missile system are available today to support the land battle. Upgrades and adaptation of these weapon systems such as the Naval version of ATACMS and later versions of the Tomahawk will provide significantly increased capability to support the land battle. Significant numbers of ATD and ACTD efforts such as Fast Hawk, 155mm Vertical Gun, smart 5” extended range munitions, and advanced Standard Missile combined with CEC offer the potential to significantly increase the Naval support of the land battle.

Joint strike programs such as JSOW and JDAM, and E2C upgrades, will increase the land battle support available from carrier aviation. The concept of the arsenal ship demonstrates a major transition in Naval forces toward support of the land battle and will be a necessary capability for the application of remote precision fires in a LESTFOR concept.

3.3 Force Protection/Survivability

PROTECT THE FORCE

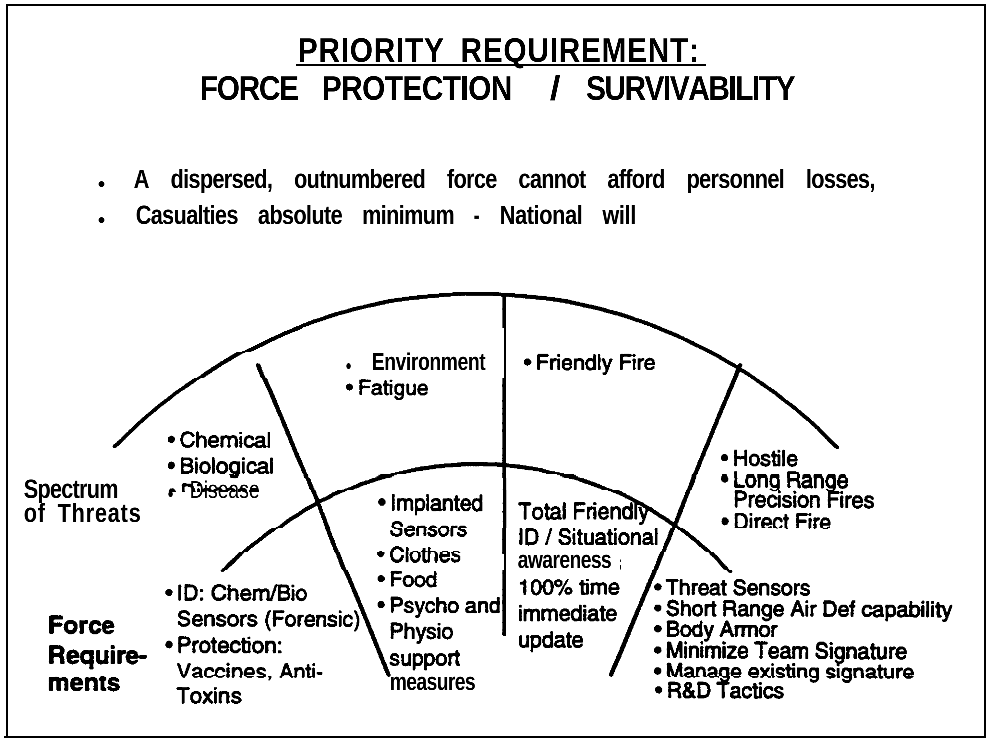
- Low priority in early stages for off-shore assets
- Reliance on info dominance
  - Don't be where the enemy is
- Best protection is to avoid detection
  - Signature control
  - Pulse strikes, then move, hide
- Deceive
  - Decoys
  - False information
  - Remote assets / remote emitters
- Self-defense
  - Thin-skinned vehicles
  - Excellent tactical mobility
  - Best available hand-held anti-armor
  - Best available point air defense
  - Organic bio-chem defense
- Prevent injury, fix immediately

The strengths of the LESTF'OR concept of dispersion, rapid delivery, high lethality, etc., are counter-balanced by several inherent weaknesses which must be addressed in order for the concept to work. Importantly, small teams have no redundancy and very little flexibility and their strength must be afforded a very high level of protection from harm and degradation. Battlefield casualty care is a key concern.

2015 - BATTLEFIELD CASUALTY CARE

- Retain greatest number within Force - reduce rate of attrition
- Immediate battlefield triage and treatment accomplished by
  - Limited number of battlefield Corpsmen
  - Implanted bio/med sensors
  - Remote medical analysis and support
  - Additional external data (video) provided by Corpsman
- Rapid evacuation as required

The chart below summarizes many of the factors which can quickly reduce a team/cell and render it ineffective. This is a major area of consideration for technological improvements from current capabilities and may well be the Achilles Heel of the concept of highly lethal small, dispersed force operations.



Force Protection/Survivability. Challenges to survivability include the following spectrum of threats.

(1) Chemical, biological, disease. Needs:
- Capabilities to identify - chemical/biological sensors.
- Protection - vaccines, anti-toxins.

(2) Environment, fatigue. Needs:
- Implanted sensors.
- Clothes and food.
- Psychological and physiological support measures.

(3) Friendly fire. Needs:
- Total friendly identification/situational awareness 100 percent of the time with immediate updates.

(4) Hostile direct and long range precision fires. Needs:
- Threat sensors.
- Short range air defense capability.
- Body armor
- Minimize team signature.
- Manage existing team signature.

Any protection / survivability requirement that can be met by non-organic forces will have to be done in that manner. Theater / air defense should be provided that way.

3.4 Mobility

CONCEPT FOR MOVEMENT/MOBILITY

- Deploy advance element to secure APOD
- Commence extended range RISTA operations (including use of NTM)
- Conduct air movement of initial force
- Deploy C3I infrastructure
- Begin air and sea movement of follow-on forces
- Deploy NSFS systems off shore
- Deploy mobility assets via sea and air (C-5, C-17, etc. plus prepo assets)
- Stage air and attack helo assets forward as required
- Prepare for reception at follow-on forces via APODs and SPODs
- Initiate CONUS-based log support ops

Ultimate Goal: To provide for a **near-seamless transition** from strategic, to operational, to tactical mobility.

The mobility objective for this LESTFOR concept is to

- reduce the weight of the expeditionary light combat forces (including their equipment and initial supplies) by a factor of two,
- transport a 5,000 troop light combat force 12,000 km (6,480 nm) from CONUS to theater within 2 days,
- self deploy intermediate lift vehicles for in-theater mobility,
- survivably move and supply force components within the theater (including assault) from sanctuary bases up to 1,000 nm distant,
- covertly insert / extract / rescue selected force elements at radii up to 1,000 nm from sanctuary bases within the theater, and
- survivably and dexterously reposition small teams within their zone of responsibility by team-organic means without undue logistics burden on the total in-theater force.

For perspective, a light combat force can be viewed as a future-configured Light Infantry Brigade with its equipment and initial supplies. Current load-out of a Light Brigade comprises approximately 5,000 troops, numerous intermediate lift and attack helicopters, wheeled vehicles for local mobility, artillery / ammunition and support equipment for a total of roughly 10,000 tons, 40 percent of which is viewed as combat and 60 percent support. For the future force, a shift to 80 percent combat and 20 percent support by removal of artillery (reliance on remotely-sourced indirect fire), self deployment of intermediate (in-theater) lift, lighter equipment, lower fuel consumption, etc., should cut the long haul lift requirement in half to approximately 5,000 tons.

As seen below, mobility can be broken into four categories for purposes of discussion:

- Global
- Theater
- Local
- Small Team Organic

Mobility for Light Force Personnel and Supplies

	Near-Term Examples	Future: Locomotion	Future: Survivability	Future: Control
Global Mobility				
Global Heavy Airlift	C-141, 5B, 17	soft field	—	—
Airborne Refueling Tankers	KC-135,10	hard field	—	—
Prepositioned Seaborne Supply	Prepo	sea	—	—
Prepositioned Land Supply	Prepo	land	—	—
Theater Mobility				
Intra Theater Lift	C-130	soft field	survivable	—
Assault & Combat Lift	CH-47, 53, MV-22	VTOL	survivable	
Deep Insert/Extract/Rescue	CV-22	VTOL	covert	—
Amphibious Assault Lift	LCAC, AAAV	amphib	—	—
Local Mobility				
Medium Trucks	MTTR, 5-ton	wheeled	—	—
Vertical Medium Truck	CH-60	VTOL	survivable	auto
Armored Transporter	LAV, M-113	wheeled	survivable	—
Light Transporter	HMMWV	wheeled	—	—
Small Team Organic Mobility				
Very Light Transporter	—	wheeled	survivable	—
Personal Cargo Adjunct	—	legged	survivable	auto
Vertical Jeep	—	VTOL	survivable	auto

U.S. forces currently possess functional capability (existing or near-term equipment and force levels) to perform each of the first three categories, even if somewhat slowly and inefficiently. For instance, C-141s, C-5Bs and C-17s can brute force the fast lift of a Light Brigade to the nominal 12,000 km (6,500 nm) radius within 3 days, but only with the added logistic burden of heavy tanker support and/or forward-based fuel. Similarly a combination of C-130s, CH-47/53s and V-22s can fairly quickly move personnel and equipment around in the theater (in both assault and support modes) assuming proximate bases normally within 200 nm of point of application. And finally, local mobility is obtainable through a traditional mix of medium trucks, CH-60s, lightly armored transporters and HMMWVs.

The last category of mobility (Small Team Organic), while presently receiving experimental attention by the SOF, has not received significant program support.

All of the first three categories of mobility face a common concern: diminution of sanctuaries in-theater and global forward basing because of political sensitivity or physical security risks. Fortunately all three categories can achieve (with development) a 2-3 fold increase in operating radius over the next 20 years due to increased propulsive efficiency, decreased structural weight, and laminar aerodynamics. This has the added beneficial effect of reducing the fuel logistics burden on all echelons.

Over the next 20 years, all of the last three categories (Theater, Local and Small Team Organic) face increasing combat exposure of support vehicles as a direct consequence of the projected improvement in enemy surveillance and precision fire, the non-linearity of the modern battlefield, the emphasis on infiltration by the enemy, and the recognized growth of violent indigenous dissidents or externally sourced terrorists. This will put a premium on in-theater support vehicle survivability through an economical mix of all-spectrum signature reduction, active detection countermeasures (ECM and decoys), and damage limitation measures (light armor and redundancy).

TEAM TACTICAL MOBILITY

All-terrain team-organic transport of sub-elements of the small team is a significant hole in the overall concept of small team functional capability. Traditional methods of sending intermediate lift helicopters from sanctuary bases out to move squads around will be increasingly difficult in the future because long transits from ever more remote bases will degrade time-responsiveness and subject the support lift to unnecessary survival risk. Lightweight, compact, wheeled organic transport may be ineffective for many terrain conditions.

Consequently, team-organic mobility could be helped by two new vehicles, both of which look comfortably feasible in the 2015 time frame:

- Mechanical cargo adjuncts all-terrain (possibly legged) autonomously controlled, remote command mules to enhance pack-carrying capacity
- Very light vertical jeeps: autonomous, commanded, low disk loading, foldable helicopters to give true all-terrain mobility, even in swamps, mountains, heavy foliage, and urban areas

Precisely because of the particular vulnerability of detected small teams, these vehicles should emphasize low observables (LO) more than the usual other survivability complements.

A second gap in capability is the covert insertion / extraction / rescue mobility function. The V-22 has neither the 1,000 nm unrefueled radius, nor the very low observables (VLO) needed to perform in the future improved enemy surveillance environment when sanctuary basing may be pushed back and over-flight rights denied by neighboring countries for political reasons.

Third, most future in-theater mobility assets (ground and air) will need much more attention paid to survivability measures and operating range for the reasons mentioned earlier.

Fourth, current heavy lift would benefit from a very feasible doubling of range capability to eliminate reliance on tankers for the long (nominally 6,500 nm) fast response, CONUS-embarked missions.

3.5 Logistics/Support

CONCEPT FOR SUPPORT - INITIAL ENTRY

- **Eliminate fixed logistics concentrations within range of enemy weapons**
- **Provide responsive (timely) resupply of food, fuel & ammunition to deployed small units. Implies**
  - **delivery by air in direct use packaging**
  - **highly competent comm/nav capabilities specifically for logistics**
- **Minimize ammunition requirements for deployed units by providing all supporting fires from remote platforms (e.g., ships at sea, aircraft operated from bases out of theater) real-time targeting and calls for fire are done by deployed units.**
- **Maintain support warehousing at sea in platforms from which direct delivery is executed. Implies**
  - **air capable platforms**
  - **ability to breakout and package to meet small unit needs**
  - **elimination of intermediate redistribution depots**
- **Logistics signature must not communicate (betray) tactical operations of the forces it supports**

National military strategy will change from one of a forward deployed presence to one of CONUS-based forces that must respond rapidly to operations anywhere in the world. As a result, the demands on the logistics systems have increased dramatically. The challenge for the LESTFOR concept is to project and sustain combat power sooner without relying on massive inventories and organic lift. The future logistics control system must support a vision of reliable sustained flow to the foxhole, analogous to the "just-in-time" inventory concepts within the private industry. A flexible and distributed logistics information system, integrated into the future information infrastructure, is an essential enabling capability, and probably the most significant condition for success.

REDUCED SUPPORT LIFT REQUIREMENT

Brigade Transport Requirements - Lift Allocation

	Combat	Support	Total
Today	40%	60%	100%
2015	80%	20%	100%

&

Reduce Support Lift Allocation by about 2/3

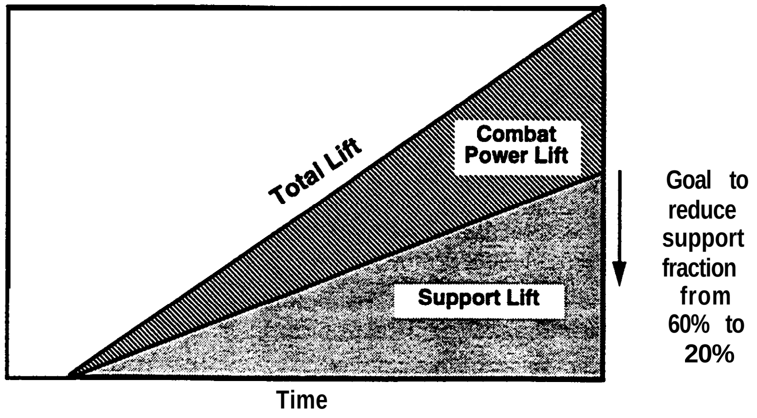
	Potential Reductions
• Sensors & Intel Function (Reachback)	>5%
• C4ISR Infrastructure	>5%
• Ammunition — Precision Technology & Theater Fires (Organic & Support)	15-20%
• Telemedicine and Biomedicine	>5%
• Logistics – Total Asset Visibility & Containers – Tailored Maintenance & Improved Reliability – Direct Precision Delivery & In-Theater Conversion • Food, Fuel, Water, Power	15%
• Reduced Tactical Mobility Footprint • Fuel, Power Supply, Materials	>10%

Today, movement of even light forces requires significant time and transport resources. Although each contingency will have a different schedule for deployment, as a general rule, a brigade requires a week, a division about a month, and a corps up to 3 months to completely close into an operational area.

This chart demonstrates two points. First, lift resources need to be reallocated to combat capability so that a deploying task force can begin competent combat operations immediately upon arrival in the operational area. And secondly, lift resources for support capabilities must be reduced overall to reallocate lift for direct combat capability, but at the same time providing adequate sustainment and support for the force to continue operations for an extended period.

In the 2015 scenario, the requirement is for the LESTFOR to close and be prepared to conduct combat operations within 48 hours. Similarly, in the future, goals for larger units will also become more demanding, e.g., one week for a division and one month for a corps to complete a deployment to a contingency area.

ALLOCATION OF LIFT BETWEEN COMBAT POWER AND SUPPORT



The overall LESTFOR logistics concept takes into account three general considerations:

1. The logistics support concept must enable the concept of dispersed, high-tempo operations to be executed.
2. It should reduce the fraction of strategic lift dedicated to support. (This will permit the fraction contributing to combat power to be increased. It has been proposed that the ratio of combat power to support can be increased from the current level of about 40:60 to nearer 80:20.) The figure above shows how such reductions in lift fraction requirements can be viewed equivalent to investments in strategic lift capacity.
3. The support provided must allow the LESTFOR to fight efficiently for at least 2 weeks.

With the level of lift constrained, future force effectiveness could be improved by changes to any of a number of logistics factors, to reduce the fraction of strategic lift dedicated to support. These include:

- Ammunition
- Maintenance
- Supplies
- Medical

Each of these is discussed in turn below.

Ammunition

"Outsourcing" of at least the heaviest fire support is key. Of course, this is one of the most often cited factors in arguing for the overall concept. As fire support is made remote, ammunition flows forward are reduced, and forward-located dumps and other stocks are scaled down in size and vulnerability. This in turn provides a cascade of other benefits, including a reduced requirement for ammunition transportation vehicles (ammunition is currently the largest single load demand on the tactical vehicle fleet) and fuel for those vehicles. Also, fewer resources would presumably be diverted to defend convoys and dumps, and greater flexibility achieved for nonlinear engagements (since the requirement to sustain literal lines of supply would be reduced).

Maintenance

Improved equipment reliability will reduce the number of maintenance personnel, and reduce the flow of spares and reparable. The reduced flows have the same advantages as attributed to ammunition, above.

More radical improvements in the maintenance burden could be realized by the application of "tele-maintenance" approaches, assuming sufficient connectivity was in place. These approaches could include:

- Remotely monitored vehicle performance
- Remote adjustment of equipment operating parameters
- Failure prediction
- Remote technician/tutor capability to enable specialized maintenance to be performed by operators

Supplies

Obviously, lightened and more fuel efficient vehicles in the force can reduce the demand for fuel flows forward. Benefits are similar to those for ammunition, spares, and reparables, namely reduced transport, stockage, and vulnerability. Taken together, these are most frequently identified as the advantages of a smaller "logistics footprint". However, the demand for exceptional — perhaps unprecedented — tactical mobility throughout the force could easily more than offset potential fuel economies, absent an unforeseen major breakthrough in propulsion technology.

Two other approaches to reduce fuel requirements are special purpose applications of alternative energy sources like photovoltaic devices (which in certain situations can be traded off against battery resupply demands); and the potential for increases in fuel energy density.

More subtly, better understanding in general, and better predictability of, the logistics demands of all kinds will permit the reduction of safety stocks of supplies. Although we can be properly skeptical of approaches predicated on improving the predictability in general of warfare, there is likely to be potential for "anticipation" of demand based on specific tactical events — for example if the logistics information system knows a certain unit has been engaged in combat, a resulting demand for resupply may be inferred.

However, with the inherently fragile tactical situation of more dispersed and autonomous small units, the reliability of the logistics flows even over short periods of time are more critical to mission success. Improvements to the reliability of the flows often fall into the category of assertions — those least likely to be credible either in this document or in tactical practice. However, there appear to be unmanned air and ground vehicle developments which can improve the flow reliability, at least as gap-fillers for specialized circumstances (although the current development state of flexible GPS-guided parafoils falls short of the sometimes-cited ideal of edibility.)

The good news is, improved "asset visibility" could enable the logistics flows to be reduced, and redundant demands avoided, even without improving the predictability of demand. This is primarily an information-based capability which can be adapted from private-sector experience (and is an area with work underway). The greatest challenge will be a system which will be trusted even in stressful environments. It will be essential that near-real-time data on order and shipment status be in the hands of the requester to maintain this trust. The ideal should be to move toward a system of distribution, not of warehousing.

Medical

Medical technology improvements for point-of-injury care using telemedical techniques offer the potential to reduce requirements for medical personnel and medical evacuation transport.

3.6 Training

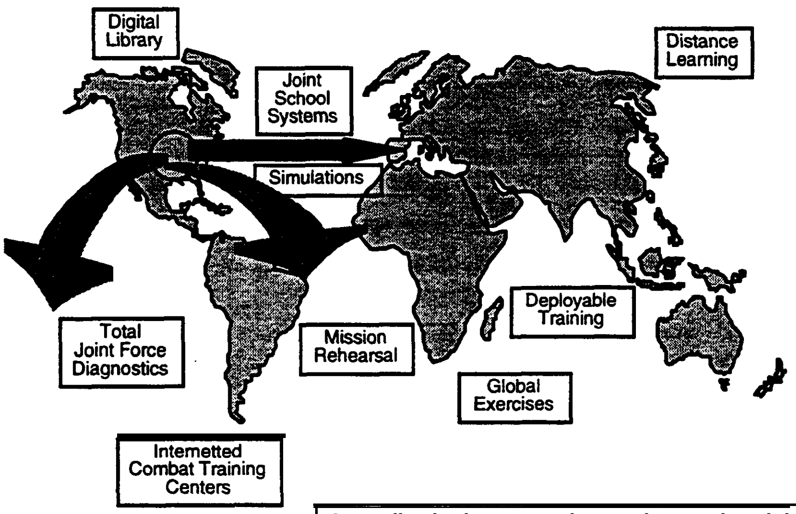
2015 COMBAT OPERATIONS
• Will demand greater levels of technical expertise • Will selectively provide access to an array of lethal and non-lethal systems to commanders from team to Joint Task Force • CONUS-based, rapid deployability will be the norm • Forces will be tailored, team through Joint Task Force • Forces will deploy directly to combat • Enroute mission rehearsal required

Today's training techniques cannot leverage potential 2015 battlespace technological advances.

GENERAL FINDINGS Training
• Train before, enroute, and during operations on one system • Global access for "distance learning" • Total joint force training readiness diagnostics • On-call access to virtual situational training in support of rapid deployment to any theater of operations • Tailored exercises to home station, world wide • Operate in a common joint telecommunications environment • Conduct decentralized new equipment training • Insure linkage between the fielding of technologically advanced equipment / concepts and the training necessary to optimize the 2015 battlefield (i.e. test bed)

- Regarding the first bullet, the operative phrase is "one system." The system for daily training must accommodate immediate transition to combat mission preparation.
- As units are pulled together for a rapid combat deployment, the system must provide for identification of individual and collective skills not currently to standard; then provide immediate tailored (individual and unit) instruction to fix the problems pre-deployment or enroute.
- Point 5 applies not only to training but especially to pre-deployment training.
- Simultaneous new equipment fielding across the force via globally accessed instruction speeds the process, eliminates mismatched units and normalizes individual / leader skill training.

TRAINING THE 2015 FORCE



Centralized classroom instruction and training center exercises must be augmented by a globally accessible interactive decentralized training system

- The challenge involves a cultural shift to the information age.
- Focus shifts from centralized schoolhouse / training center training to a decentralized globally accessed interactive system.
- Joint exercises must be distributed globally to home stations.
- Global access and simultaneously distributed new equipment training is required.
- Upon notification to deploy, a global access system must provide individual and unit diagnostics followed by tailored remedial and refresher training.
- Virtual simulations must be the training norm and immediately available for pre-deployment, enroute, over the shore, and over the hill mission preparation.

<u>Bottom line:</u> The training challenge is to provide a seamless, synthetic environment where training can be received on demand and where geographically dispersed students can interact with instructors, each other, and interactive simulations for individual or collective training and mission rehearsals.

Annex A - 21st Century Regional Adversary

A competent regional adversary will recognize that he cannot take on dominant U.S. forces, and so will act asymmetrically to exploit his inherent advantages and our inherent limitations, which include:

- As a hedge, buying some "medium-tech" systems to counter potential U.S. intervention
- Willingness to employ WMD — biological agents in particular
- Use of his local initiative and timing to his advantage
- Use of urban areas and deep underground facilities to conceal and protect military systems

WAYS THAT 21ST CENTURY ADVERSARY WILL TRY TO THWART U.S. RESPONSES

His Revolution in Military Affairs, Goals, and Objectives

- **Degrade U.S. pre-conflict intelligence on intent and forces**
- **Use Information Warfare against the U.S. sanctuary**
- **Plan to mitigate U.S. precision strike capabilities - navigation warfare and deception**
- **Raise price and delay U.S. entry into theater - attack strategic lift and prestocked supplies**
- **Inflict large U.S. casualties during entry phase**
- **Possess survivable "strategic delivery means in large numbers - many covert hiding places and fractionated**
- **Deny U.S. rapid victory by asymmetric responses and pre-conflict preparations (buried facilities, WMD, cover and deception, and mass)**
- **Fight a "CNN War" to influence global policy**

The force structure and combat capability of Country A is based on the regional threat postulated in the 1995 DSB Summer Study. The chart above summarizes major actions Country A will take if confronted by the U.S.

Country A's Order of Battle will contain the following:

- Ground Forces
  - 7 Armored Divisions
  - 5 Mechanized Infantry Divisions
  - 12 Infantry Divisions
  - 5-7 Corps Artillery Brigades
  - Forward Artillery GHQ Brigades
- Air Force
  - 170 Fighters
  - 70 Fighter/Bombers (Close Air Support)
  - 2 AWACS
  - 4 Heavy Lift Transports
- Naval Forces
  - Small number of coastal PTG Boats (with anti-ship cruise missiles)
  - Small number of diesel submarines (with torpedoes, SSM, mines)
  - Coastal defense systems (with radar, SSM)
  - Mines
  - Maritime Patrol
  - Fishing/Intelligence Fleets

In addition, we may assume the competent regional adversary will possess the following technologies:

- Biological Warfare manufacturing base
- Non-lethal anti-electronic contaminants
- Advanced integrated air defense and requisite C^4I
- Advanced Electronic Warfare capabilities
- Precision Guided Munitions
- Indigenous production of image intensifiers, importing sophisticated thermal vision systems
- GPS systems widely deployed and fully integrated
- Leased satellites (imaging, infrared)
- Theater Ballistic Missiles with GPS
- UAV (Similar to Tier III-)

COMPARATIVE ADVANTAGE ASSESSMENT

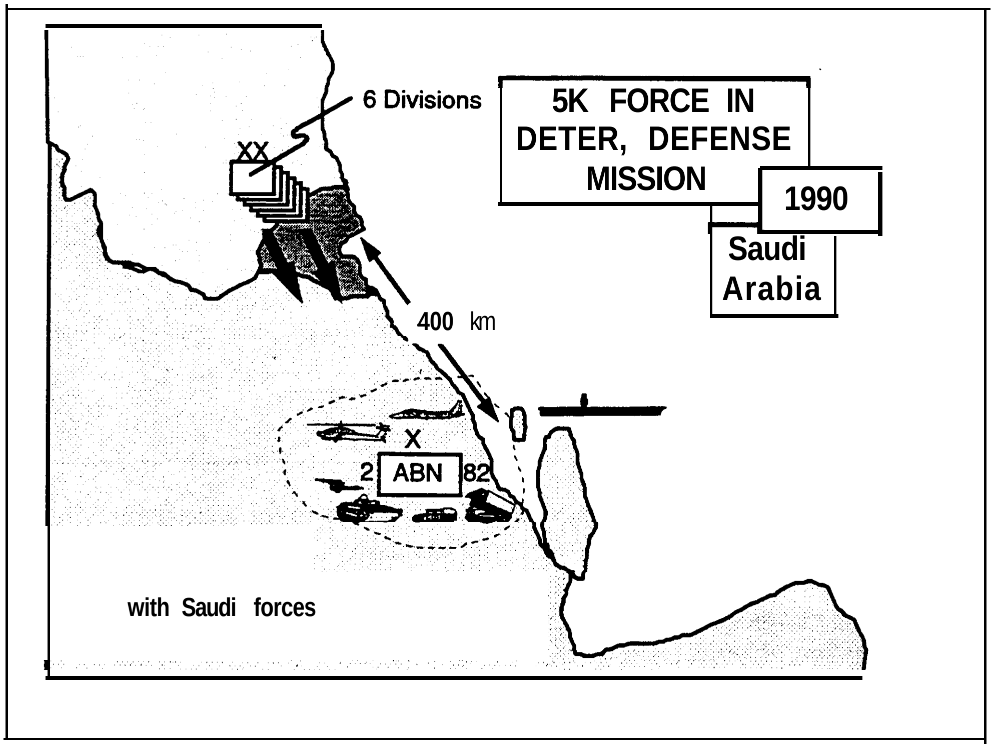
- Our disadvantages
  - Outnumbered
  - Not forward based
  - May have few / no regional allies
- Where both sides are about equal
  - Basic technologies
  - Weapons and related systems
  - Information systems
- Our advantages
  - People
  - Leadership
  - Training
  - Integration of technical and operational matters
  - Use of information and its timely integration

Given this picture of the future enemy force and environment constraints, we may draw certain conclusions about our comparative advantages/disadvantages. Numerical advantage clearly lies with the enemy; indeed, that advantage will remain with them throughout the initial phases of the conflict, even after the introduction of follow-on forces. The fact that we are devoid of forward bases (ground or air) raises significant obstacles in the realm of deployment and sustainment that will have to be overcome. And the relative absence of regional allies will add to our operational burden, as well as complicate efforts towards building a coalition.

The steady evolution of a "global economy" and open access to information technologies will combine with other factors to "equalize" U.S. forces and future competitors on a number of fronts, including basic technologies, many weapons systems, and information systems. Assuming any overwhelming technological edge over an enemy may be courting disaster in the future.

Our advantage, therefore, will lie in the employment of technologies. Most markedly, that advantage will show itself in the human dimension: in our People, their Leadership, and their Training. Growing out of that training will be a means of integrating technical and operational matters that will pay heed to the historical lessons of misapplied technologies and the devastation it can bring to the battlefield. Finally, our forces will carry a greater appreciation for the use of information on the battlefield, understanding that data must become information, and information converted to cognitive understanding before it can be rapidly applied on and across the battlefield.

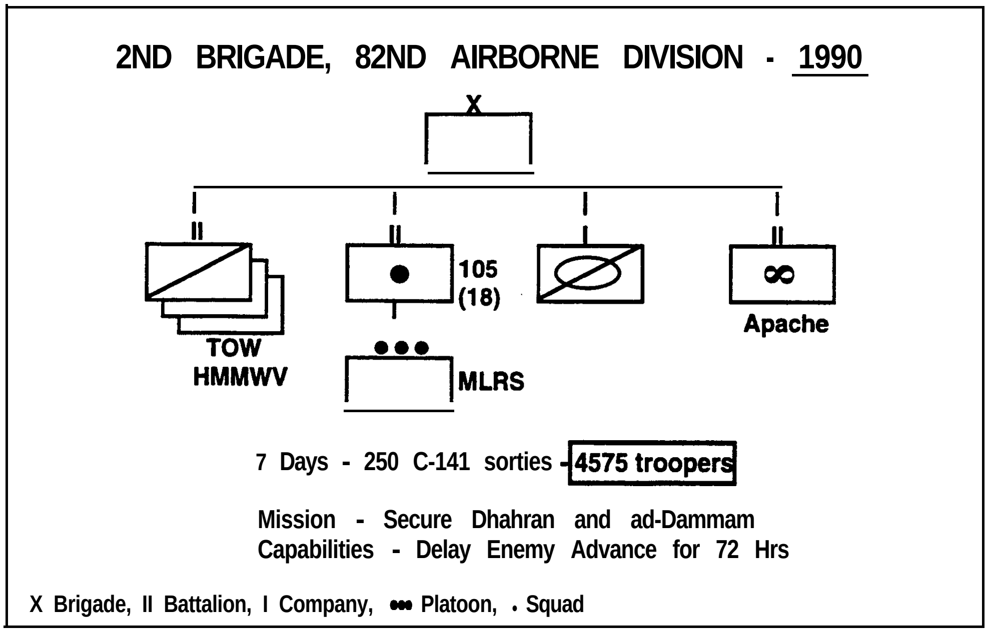
Annex B - Historical Perspective



As a base case, for comparison with a 2015 LESTFOR, we selected a recent historical example of rapid deployment of a brigade size force expected to be all it could be and then some — to literally fill the gap that should have been filled by several divisions.

Historical Baseline — Brigade Type Force. DESERT DRAGON I (Toehold) — On 9 Aug. 90, 2d Bde, 82nd Abn Div, closed in Saudi with the mission of "securing the Dhahran air base and the port of ad-Dammam, far enough outside the city to keep the port and air base beyond Iraqi artillery range." *

* "Certain Victory: The U.S. Army in the Gulf War," Brig. Gen. Robert H. Scales, Jr., USA, Brassey's Inc. 1994, page 82



The Brigade task force was composed essentially as indicated above.

The deployment of this first Army element took 7 days and 250 C-141 sorties to place some 4,575 troopers and their equipment on the ground. The brigade included three infantry battalions, an Apache battalion, a Sheridan light tank company, a battalion of 105mm howitzers, a platoon of MLRS, and organic command and control and support elements. As deployed it had the capability to sustain itself and delay an enemy advance for 72 hours. For a brief period of time, the brigade was the lone U.S. presence on the ground, facing a potential threat of six heavy Iraqi divisions. The current organization of 82nd Abn Div Ready Brigade (Heavy) is provided below.

Current 82nd Abn Div Ready Brigade (Hv) Configuration

HHC Bde
3 Inf Bn
FA Bn
Sig Co
MP Plt
ADA Co
Eng Plt
Chem Plt
MI Det
Atk Avn Bn
FSB

Lift Requirement is 271 Cl41 sorties

40 percent combat - Inf, FA, Avn, Eng
60 percent CS and CSS

95 RSOP

Pax 50 percent Military Air
50 percent Commercial Air

In his book, "Certain Victory", MG Scales addresses the conditions for dismounted "light" soldiers to defend against mobile armored formations:

- Break the charge of the heavier force. The 2d Bde planned to do this by engaging the advancing Iraqis on the coastal road bordered by salt flats not trafficable by the heavy tanks.
- Engage at long range before advancing force can close. 2d Bde planned to do this with a variety of systems from Air Force Close Air Support (CAS) and Apaches out to 20+ miles to artillery, to TOW/Sheridans at 3000 meters.
- The force must have enough confidence in leaders and weapons to not be intimidated by the advancing threat. 2d Bde had veterans of two decades of training for just such a mission.
- There must be a sufficient number of non-organic weapons to supplement the organic capability. These non-organic weapons must respond in the same manner as organic systems.

For whatever reasons, the Iraqis did not attack and DESERT DRAGON proceeded. A full analytic assessment of the potential outcomes, had the Iraqis opted at this point to move south out of Kuwait into Saudi with all or part of the six divisions, is not a part of this report. However for purposes of this effort we have tried to estimate the result had the Iraqis attacked on 9 Aug. The purpose is to establish a capabilities base line for describing the enhancements to a similar size force, in the 2015 time frame, that would increase the success of such an effort. Intuitively, we believe the Brigade, while initially able to disrupt advancing elements, would fairly quickly have been consumed. Following are the main reasons why the 82nd most likely could not have stopped an Iraqi assault with up to six divisions:

- Sheer numbers - Force ratio of up to 18:1 favoring the Iraqis
- Intelligence and update of situation shortfalls.
- Insufficient immediately available firepower sufficient to channel the attack onto the main road and disrupt it.

FORCE RESULTS

1990

- **Initial force to Desert Shield was an air-delivered, light infantry brigade from the 82nd Airborne Division with limited ability to repel a heavy force**
  - **The Force was labeled a "speed bump"**
  - **Deterrence was successful because the threat was uninformed and indecisive - Did not attack**

2015

- **Potential 2015 adversaries will have learned from Desert Shield, and today's light brigade in a similar 2015 scenario would not be successful if attacked**

The chart above. displays a rough order comparison of the 82nd in Desert Shield and of a similar unit in the 2015 time frame, if we do not provide it any more than what the 82nd had or was programmed to have.

- 1990: The initial force deployed to Desert Shield was an air delivered, light infantry brigade from the 82nd Airborne Division with limited ability to repel a heavy force. The force was literally labeled a "speed bump." Deterrence was successful because the threat force was uninformed and indecisive. It did not attack.
- 2015: Potential 2015 adversaries will have learned from Desert Shield, and today's light brigade in a similar 2015 scenario would not be successful if attacked.

Section II
Concept of Operations 2 - "Territory Control"

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Concept of Operation 2

"Territory Control"

Table of Contents

The Distributed Combat Cell Concept: What is it?

- Combat "cell" of 10-15 individuals
- Stealth insertion, operation, extraction
- Mission: provide territorial control over a geographic area
- Empowered by:
  - access to effective situational understanding, on-demand connectivity, and responsive, long-range fires
  - stealthy operations and enhanced mobility

The 2015 combat "cell" is a team of 10-15 individuals that is inserted into, and operates stealthily within, a combat area to provide territorial control over that geographic region. It is empowered by access to situational understanding, assured connectivity, and responsive, long-range fires. It achieves survivability through enhanced mobility, stealthy operations, and sufficient self-defense capability.

Distributed Combat Cells

Why?

1. **Asymmetric threat**
   - The enemy has effective area weapons (e.g., TBM, CM's, WMD's) and unconventional employment methods (terrorists/SOF)
   - We react by becoming non-targets
     - » Do not present a large target for exploitation
2. **It's all you have early on**
3. **Large formations should not be deployed until**
   - WMD threat significantly reduced
   - Adequate theater defense in place

The Distributed Combat Cell (DCC) concept counters an emerging, asymmetric threat to U.S. early-entry forces. Future adversaries may have effective area weapons consisting of theater ballistic missiles and cruise missiles carrying weapons of mass destruction. These weapons may be employed by terrorists and other non-governmental organizations in unconventional ways. The "cell" concept reacts to this threat by minimizing large unit signatures. The cells inserted to control territory are not viable targets. They are hard-to-find, hard-to-target, and they can move, i.e., they don't warrant the use of large weapons. However, when the situation warrants, the cells can coalesce into a complete rifle company.

Another strength of the DCC concept is that a force similar in concept has operated successfully for 20 years: the Marines and the Navy have had two units similar to the DCC's deployed for two decades in the Mediterranean and in the Far East. In many cases, this is all that is available to the CJTF early-on. However, while the experience operating with these units has been successful, these units are organized in such a manner that the entire battalion is deployed as a single force, instead of deploying as 30 separate squads.

The forces still need large formations in order to discourage the antagonist, or convince him to think about "coming to the table" before those large formations arrive. Large forces should not be deployed until the threat of WMD is significantly reduced, and adequate theater air defense is available. The purpose of the DCC is to control a large area and permit the introduction of follow-on forces as required.

Why Empower Combat Cells?

- **Control more area**
- **Engage and win against much larger enemy units**
- **Significantly reduce logistics**
- **Greatly improve survivability**
  - An isolated infantry unit engaged in direct fire fight by a similar unit of larger size dies
  - Best protection against direct fire weapons
    - » distance
    - » dirt
  - Distributed combat cells are non-targets

In the past, $$$, bandwidth, and intellectual investments stopped at Division HQ!!!

Small units, properly supported and empowered, have three critical attributes: they more effectively control area, they dramatically reduce the logistics tail, and they greatly increase their survivability.

- A small unit, with a unit-controlled UAV and remote fire, can control an area ten- to one hundred-times its direct-sight area.
- The small size of the force, enabled by remote fires, dramatically reduces the on-field logistics support.
- Small, distributed forces are hard to find and kill. Military experience points to the key: avoid direct fire fights. The best protection against direct-fire weapons is distance and dirt — both are great armor-plate.

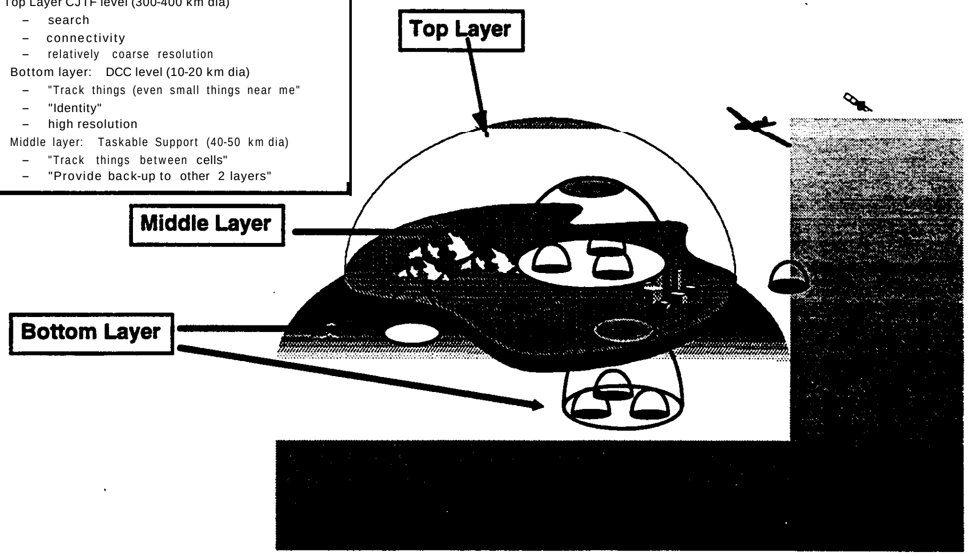
Survival of the combat cells requires effective situational understanding and on-demand connectivity so that they are not surprised and come under attack. These combat cells require good connectivity with sensors that are probably not even controlled by the cell in order to get them disengaged and rescued. Highly lethal fires that are very responsive are critical to the survival of the cell and/or mission continuation.

Once again it is emphasized that distributed combat cells are non-targets for weapons of mass destruction and for attack by large formations — because they're just too hard to find and too hard to pin down.

In order for this concept to be realized, we must dramatically change our orientation. In the past, we have worked from the "top-down." For fifty years, the Allies have prepared to fight a continental war in Europe against a large, mechanized threat. So DoD ran focused resources, communication bandwidth, and intellectual investment at the Division Headquarters level and above. DoD planners never got down to the squad, fire team, or platoon levels to look upward and ask, "What should be done to empower these units to become more powerful, more useful?"

Effective Situational Understanding is Achieved by the Integration of 3 Layers of Surveillance and Connectivity

- Top Layer CJTF level (300-400 km dia)
  - search
  - connectivity
  - relatively coarse resolution
- Bottom layer: DCC level (10-20 km dia)
  - "Track things (even small things near me"
  - "Identity"
  - high resolution
- Middle layer: Taskable Support (40-50 km dia)
  - "Track things between cells"
  - "Provide back-up to other 2 layers"



Situational understanding is the key to the Distributed Combat Cell concept. Effective situational understanding permits the cells to control substantially more territory than their opponents.

Situational understanding demands automated systems that provide the following information in real-time to the combat cells:

- Where am I?
- Where are the other friendlies (this cell, members of other cells, supporters, fire support, etc.)?
- What's in the air?
- Where is the enemy (from all sensors), and what is he doing?
- Where are the fixed assets (depots, bridges, etc.) of interest?
- What is my supply and sustainment status?
- What is our plan of operations?

The automated systems that provide this information are an integration of communications equipment, computers, networking equipment and constructs, data fusion elements, command-and-control equipment and procedures, sensors, sensor tasking rules, etc.

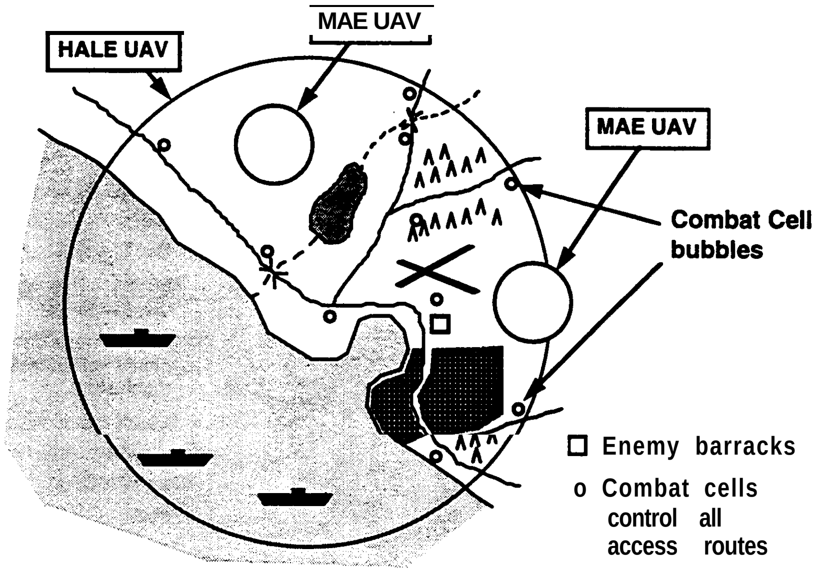
The situational understanding system for the DCC must be highly reliable and highly credible. We postulate that the most effective way to achieve these objectives is through a multiple-layer architecture, where each layer has specific responsibilities, but also has the capability to provide back-up functionality for adjacent layers. We have selected three layers of automation for our baseline concept, as follows:

- **The top layer:** "Commander, Joint Task Force" level of operations (300 to 400 km in diameter). Key functions: (i) detect and track entities at a relatively coarse resolution (detect and track single vehicles), and (ii) provide communications connectivity for a robust, dynamically reconfigurable, demand-allocated network that provides speed-of-service and guaranteed delivery.
- **Middle layer:** Taskable support (40 to 50 kilometers in diameter). Key functions: (i) detect and track entities that are located in between DCC's, and (ii) provide a back-up capability to the other two layers.
- **The bottom layer:** "DCC" level of operations (10 to 20 kilometers in diameter). Key functions: (i) Detect, track, and identify entities that are near the DCC; (ii) receive sensor data from higher layers, integrate with organic sensor data (high resolution, detect and track individuals, identify individual vehicle types), and fuse to an integrated local situation data set, capable of being displayed through user-set-filters to support varied needs in real-time, and (iii) local processing that integrates situational understanding with command-and-control constructs, and can automatically generate alerts, alarms, reminders, etc.

Working in conjunction with these three layers of automation is the "fourth layer," the human. The human provides important target recognition, situation assessment, data integration, and identification functions at a layer of accuracy and depth not available from machines in the time-frame under consideration. The human also provides the local command structure, and makes use of the automation system to disseminate those commands and to track progress on tasking.

Situational understanding is used both *before entry* and *during the operation*. "Pre-entry situational understanding" is focused on finding the areas to watch, the likely routes to be used by our forces and by the enemy, entry and exit points, candidate landing zones, etc. A key goal of pre-entry situational understanding is to reduce the size of the area that the top-layer bubble must monitor at a high rate.

Applying the Bubbles



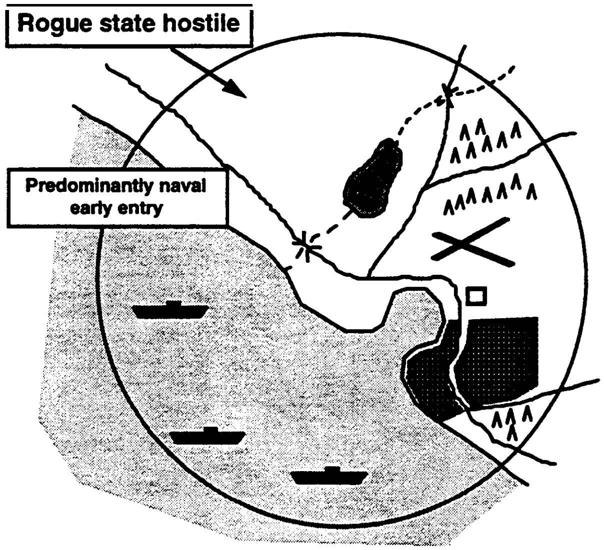
The layered set of “bubbles” described in the previous chart are used to provide situational understanding as follows:

The HALE bubble provides a field-of-regard over the entire engagement area, 200-300 km in diameter. For a 200 km zone, there are approximately 3 ¥ 10^{10} one-meter areas, which is our assumed resolution, enabling detection of vehicles and groups of people. Assuming a 1000 ¥ 1000-element focal plane, each “picture” covers a square kilometer at the appropriate resolution. This bubble is established, initially, in conjunction with RIVET JOINT, AWACS, and other national systems to build a situational understanding. This bubble also defines our objective area where we want to seal it off and prevent enemy control.

An intermediate “bubble” is provided by a MAE UAV (e.g., PREDATOR), providing l-meter resolution over a 40 km diameter field-of-regard. This system is used to support many DCC elements by observing areas between them to track previously tagged targets and to detect threats or areas of safe advance to DCC elements that are moving.

The key bubble is that provided by an Advanced Air Vehicle (AAV) to each DCC. This system will have a l-foot resolution over about a 300 ¥ 300 meter square to detect threats in the form of vehicles or people. We expect this AAV sensor system to respond to queuing from Unattended Ground Sensor (UGS) detections at the edge of the area-of-regard for the unit. Because it is used only for response functions received from the MAE UAV or the combat cell leader, we believe that the VTOL UAV’s duty cycle is low, spending almost all time on the ground waiting for the 2 or 3 missions per day it is assigned.

DCC Concept Works Across Many Situations



Strengths - current forces

- No peer/rogue very capable in deep blue water
- Mobile floating airfield
- Mobile floating logistics (suboptimized)
- Ground force DCC available (not yet task organized)
- Already forward-deployed

Weaknesses - current forces

- Zero LR NSFS
- ASMD
- TBMD

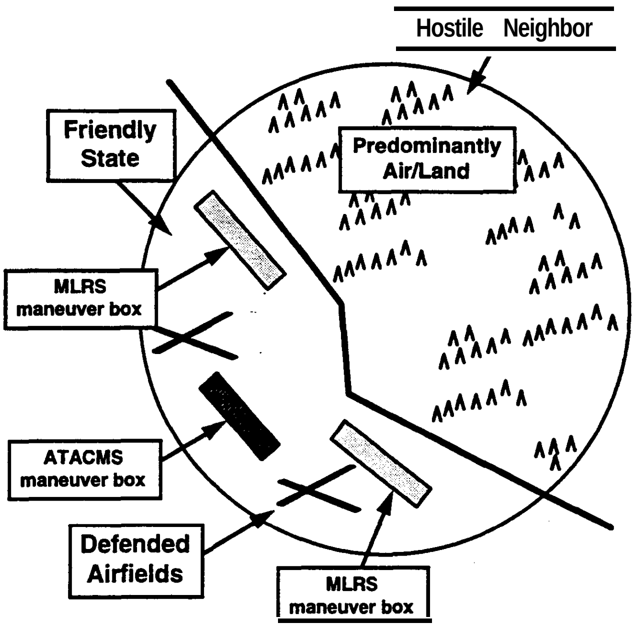
The DCC concept can be employed in many different situations, and many of the needed capabilities are already present in current forces. Consider first the deployment. of the DCC near a port city of a hostile rogue state. No present near-peer or rogue state is very capable in deep blue water, so the DCC will be supported by a mobile floating airfield and mobile floating logistics. We already have forward-deployed ground forces of the required size, though not yet organized, trained, or equipped as a DCC task force.

Lacking from present forces, but necessary for the DCC in this scenario, are adequate anti-ship missile defense, tactical ballistic missile defense, and, most important, long-range naval surface fire support.

A misconception about fighting in another's territory is that "He occupies every square yard of the ground." This is not true. Consider the West Coast of the United States. If one wanted to bring people ashore in Santa Barbara, how could that be stopped? The Marines in Camp Pendleton (which is the nearest combat force)? There are vast areas that are not populated. And military units are not in the field all the time — especially Third World or Rogue State units. They're not that good, logistically; they spend a lot of time in the Kasem with everything parked and all the troops in the barracks. They only come out of the Kasem when they perceive trouble, at which time they prepare to deploy.

We'll start with the 200 nm-diameter HALE UAV "bubble", in addition to off-shore sensors, to develop a picture of the enemy's area of interest. Then we'll create the intermediate bubbles with MAE UAV's to look at key points that allow access to the big bubble. We insert the DCC's at clear locations where they can watch the big activities (e.g., the Kasems), the road intersections, and the access routes (e.g., mountain passes), so when "the balloon goes up," we can seal this area off. Anything that moves inside it dies. We simply take this piece of territory away from him without physically occupying it with large numbers of men.

DCC Concept Works Across Many Situations (con't)



Strengths - current forces

- MLRS/ATACMS active & deployed
- Some early warning/ observation available
- Airlift available
- Minimal TBMD in force
- Ground Force DCC available (not yet task organized)

Weaknesses - current forces

- Fixed facilities (WMD)
- Heavy logistics burden/ time-weight burden
- Political will to make early decision
- Subject to enemy SOF activities

The DCC concept applies to a predominantly air/land theater as well. The primary differences between the naval and air/land scenarios are that long-range indirect fire support capabilities (ATACMS/MLRS) and minimal TBMD (Patriot) already exist. Conversely, if the air/land forces are not forward-deployed, their deployment imposes a heavy logistics burden (time/weight), and they are more vulnerable to enemy long-range and area weapons. If forces are not forward-deployed, long-range air will be far more important in the early phases.

There are four separate order-of-magnitude gains in the DCC concept

- Remote fire effect (accurate, inexpensive)
  - reduces logistics burden (~100x)
- Layered, integrated, "all seeing" situational understanding
  - increases "area of control" (~10x)
  - decreases number of forces needed (~10x +)
- Kill at will (~10x +)
  - choose time to engage, maximize effects
  - one shot kills, strong psychological impact
- Reduced casualties
  - fewer people in harm's way
  - stealth/warning

We believe this DCC concept provides four separate "order-of-magnitude" scale improvements over current operations, if it proves achievable. The following charts articulate the logistical advantage we postulate.

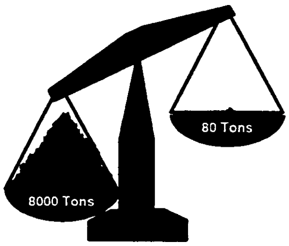
The improvement in area covered per person is achieved by the layered (tiered) "bubbles" providing situational understanding and the removal of personnel associated with direct fire, because the DCC concept assumes virtually all fire is indirect.

The lethality of this concept is improved by choosing the time of attack, for example, when the enemy is refueling or gathering for meals. The concept of first-shot-kills, achieved by GPS precision and proper choice of time, improves effectiveness because no reaction is allowed, and it provides a large, unquantified psychological impact.

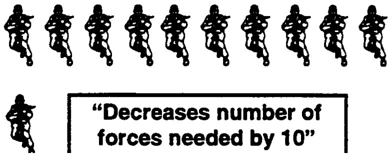
We believe these improvements are independent, and they are supplemented by an order-of-magnitude reduction in casualties because we are deploying fewer people and giving those people the option of moving, hiding, and generally avoiding threats. This is quite different from forcing them to become targets because we insist they bring direct fire or engagement to the enemy.

We illustrate three of the orders-of-magnitude gains in the following figure.

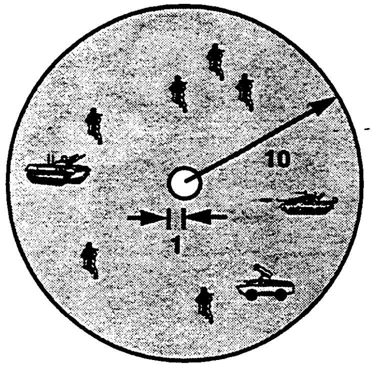
The DCC Concept Enables an Order-of-Magnitude Reduction in Deployment



"Reduces logistics burden by 100"

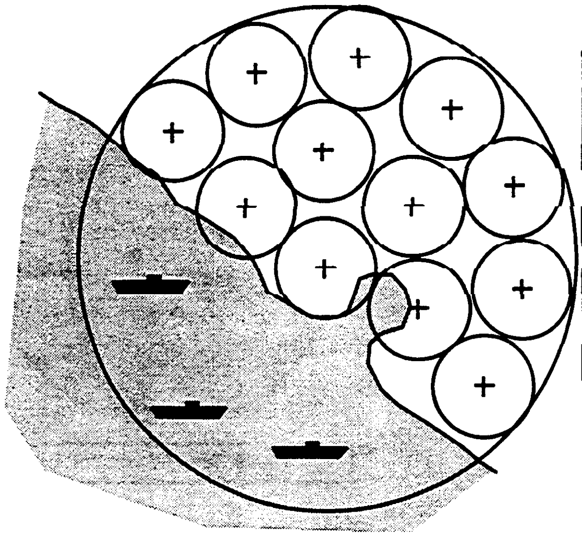


"Decreases number of forces needed by 10"



"Increases 'area of control' by 10"

Long-Range Indirect Fire Support vs Conventional Artillery



The Conventional Approach

13 batteries, 6 guns each, 155 mm

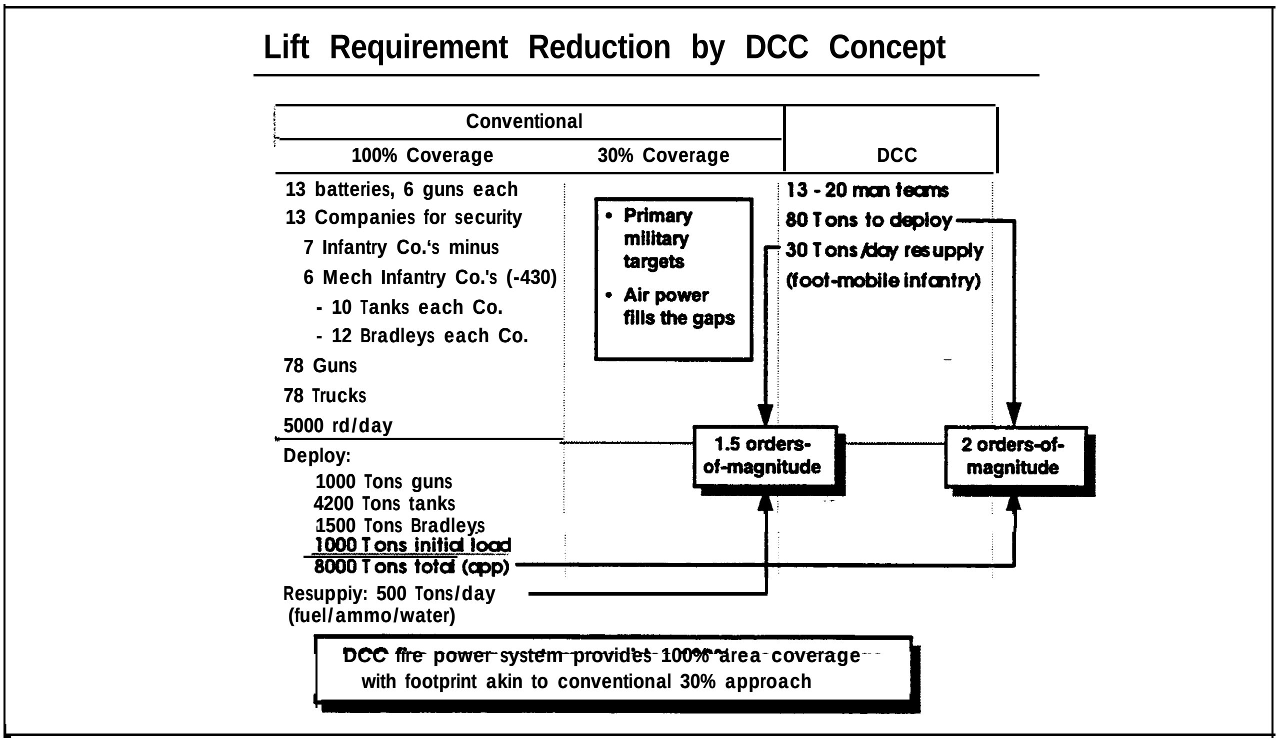
- 5000 rounds, 150 lbs each
- 78 artillery pieces, 78 ten-ton trucks
- 70 rounds/day

Security Forces:

7 Rifle Companies (100 members each)

6 Mechanized Infantry Companies (70 members each) [10 tanks, 12 Bradleys each]

As an example of the advantage of the DCC concept of indirect fire over a conventional artillery direct fire solution of terrain control, we have assumed, as a case in point, the requirement to control the total area. We further assume that control was effected by artillery with 20 km range and 360° field-of-regard. Approximately 13 batteries of 6-155 mm guns each would be required, with supporting vehicles, ammunition, and security forces (divided between rifle companies and mechanized infantry companies). While such a deployment is theoretical, indirect fire from off-shore could, in fact, cover the same, entire area with missiles or long-range gun fire.



We calculate the lift required onto the land area for the approach just considered versus the DCC approach.

We estimate the initial load for the artillery solution is 8000 tons, versus 80 tons for the DCC solution. This advantage is carried on by dramatically reduced re-supply quantities: from 500 tons per day to 30 tons per day (and this difference would probably be substantially greater after further analysis). We recognize that the cells cover only about l/3 of the total area, so a purist may divide the factors of "2 orders-of-magnitude" and "1.5 orders-of-magnitude" by 3 for consistency, but we believe the reduced-sized cells will cover all realistic areas of interest with dramatically reduced logistics demands.

Why Human Sensors

- They think/integrate faster and better than machines
  - Can see/interpret human activity
  - Sort out civil/military targets
- Location and orientation
  - Be at key locations to make critical targeting and engagement decisions
  - Ability to concentrate and become a lethal combat entity
  - Precise placement of sensors
  - Ceiling and visibility restrictions less important A/W
- Local tasking optimizes duty cycle of sensors, comms, etc.

Human sensors are important because they think, they integrate, and they recognize and interpret human activity. Consider the importance of knowing when to hit the enemy. Currently, remote sensors cannot provide this information. Today's remote sensor says "Blob," or "Rumblings"; it cannot, and does not, say, "Rumblings that have their hatches open and have fuel trucks alongside and have the hoses out," i.e., a description of a very vulnerable tank column. This is very different from a tank column that has hatches closed and fuel trucks that are 5 miles away, where the net result of an attack with an indirect fire weapon will be, probably, just an irritation. In all fairness, technology by the year 2015 could very well advance to the point where today's requirement for situational awareness — that a human must be on the ground — is removed. However, situational understanding will *always* require that a human be present on the ground.

For the foreseeable future, humans will think faster and better than machines. They can easily sort civilian and military targets, and they can understand the significance of a local event in the context of a larger enterprise.

Second, human beings are superior to machines for optimizing the location and orientation of sensors and the application of forces. Humans can occupy key locations, which allow them to make critical targeting and engagement decisions. They have the ability to concentrate and become a lethal combat entity that can, for example, hold a mountain pass for a day or two. Humans are less susceptible to ceiling and visibility restrictions than airborne sensors, and they can maximize the effectiveness of ground sensors by being able to place them precisely.

Insertion of DCC

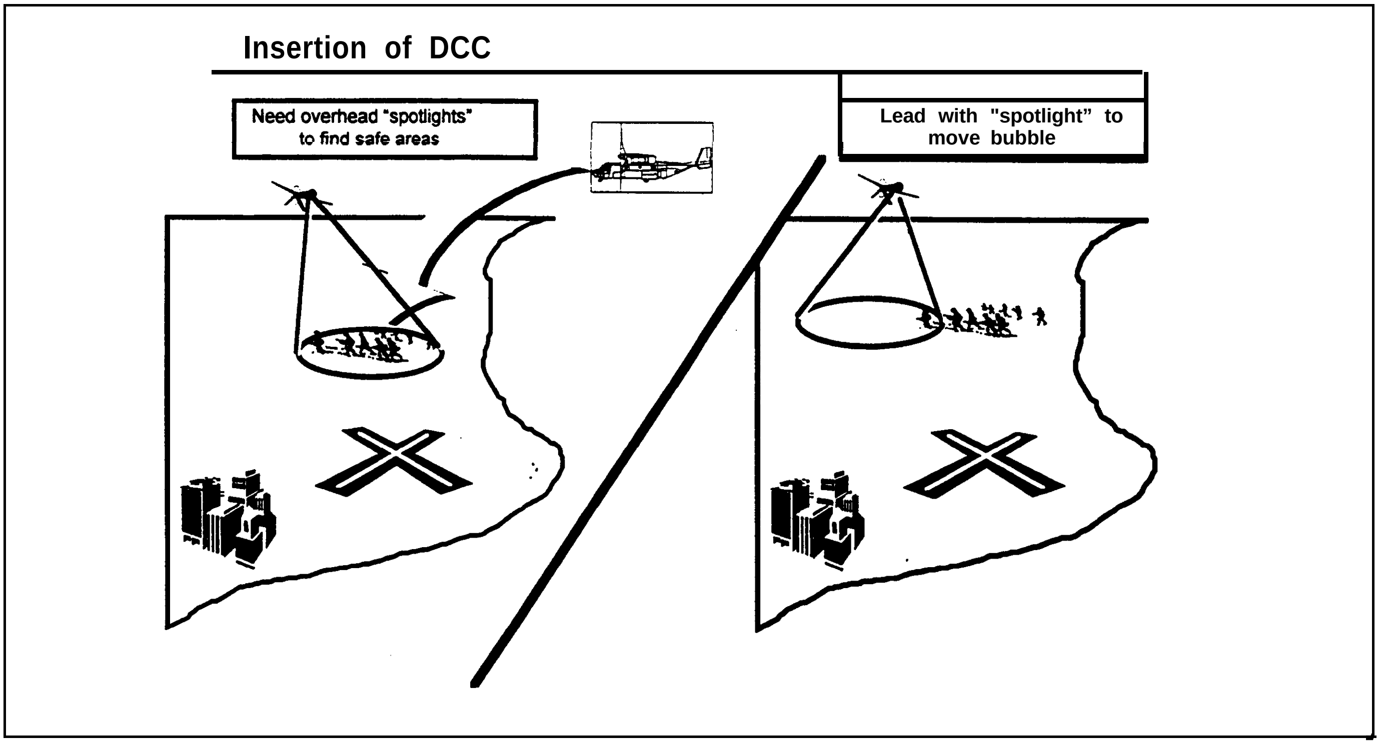
- Need overhead "spotlights" to find safe areas
- Reduced signature of insertion vehicles increases survival
- First hour on the ground critical
  - UGS (air- and hand-emplaced)
  - Learning his piece of country
- To move bubble, lead with spotlight - help maintain combat cell security
  - Jungle - No sensor available today
  - Timber - " " " "

If the triggering event has been an air strike to take out the enemy's air defense, then our forces are entering a hostile situation and the need for overhead "spotlights" to determine that the cells have some "safe time" is exceptionally important.

Buying this first hour undisturbed on the ground makes the combat cell the owner of a certain piece of territory. The longer the cell is there, undisturbed, the more it can "grow its bubble."

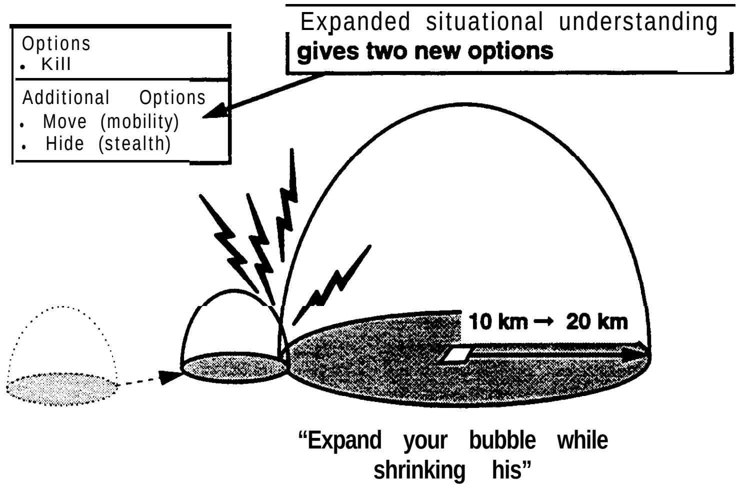
If the bubble is to move, it should be led by a spotlight that says, "OK — you can move West/Northwest 6 miles: there's nothing there." As we'll see shortly, the size of the bubble determines the cell's options: the bigger the bubble, the more options it has.

We illustrate the first and last "spotlight" insertion issues on this chart in the following graphic.



Insertion of DCC
Need overhead "spotlights" to find safe areas
Lead with "spotlight" to move bubble

Distributed Combat Cell Operations within the "Bubbles"



The key concept for DCC mission success is maintaining a local awareness bubble larger than the enemy's. Sensor and information technologies 20 years from now will allow an increase in overall capabilities of at least an order-of-magnitude. The expanded bubble enables the DCC's to detect and monitor enemy actions well before being detected themselves. This places the critical advantage of time for action with the DCC. Coupled with enablers for stealth and mobility, the DCC also has at its disposal several options for action: (1) enemy engagement/kill; (2) hiding while continuing to observe the enemy, or (3) moving to a safer or more advantageous vantage point. Options (2) and (3) are the ones that allow indirect fire to become the primary enemy kill approach.

Conversely, when the DCC's bubble shrinks to the same size as the enemy's and, in the extreme, becomes limited to the collective human senses in the cell, then all options collapse to simply "kill or be killed." The situation becomes one of who-sees-whom-first, and survival overwhelms any other task the DCC had set out to accomplish. Inevitably, this becomes a losing proposition for the DCC, being well within enemy territory where reinforcements for the enemy are much less problematic than for the DCC.

Critical Attributes of the DCC Concept

Requirements

- **Situational understanding**
- **Connectivity**
- **Responsive fire support**
- **Stealth**

Enhancements

- **Mobility**
- **Self defense**

There are six areas that need work: situational understanding; absolute connectivity; responsive fire support; land-based stealth; enhanced mobility (other than feet), and self-defense.

The first four are absolute requirements for the DCC concept; the last two will enhance its effectiveness.

Deficiencies - Situational Understanding

Can't Do

- Organic overhead sensor (man-portable and/or externally-provided VTOL for limited duty cycle)
  - » "Eyes" for the DCC
  - » Performance (endurance/range/resolution)
  - » Reliability/signature/consumables
- UGS
  - » Networking
  - » Report on event via airborne relay
    - • Information retrieval

Can Do Poorly

- Middle- and Top-layer activity detection
  - » Foliage penetration
  - » Availability

We believe that situational understanding is the highest-priority deficiency relative to implementing the DCC concept. If the DCC's do not have situational understanding that is significantly better than their opposition, sooner or later they will become involved in a direct firefight, and they will lose. The DCC depends on employing engagement patterns other than kill-or-be-killed, and, to implement those patterns (precise long-range indirect fires, hide, move, etc.), they must have better knowledge at a longer range than the enemy.

As described earlier in this briefing, we believe that what is required is total situational understanding, integrating sensors, communications, and many other elements. We believe that organic sensors, linked and netted with all broad-area assets, are required. We have identified two types of such organic sensors as initial candidates: Unattended Ground Sensors (UGS's) and a small (man-portable) organic vertical take-off and landing (VTOL) UAV.

UGS's can be emplaced by air prior to DCC insertion, but there will be many circumstances where hand-emplacement by DCC members will result in more effective sensor performance. UGS will asynchronously report upon an event to the DCC situational understanding network, probably via a theater-wide airborne relay (top layer of our situational understanding architecture). DCC's can also send commands to their UGS via the same link.

We strongly believe in the role and utility of the man-portable VTOL organic overhead sensor. This device should permit the DCC to operate it remotely in night and all-weather conditions. It should provide very high resolution identification and track information, and be able also to load and unload data from the UGS's. Together with the UGS's, it provides the significant range extension to the area controllable by the DCC. In combination with the UGS and human sensors, the VTOL could be operated on a reduced duty cycle that is consistent with the endurance and stealth requirements of the DCC.

We have identified resolution needs for the top and middle layers of the surveillance architecture which we believe are readily achievable. The topics of concern for these layers are *availability* (e.g., effective duty cycle on station, a serious-short-coming of current systems) and *penetration* of foliage and other types of obscurants.

Deficiencies - Connectivity

Can Do Poorly

- LPI/LPD
- CDMA technology
- AJ
- Limited video transmission ability
  - » Mostly snapshots
- Adopt commercial technology

Connectivity-on-demand is required for this concept to be effective. Commercial advances in satellite cellular systems will provide much better connectivity than is available today, but we believe further improvement will be required.

This concept needs intermittent communications from a few thousand distributed UGS's. Selected readout of specific results, including snapshots, may be required — but not often. Sensor outputs from the "bubbles" need to be communicated, which will probably lead to the maximum bandwidth requirements, but time is available to spread out peak loads. Also, the groups will require voice communications-on-demand for coordination and C?

The primary communications system, we assume, is a COMM payload carried by a HALE vehicle identical to that providing the wide-area "bubble." A CDMA, demand-assigned system over a wideband payload, should provide the required communications. Both ground-to-ground and ground-to-air links must be supported, as must flood-search, dynamic routing, speed-of-service, selective-directed broadcast/multicast, guaranteed delivery of selected messages, and dynamic re-allocations of bandwidth. The HALE will be used as a common node for all communications between the CJTF and the cells. Services such as paging (e.g., alarms, reminders), voice/video conferencing, and collaborative white-boarding will be provided.

Commercial technology should provide solutions, including use of open-loop tracking antennas using GPS coordinate coordination. It is crucial that use of COMM equipment does not reveal the location of either the UGS's or the members of the cell.

Deficiencies - Responsive Fire Support

Can Do Poorly 1 Dimension	– Long-range (day, night, all-weather, high duty cycle) – Loitering – Weapon shoots to basket (position/time) » Targeted prior to arrival » Can change target en route » Cell designates target – Quick Response - leakers

Today only air provides long-range fire support

Today, we deploy artillery, mortars, and other elements comprising a tremendous logistics "tail" to achieve responsive fire support. It is also the type of fire support that is "dumb." By "dumb" we mean that the first round lands close by (thereby warning the enemy, who immediately takes cover), the second round lands closer, and the third round arrives directly on target — and we commence to fire-for-effect. The net result is to irritate the enemy and pin him down so we can maneuver (which is how we use indirect fires today) — but minimal actual damage is inflicted on the enemy.

If we wish to use long-range indirect fire support, we have one dimension: aircraft. We have no other long-range indirect fires that are available today (unless we "own" a large plot of ground and we have Army TACMS and MLRS — which are themselves TBM targets). We want to avoid presenting our own large targets on the beach at this stage — we only want "small items" on the beach-head at this stage of the incursion. And we want our indirect fires to come from a great distance (e.g., ~75-100 nm), and they probably should be sea-borne initially. The indirect fires could be airborne if the airplane were a large "truck" carrying a wide variety of smart munitions that the cell can call for. Ideally, munitions would be directed to a basket defined by position and time. These weapons could be: (i) targeted prior to arrival, (ii) loitering and targetable (like a lethal, loitering UAV), or (iii) directed to the target by the DCC members. Today we have neither an air-delivered nor a sea-delivered munition that can perform these tasks.

In the event of leakers, the ability of the cell to evade becomes the critical element for a cell which has forgone direct firepower weapons in favor of increased mobility and stealth.

Value of First Round Indirect Fire Kill

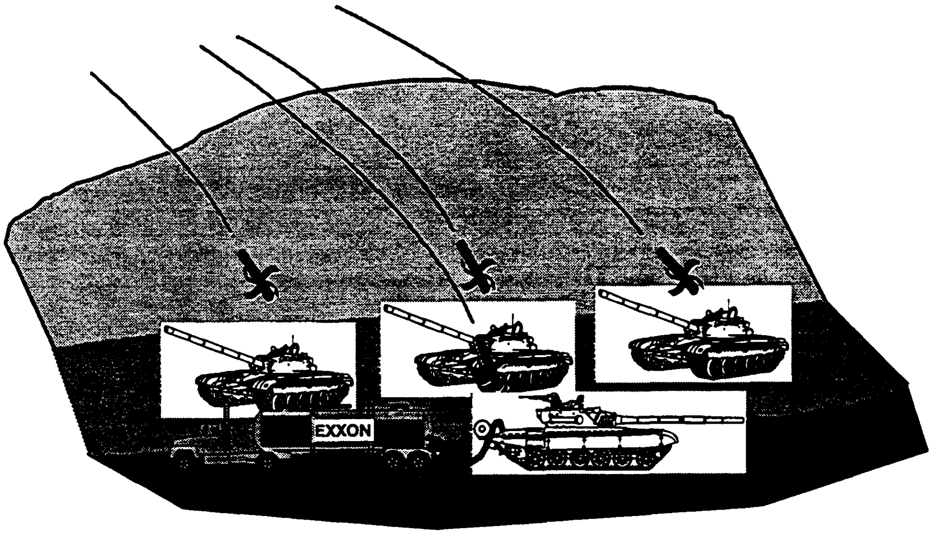
- Total surprise = maximum vulnerability
- Old Paradigm - see - shoot - adjust - kill a few?
- New Paradigm - see - track - tag - watch - DESTROY
- Unknown value - suspect 1-2 orders of magnitude benefit
- Drastic reduction in ordnance requirements

There is great value in the first-round-kill. This hasn't been examined in much detail, but, as just described, today's indirect fire weapons provide the enemy with a warning that says, "Stop doing what you're doing, get under cover because I'm going to fire at you." If the enemy human activity believes it is secure, believes it is not under observation, and the first round that comes in is lethal, then "See-Shoot-Kill-Maybe," becomes "See-Track-Tag-Watch-Destroy" (when the enemy is vulnerable), with a strike that he doesn't expect. The CJTF can now decide when to destroy the enemy formation by using information provided by the DCC that indicates when the enemy unit is most vulnerable. This permits a new military capability for the DCC: see-track-tag-watch-destroy.

We do not yet have precise, quantitative estimates of the value of first-round-kill, but we believe it will result in a drastic reduction in number of ordnance tons and l-2 orders of magnitude in benefit.

We illustrate the value of total surprise in the following graphic, where we depict a BAT (Brilliant Anti-Tank submunition) attack on a group of parked enemy tanks in the process of being refueled i.e. in a completely vulnerable posture.

The Value of First-Round Kill



Deficiencies - Stealth

"Do-Able" Training

- No electronic unique signature
- Noise
- Heat
- Visual
- Lethal weapon with low visual and audio signatures

Deficiencies apply to

- Man
- Insertion means
- Sustainment
- Means of ground mobility

There is currently little/no investment in stealth for the man, his lift vehicle, and his land vehicle. We invest in stealth today for large, complicated systems. We must reduce heat, noise, and visual signatures for these other small systems.

We must consider "leakers" that will, in fact, penetrate the soldier's bubble and surprise him, forcing him to use his self-defense system. This system must have very low signature and must be lethal. He must be able to take care of leakers without warning everyone else in the vicinity (which would shrink the soldier's situational understanding bubble while expanding the enemy's).

Training of individual cell members can significantly contribute to reducing sound, IR, and visual cues to an opposing force trying to detect our forces.

Stealth is absolutely critical to all elements of the system, including man, the insertion process, logistic sustainment, and any system of ground mobility.

Deficiencies - Ground Mobility

Limited by Lift & Logistics

- Foot mobile - pack weight
- Vehicle mobility
  - Fuel efficient
  - Lightweight
  - Stealthy (low audio, visual, radar)
  - Need vehicle that will fit in new VTOL transports

We principally consider bad terrain — mountains, forested regions, jungle. Mobility today is by foot, and must be improved for successful warfighting in such surroundings. First of all, the troop should not enter with an 80-90 pound pack; he should be carrying a 30-35 pound pack. If we must utilize foot mobility, then we should drop the soldier's other supplies by guided parachute or by some other means. By caching supplies that he can retrieve when he needs them, he is relieved of having to carry them with him. If he must be foot-mobile, we must find the means by which to enable him to achieve ~2.5 miles per hour (not possible today with an 85 pound pack except for very short intervals).

If we provide the troop/combat cell with some type of mechanized device, it must be: (i) fuel efficient, (ii) lightweight, (iii) stealthy, and, whatever he is to use, (iv) V-22-compatible to take full advantage of the airplane's 300 kt speeds.

We recommend the investigation of super-quiet scooters and "dune buggy" type vehicles for ground mobility.

We are also concerned about the signature of transport aircraft, especially the noise and radar signatures. The V-22 is a significant improvement over helicopters in terms of noise during horizontal flight, but it is still highly vulnerable.

Deficiencies - Self Defense

Can Do

- **Snipers**
  - » **best self-defense**
- Terrain
  - » limits mobility platforms
- Mobility means
  - » determines how much you can carry
- Size combat cells
  - » to terrain and mobility means
- Obscurants/smoke to break contact

Making contact is undesirable — breaking contact requires smoke/obscurants and Lethal Unattended Ground System (LUGS)

We can obviously do self-defense today. The combat cells that we insert will be sized and equipped based on the kind of terrain into which they will be placed and the mobility means with which we can provide them. Terrain limits the mobility platforms. In many cases, if the terrain is too severe, "mobility" might be comprised of "llamas and feet."

Obscurants and smoke may be the best means for breaking contact with the enemy.

The friendly sniper is probably the best means of self-defense for the combat cell. He can be deployed out to large distances, he's patient, he becomes an excellent observer, and he can own a very large piece of territory and provide very early warning. A technology need that has been identified is for a quiet sniper rifle that is effective at ranges up to 2000 m.

Tradeoff

+ Mobility
+ Self Defense

= More Logistics Required

+ Situation understanding
+ Stealth

= Less Logistics Required

The more we invest in mobility and self-defense, the more we have to pay the price in logistics. The troop will carry, more ammunition, weapons, fuel, and bring with him a vehicle (that he has to maintain). In some terrain, these are certainly very important. The CJTF needs to have a "toolbox" of options from which to select as he emplaces these cells in a variety of settings. These cells' sizes and equipage will depend strongly on the terrain.

We believe that investing in situational understanding and stealth probably means less and less logistics because there would be fewer firefights, less mobility (troops spend more time hiding and less time running). The payoff would be a strongly reduced logistics burden if we invest in situational understanding and stealth.

Training/Experimentation

Don't believe measurements you get from a sterile military area

- **Populate the area with non-combatant entities**
- **Military foot/mech patrols**
- **Construction crews building caves**
- **Trading posts**

Training is a sensitive subject. At the root of this is the question of urban warfare/mountain warfare/desert warfare.

Historically, our military units have been almost identical, mirror images (e.g., Infantry Divisions). There may be, perhaps, some requirement for future warfare of the type we have been discussing where we have an urban regiment (that is effective at urban warfare and is equipped for it), a mountain warfare regiment, etc. In this way, the divisions may look different because of their very different specializations. As we become more and more sophisticated, and are drawn into these tougher and tougher military situations, we can no longer afford to train everyone to do everything. Our training load and our patient load (i.e., the time we have lost our people) can get out of hand. So we may have to consider non-standard divisions or regiments that have specialties, so that the makeup of the response to a given situation becomes tailor-made to the characteristics of the problem (as the follow-on force, not necessarily the introductory force).

We need to be especially careful of measurements taken in "sterile" military training areas such as Twenty-nine Palms or Ft. Irwin. These are not fully representative of the parts of the world where we might deploy troops. We need more complete training environments: we need areas that have indigenous people present, mule trains, camel trains, a construction outfit, military patrols (mechanized and foot patrol). We must practice by studying the patterns and by learning the habits of the local people without intervention or control by umpires. We need to learn what the indigenous people do, insert our people, and then take measurements. To do otherwise would be misleading and dangerous.

Observations on Combat Cell Territorial Control

- **A modest force of distributed combat cells can control a large area of enemy territory provided that they have adequate (1) situational understanding, (2) stealth, (3) assured connectivity, and (4) long-range indirect fire support.**
- **All galaxy sensors are netted plus organic sensors (VTOL, UGS) are required**
  - Cell controls its own OPTEMPO; use sensors when they want with minimal coordination
  - Decreases fragility of system construct (loose coupling, low duty cycles)
  - Permits See → Tag → Track → Pick Time → DESTROY

Observations (con't)

- **There are four separate order-of-magnitude gains in this concept:**
  - Remote fire effect (accurate, inexpensive)
    - » reduces logistics burden (~100x)
  - Layered, integrated, "all seeing" situational understanding
    - » increases "area of control" (~10x)
    - » decreases number of forces needed (~10x +)
  - Kill at will
    - » choose time to engage, maximixe effects
    - » first shot kills, strong psychological Impact

    (~10X +)
  - Reduced casualties
    - » fewer people in harm's way
    - » stealth/warning
- **Just-in-time stealth logistics delivery is required**

Recommendations

- Establish an evolutionarv integration process, not a development process
  - Start now
  - Experiment (a la Task Force XXI, Sea Dragon)
  - Learn, don't prove
  - Stress incorporation of COTS and commercial practices
  - At all times, be prepared to field the best of the most recent experiment in a short time
  - Appoint ACOM as single POC for this process

Recommendations (con't)

- Invest in empowerment of DCC in the following priority and magnitude by FY:

Situational Awareness	$100M*	Incremental invest/ reallocation	Few new $$$
Connectivity	$90M*		
Long Range Fire Support	$75M*	Bottom-Up vs Top-Down	
Stealth	$40M	No investment today	New $$$
Mobility	$35M	Absolute minimum $$	
Self Defense	$20M		

*Largely in annual experiments and integration

The ability of a combat cell to operate clandestinely in a denied/contested area can be improved with precise and real-time information on human activity in a selected operation area.

Sensors with greatly enhanced capabilities for detection, localization, and even identification of humans, is required.

This capability needs to be in the hands of the operators to seamlessly fuse this information into planning and operations.

The vision is to be able to "spotlight" sensors on an area (several km grid square) for a dynamic picture of human activity before committing troops.

— Quote from a warfighter

Appendix
Vulnerability Assessment

Enemy Countermeasures

- Attack situational understanding “bubble”
- Neutralize cells
- Prevent insertion/sustainment

Analysis of potential enemy countermeasures reveals three major areas of concerns. Enemy attacks on the situational understanding bubble threaten the basic requirements for success of the “cell” concept. Measures to prevent insertion and sustainment threaten basic survival, and neutralization of individual cells obviously degrades overall DCC mission effectiveness.

Attack Situational Understanding Bubbles

"CM"

1. Jam GPS
2. Jam COMM
3. UAV's disabled
4. Loss of COMSEC

"CCM"

1. Historically have survived
   - With little help, "Stingray" survival was very high
2. Many layers of redundancy within small bubble
   - Snipers
   - LUGS/UGS
   - Micro UAV's
   - VTOL UAV
3. One cell loss doesn't mean catastrophic failure
4. Taskable layers above first tier bubble
5. Physiological ID on terminal
6. Don't depend on GPS
   - Save/update PLRS/EPLRS technology
7. COMM redundancy in links and nodes

One category of potential vulnerability of the DCC concept relates to strategies of the enemy that involve attacking the situational understanding "bubbles" that provide the DCC superior and longer-range understanding of the battlefield situation than the enemy. If the enemy can reduce the range and/or effectiveness of the situational understanding bubbles, the effectiveness of the DCC could be drastically reduced.

There is specific experience that indicates that teams similar to the DCC's can survive (e.g., STINGRAY). Furthermore, the postulated architecture for situational understanding incorporates many layers of redundancy with the smallest "bubble" (e.g., snipers / observers, LUGS/UGS, micro UAVs, VTOL UAV), and also taskable layers above the first-tier bubble that can provide on-demand back-up to local bubbles problems. Nor do we believe that the loss of a few cells would lead inevitably to a catastrophic failure of the overall DCC mission.

We have identified four broad areas of potential vulnerabilities (counter-measures), and for each have also identified potential methods of reducing those vulnerabilities (counter-counter-measures):

- **Jam GPS.** The enemy may wish to deny U.S. forces the use of GPS positioning data. This is considered within the envelope of measures that could be feasible for an enemy in the specified time-frame.

  Counter-counter-measures: We do not expect U.S. forces to depend exclusively on continuous GPS coverage for position, navigation, and time-mark data. Alternative and supplemental technologies (e.g., refinements of the PLRS/EPLRS technology, integration of relative triangulation into combat identification devices, etc.) will be employed that can permit the U.S. to elect selectively to terminate, degrade, or spoof GPS coverage, since, in fact, the enemy is likely to depend on GPS or equivalent systems, and the U.S. forces have alternative and supplementary technologies.

- **Jam Communications.** The enemy may wish to attack the effectiveness and credibility of the situational understanding bubbles by attacking the communications links that service them.

  Counter-counter measures: We expect that there will be significant redundancy in communications links and nodes, reducing or eliminating systemic collapse of the situational understanding network by small numbers of successful jamming attacks" To jam large numbers of communications links would require jammers with large signatures in close proximity to our cells, which makes these jammers highly vulnerable to U.S. attack.

- **Attack and disable U.S. UAV's.** The enemy may wish to attack the U.S. UAV's that provide sensor and communications relay services to the DCC's. Due to the critical role played by U.S. UAV's, however, research is warranted into breakout UAV-hunter concepts (e.g., animals).

  Counter-counter measures: We expect that redundancy will make this counter measure relatively ineffective, e.g., we believe that the cost of finding and killing our relatively stealthy UAV's will make direct hunt-and-kill strategies against our UAV's undesirable.

- **Loss of COMSEC.** The enemy may wish to obtain intact U.S. equipment that displays situational understanding (by overrunning and capturing a DCC, for example).

  Counter-counter measures: We expect that physiological identification technologies (e.g., fingerprint-controlled access) will be incorporated into U.S. equipment. This would prevent effective enemy use of captured equipment.

Neutralize Cells

"CM"	"CCM"
	Keep your bubble bigger than his
1. Many small teams (animal-assisted)	1. Large area, large # problems
2. Enemy UGS/LUGS	2. Self defense/stealth/mobility
3. Turn loose the militia	3. IW his UGS net
• Enlist populace	4. Active spoof
4. Small UAV's in large numbers	• decoy cells
	• decoy UGS/high false alarm
	5. React against aggressor armed force
	6. PSYOP the populace
	7. Hunter-killer UAV-killers
	8. Stealth for cell-on-the-move
	9. Put lame errors in GLONASS/GPS

One class of countermeasures to the DCC concept involves approaches for neutralizing the combat cells after they are inserted. The enemy could form many small teams which have a search-and-destroy mission. These enemy teams could use animal assets to improve detection capability (e.g., tracking with dogs). A more sophisticated (or wealthy) enemy could develop (or buy) high performance UGS/LUGS and UAV's to detect the movement and operations of the DCC's so that enemy units are tipped off and can track down and neutralize the DCC's. Enemy units would use random and inadvertent interactions between their population and the DCC's to leverage information gathered by remote sensors to find and target these operations. A large, indigenous militia can be used to detect and attack the DCC units.

These countermeasures can, themselves, be effectively countered. The enemy has a large area to search in order to find and neutralize the DCC's. Even though they may have a rough idea of what militarily important areas DCC forces may want to control, as long as the DCC's situational understanding is superior to the enemy's, the DCC's can use self-defense, stealth, and mobility to remain covert. Other tactics would include the use of IW against the enemy's UGS/UAV net, active spoofing to increase the enemy's search area, hunter-killer UAV-killers to negate enemy UAV operations, and active jamming of enemy GLONASS and GPS receivers. DCC sniper operations against armed militia and other aggressor forces would greatly reduce their operational effectiveness and might lead to a catastrophic break in their will to fight. External PSYOPS can be used to influence the actions of non-combatants and militia forces to degrade their support of enemy operations against DCC units.

Prevent Insertion/Sustainment

"CM"

1. Widely distributed MANPADS
2. Take out parafoil navigational system
3. Targeting support bases
4. Cueing on drop site
5. Cables/balloons/etc. low-tech
6. IW support system

"CCM"

<u>Keep your bubble bigger than his</u>

1. Invest in signature-reduction of insertion/sustainment vehicles
2. Volume- and numbers-problem for search systems
3. Landing zones **remote** to Area of operations
4. Active CM against MANPADS
5. TMD/WMD deterrence — "Pearl Harbor Threshold"
6. Chem/bio defense
7. Reduce reliance on theater support

Another potential vulnerability is the enemy's attempt to prevent/disrupt the insertion and sustainment of combat cells. Insertion aircraft could be attacked with distributed air defense assets, low-tech barriers could be erected on likely ingress routes, potential insertion sites could be monitored, and theater support bases (land and sea) could be targeted with long-range/wide-area weapons.

Potential counter-counter measures include signature-reduction of insertion/sustainment vehicles, remote insertion, new active and passive defenses, and increased capability for extended range (extra-theater) operations. Insertion/sustainment/extraction vulnerability can be further reduced by substantially increasing the mission duration of combat cells by a factor of three or four, and, perhaps, by as much as an order-of-magnitude from the 3-4 day historical norm.

Section III
Concept of Operations: 3 — Military Operations in Urban Terrain (MOUT) Team Report

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Volume 2, Part I
Conops 3 — MOUT

MOUT TEAM REPORT

CONTENTS

1. FUTURE URBAN ENVIRONMENTS.

The "great cities" of the world are communities in which millions of persons live, work, and share civic services near high art and culture. The high density of people and their activities in an urban environment leads to a myriad of complex interrelationships that must be balanced carefully if the urban ideal is to evolve gracefully as the city grows. Unfortunately, the recent growth of urban centers in many parts of the world has become explosive and poorly planned. The number of cities with populations greater than 1 million has increased from 83 to 335 in the past 40 years, and over the next few years the crush of population in these cities will redefine "large city" to mean a metropolitan area with more than 20 million residents. Uncontrolled growth is particularly acute in the large cities of the Third World, where city services are least able to keep pace with the population growth. Nevertheless, since large cities often contain the economic engines of a developing country, it is expected that the promise of economic opportunity will lead to further population growth, and increase the probability of military operations in urban terrain (MOUT). Consequently, those issues outlined in Vugraph 1 must be considered.

Urban's Future Significance

- Very high probability of occurrence
- About 75% of world population lives within 100 miles of the world littorals
- Populations will be used as tactical, operational, and strategic assets
- MOUT generates very unique military requirements
  - technology
    - robotics
    - communications
    - navigation/position fixing
    - mobility
    - reconnaissance/surveillance
  - training
  - specialized lethal and non-lethal weapons
- Non-combatants and their exploitation will be the rule
- WMD sites in urban area

Vugraph 1

Overpopulated cities with poor services and unreliable employment opportunities will contain increasing numbers of dissatisfied persons. There has always been a banding together of the disaffected, but with the availability of increasingly more lethal weapons, gang activity has become more deadly. We expect this trend to continue, especially in Third World countries where civil authority can be challenged directly by armed bands. No one is surprised that an armed-band can cause major social disturbances, such as a disruption of food supplies. Future Somalia-like humanitarian operations for the U.S. military are therefore probable. These missions will pose an increasing risk to U.S. personnel as the lethality of the rogue elements continues to grow.

Any potential U.S. adversary with competent leadership learned well by comparing the results of Operations Desert Storm and Restore Hope that the U.S. military is most effective when engaging isolated hostile forces, rather than forces intermixed with a civilian population. This provides an obvious incentive for a rogue leadership to locate strategic targets within population centers. A sense of impunity may be promoted by the belief that international opinion has little tolerance for collateral damage. The act of locating key national assets, such as a Weapons of Mass Destruction (WMD) facility within a population center could be portrayed as a less hostile act than the civilian deaths that accompany its destruction.

The high density of urban clutter isolates personnel and impedes the massing of forces. Over an area of 10 miles square, achieving a modest density of 10 soldiers per city block requires 100,000 troops. As large numbers of troops collide with the local society, consequences are unpredictable. In contrast, small terrorist groups have been highly effective in accomplishing limited missions within urban environments. The complexity of the urban terrain is more conducive to short missions, such as raids, by Combat Cells.

Historically, urban operations have produced lessons in tragedy (Vugraph 2). Large unit operations such as Hue City, Vietnam in 1968 and Grozny, Russia today, resulted in massive damage and high casualties. Small unit operations, such as the 1981 Desert One raid, have been high risk due to the complexity of urban terrain and the specific mission. Nevertheless, it is clear that successful operations within a city are the sum of small Combat Cell engagements to achieve tactical objectives.

MOUT OPERATION

Vietnam (Hue City)
- **Walled city, small bldgs, river people**

Lessons Learned:
- **Restrictive ROE**
- **Poor Comm**
- **Stressed C^2**
- **Leaders/Marines not trained for Urban warfare**
- **Casualties 6x normal**
- **80% of city destroyed**

Today (Grozny)
- **Large buildings, ancient infrastructure, sizable populace**

Current Situation:
- **Poor Communications**
- **Stressed C^2**
- **Poor Conops/untrained soldiers**
- **High Casualties (military and civilian**
- **20 Man teams**
- **Most of city center destroyed**

- **Even more significant and difficult in future**
  - **Urbanization ➡ political instability**
  - **Cities are where power resides**
  - **Enemy exploitation of non-combatants limits our options**
  - **WMD sites in urban areas**

Vugraph 2

To provide a focus for it's investigation, this panel considered a possible 21^{st} century raid involving small Combat Cells to rapidly execute a formidable mission in a difficult MOUT environment. Although we have selected WMD as the targets, hostage rescue could be substituted and still pose similar challenges. We will describe the fire structure, mission definition, CONOPS and potential vulnerability of our units. We will also suggest developments in technology as well as the training of the individual and their units that will increase the U.S. military capability for such inherently small infantry unit missions. We first provide a general characterization appraisal of the MOUT environment.

2. CHARACTERIZATION OF MOUT.

The characteristics of MOUT are well-known. They apply to precision, rapid operations directed against high-value targets to the extent that they must not be allowed to slow the U.S. forces: tactics and equipment to minimize the difficulties that arise from this environment is essential. The urban environment is characterized by a number of features that make it a particularly difficult one in which to carry out military operations. The local defenders in MOUT have many intrinsic advantages: they know the terrain, they speak and read the language, their supplies are available locally and they have limited logistics problems, they may operate under less restrictive rules of engagement than U.S.

forces. In a prolonged operation, or in one in which the defenders are allowed to prepare, these advantages will translate into very substantial difficulties for U.S. forces. In a successful MOUT — especially one directed toward a specific, high-value target, where the objective is not to pacify the city but rather to neutralize a threat to U.S. military operations outside the city and other national security concerns — speed is essential. If U.S. forces can enter, move rapidly and directly to their objective, accomplish what they came to do, and get out as quickly as possible, they will minimize casualties and maximize the chances of accomplishing their mission. A rapid operation — modeled more on the tempo and preparation of a SOF operation than on typical ground maneuver — must be based on detailed intelligence, mission planning and rehearsal for the key elements. Outlined below are some of the unique challenges that must be considered as routine for the future:

- **Constrained mobility limits maneuver tactics**
- **Potentially hostile civilians in combat zone**
- **U.S. collateral damage policy limits weapon choices**
- **Urban structures provide good adversary cover**
- **HUMINT vs technical intelligence required**
- **WMD targets may be extremely difficult to "neutralize"**
- **Local and global communications and position location are more difficult**

Urban terrain is complex, and provides limited opportunity for maneuver, and abundant cover for defenders. The availability of many protected spaces makes the urban environment particularly hazardous for ground forces. These spaces provide cover for snipers, limited mobility, and increase vulnerability to mines, car bombs, and booby traps. The complexity of urban spaces provides a natural advantage to native, defending forces.

Inhabitants. Cities are filled with people, most non-combatants; It may be difficult or impossible to distinguish hostile, neutral and friendly inhabitants. Restrictive rules of engagement may make it very difficult, especially for a rapidly moving military force, to apply force selectively. U.S. forces will, therefore, often operate with great uncertainty and need to make many difficult decisions about proper application of force..

Unconventional Tactics. The ingenuity of local forces, combined with their intimate knowledge of the city and the commercial availability of sophisticated weapons, will expose U.S. forces to tactics and threats for which they have had no training. Even familiar weapons — mines, RPGs — are especially effective in the limited spaces and against the channeled flow of personnel on the ground that characterize MOUT. Perhaps more importantly, tactics that we may regard as ethically unacceptable — the use of the civilian population as a shield or even as forced combatants; the use of chemical or biological weapons in a densely inhabited region — may be acceptable to an adversary, especially in defending very high-value targets.

Communications. The many reflective building walls and other radio-opaque components of buildings make radio frequency communications difficult in MOUT.

Although the degree of this difficulty depends on the detailed architecture of the city, it can make GPS geolocation highly problematic, limit line-of-sight communications, and generally interfere with radio frequency communication.

Public Exposure: "CNN" and Other Public News media. Wherever there are military operations in urban areas, there will be heightened public exposure. Even if international TV crews are not there to give global coverage, local news media will be, and will be active in distributing images and information to international news media. This rapid flow of information has two adverse consequences: first, it makes operations more public, and partially neutralizes the intrinsic strength in information technology that is one component that the U.S. relies on to provide advantage. Second, it amplifies the public impact of civilian casualties and collateral damage caused by U.S. forces. On the positive side, prompt news coverage imagery has provided valuable intelligence and strike assessment information for the U.S. and its allies, and often reveals to the public the diabolical nature of an adversary's tactics.

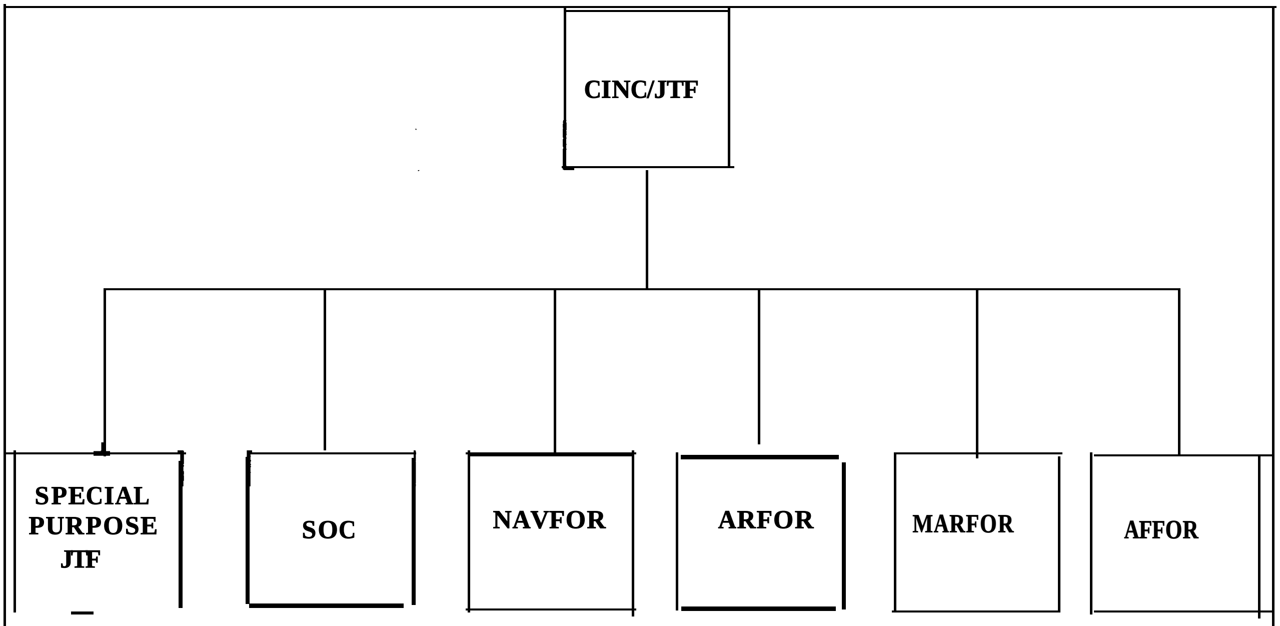
Maps and Plans. Operations in cities are hindered by the intricate topology of the urban environment. Information concerning essential features of the city may be obsolete — especially features that cannot be imaged from the air such as tunnels, subway systems, electrical, water and sewage systems, interior layout of buildings.

Rules of Engagement. Concerns about limiting collateral damage constrain the weapons and tactics that can be used by U.S. forces. Even in difficult military operations, rules of engagement may severely limit options for U.S. forces. (Hue City is a case in point. Vugraph 2). There are important problems in policy about the interaction between U.S. forces and the population of the city. What lethal weapons will be allowed? What classes of non-lethal weapons are allowed? What factors should govern the transition between non-lethal and lethal weapons. What should the rules be regulating the protection of the population against release of chemical/biological agents or special nuclear materials from any WMD facilities neutralization? Given the great difficulty in neutralizing buried and hardened facilities, is it sufficiently effective and acceptable to consider using non-lethal chemical or biological agents against these types of targets?

Casualties. Casualties are inevitable to U.S. forces and to civilian non-combatants in MOUT, and these casualties may be disproportionately important, when amplified by international electronic news media, in shaping public perception of the operation. Given the inabilityto capitalize on the advantages of maneuver warfare the casualty rate will be higher.

3. FORCE STRUCTURE.

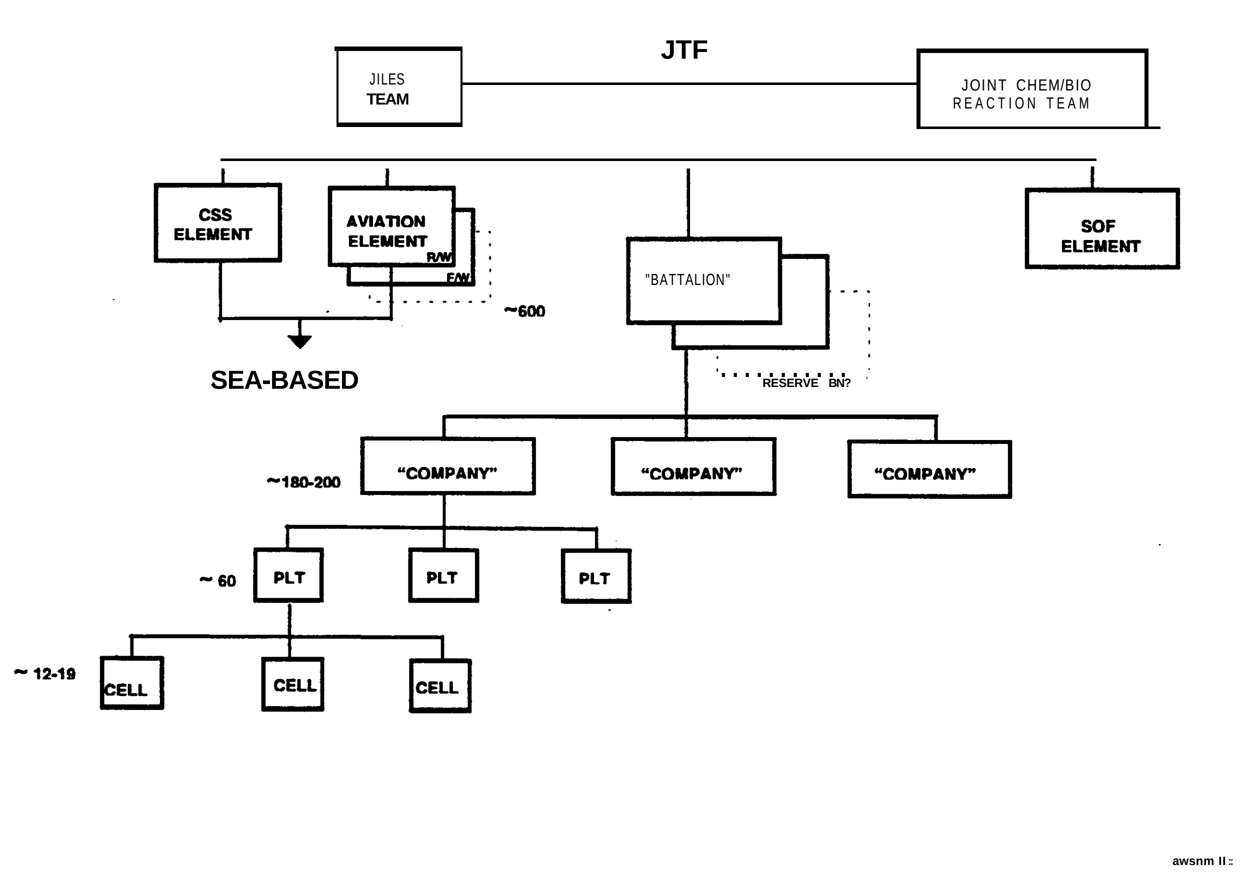
The Special Purpose Joint Task Force (SPJTF) operation will employ small, very light, mobile and situationally aware combat cells emphasizing sensors and fires, rather than classic maneuver and fires. These combat cells will be empowered by technology such as communications, sensors, robotics, and special weapons to increase probability of success. The SPJTF will train extensively with virtual reality/simulation.



Vugraph 3

The urban raid mission would be assigned to the appropriate theater CINC (Vugraph 3) as part of the existing theater command structure, a carrier battle group (CVBG) and an Amphibious Ready Group/Marine Expeditionary would be deployed. The CINC would form the Special Purpose Joint Task Force (SPJTF) using these forward presence units. In addition to the embarked troops, augmentation from CONUS or other forces would complete the elements required for the SPJTF (Vugraph 4). Augmentation would include a USSOCOM element for pre-raid reconnaissance, surveillance and target acquisition (RSTA); command intelligence support with JILES (CIA) MIST (DIA), and SMU Cell capabilities; appropriate expertise on the target WMDs from a Joint Chem-Bio Reaction Force Cell; and necessary additional fixed and rotary wing aircraft and ground combat units. Assembly of the SPJTF would be inconspicuous, and designed to appear as normal operations as the ships move closer to the adversary target area.

All air operations would be under the command of the JTF commander (and his JFAC), as would the intelligence teams and the Special Operations Forces (SOF) for pre-raid operations. A composite rotary-wing squadron would be assigned to support each battalion of the SPJTF. The SPJTF would comprise two battalions with an additional one in reserve. Each battalion of the SPJTF would include approximately 600 troops, nominally organized into three companies of three platoons each. Each platoon would be composed of three combat cells containing 12-19 persons. The combat cells would be trained to operate independently, or reaggregate into larger units as dictated by the tactical situation (see Vugraph 4).



Vugraph 4

An Example MOUT Combat Cell

- Team size/organization:
  - 1 combat cell leader - C^4 suite
  - 2-3 micro UAV (situation awareness)
  - 2-3 countersniper (sensor-shooter)
  - l-2 robotic operator/cover
  - 2-4 riflemen
  - 1 1anguage/psyops specialist
  - 1 medic
  - 1 assistant combat cell leader - C^4 suite
  - l-2 patrol support vehicle operator

12-19 total

Vugraph 5

The SPJTF combat cells would consist of 12 to 19 individuals (see Vugraph 5). The Cell leader will be outfitted to serve as a C^4 node. With support from an assistant Combat Cell leader (a Demo/Bio/Chem specialist), he/she will lead two to three counter sniper riflemen, two to three UAV operators (for situation awareness and munitions delivery) , one to two robotic operator(s), two to four riflemen armed with very light-weight lethal weapons (including anti-armor and non-lethal capabilities), one language/psyops specialist, one medic, one to two support vehicle operator(s). Cross training in all skill levels will be the norm.

Due to the lack of open areas and runways, a vertical take off and landing (VTOL) capability is required for the infiltration/exfiltration of combat teams operating in an urban environment. Obviously, the new development high speed, stealthy delivery platforms offer enhanced potential to reduce the chances of compromising a Combat Cell during infiltration. However, no such platforms are currently in the acquisition cycle reflected in the fiscal year 98-03 POM. Unless a new platform development is initiated very soon, the force structure of 2015 will look much like what we're acquiring today — the CH-47, CH-53, A-60, V-22 and OH-6 family of aircraft. Improving the survivability and electronic enhancement of these currently fielded infiltration/exfiltration systems should remain a high priority. Vugraph 6 provides an example of the operational concept:

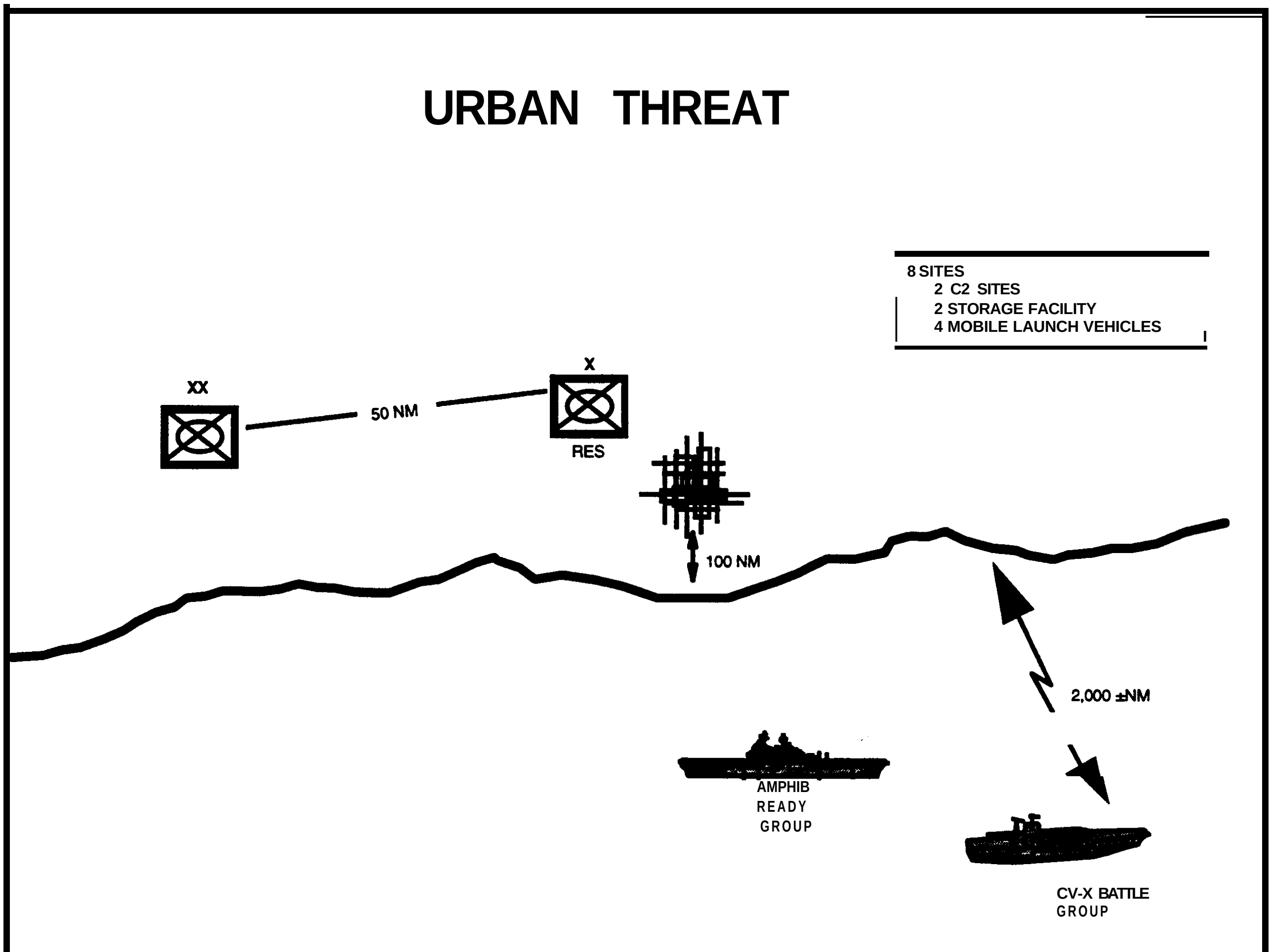
Operational Concept Example

- Urban Area Raid to Neutralize WMD (2015)
  - Elite Force with Special Training
  - Target NBC Storage, Theater Missiles and C2 Sites
  - Real-Time HUMINT and SOF Pre-ops
  - Battalion-sized Urban Entry Force, Helibome
- Support Elements
  - Directed Remote Fires Fixes Defending Division
  - Fixed Wing Air Attack Fix Regimental Reserve
  - Remote Fire Support; Host Country or Shipboard
  - Combat Air Patrols
  - AWACS, JSTARS, UAV Recon, and National Systems
- Objective: Permanently Neutralize WMD, Facilities and Missile Launch & C^4

Vugraph 6

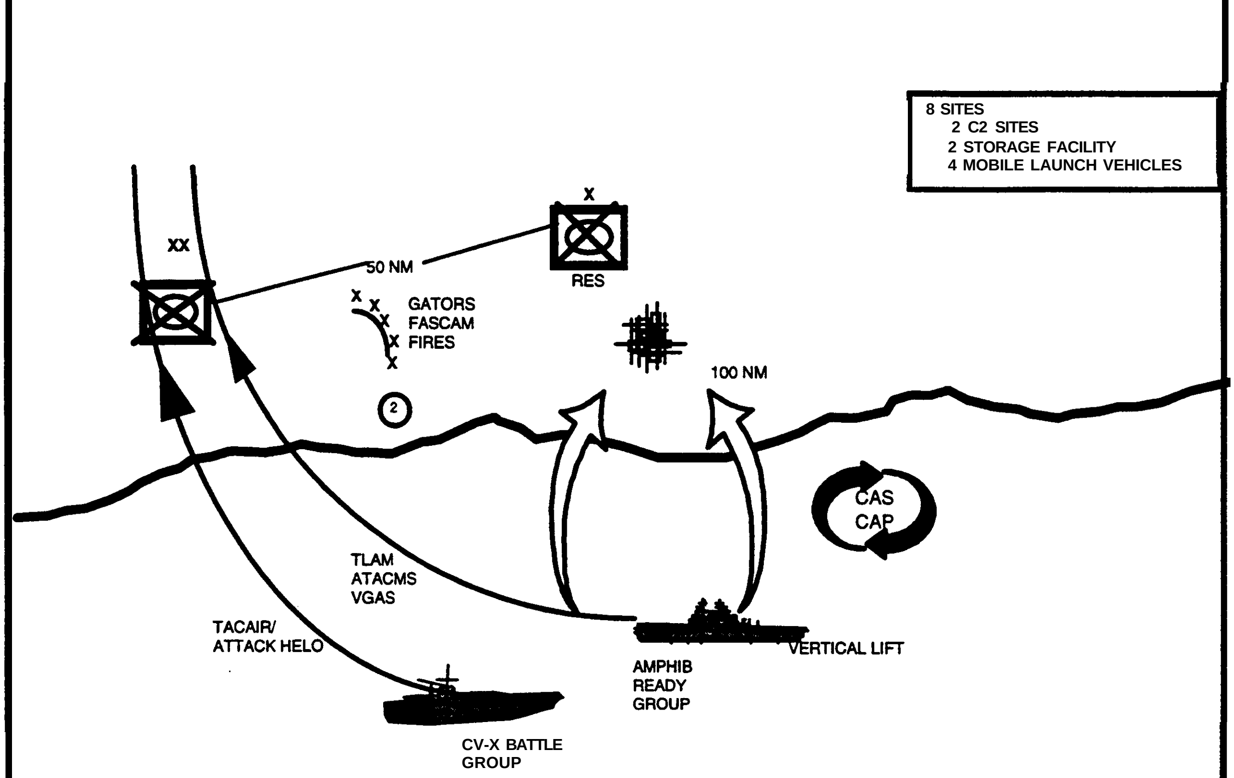
4. MISSION DEFINITION.

This mission is set within a large urban area, and is to neutralize known WMD, cruise/ballistic missiles and launch facilities, command and control nodes and associated security elements. The urban area is located 100 NM from the coastline/national border of the adversary country. (Variations on this mission could include the freeing of hostages or taking down enemy leadership.) The region is defended by a highly mobile, armored, well equipped and trained "elite guard" division, with a regimental reinforcement element within 50 nm. It is estimated that the WMD missiles and launch capabilities must be neutralized within 24 hours. Complete force extraction should take place as a conclusion to this operation. Clearly, conducting MOUT against high-value targets such as these is going to be a last choice endeavor. Both parts of the problem are difficult — hard targets such as WMD facilities, and urban operations. Vugraphs 7A-C outlines the mission.

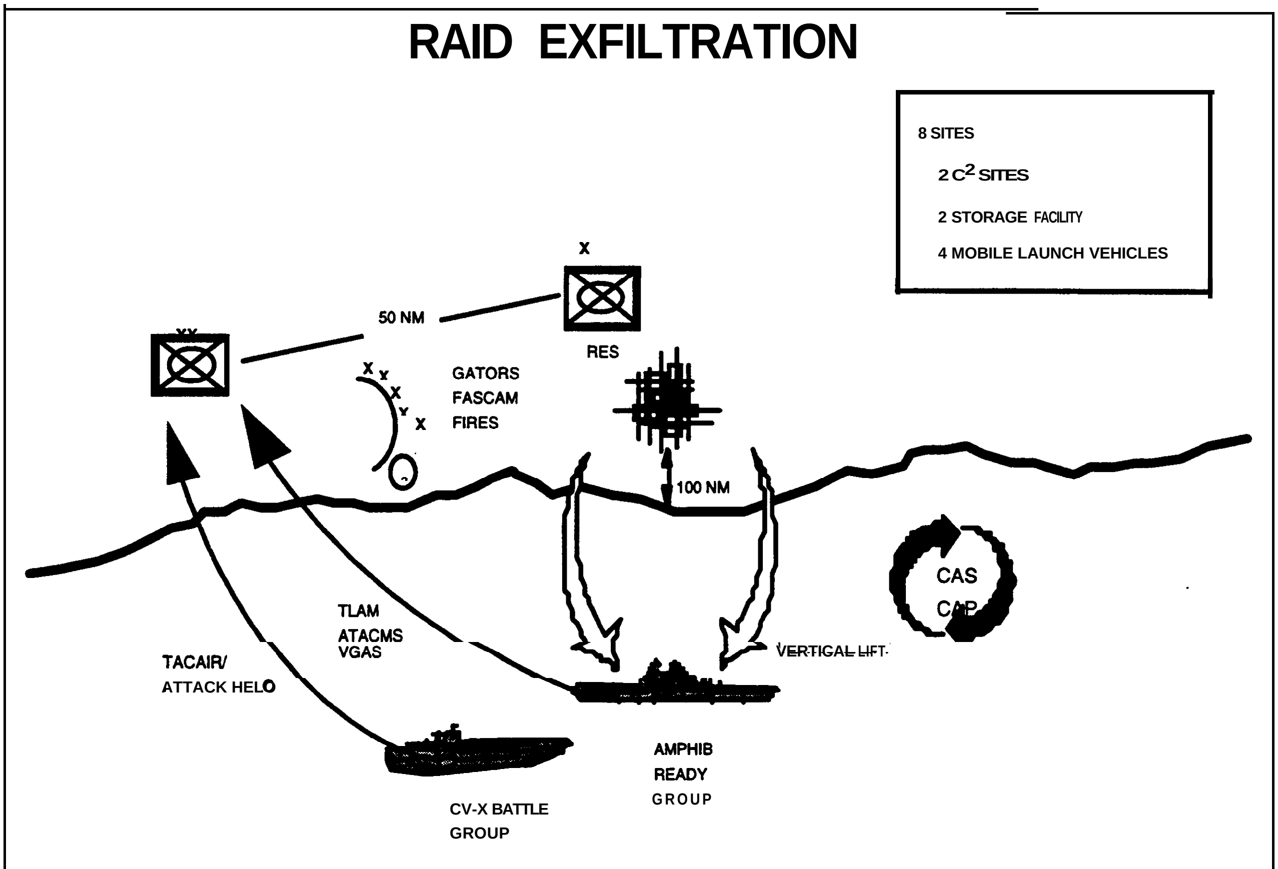


Vugraph 7A

RAID INFILTRATION



Vugraph 7B



Vugraph 7C

5. CONOPS.

5.1 General.

Commanders Intent. Pre-hostilities insertion of SOF will provide surveillance of target sites and enemy/civilian activities along lines of communication and approach routes to the targets. SOF will also emplace unmanned sensors to be used by the raid. Surprise for the night rotary wing landing of the raid will be achieved by deception and psychological operations. The raid will conduct combat cell direct actions to destroy/neutralize enemy WMD facilities. Remote fires from aviation and sea-based launchers will be used to fix/delay the elite guard division and regiment responsible for reinforcing local adversary forces in the urban area. The adversary's strategic center of gravity consists of his command and control and the WMD. His operational center of gravity is the elite guard and reinforcing guard units. His critical vulnerability is the lines of communication units must take to the urban area and his inability to interdict our remote fires. The U.S. strategic center of gravity is information dominance/assurance. Our operational center of gravity is the raid force. Our critical vulnerability is infiltration/exfiltration of the raid force.

Concept of Operations Using the deception of routine forward deployment of naval forces in regional international waters, conduct raid (24 hours) in adversary's urban area

Concept of Operations. Using the deception of routine forward deployment of naval forces in regional international waters, conduct raid (24 hours) in adversary's urban area to destroy/neutralize WMD targets (weapons systems, launch and C^4 facilities, and storage sites), (Vugraph 7b). Air and sea control will provide battlespace dominance while a combination of space-based, airborne and ground sensors and SOF will enable information dominance. As a result, our tactical mobility and ability to rapidly employ remote fires will be the key elements of operational surprise. Adversary reaction forces will be neutralized by deception, fixing fires, or delayed/attrited as they attempt to move to contact with the raid force. Tactical surprise will be achieved by the rapid infiltration of two raid battalions to their urban areas of responsibility. Vertically landed by companies, the force will quickly move to isolate targets using platoons to surveil/block exterior lines of approach as combat cells clear the interior approaches to the targets and attack them. Thus, the SPJTF's battalions will be able to rapidly disaggregate into appropriate elements for the attacks and reaggregate for mutual support as the situation develops and withdrawal for exfiltration (Vugraph 7c). These combat cells will be effective for three principal reasons: they will be composed of individuals who are specially recruited and trained, they will be formed and retained in cohesive tactical combat cells, and they will be empowered by equipping them with effective unit and personal communications, sensors, robotics, and appropriate weapons, as well as, use of physical and virtual simulation for both home based and deployed mission training. Employing small, very light, mobile and situationally aware combat cells, the SPJTF will emphasize mobility, Observation, Orientation, Decision, Action (OODA) principles, indirect sensors and precision fires rather . than classic massed forces and massed fires.

5.2 **Employment.**

The operation will be conducted in three phases.

Phase I - Deterrence

a. Forward deployment
b. Conduct surveillance
c. SOF infiltration

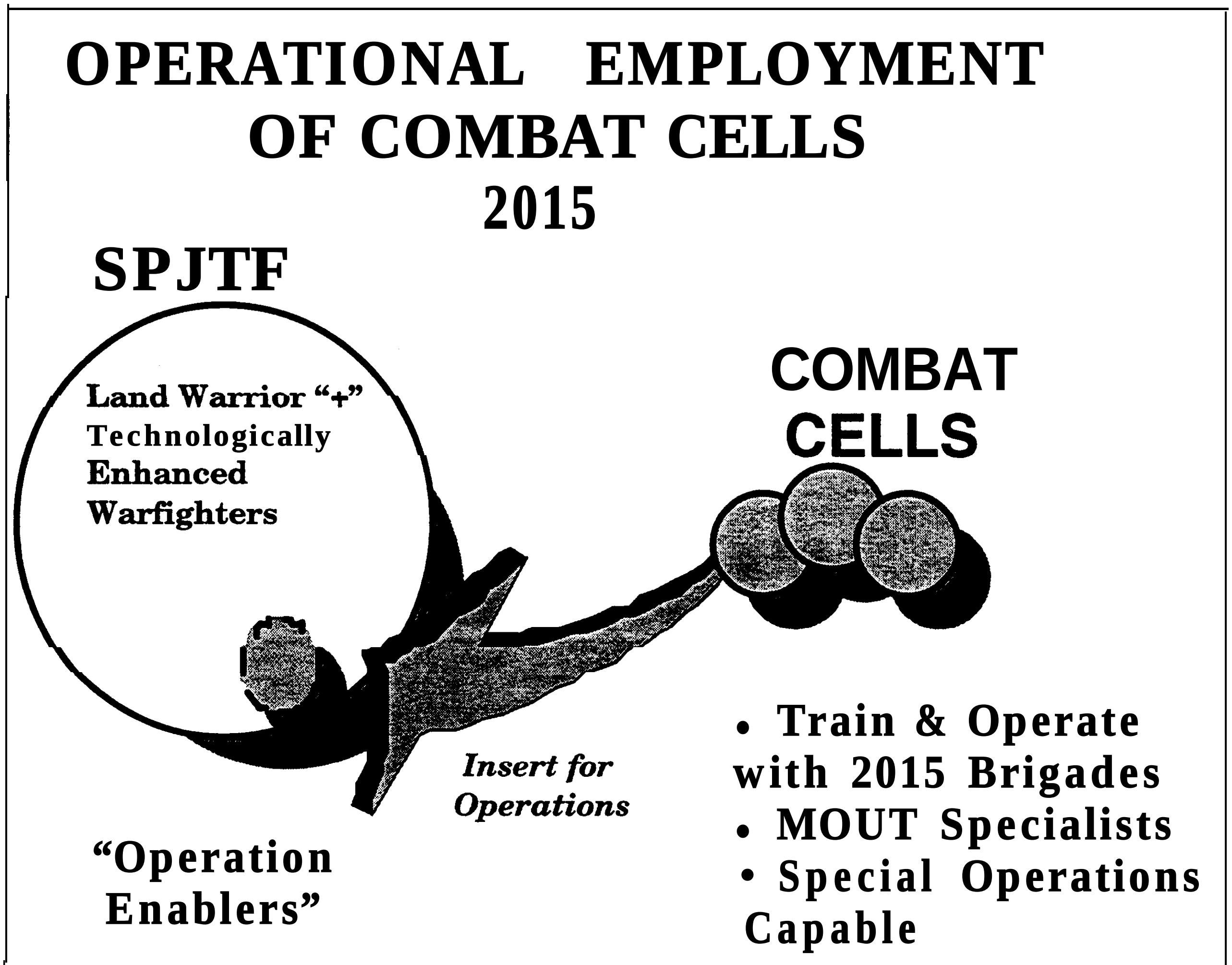
Phase II - Raid

a. Rotary wing or surface effect infiltration of adversary's target area
b. Destruction/neutralization of targets
c. Strike on forces outside the city to fix and deny movement to the objective area
d. Exfiltration

Phase III - Post-hostilities

a. Battle Damage Assessment (BDA)
b. Leave behind sensor/HUMINT
c. Recon

6. CONCEPT.



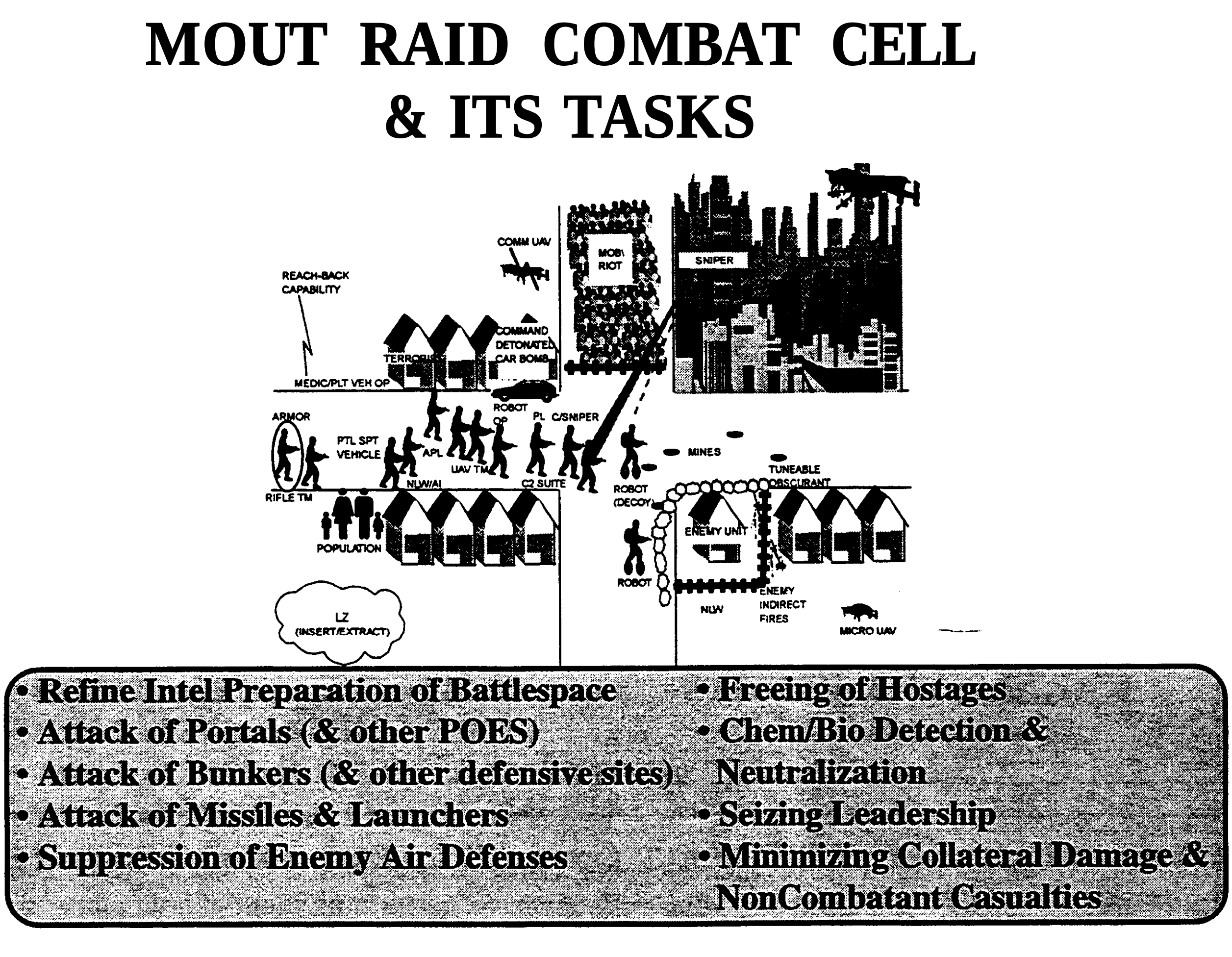
Vugraph 8

The premise at the core of this concept of military operations is that it is possible to design ground forces (see Vugraph 8) whose effectiveness is the equivalent of much larger conventional forces taking advantage of training and technological superiority. This advantage would give these forces four enabling characteristics to dominate the battlespace:

- ***High Situational Awareness***
- ***The ability to operate in small, dispersed groups with a high degree of autonomy, with tailored logistics***
- ***High maneuverability and the capability to complete the mission quickly***

High lethality, through the ability to rapidly call in precision fires from a distance, including special purpose demolitionInformation architecture and assured communications

Situational awareness allows the force to know the disposition of the enemy: both targets and threats. The ability to call in precision fires would empower the Combat Cell tactically and reduce the signature, and give it much greater mobility, offensive capability and defensive capability than would be expected from a conventional force of the same size: the energy requirement would be supported by the logistics elements of the main force at a distance; the small, dispersed forces would have the mobility and timeline of a small group but the muscle of a large one. Vugraph 9 depicts such a small Combat Cell and tasks associated with this MOUT type rapid operation:



Vugraph 9

One of the most challenging of problems facing early entry forces will be neutralizing the major threats to the main force: WMD, competent enemy C^4 systems, and other hard targets. Adversaries may shield these assets in cities, often in facilities hardened and obscured by burial. It may not be possible to attack these targets successfully from stand-off air for a variety of reasons: concern with collateral damage, inability to determine the precise location of the essential materiel or people other than through local action; inability to breach buried targets with any known technologies; unwillingness to use explosives against certain types of targets because of unacceptable risks of collateral damage (for example, BW storage facilities). In these circumstances, ground forces may be required to *attack the facilities; to provide on-site information about the targets for subsequent attack from the air; to enter the targets; to remove nuclear weapons and otherwise defeat the target's primary military functions. These MOUT undertakings may be beyond the scope of SOF operations in terms of scale and the ability to fight a short duration, but high-intensity conventional military engagement in a very difficult operating environment; these operations will require high mobility, the element of surprise, high lethality, and specialized* ***technical competence to be successful.***

7. WMD SPECIAL ISSUES.

7.1 WMD Facilities.

The WMD targets located in the postulated urban area are constructed to survive the damaging effects of conventional weapon attack. That is, they are buried at depths below the penetration capability of anticipated precision guided munitions (PGM), possess redundant external access routes, portals, ventilation openings, external cable connections, and communication antennae. The facilities are assumed to be capable of operating for periods of months in a "buttoned up" configuration. Layered security provisions are anticipated, as well as employment of camouflage, concealment, and deception (CCD) design elements (e.g., decoy portals and antennae). As a consequence, mission planning must consider basic information requirements concerning target intelligence, damage criteria, and weapon attributes the combination being referred to as Intelligence Preparation of the Battlespace (IPB).

The military objective in attacking a WMD target is to neutralize its functionality. Generally speaking, this means inflicting a-severe level of physical damage to the interior of the facility. In a hardened and compartmented C^4 facility, for example, detonation of as much as 50 lb. - 100 lb. of high explosive may be required within each mission-critical compartment. The presumption is that this cannot be done reliably by a standoff weapon (remote fire) for various reasons, such as a lack of knowledge or an inability to penetrate the facility. In this event, two classes of options must be considered for the Combat Cell: (1) gaining entry to the facility for the purpose of destroying mission-critical equipment, or (2) making a final determination as to the efficacy of a standoff weapon by locating and calling in the weapon. In either event, it also may be necessary to consider lesser damage objectives than complete destruction, such as mission disruption or denial (e.g., hours-to-days down time). The probability of successful attack under these conditions, as well as confident BDA, will depend strongly on the quality of target intelligence information, including knowledge of target mission functions, concepts of operations, facility construction details, architectural layout, equipment locations, and other relevant details. Depending on the nature of the WMD materiel and the risk of collateral damage from the mode of its destruction, additional information relative to venting, recovery, etc. may be required.

Mission success will depend critically on the ability to adequately define intelligence, surveillance, and defeat assessment requirements for these hardened targets. At the core of this effort we visualize a functional damage assessment procedure to analyze each target and identify potentially exploitable vulnerabilities (e.g., Achilles' Heels), as well as associated observables. We presume that this will be an ongoing, high-priority, intelligence community activity, supplemented (with increased tempo) during pre-raid operation preparations, to include in-country infiltration. From a technology requirements perspective, the potential for remote sensing devices (including applicable sensor/platform systems) to identify key observables must be evaluated. Sensor types might include acoustic/seismic; chemical, radiation, thermal emissions, E/M emissions and anomalies, active (radar/lidar) imaging, passive imaging. Sensor location can be in space, air, or on the ground. The potential leverage offered by emplacement, interpretation, and fusion of ground-based sensors by the Combat Cell or precursor operations, supplemented by air borne sensors, will be a unique attribute of the pre-raid operations preparation and trans-raid phases of the operation.

The functional damage assessment procedure seeks to identify individual elements associated with each critical target system (subsystem) which might provide an exploitable vulnerability, especially as it may constitute a common failure mode. Using the C^4 sites as an example, critical systems would include penetration protection, structure, power, communications, mission equipment, environment control, supporting infrastructure (environs). With reference to the communications system, critical elements might include transmitters, switch rooms, cables/vaults/pull boxes, antennas, computers, modems, UPS, EMP filters, entry points, technical control center, etc. Clearly, the assessment of criticality depends on facility function and mission objective, and the extent to which detailed information is available to the mission planners.

Special consideration must be given to target lethality and the means of target neutralization. Depending on the nature of exploitable target vulnerabilities, it may be impractical for the Combat Cell to bring suitable demolition charges, or equivalent munitions with them. Particularly in the case of chemical/biological agents, special means of detection and neutralization may be required. A major mobility consideration, then, is how munitions and other specialized equipment needed by the Combat Cell can be delivered from remote location within the timelines dictated by the Combat Cell.

7.2 Nuclear Weapons.

An objective of a mission against a rogue nation that has acquired one or a few nuclear weapons would be to capture and remove those weapons. Locating and recognizing such weapons, especially in the presence of decoys, will require specialized equipment and skill. Disarming protective systems and transporting these heavy objects will place a substantial tax on the efficiency of the operation. Trying to destroy them in place may not be practical, both because of the hazard of trying to neutralize them without a careful analysis of their structure and of timing/fusing circuits, and because of the risk that they could be salvaged and repaired if the destruction was not complete. Environmental impact of destroying nuclear weapons in various ways also must be considered.

7.3 Chemical Weapons.

Chemical weapons in bulk are difficult to destroy. If they are present as complete weapons, simple explosion may destroy some, but leave others intact. Effective technology for destroying chemical weapons is needed. Manufacturing and bulk storage facilities are more vulnerable, if they can be reached. In MOUT, the problem of release of chemical agents into the environment may require special procedures to make sure that the facilities are sealed after they are destroyed.

7.4 Biological Weapons.

Biological weapons pose particularly difficult problems. It is important to limit release of debris from a biological weapons facility: a dust containing anthrax spores, for example, could easily cause an anthrax epidemic. Simply recognizing a biological weapon and characterizing it require highly specialized skills and sensors/analytical systems. The type of operation carried out to neutralize a BW facility will clearly have to be carefully tailored to the nature of that facility.

7.5 Missile Sites.

These are unconventional targets by virtue of the missiles being located in hardened tunnel complexes. While destroying the external launch pad does not pose a problem, gaining access to the protected missiles is extremely challenging. Disruption of launch operations could be achieved by collapsing or otherwise damaging the egress portals, but this probably would leave the missiles operational and may not deny operations for the desired length of time. Functional damage analysis must be relied upon to identify/alert the Combat Cell to unique vulnerabilities that can be exploited. Physical destruction of missiles is straightforward if they can be reached.

7.6 Command, Control, Communication And Computer (C4) Centers.

Hardened C^4 centers tend to be multi-compartmented facilities in which critical operations are conducted in separate areas of the facility. Explosive charges detonated in one such compartment, while destroying the contents of that compartment, will not destroy adjacent compartments. It is also reasonable to anticipate that countermeasures against the spread of fire, smoke, and other airborne contaminants will be in place. The physical destruction of a command center may well require the destruction of multiple compartments.

The nature of operations within a command center, and need to communicate with the outside world by a variety of means, offer various opportunities for disruption and denial missions that do not require extensive physical destruction of the facility. As discussed earlier, functional damage assessment is expected to reveal a number of exploitable vulnerabilities for a specific target facility, such as cable vaults, power sources, antenna connections, etc. Conceivably, it would be possible to selectively destroy communications channels to make the facility critically vulnerable to SIGINT.

8. VULNERABILITIES OF MOUT.

MOUT will encounter non-traditional threats. These threats often originate with the confined nature of the battlespace, and the presence of a local population. The non-traditional threats may not be identified readily by traditional intelligence analysis. U.S. forces will always be vulnerable, and vulnerability will increase as the intensity of conflict increases. There are several generic classes of threats, and efforts in tactics and technology should be focused on trying to solve these problems.

8.1 Reduced Mobility.

The confined nature of the urban battlespace is a formidable disadvantage for the Combat Cell. Their movements may become channeled into potential hostile direct fire zones. High mobility will help overcome this vulnerability. An adversaries' defensive techniques -- sniping, mines, CW, barricades — are easily mobilized, if the adversary has warning, or can slow an advance sufficiently to organize defensive activities. Technologies that leverage tactics and increase mobility — weapons to counter sniping and remove barricades; mine detection and light-weight protective armor — are important.

Nevertheless, the confined nature of an unfamiliar battlespace is a formidable problem today and will remain a problem for 2015 without dedicated solutions.

8.2 Information Dominance.

If the information provided to the SPJTF is not adequate, the mission will fail: there will not be enough time to follow many false leads in this kind of operation. The not uncommon approach to ground warfare — "Get there and figure it out!" — will not work; pre-operation planning and information must be detailed. Intensive training of the Combat Cell members in simulated urban environment, and a detailed database about the city will be a requirement for mission success. In the absence of this type of information dominance this raid mission would be aborted.

Intelligent preparation of the MOUT battlespace is not well understood. The-technological development of better sensors is required, such as for sniper detection, detecting and classifying people and surveilling buildings. It is likely that the confined nature of urban terrain will cause blind spots in the sensor arrays. Urban clutter may aid in the concealment of small sensors, but urban clutter may also provide numerous undesired sensor signals, such as the movements of non-combatants. A continuous broadcast of sensor information endangers the sensor and perhaps the MOUT operation itself. Intelligent sensor arrays are needed to cut through the urban clutter of civilian activities, and broadcast only information of value.

We expect the Combat Cell to depend heavily on electronic communications and information systems for their battlespace awareness and electronic reachback to the JSPTF command. The Combat Cell will be vulnerable to disruption of communications, sensor information, and GPS information, caused by the urban terrain. Signature reduction by limiting transmissions to important information can help, as can other electronic methods expected in other operations in future warfare.

8.3 Unconventional Tactics And Weapons.

Specialized training is required to operate in cities. Beyond the training required for MOUT, however, defenses may be organized for high-value targets that present totally new challenges: CW in a crowd, use of civilians as barriers or shields, high-technology weapons (lasers for blinding) or "non-lethal" weapons (disorienting agents). These threats may not be "validated" before the operation, but it is essential to train against the unknown as well as the known.

The local population is likely to present a broad spectrum of threats. These threats may change with time, since the hostility of the urban population may change if cultural norms are violated, for example; a lack of understanding of the local language and culture would leave the Combat Cell vulnerable to problems caused by attempts from hostile forces to manipulate the psychology of the urban population. Even if it is impractical to counter such actions, it is important for the Combat Cell to know if such efforts are underway, and to know their probable effectiveness.

The desire of the Combat Cell to minimize collateral damage can become a vulnerability. Positioning hostile forces within the civilian population is already a common situation. Non-lethal weapons may be useful in situations involving intimate intermixing of civilians and combatants. For non-lethal weapons to be used against lethal fires, however, the effectiveness of the non-lethal weapons must be assured. It is absurd to respond to lethal. fires with ineffective weapons even if the desire to minimize collateral damage may dictate such limiting rules of engagement.

Police forces and armed militias pose a special problem for the Combat Cell. These hostile forces are trained to operate in an urban environment, and may have developed special expertise in routing internal forces that had previously opposed the regime in power. Although these forces are probably lightly armed, their "home court" advantage is formidable, and they may be outnumber the members of the Combat Cell. It should be a priority to leverage technology and develop tactics that will nullify the home court advantage of these forces, such as methods for deception and disorientation that may include semi-autonomous weapons and non-lethal mines. It is not clear that nighttime operations will be an advantage for a Combat Cell in 2015. For application in specific actions, such as exfiltration, it may be possible to develop obscurants (smokes) that work with portable imaging radar systems to provide the Combat Cell a daytime visibility through an artificially-darkened sky.

The confined nature of the urban battlespace is a disadvantage for the Combat Cell. Their movements can become channeled into direct and indirect hostile fire, or large non-combatant groupings. High mobility will help overcome this vulnerability. Although necessary, high mobility alone is not sufficient. "Through-the-wall" imaging radar systems will help with battlespace awareness and reduce the risk to the Combat Cell. Intensive surveillance of the battlespace will probably be required to guard against terrorist weapons such as car bombs.

8.4 Inadequate Tools For Neutralizing High-Value Targets.

The class of targets represented by, for example, a large, buried WMD facility located in a city represent a type of problem for which we must develop doctrine, tactics and weapons. It is not clear that a Combat Cell can fight its way into such a facility, or that once there it would have the time to systematically destroy it. What *should* be the action that the force takes when it reaches its objective? Closing and mining entrances requires large quantities of explosives, and would require delivery in appropriate warheads from afar once crucial locations were identified by local inspection. Blocking air vents might be accomplished by relatively small volumes of foams that hardened into rigid materials. Cutting communications and power again involves tools for identifying where the essential antennas and cables lie. There is no doubt that many of these problems might have good solutions, but the problem of neutralizing buried facilities with additional constraints will require a careful systems analysis, development or adaptation of appropriate equipment, validation in exercises, and training. Robotic devices, if quick and adaptable, may help reduce the risk to humans.

Finally, air supremacy is assumed throughout this MOUT Raid operation. We expect a non-negligible threat to air cover from anti-aircraft artillery and MANPADs. Some of these hostile fires may be identified by their actions against decoys or the UAV's in the area, but some will remain to pose a threat to air operations. Loss of air supremacy would be catastrophic to the Combat Cell infiltration/exfiltration.

9. ARCHITECTURE

9.1 Underwriting The Concept Of Operations (CONOPS).

Achieving the objectives of the CONOPS will require not only a set of specific improvements, but also a framework or architecture intended for their integrated employment and correspondingly greater benefit. To put these into perspective, we return to objectives and characterize the means to achieve these.

The objective is to create future light forces capable of successfully carrying out tasks normally requiring larger and/or heavier forces and their support and the presence of both components-tooth and tail. The process of making light forces more capable is described as empowerment which is carried out at the individual and Combat Cell level. Through empowerments' aggregation its full impact enhances the Brigade's and exponentially improves the combat power of the SPJTF.

9.2 Empowerment.

Empowerment as employed in this context involves a) new and improved concepts b) an architecture which integrates specific improvements and c) the specific improvements themselves.

Along with these, there would also be major contributions made with more traditional concepts associated with achieving air and sea superiority, freedom of movement in the theater and in strategic sea lanes and airways.

Empowerment of the individual and Combat Cell involves the greatest innovation in concept. Much of the empowerment derives from the ability to communicate and the use of information and knowledge. Similarly, the needed training, preparation and mission rehearsal are achieved with much of the same information and knowledge. The same sort of reasoning applies to the other major conceptual innovations. Cooperative engagements will surely involve substantial information enrichment over today's fire support.

When the technology and architecture fully underwrite the concept set, the U.S. should have a rapidly deployable force (in one or a few days) that will fill a current void in actual deployable capability. It will also have a multiscenario applicability and, when understood by potential adversaries, will provide a deterrent not available today.

During the Gulf War and its preceding preparatory phase, the U.S. used the capabilities shaped for the Cold War to deploy forces. The time lines for deployment of heavy forces in that setting have been substantially improved by an investment of $60B in more capable air and sea lift and in prepositional forces at sea and on land. The remaining gap can be closed by empowering future light forces with a modest investment.

The architecture described here has a truly broad range of components. It could be described in fundamental technical terms - collections of synapses streams of bits and bytes and small and large scale collections of atoms. It could be described in terms of networks - neural networks, information networks and action networks. It could also be described at an activity level - training and experimentation, information and knowledge formations, and exchange, technology integration. However it is described, its realization will involve a sophisticated means to describe it (and its requirements) and truly sustained efforts in system engineering.

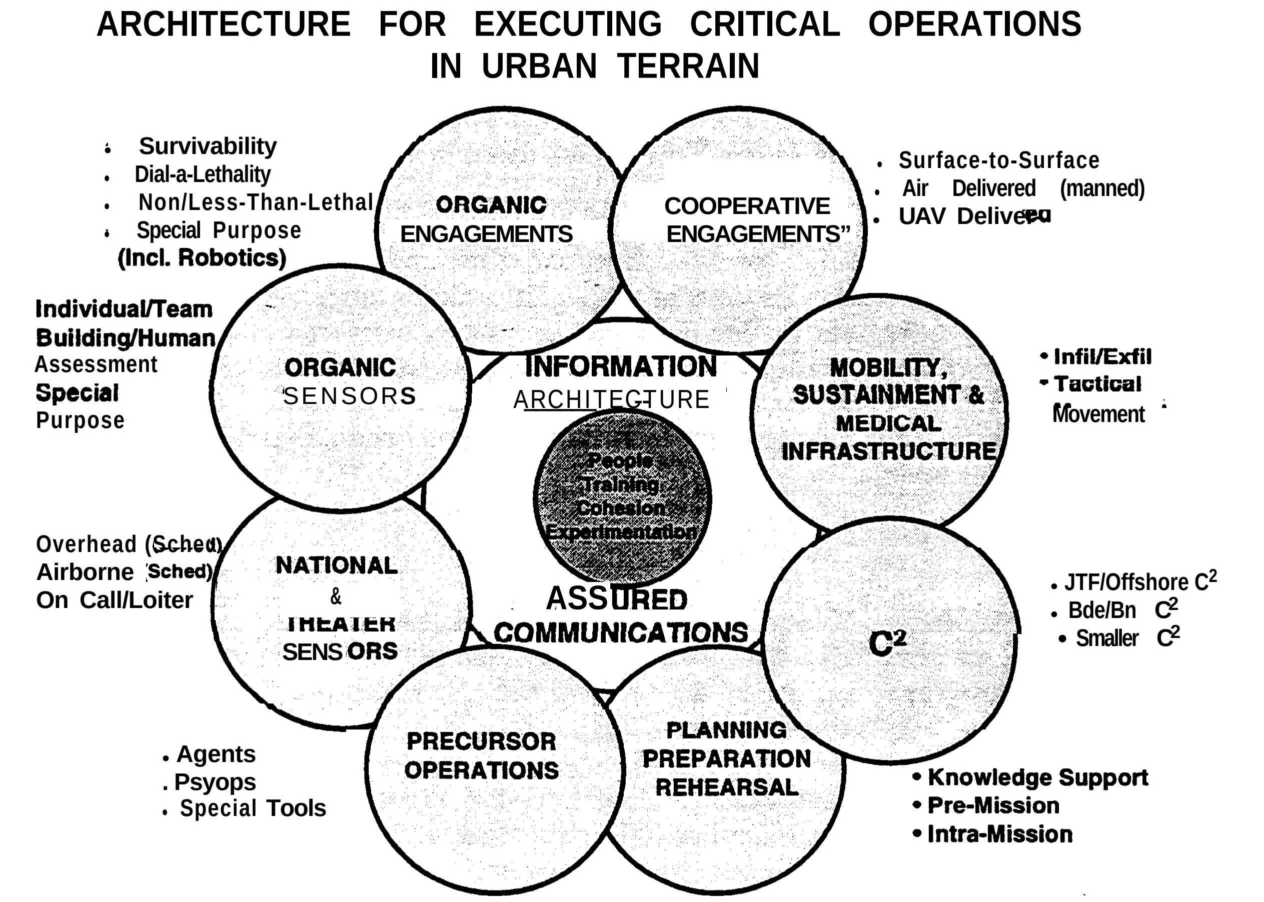
9.3 Concepts.

These are best described in terms of what is different because many existing concepts are employed unchanged from today. An example in this latter point is the generic concept of suppression of enemy air defenses (SEAD) which is a necessary part of the CONOPS.

New concepts include those which deal with the force as a whole (top down) and those applicable to individuals and Combat Cells (a bottom up description). The former would include a) deploying a light combat force ashore with its normal tail and the remainder of the joint force afloat (not to mention more remote basing of theater and national support) and b) employing raids and sequences of intense engagements versus sustained presence to achieve objectives.

The latter set of concepts would consist of a) employing the integrated effect of 12-19 minds and men with diverse skills versus the classic one mind and 12-19 men with a few different shills (after the article of the same title by Gen. William Depuy, USA (Ret) b) evoking enemy vulnerabilities at times and places of our choosing for efficient, effective and more affordable engagement (directly or cooperatively) c) effecting cooperative engagements with limited or no on-the-ground force contact d) effecting enhanced individual and Combat Cell survivability and endurance with low unit signatures created with the favorable integration of low unit footprint, information and knowledge enhancements cooperative engagement and on-call resupply along with technical protective measures.

In the case of each of these and other more traditional concepts, combinations of training, information and technology (weapon, platform, etc.) are integrated to achieve the desired level of performance. The architecture is described next to explain its components and, with a few examples, the interaction between its parts to achieve particular performance enhancements. The symbology chosen to represent the architecture is that of concentric layers or circles much like a solar system which is depicted in Vugraph 10; and that Vugraph is now discussed relative to each building block of concentric layers/circles.



Vugraph 10

9.4 People Their Training and Cohesion--The Central Element.

The central element involves people, their education and training and their ability to learn through experimentation. This triad is the "sine qua non" of empowerment. It is here that the intellectual empowerment starts and grows. The methodology proposed is one proven in other military settings (the Army's Combat Development and Experimentation Centers and its two decades of experiments to develop and refine concepts in the large and small; the wargaming environment which led the Navy to emphasize carriers and aviation, etc.) and in others including knowledge advancement research in the physical sciences.

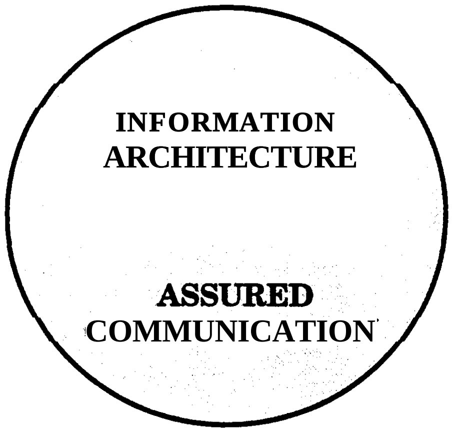
People will need an educational and experimentation period each time a new set or modified set of concepts is addressed. In all circumstances individual and collective innovation well be needed to bring life to the concepts and make them robust.

ARCHITECTURE FOR EXECUTING CRITICAL OPERATIONS IN URBAN TERRAIN

Vugraph 10A

9.5 Information Systems And Assured Communication.

The next layer (contribution) to empowerment involves the formation use and exchange of information (not data) and knowledge. Assured communications is a technical "sine qua non" since we expect to have all individuals capable of sensing, communicating and acting in an integrated manner. We view information and knowledge as the major enabler just as we consider people as the center of creativity, innovation and motivation. Communications is also a part of cohesion which is central to the health and performance of individuals and Combat Cells.

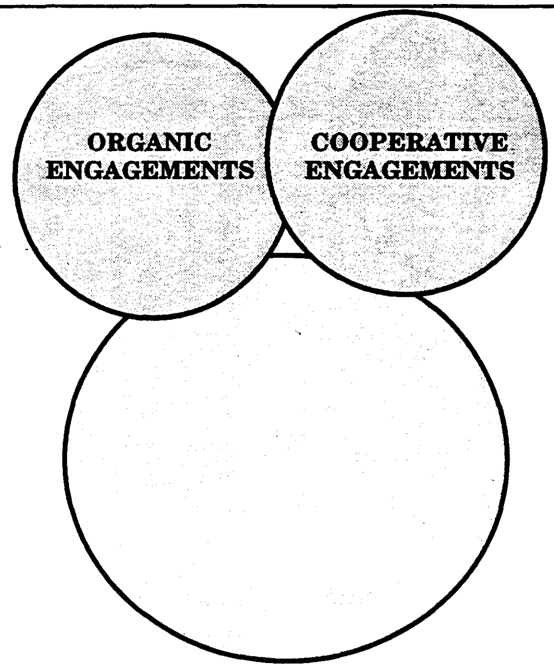


Vugraph 10B

9.6 The Engagement Set.

Two types of engagements form part of this eclectic architecture. Engagements conducted by an individual and/or part of the entire Combat Cell are termed organic (in the sense of the ashore Combat Cell). Engagements enabled by information from a variety of sources and including other individuals or teams, are deemed to be cooperative. Others included could involve employing an off shore or airborne provided weapon to meet the needs of an individual or Combat Cell. When teams are aggregated their engagements are described as organic. Aggregated teams can be supported with cooperative engagement assets. Essentials for organic engagements include weapons tailored to the MOUT and WMD missions. For the former and the latter, there is a clear cut need for lethal and non-lethal, including dial-a-lethality, and possibly an adjustable, point and area, non-lethal set. In addition, special weapons and devices will be needed for the WMD missions. This is particularly the case with devices and/or weapons needed to disable or destroy a variety of WMD warheads, reloads, and production and storage facilities. This variety suggests that the solution has a strong component in site assessment of the need (done in the facility) and rapid delivery of what is needed.

Cooperative engagements would employ the full variety of today's and tomorrow's weapons and a UAV set or multiple UAVs to meet short demand timelines.



Vugraph 10C

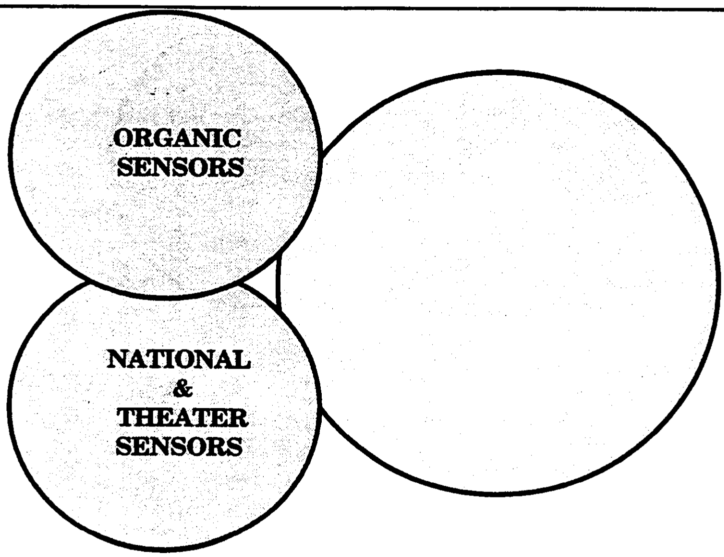
9.7 Organic, Theater and National Sensor Systems.

It is obvious that even in the simplest of cooperative engagements (or organic for that matter) that small or even larger quantities of information will need to be exchanged and processed. Thus, the value of the man on the ground and his truly vital pieces of information will be leveraged.

Combat Cells will carry or be supplied with sensors for the variety of tasks to be performed. Examples of these would include: (a) a helmet borne acoustic sensor whose aggregated use would assist in rapidly localizing threats (e.g. snipers); the Combat Cell or individual would not do the processing, but would simply receive the essentials; processing, analysis and reporting (the editor functions) is done in the rear or off-shore; and, (b) sensors to detect people and characterize structures in urban terrain; the Combat Cell might carry or deploy these. Again processing is not done by the Combat Cell. A special set of sensors is demanded by MOUT activities. The ability to detect and classify humans and to "see" through roofs and walls is needed.

At the other extreme, theater or national sensors and editors might publish a continuing series of maps (possibly every 20 minutes) of the city, its sections and/or the entire area of interest; updating information on the location of non-combatants, possible combatants, possible reinforcements etc., for use by the various echelons and support activities and for individuals in Combat Cells. Echeloned space, high and lower altitude theater and tactical UAV's will be needed for sensor (and communication) missions.

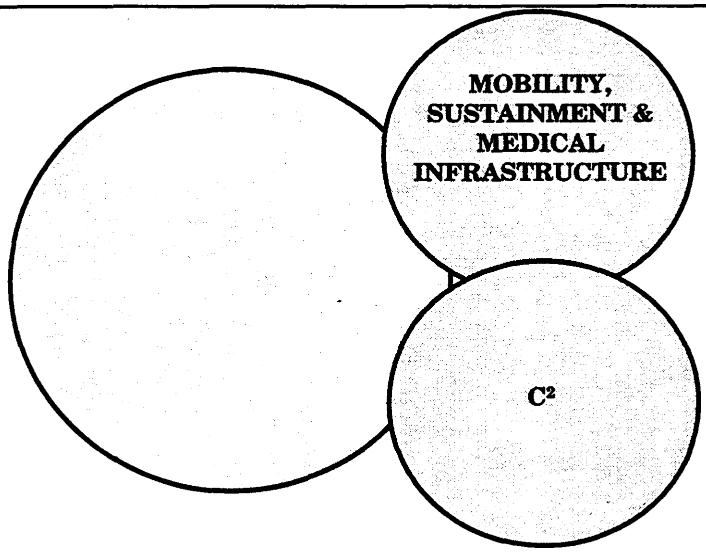
Great value will be derived from HUMINT collected for years prior to any operation, plus information derived from contractors, installers and suppliers concerning specific facilities, capabilities, systems, etc. Past experience demonstrates the invaluable character of these inputs. Efforts must be made to target, collect, organize and train editors to derive appropriate information and knowledge for the benefit of appropriate elements of the SPJTF, including Combat Cells and individual specialists. The precursor group and the Combat Cells would also deploy Unattended Ground Sensors (UGS) and their buried variants.



Vugraph 10D

9.8 Mobility And Its Infrastructure.

Fortunately, a major portion of the needed mobility is in the process of acquisition as is prepositioning which can provide substantial support and timely reinforcement if/when needed. The panoply of lift needed includes strategic air, sea and land (where appropriate and useful) and theater lift for infiltration/exfiltration, supply, and medevac. Mobility is one enabler for logistics and medical support, but others are needed. Just-in-time logistics tuned more finely than today are required in some cases, unmanned delivery might be the best solution. Telemedicine and rapid exfiltration are needed for medical support. In the specific case of MOUT, a three dimensional lift capability is needed for teams. In these circumstances, a premium should be placed on a low signature.

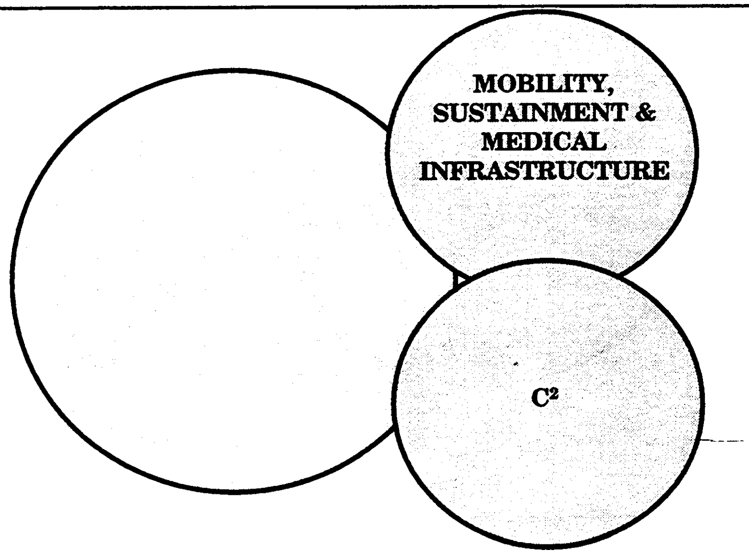


Vugraph 10E

9.9 Command and Control.

Traditional forms of command and control should be appropriate for virtually all aspects of the force. A possible exception could be in individual Combat Cells and in some aggregation cases. Skill, training and ratios of officers, NCOs, and specialists will be non traditional in these Combat Cells and probably in aggregation of Combat Cells.

Technical support for C^4 must include a beneficial merger of communication, man machine interfaces, the ability to plan and replan with rapid alternative assessment and, of course, seamless capability to prepare, train and rehearse. Comments concerning assured communications made earlier are applicable here as well. C^4 is also the proper locus for decision making and implementation of the information warfare campaign. Detailed experimentation in great depth is needed to assure the knowledgeable support at all levels of command.



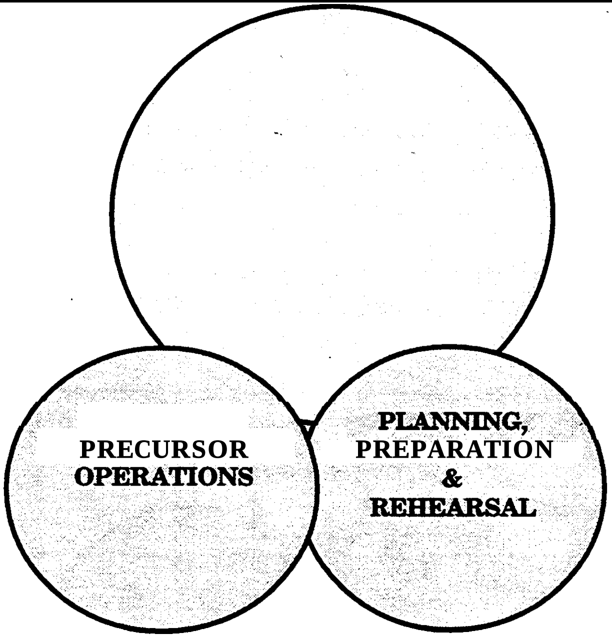
Vugraph 1OE

9.10 Precursor Operations.

These are described in general because it is only possible to state specifics in the instances of detailed scenarios.

The case at hand involves circumstances which have a tightly bounded strategic setting — rescue hostages, seize leadership, neutralize WMD, the few truly central assets of a country or a terrorist group or involve executing focused priority tasks in a city (the MOUT case). Other equally important circumstances which are subjects of this DSB study — blunting an armored incursion, controlling a large mountainous and or forested area — would have a substantially different set of precursor activities.

The high value target in a MOUT setting would require several sets of precursor activities, some previously discussed in the "Organic, Theater and National Sensor System" section. Added to those are focused HUMINT collection and other activities which provide information inputs and preparation for the raid to include its deception and PSYOPS components. Appropriate organizations would provide the people and means for these activities.



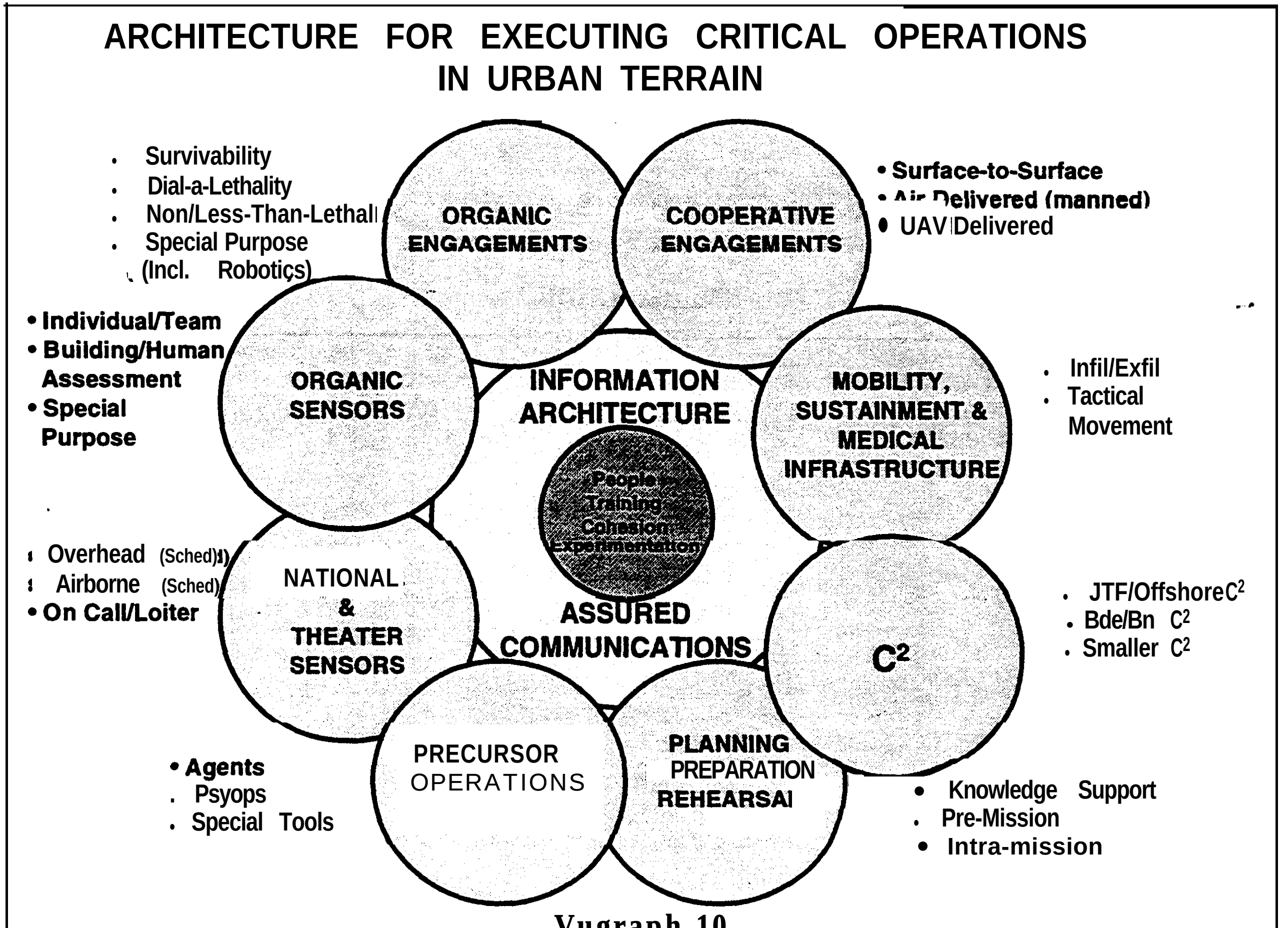
Vugraph l0F

9.11 Planning, Preparation And Rehearsal.

Some of the aspects of these activities have been addressed in previous sections. Specifically for this activity, means would be provided as well as information to execute these functions inside overall mission timelines.

A panoply of tools would be employed by the various components of the force which are most likely to be and become geographically dispersed. Advanced simulation tools, appropriate communications, the assistance of organizations with models or man in the loop equipment will all play an important role in all aspects of these-functions.

For those force components which will spend substantial periods of time aboard strategic or intratheater lift assets, means should be provided to train (if possible) and rehearse (for certain) en route.



Vugraph 10

10. CONCLUSIONS AND FINDINGS.

10.1 Nature Of Needed Improvements: People And Combat Cell Related. (Vugraph 11)

Nature of Needed Improvements

People, Combat Cells and Cohesion Related:

- Advanced specialist skills available in average infantryman
- Integration of cooperative engagement concept at team level
- Team and parent command cohesion consistent with current SOF-like operations
- Ability to collapse and expand unit structure according to the threat

Status of Today's Capabilities:

- Severe shortfall in training methodology and technology including ROE and lethal/non-lethal use
- Very limited capability for experimentation to address integration and information management
- Personnel system inconsistent with needs (to much turmoil)
- Simulation only in embryonic state, virtual reality still limited for infantry

Vugraph 11

10.1.1 Unit Cohesion.

The ultimate success of the SPJTF will depend on the recruitment, selection, and training of the members of the Combat Cell. The importance of the SPJTF demands that they be considered as an elite force. To think otherwise would probably cause the concept to fail. Once the SPJTF is chosen, training, both individual and unit, is the key to success. The failure of many high value and high visibility operations can be traced to the lack of training of the Combat Cell as a cohesive force prior to hostilities, e.g., Desert One insertion into Iran. Commanders and their men must know and trust each other prior to operations. The number one reason why people fight well is their loyalty to fellow Soldier, Marine, Sailor, and Airman. It is essential that unit cohesion be established well before the operation begins, and that cohesion must be maintained for the duration of the mission.

10.1.2 Training.

Combat Cell cohesion requires a new approach to the training of the SPJTF. The Combat Cell members must believe in each others' skills, abilities, and integrity. This level of trust and loyalty can be achieved only by close interpersonal interaction over sustained periods of time. The training must of course include the generic skills required of a warfighter, but two new features of training are noteworthy. First, the self-reliance of the members of the team will require cross-training of the Combat Cell members. Specialists in communications and autonomous vehicle control should have some level of competence in each others' specialty. Second, and perhaps most important, the training program must include a range of inter-operational exercises between technical specialists and members of the Combat Cell, and between the Combat Cell and the larger force structure.

In the MOUT mission to neutralize a WMD facility, for example, the Combat Cell will be augmented by technical specialists with skills in biological weapons detection, characterization, and destruction (as depicted in Vugraph 8). Cohesion of this augmented, mission-ready Combat Cell will require training exercises where the core members of the cell work with technical specialists of various types. At a higher level, the Combat Cells themselves will need to train as part of a larger force in exercises focused on specific missions such as the MOUT operation described here. For example, the heavy reliance of the Combat Cell on remote fires from aircraft, ATACMS, and new platforms such as loitering weapons will require training beyond that which is presently in place. Other types of joint training exercises will likely be required, and experimentation will help to identify them. The command and control of the SPJTF will demand advanced communications equipment, and extensive training to ensure synergism between the Combat Cells that leads to an overall force of overwhelming superiority.

The Combat Cells will be made effective by leveraged technology, mission planning, and rehearsal. Once the mission of the individual cell has been determined, the cells would avail themselves of all intelligence available concerning the objectives; this would include HUMINT, real time videos of the objective, adversary infrastructure and plans, and any cultural\language peculiarities of the adversary's urban area. End-to-end mission rehearsal and training prior to and enroute to the potential area of operations should include conduct of infiltration and exfiltration operations, execution of Combat Cell C^4I and IFF capability, deployment and management of ground and airborne sensors, rehearsal of target tracking and tagging systems, and plan and execution of long-range precision fires. Virtual reality simulation coupled with actual field exercises in a mock environment are central enablers of this training and rehearsal.

10.1.3 Experimentation.

Our study effort suggests possible new concepts and technology combinations which could be for the warfighter. Parametric experimentation using the various potential combinations is essential to analyze all the possibilities and focus down to the optimum available choices. The scale of this experimentation is broad and should encompass on-going and planned AWE, ATDs, and ACTDs; exercises such as being planned under Sea Dragon, as well as a parametric analysis using far more sophisticated modeling and simulation which will be enabled by substantial improvements in computational capability available in the first decade of the next century.

10.2 Nature of Needed Improvements: Information Architecture Relate. (Vugraph 12)

Nature of Needed Improvements

Information Architecture and System Related:

- Assures connectivity
- Non exploitable for Position Location, etc. for raid duration
- Database/editor combinations to push and perform timely query/response tasks for all echelons involved in raid
- Interoperability to support training through execution
- Organic sensors to find and characterize people
- Ensured NLOS Communications

Status of Today's Capabilities:

- Serious technical connectivity shortfalls and requirements having technical meaning but not much operational justification
- Non exploitability has some of the same character but the balance between technical and operational is better
- Requirements not understood for database/editor functions
- Interoperability is a continuing challenge
- Organic sensors
  - to characterize sites, buildings, other structures
  - to characterize internal site operations
  - intra-urban navigation (GPS-based ineffective in channelized/indoor and underground)

Vugraph 12

10.2.1 Local Area Overhead Surveillance and Communication Systems.

A highly competent but portable UAV is the solution for larger-area overhead surveillance, and the experience with Predator and related systems are developing operating experience. Adapting these concepts to the particular requirements of the urban environment — high levels of background light, heat, and EM radiation, requirements for low observability to protect from air defenses, development of sensors suitable for listening to cellular phone communications, etc. — is technically achievable now. More difficult is developing a system that presents the information to the Combat Cells in useful form.

Assured communications is a topic addressed at length in section 9 of this study. Here we point out that obstacles to electromagnetic communications abound in an urban terrain containing tall buildings and structures. Furthermore, communications are needed for troops located within buildings and tunnels — environments that are particularly difficult for high bandwidth channels. Technological developments are needed to assure communications and geopositioning information in urban environments. A combined overhead and relay system is the most plausible solution to the problem of providing robust communications and interconnectivity in an environment in which line-of-sight is often blocked.

10.2.2 Sensors.

There are again two classes of sensors required: those that are generic for MOUT — people, through wall detection and anti-sniper — and those that are specialized for facilities involving WMD — neutron and gamma detectors, systems for detection and analysis of WMD weapons. MOUT also requires development of appropriate sensors and platforms for surveillance. Modification of current UAVs so that they can provide real-time images to the local commanders is a step in the right direction; more specialized UAVs capable of low-altitude hovering and accompanying the force more closely should be pursued aggressively, since they are integral to the "situational awareness" that is at the heart of this concept. Some of these sensors must be small enough to be deployed with the Combat Cell (robotic carried sensors fall in this category).

All sensor arrays should have the innate intelligence to process raw information to identify specific enemy forces and actions. Analysis specialists and editors will be required even with powerful software agents to push information to Combat Cells and respond to their queries. It will be necessary in some cases to provide the warfighter with software agents to answer his natural language questions of the sensor arrays. It may also be desirable to allow the individual warfighter to address directly an individual sensor.

10.2.3 Combat ID.

The problem of minimizing fratricide in the close quarters of MOUT, especially if there is external bombardment, requires high quality combat ID and excellent precision in targeting. In some cases, teams will be quite close to targets struck with cooperative engagement fires. Current efforts which will solve platform related problems may not suffice for the situations described herein.

10.2.4 Situational Awareness.

The key to the operation of small groups is the use of situational awareness, coupled with high mobility and the ability to call in remote support (remote fires, but also remote supply and intelligence). MOUT has historically involved small unit actions, by members of larger commands, so this part of the proposed system is not completely new. Providing these groups with much enhanced situational awareness *is* new, and will require new technologies. There are three key technical elements that must be developed to give the groups excellent local and city-wide awareness. They are discussed below.

Accurate tactical intelligence is essential to these missions. The force will be operating in a very difficult environment, under extreme pressure of time, and it will not have the leisure to explore multiple targets and improved, incomplete or incorrect intelligence. It goes without saying that overhead data must be timely and accurately interpreted, but the U.S. has excellent systems for this purpose. The problems lie with aspects of the target that cannot be characterized by overhead surveillance. The major challenge is to define the *interior* structure of the target, and to identify the people within that structure. It is not clear whether there is a useful technical solution to this challenge, but several should be explored, such as seismic methods for underground facilities, and wall-penetrating radar for buildings.

10.2.5 Autonomous Platforms for Local Situational Awareness.

Many of the problems of MOUT are very local: locating snipers, watching movements of people in and around buildings, movement of vehicles, formation of crowds. Micro UAV's may be useful video sensors in a cluttered environment. The technology of small air platforms has evolved to the point that it is plausible to develop UAV-based sensors for these small groups. A particular requirement in the city is going to be the ability to hover.

Small robotic tethered or autonomous ground vehicles would also be very useful in a range of roles: mine detection; around the comer imaging, determine a possible CW/BW situation. They might also be useful, in more advanced form, for mine detection for obstacle elimination. Although there are programs being directed toward such systems, it is unclear that present designs will have the robustness necessary to handle the urban environment. In particular, a small system, whether wheeled or tracked, will have difficulties with barricades, rubble, and craters. These systems also lack the ability to right themselves if they tip over, and are poor in operating in narrow spaces. There is no system now that has the adaptability to terrain that a mammal does, and a program to consider more adaptable, biomimetic platforms will probably be required to generate truly useful ground systems. Supplying power to these system also remains a serious unsolved problem.

10.2.6 Technology for Information Warfare.

A key element in this type of operation is surprise. The force will be vulnerable to relatively light weapons — RPGs, heavy machine guns, anti-aircraft and anti-tank weapons, shoulder-fired missiles — if the resistance is organized. A key element, therefore, is to maintain confusion and disrupt communications as much as possible.

We must deny the adversary his "home court" advantage of operating in his own city. "Smart" devices may allow disorienting tactics and diversions that could be important to MOUT. Lightweight millimeter wave imaging radar systems could provide visibility through obscurants (smokes) that would impede the adversary's operations. Similarly, local jamming of enemy communications will add to these effects.

10.2.7 Remote Expertise.

The Combat Cell brings people to the mission and the target; other essential components have to be supplied remotely. For conventional missions, indirect attack weapons are the major component that must be supplied remotely. In attacking hard targets, there are additional components that must be supplied: one is weapons for use *at the site*; a second is *expertise.*

Attacking WMD targets may require more expertise in engineering and science than the Combat Cell can be expected to have. This is especially true in a WMD facility that is making unknown classes of weapons. The expertise to evaluate the target and its vulnerabilities, and to advise the Combat Cells about procedures that will enable them to survive their actions, may best be supplied externally. Electronic reachback to experts located elsewhere will be an essential part of the mission. The Marine Corps has begun to experiment with this type of reachback system in its chemical/biological incident response force; this experiment should be encouraged to understand the difficulties in distant connectivity, and studied carefully for lessons learned. Lessons learned from telemedicine experiments should also be evaluated.

A similar example is the DOE NEST (Nuclear Emergency Search Team) program. Under this effort, expertise in nuclear weapons design and technology at the DOE weapons laboratories can be provided electronically to Combat Cells deployed in the field to advise them how to deal with the threat of a nuclear weapon.

10.3 Nature of Needed Improvements Technology Related (Vugraph 13).

Nature of Needed Improvements

Technology Related

- Technology voids
  - Mobility of Combat Cell in MOUT execution zones
  - Survivability suite for individuals
  - Means to physically neutralize WMD warheads and storage
- Technical shortfalls
  - Directed lethality weapons
    - Power sources
    - Non/less than lethal weapons
    - Remote supply & resupply
- Status of today's capabilities where voids are judged to exist

Combat Cell	No programs, some non-DoD ideas.
Survivability	Some physical protection, no screening/ stealth/mobility components.
Ensured Comm	No R&D for in-building, tunnel, etc.
Organic sensors to characterize structure internals and their operations	Some DoD efforts ongoing spinoffs of paper work. Other appropriate (seismec, accoustic might be integrated) systems approach and R&D required.
Direct lethality weapons	OICW is first step. Required weapon is probably two generations away.
Means to neutralize NBC warheads, manufactures and resupply	Would be done by today's means (e.g. thermite). Need more comprehensive approach, possibliy with very energetic /reactive agents. Consider nuclear heating also.
Non/less than lethal weapons	Intial work underway. Being done as a stand-alone Should integrate into OICW and its follow on.

Vugraph 13

10.3.1 Mobility.

The ability to move rapidly, and to keep moving, is essential for the success of a rapid-strike mission. High mobility will permit the mission to be accomplished within the adversary's OODA (Observation Orientation Decision Action) loop. Understanding the mix of vehicles — light armored vehicles, helicopters, other personnel movers — required to move rapidly and to circumvent barriers (physical or crowds) are required, but all require testing and evaluation. A versatile ground/air vehicle is needed for the three dimensional operations of the team. This vehicle should emphasize mobility over armor. The key infiltration/exfiltration craft enhancement areas that appear to offer the highest potential to improve Combat Cells infiltration and exfiltration are:

(1) Improved planning and employment through high fidelity, interactive, intelligence data bases capable of supporting full pre-mission planning and rehearsal as well as provide real time battlefield situational awareness.
(2) Technology improvements to upgrade platform performance and survivability while reducing weight, logistics and support at all levels.
(3) The potential of a new generation of high performance stealthy platforms capable of long range, high speed, vertical take off and landing (VTOL) operations supporting team employment.
(4) Vehicles that operate in surface effect should be examined because of the potential surface fingerprint reduction and obstacle clearing capabilities.

10.3.2 Personnel Protection.

A Combat Cell is very vulnerable to losses. Providing much enhanced personal protection — both through body armor and through anti-sniper and anti-mine capability is much more important for this type of mission than for one in which it is more practical to replace and exfiltrate casualties. Improved personal protection will allow more rapid and bold actions by the Combat Cell. Incremental improvements in kinetic energy protection (personal armor) are possible. Personal protection against blasts should be developed, as should lightweight, less-confining CBW protection. Some progress is being made in these areas. There should be an integrated effort to combine them with screening, stealth and mobility to reach needed levels of survivability.

10.3.3 Means To Physically Neutralize WMD Warheads and Storage

Once there is access to the interior of a structure — either by breaching entrance defenses or by lateral attack by digging or blasting, there is a new problem of what provides the best way of destroying or disabling the interior. Explosives may not be the most useful approach: both they, and heat weapons, are useful, but the best procedures to use them need to be developed. Systems such as fuel-air explosives have, in principle, a higher energy density than conventional explosives, and the advantage that, as a gas, they can penetrate many parts of a structure that would not be reached by a localized explosion.

One of the most effective means to neutralize a buried facility may be to use chemical or biological weapons which could put the a facility out of operation for months.

However, the US has had a long standing policy (since - 1920) of no use of BW, an even longer standing policy of no first use of CW and recently has renounced all CW use and possession.

Analyzing the possible applications of C/B agents in this context, and understanding the relation between the useful classes of materials and the restrictions of treaty and policy would both identify possible opportunities and provide technical guidance to policy makers. A core question is whether a material designed to disable a facility for production of CB weapons is offensive or defensive, and whether individuals working in these facilities are combatants or non-combatants. These considerations seem irrelevant, but they are essential in understanding the application of policy.

10.3.3.1 Nuclear Explosives.

For those facilities which are very deeply buried, we considered the options of using small nuclear weapons. Deep explosives reduce the risk of venting to the surface. A nuclear device with a dial-able yield in the range of 10 to 100 tons of TNT could be effective in crushing the entire facility. In an energy-absorbing geological structure, however, where tunnels are widely dispersed, several weapons might be required to achieve the objective. Although no such weapon in this range of yields remain in the nuclear stockpile, the capability remains to develop and produce such weapons well within the 2015 time period for this study. Although there are unquestionably political problems with nuclear weapons, they may be the only technical solution for some of these missions.

10.3.3.2 Nuclear Heat Generation.

A variety of technologies, other than explosive devices, might be employed to neutralize the facility from within. These include high energy thermal sources intended to "cook" the facility over a prolonged period of time, such as fire accelerants and fast setting expanding foam materials. Another approach worthy of consideration is the use of a nuclear device as either a heat source and/or radiation emitter. The SP100, formerly under development as a nuclear electric power source for space systems, could be used as an extremely high energy density heat source to raise entire underground facilities and their contents to equilibrium temperatures adequate to oxidize all flammable materials and neutralize all chem/bio agents. Reactor designs developed during this decade-long program, using advanced pebble bed reactors, could deliver sustained thermal power densities of 60 kilowatts per kilogram delivering 5 to 10 megawatts within a package of 3 to 6 cubic feet. Such a heat source could be combined with a heat engine driving a very high volume air handling system to flood an underground facility with superheated air (e.g., ~2000°F). Such a man-portable system (viz., 400 lb.; 6 cu ft; two pieces) could deliver 10^{12}joules of heat energy within 24 hours if left behind in the underground facility, which had been sealed by explosives on exit of the Combat Cell. This would be the energy equivalent of about 100 metric tons of thermite. At the end of operations, the reactor could destroy itself and disperse highly radioactive fission products throughout the facility.

10.3.3.3 Radiation Generators.

Intense radiation generators could be used to neutralize chemical or biological agents in underground facilities. A powerful radiation source would have the added bonus of denying future access to the facility for extended periods of time. Devices weighing a few hundred pounds could produce ten to hundreds of megarads of radiation, sufficient to neutralize the most lethal bio agents. Depending on the choice of radioisotope employed in the generator, human access could be denied for periods of as short as sixty days or as long as desired.

10.3.4 Directed Lethality, Organic and Non-Organic, to the Combat Cell

The need to neutralize extremely hard targets--targets that can resist direct attacks of 1000 LB penetrating HE precision guided munition--while limiting collateral damage distinguishes the MOUT missions considered here from other types of military operations. The hands-on attack by the Combat Cell requires special weapons and capabilities to neutralize the WMD targets themselves.

There is a need for man-portable weapons of appropriate lethality needed for engaging a range of targets from adversary soldiers to adversary armor. Low settings on the "lethality dial" would be effective against light targets without the risk of surrounding collateral damage. The current OICW (Objective Infantryman Conventional Weapon) with its direct and indirect ballistic modes is a start in the correct direction, but will have to be improved substantially. The development of fractionated warheads specialized for MOUT is important, as is the ability of the team to call in timely, and appropriately lethal, remote fire. Remote fire means will also need the same kind of discriminate character.

For a Combat Cell MOUT environment three levels would be useful for the delivery of supporting arms. New lightweight weapons should be carried by the Combat Cell warfighters for immediate response. Quick response can also be provided by weapons that loiter overhead, freeing the Combat Cell from carrying extra weight. Finally, remote platforms promise low-cost multiple fires, albeit with some time-to-target delay. An information system and cooperative engagement protocols would greatly assist in choosing and efficiently employing these different sources of fires.

10.3.4.1 Weapons and Tools for Neutralizing Buried Facilities.

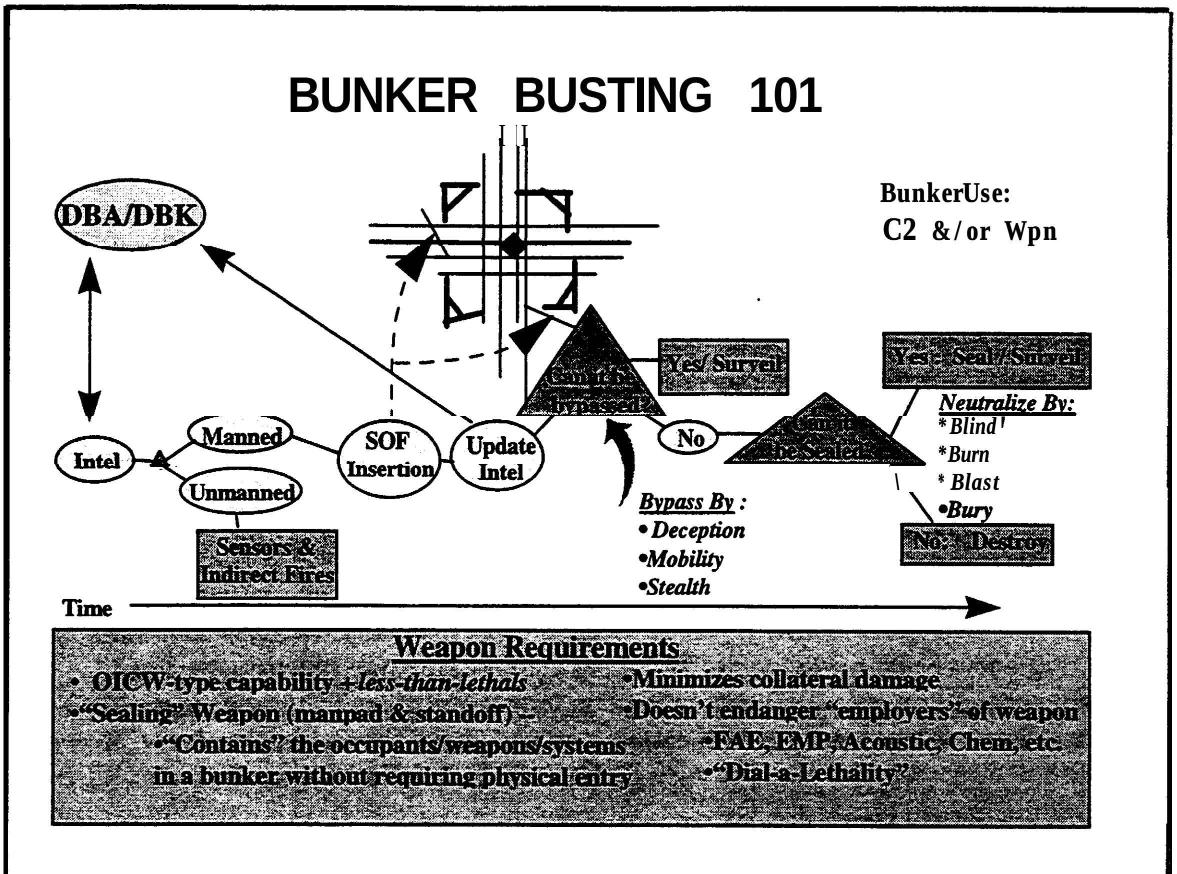
The major technical shortfall in this mission is that of suitable weapons for attacking hardened, underground targets. The reason for putting troops on the ground is that remote fires will *not* work: if a way of attacking the target successfully by remote fires were available, there would be no reason to engage in a very difficult and hazardous manned mission. The problems of infiltration and reaching the objective are difficult, but familiar. The new problem is *to attack and neutralize* the facilities. When a relatively small group of troops have reached the site — a tunnel complex, a food plant believed to harbor a WMD facility, a set of hardened underground bunkers etc. — what do they do, and what weapons do they use to do it with? There are many analyses now ongoing to identify the weaknesses of underground and hardened targets. Most deal with vulnerability to penetrators and conventional explosives. A broader look at the vulnerability of these structures is required.

Functional analysis of hardened buried facilities may reveal vulnerabilities (e.g., entrance portals, utilities connections (lifelines), communications lines, air intakes) that can be exploited either by remote fire or emplacement by the attack unit. In the latter case, either "neutralization devices" would have to be sufficiently light weight to be carried by the team, or means developed for "just in time" delivery to the target site. Some of these weapons — for example, air-delivered bunker-busters — can be accommodated by the idea of external precision fires. The capabilities of air-dropped devices to penetrate a hardened facility can be readily outdistanced by an enemy who digs very deeply. For this reason, the internal destruction of deep, hardened facilities may require the Combat Cell to physically enter the facility, either personally or robotically, in order to ensure neutralization of these hardened targets.

10.3.4.2 Breaching Weapons. (Vugraph 14).

Some current and many future facilities will have sophisticated systems for protecting entrances: berms to defeat direct attack, multiple blast doors, local antipersonnel defenses. Understanding the vulnerabilities of these systems, and designing weapons that are light-weight and capable of breaching them, is important. It is clear that determined defenses can make it very difficult for a Combat Cell to gain entry. What, then, should be the strategy?

Forced entry to a facility may be possible with shaped charge munitions or special purpose cutting/drilling equipment. It will be necessary to address the concern that collapse of the tunnels may occur when breaching doors. Concepts involved in advanced penetration weapons being considered for OSD's Hard and Deeply Buried Target Defeat Capability may be adaptable to breaching devices. One such example is the "deep digger" concept, a self-contained explosive boring device for rock and other earth medium, being explored by SOCOM as a breaching tool.



Vugraph 14

10.3.4.3 Robotics.

Agile and deft robotics devices could offer advantages in urban terrain Robots — unmanned ground systems — are attractive as sensor platforms; development into tools for anti-mine activities, and perhaps for light weapons platforms is now plausible and is being pursued. Whether robotic systems can be developed into a broader range of roles remains to be seen. They have the enormous attraction in that they remove the troops from danger; their disadvantage is that they require energy, and lack believable concepts that look like anything other than an unmanned wheeled or tracked vehicle. Larger UAVs may serve as robotic delivery vehicles for high-value supplies, tools, and specialized weapons.

10.3.5 Non and Less Than Lethal Weapons.

Non-lethal weapons may prove especially useful (and possibly mandatory in the future) in conducting military operations in the expected urban battlespace with the presence of non-combatants and restrictive collateral damage ROEs. In addition to non-lethal weapons for these congested urban areas, an abling equipment and vehicles is important in MOUT. It is difficult to assess the full promise of non-lethal weapons because these technologies are still maturing. Nevertheless, acoustic emitters for crowd clearance would have obvious value for keeping the civilian population away from the Combat Cells. These acoustic emitters would probably be deployed on a robotic platform. Binding agents such as sticky foams could be advantageous for entangling personnel who are forced to exit a building. Because the binding agent is a weapon that waits, it may be easier to ensnare the enemy with the binding agent than to engage the enemy by direct fire, especially if civilians are also exiting the building.

Some classes of non-lethal weapons may be applicable to WMD targets. EMP is a way of destroying electronic equipment in a communications center. Foams and corrosive agents might be useful in disabling weapons, blocking air vents and disrupting operations.

Non-lethal weapons may elicit lethal responses from the adversary. For this reason it is important that non-lethal weapons be effective when they are used. The ideal non-lethal weapon would produce consistent effects on all persons, without a wide distribution of effects ranging from nil to fatal. More data on biological effects are required to assess this feature of non-lethal weapons. It is also extremely important that ROEs that allows for immediate transition to lethal weapon, if the situation warrants, when responses from the adversary are lethal.

10.3.6 Remote Supply and Resupply.

Successful attack on a hardened target will require more than getting there: it may require substantial quantities of weapons and explosives or chemicals for neutralizing this facility. The idea of putting the force on the ground is that it can do a job that cannot be done by remote fires. In this mission, it will probably be necessary to develop concepts for delivering the weapons and tools the team will need at the target, rather than having the the team carry these weapons with them (with the attendant decrease in mobility and the risk of capture). An example of a need for "just-in-time" delivery would be a means to neutralize or destroy a buried site after it is located. It would be burdensome to say the least to have the team move through the city with such a weapon. The weapon device would be delivered only when the facility was reached and the defenses breached. At that point, rapid delivery would be essential.

There are a number of strategies for remote supply:

- **Parachutes and parafoils**
- **Helicopter or V-22**
- **Cruise missile** (an advanced Tomahawk, for example) designed to dispense weapons in a package designed for precision soft landing
- **Low-observable lifting body or glider** released from a stand-off aircraft
- **UAVs**

The best approach will depend on the target and the mission. In the next few years, a helicopter may be practical. In the future, anti-helicopter mines with combined acoustic and optical sensors will probably make it impossible to fly a rotary-wing craft over a protected airspace, and some silent, low-observable strategy will be necessary.

10.3.7 Power.

An Achilles Heel in the entire concept of the Combat Cell, especially in difficult environments, is the availability of power. If the team has to carry weapons, use sophisticated sensors and communications systems, move rapidly, and operate in CB gear, it is faced with needs for power that cannot be met by existing power sources. The limits of batteries are set by their chemistry, and they simply do not have the capability to provide for the power needs of this type of mission. This problem has been analyzed thoughtfully by DARPA, with the conclusion that the best solution is some system that uses a hydrocarbon fuel (diesel; gasoline) and converts it to electricity. It is important to recognize that gasoline has an energy content (on a weight basis) that is 100 times that of the best batteries, and twice that of high explosives.

Good systems for converting hydrocarbon fuels to electrical power are crucial, and the DARPA programs in this area — small turbines and internal combustion engines, perhaps direct diesel/gasoline fuel cells in the future — should be strongly encouraged. (Another advantage of hydrocarbon fuels as a power source is that they are also always available locally in urban areas.)

For some missions, it may also be worthwhile to re-explore small nuclear power sources: the weaknesses of these sources at the moment is that all of them operate, very inefficiently, using thermoelectric converters. Both ONR and DARPA now have programs starting in advanced thermoelectric systems, but there may be other ways to convert nuclear energy into electrical power.

11 RECOMMENDATIONS.

Recommendation 1

- **What:** Develop concepts, tactics, techniques, procedures and training for urban operations
- **How:** Provide competitive testbeds for urban scenarios
- **Who:** Army and Marine Corps
- **Why:** Understand requirements and test solutions to field operational capabilities in the FYDP
- **When:** Initiate activity now

Vugraph 15

There is a need for sustained long term effort to develop concepts, tactics, techniques, procedures and training as well as appropriate technologies to fulfill the warfighting capability objective for MOUT. This sustained effort must focus on individuals and their equipment as well as the series of small unit engagements characteristic of urban environments. It should build on previous S&T initiatives and provide an over-arching mechanism to integrate ideas and technology.

It is necessary to sustain competitive Service testbeds to overcome existing deficiencies and to develop system of systems approaches to enhance MOUT capabilities. The nature of MOUT requires an intense focus on the individual, who must be superbly recruited, trained and equipped. Equally important is the element of cohesion of the Combat Cell, a situation that is perishable very soon if not provided for in the organization and training of Combat Cells. The objectives would be to fund Combat Cell level testing of integrated concepts, tactics and techniques as well as to provide operational capabilities within the F'YDP.

Activity should be initiated now with funding for operational testbeds and Combat Cells, planning for FY-98 ACTDs, procurement of existing technologies such as COTS cellular communication, laser range finders/designators, exploration of new technologies such as mobility means, mini/micro UAVs, small warhead, aerial stand-off precision guided munitions (PGMs), and robotics for sensor and weapons employment, in order to provide a process of continuous improvement through sustained warfighting experiments.

As compared with past efforts, it is much closer to developing and realizing Airland Battle or more straight forwardly a future and very flexible ATO, than it is to developing a new platform or even a distributed but multipurpose command and control system. This architecture has the most complex characteristics of the combination of all of the examples above.

Airland Battle was realized, as was the JFAAC and AT0 concepts, because they were deemed to be needed advances and one or more Services committed to their success. The same kind of commitment will be needed to realize the empowerment to be achieved through the architecture. It will require the influence, weight and staying power of a Service.

Since the activities are joint, an Executive Agent is needed for this activity. The Army or the Marine Corps would be the most appropriate choice for this assignment. Both Services have on-going modernization activities intended to field improved forces in the 2005 time frame, better focused on the perceived challenges of that era. The Army's effort is directed at both heavy and lighter forces, but in the near term will do much more with information for heavy (platform based) forces than will the Marines. On the other hand, Sea Dragon has placed its initial emphasis on lighter forces and their component small teams. Its exploitation of information is yet to be seen. Part of the path ahead will be seen in the upcoming Sea Dragon ACTD and in a different but related Army ACTD for early entry forces.

Recommendation 2

What: Vastly improve urban tactical team situational understanding through:

- Reliable, covert, secure communication
- Coordinated sensor management
- Squad level access to all data bases
- Testbed programs as in C^4I for Land Warrior
- MOUT Experiments via distributed simulation, live, virtual and constructive means

- **Who:** Create a Joint Service MOUT Program with Joint Staff as coordinator using COTS technology
- **When:** Start in CY97 with program development
- **Why:** Urban warfare is more likely and most demanding. Use MOUT needs as standard for 21^{st} Century

Vugraph 16

Reliable, covert, secure communication, robust against electronic countermeasures and build upon emerging commercial Personal Communication System (PCS) concepts are an enabling system technology for MOUT. Urban radio transmission is subject to extreme attenuation, multipath interference and signal fading at line-of-sight radio frequencies in urban canyons and inside buildings. Positioning of distributed, PCS-like transponder cells by precursor SOF forces or by leading edge SPJTF Combat Cell members will be required to assure totally reliable connectivity. DoD should adapt COTS technology in these areas to MOUT experimentation to develop advanced future capabilities.

A redundant overlay of transponders deployed in medium and high altitude UAV and satellites will be needed reliably to connect with remote supporting forces and C^2. Digital, multifrequency, spread spectrum radios, operating near the 10 centimeter waveband for in-building communication and 10 millimeter wave band for secure, robust remote communication will be required in hand-sized packaging. Combined with GPS and close coupled, advanced micromechanical IMUs, these radios must combine communication and data processing power sufficient to drive a personal situation display for each Combat Cell member providing the basis for total local situation understanding. All transponders will also act as GPS pseudolites to enhance pos/nav during GPS satellite obscurations. Defense should invest in a focused development program to rapidly develop this unique capability to support likely future MOUT. Combat ID must be provided to separate friendly and neutral elements from combatants on the street, in buildings and in underground facilities.

Particular emphasis must be placed on experimentations for learning, not for test and evaluation. The Combat Cell concept and MOUT situation must be addressed experimentally because we do not know if we have an appropriate solution operationally; or that it can be underwritten with people, training and technology. Until we can assure ourselves that we have some kind of solution, we must regard the undertaking with some degree of objective skepticism.

Recommendation 3

What: Address technology voids and shortfalls in infiltration and WMD target neutralization capabilities: mobility, situational awareness sensors, team survivability, assured communications, target entry and WMD defeat is needed

- **Why:** Mission feasibility in the demanding MOUT environment
- **Who:** Have DARPA and DSWA lead the effort for the first few years with JPO involving Army and Marines
- **When:** Accelerate selected ongoing developments (e.g., AF's Agent Defeat and DSWA's Tunnel Defeat programs); start with search for new concepts in FY97

Vugraph 17

Significant voids and shortfalls exist in our capabilities to infiltrate to the hard target, gain entry and neutralize the WMD, to the extent that the feasibility of a particular MOUT mission may be in question. Success of the infiltration phase of the operation depends on gaining situational awareness, coupled with high mobility and navigational capability, organic sensors to find and characterize people, personnel protection and ensured NLOS communications. The WMD neutralization phase requires organic sensor capabilities to adequately characterize the operational site and internal operations, along with a highly efficient breaching capability, and the means to deal appropriately with the WMD itself.

Mobility is essential to the mission. It may be that circumstances will require an initial landing outside the city, and movement some distance through the city. A small armored vehicle adapted for an urban environment and practically portable by air, would be useful in a range of missions. Individual lift systems that would enable troops to move over buildings, barricades and mines have been used experimentally, but never practically, and would be invaluable in this type of mission.

Improved personal protection will allow more rapid and bold actions by the Combat Cell. While some progress is being made in the area of kinetic energy protection (personal armor), there needs to be an integrated effort to develop such capabilities as personal protection against blasts and lightweight, less-confining CBW, combined with screening, stealth and mobility to reach needed levels of survivability.

Many of the problems of MOUT are very local: superb situational understanding is crucial locating snipers, watching movements of people in and around buildings, movement of vehicles, formation of crowds. There needs to be an accelerated effort to develop micro UAV-based sensors for surveillance of local terrain, and a family of robotic ground sensors for such purposes as mine detection and around the comer imaging.

Recommendation 4

What: Develop loiter capability for indirect precision munitions that can be controlled and directed by Combat Cells for immediate fire support (l-8 minutes). These munitions should have a range of at least 200 NM and be able to loiter as long as possible (at least 30 minutes)

- **Why:** Forward deployed Combat Cells need immediate fire support which can't be provided by current fire support systems because of C^4I, geography, logistics and weather

- **Who:** OSD, Army Navy, Air Force, Marines, and Joint Cruise Missile Project Office

- **When:** Start planning now and include in FYDP

Vugraph 18

A "long pole in the tent" for the distributed Combat Cell concept is the inability to provide immediate fire support around the clock. Immediate fire support is identified as less than l-8 minutes. Almost all fire support studies list the lack of immediate fire support as a major shortcoming. It is further aggravated when trying to provide all or most fire support from long standoff ranges.

Forward deployed Combat Cells need immediate fire support around the clock which can't always be provided by current fire support systems because of geography, logistics, weather, and/or scheduling. Long range cruise missiles stationed miles off shore can't meet the short time requirements either. An adequate number of loiter weapons must be provided by other means.

The panel recommends OSD develop a loiter capability for indirect precision munitions that can be controlled and directed by the Combat Cells for immediate fire support. The rounds should have a range of at least 200 nm and be able to loiter as long as possible (at least 30 minutes). The weapons should allow adaptive packaging for: area lethal/non-lethal munitions, small CEP and/or terminally guided munitions, deep penetration, and different size explosives. Some of these weapons should have terminal guidance capability that will allow the Combat Cell to hit cave/tunnel doors and ventilation shafts. All munitions should be considered but some of the more likely candidates would include an inventory of cruise missiles, UAVs as weapon platforms, and/or 155 mm shells.

The objectives for immediate fire support is to develop an inventory of weapons that will allow the SPJTF Commander to provide around the clock coverage by scheduling a combination of aircraft and loitering precision weapons such as UAVs, cruise missiles and 155 mm shells.

The major changes this recommendation will have on the current fire support culture is reducing the response time to 1 minute and turning over final control of some of the weapons to a member of the Combat Cell.

Section IV
"Understanding Distributed-Force Concepts for Rapid Deployment Operations: Report of the DSB Panel on Analysis and Modeling."

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Analysis and Modeling

Summary

Context of Report[1]

A conclusion of a 1995 DSB summer study was that the United States needed to improve the combat power of early deploying forces, forces that could be employed within days of an order to move. With adversaries having learned from Desert Storm, the United States might reasonably expect future invaders to maneuver toward objectives rapidly and without pause. An important question, then, was how much might be accomplished to thwart such an invasion with forces that could be deployed within days (e.g., with respect to ground forces, a brigade-sized light force with 5000 personnel). It seemed plausible that the emerging technologies associated with information dominance, distributed communications, and long-range precision fire might make it possible to make such an initial force very potent. It was decided, therefore, to explore operational concepts for making this a reality in the 1996 summer study, *Tactics and Technology for 21st Century Military Superiority.* It could draw upon related work in the Marines' Sea-Dragon and the Army's Army-After-Next efforts. Since initial forces would almost surely have to be dispersed to accomplish multiple objectives in parallel, the study began with particular interest in examining ways to enhance the power of small units or cells by assuring superb communications, situation assessment, and long-range precision fires. The postulate here was that this support could be provided from operations centered around naval ships and relatively distant air bases. Such support might be available very early in conflict. A central issue then became whether such support could both protect the small units and be exploited by them to engage the enemy. Could the "close battle" be virtually eliminated in favor of effective engagement at long range? Would distributed force concepts involving small, dispersed, but well connected and supported ground forces work?

Purpose of Report

Against this context, then, the purposes of this supporting report from the summer study's analysis and modeling panel are threefold: (1) to present initial insights, based on brief preliminary analysis, about the feasibility and effectiveness of the new operational concepts created and examined in the summer study; (2) to characterize analysis requirements for force planners and designers considering the class of new concepts; and (3) to recommend analytic approaches and priorities for management of both analysis and the models and simulations used for that analysis.

Substantive Findings

Our analytic work in the summer study was a first brief look at a very complex problem, but we have a number of findings. Some are relatively firm, while others should be viewed

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[1] Panel members and contributors are listed in Appendix A.

as more tentative hypotheses for further work. Starting from the most general and working toward the more technically specific, they are as follows:

General

- *Change Could Be Fast.* Much of the technology envisioned under the rubric of the revolution in military affairs (RMA), including that for distributed-force concepts (e.g., that for achieving high situational awareness and connectivity), can be achieved in 10-15 years without invoking assumptions about exotic systems. The principal issues in achieving change are now organizational, doctrinal, and cultural, not technical. There is reason for DoD to push much harder and faster for change. Arguably, if cultural and organizational obstacles can be overcome, the "military after next" should be a goal for 2005-2015, not 2025.

- *Change Is Needed, Not Just Desirable.* The impetus for distributed-force concepts should be two-fold: opportunity and vulnerability. Initial analysis suggests that with distributed-force operations the U.S. will be able to greatly leverage its early-deployment forces, even down to the level of the small team. In addition, however, the U.S. will *need* such operational concepts to reduce the vulnerability of its forces to even second-rate adversaries, who will have increasingly effective weapons that are available inexpensively on the world market.

Effectiveness of Distributed Forces

- *The Best Case: Armored Invasions.* Given current and programmed RISTA capabilities, distributed-force operational concepts could in many circumstances be highly effective against classic armored invasions. The United States should be able to make such invasions obsolete, thereby seriously undercutting the value of many potential adversaries' force structures and doctrine. That would be quite an accomplishment.

- *Other Cases.* The same capabilities and concepts look much less promising for operations in difficult terrain, including urban settings. There are exciting technological opportunities for improvement, but the systems are neither far along nor well demonstrated. Infantry-intensive operations will be necessary for many years into the future.

- *Countermeasures and Exaggerations of Capability.* Even in favorable cases, evaluations of the new concepts (such as distributed force) tend to exaggerate substantially the effectiveness we should expect. Most war games and studies concatenate planning factors without adequately accounting for situational details and statistical complexities with big effects. A wide range of countermeasures must be expected, many of which do not require high technology or high expense. We should not rule out the possibility that with a combination of changed maneuver tactics, exploitation of terrain, decoys, GPS jamming and a few other measures, adversaries might reduce effectiveness by an order of magnitude relative to "nominal" levels.

Implications for Force Design

- *Focus On High-Payoff Improvements.* In dealing with these issues there is high potential payoff in several technological improvements: (a) "zero time of flight" weapons (e.g., guardian UAVs, tactical aircraft hovering in the immediate region, and loitering munitions); (b) in-flight updating to provide late-in-flight target location information and — more challenging — target designation to reduce multiple kills and to discriminate between enemy vehicles and hostages; (c) superb sensor management, which will be extremely difficult; and (d) improved counter-infantry weapons for aircraft forced to high altitude by missiles. The first two of these would reduce effectiveness of many countermeasures and would probably be more reliably able to achieve the effectiveness *assumed* in standard calculations that misrepresent spatial and other correlations among targets (configuration effects).

- *Assume Leakage Will Occur.* In designing distributed-force operational concepts with small precision-strike teams deployed in depth, it should be assumed — even in first-order calculations — that external fires will not alone be able to destroy attacking forces. Except in the most ideal of circumstances, there will be significant, and sometimes quite substantial, leakage.

- *Balance Organic Capabilities and External Fires.* Because of leakage, designs should seek a prudent balance between providing the teams with organic capabilities such as short-range precision fire (e.g., EFOG-M) and depending on lavish external fires. This conclusion may seem to be inconsistent with the spirit in which the study was begun, which included the notion that the initial ground forces should be as light as possible, but analysis demonstrates that it is feasible — without increasing requirements for airlift — to greatly enhance the capabilities of something like the 82nd Airborne Division's ready brigade or Marine expeditionary units of battalion or brigade size.[2] In our view, design of concepts should start with the requirement for task-organized joint task forces with balanced capabilities, tactical mobility, and significant short-range precision organic fires to hedge against leakage. This, coupled with lavish external fires, would provide formidable capabilities in many circumstances.

Findings and Suggestions About Analysis and the Research Base

The United States is entering a new era of warfare and examining operational concepts that are radically different from those they may supplant. It is a time of great opportunity, but our knowledge base — gained from decades of experience that included shooting wars — is quite inadequate: we don't even know what we don't know. We should be approaching the new challenges with humility and the determination to search out the knowledge needed. The panel concluded that doing so will require organizational change and a rebalancing of approaches to analysis itself.

[2] See reference in bibliography to papers by Steeb and Matsumura of RAND.

Need for a Dedicated Research Organization

As we contemplated the knowledge base for evaluating the new operational concepts, we were struck by the nonexistence of an appropriate *research organization.* In recent years the DoD had vigorously expanded the technological frontiers in many domains, drawing heavily on civilian technology in the process. By contrast, it has neglected research on relevant phenomenology, leaving such research to be done at low levels of effort and with great fragmentation. This situation can and should be remedied:

> We recommend that the DoD (and perhaps the DDR&E specifically) establish a multiyear research program devoted to issues related to information dominance, long-range precision strike, and a wide variety of operational concepts exploiting those and other emerging pillars of future U.S. military capability.

This would not be an aloof activity happily building models in a vacuum, but rather a program devoted to "cracking the issues" of a new subject area. It would be strongly tied to the warfighting community and could be added to the effort described in the DDR&E's new Joint Warfare Science and Technology Plan. Table S.l describes the program's mission.[3]

[3] A broader study of analytic issues might also be conducted by the DSB. This could cover a range of substantive subject areas, methods, and models. It could, among other things, examine DARPA's "continuous war" vision of a synthetic battlespace and how it could enhance analysis as well as training.

Table S.l — Mission of a Distributed-Force Research Program

Mission Statement	Examples
Identify analytical issues needing improvement, derived from both customer concerns and research	Countermeasures, realistic effectiveness calculations, behavioral assumptions at both small-unit and commander level.
Collect and analyze empirical data from all sources, both existing and program-generated	History, structured interviews, instrumental training exercises, virtual exercises, field tests.
Collect and analyze results from all types of M&S both existing and program-generated, at all relevant levels of resolution	Encourage integrated hierarchical families of models, including selectable resolution; exploit data from all levels of resolution.
Create and maintain an overall intellectual framework by engaging customers, actively guiding the research program, and stimulating both peer review and open debate	Provide strong problem definition and analytic plans to those conducting virtual experiments. Create subject-area forums for in-depth exchange and peer review.
Serve the customer community by providing expert advice and advisors, making available new and better analytical modules for widespread use, and evaluating analysis at request of customers	Provide red teaming, definitive effectiveness calculations, and analytically sound modules (while recognizing uncertainty)

This effort might parallel the detailed field experimentation and associated analyses of the 1960s and 1970s on attack helicopter tactics, visual detection, air-to-ground tactics, laser designation, and other phenomena. That work laid the basis for simulation models developed in the 1970s and 1980s.

On the Conduct and Use of Model-Supported Analysis

The panel and many DSB colleagues have been troubled by a trend in DoD studies away from classic principles of good analysis and analytical discourse, and also by how resistant the DoD has sometimes been in confronting the reality of massive uncertainty in many dimensions (e.g., details of political-military scenario, enemy strategies and forces, and both enemy and allied fighting effectiveness). Table 2 summarizes, in admittedly stark terms, the contrast between the current culture and what is desirable. To be sure, there are many good examples of analysis that could be cited, but we are concerned about trends with attributes such as closed processes with more attention to bureaucratically dominated model and data accreditation than to substantive review and the search for truth through exposure and debate of ideas. At the level of models themselves, we see continuing dependence on models that can chum out results mechanically, but that require extensive data preparation, rigid approval processes, and more emphasis on continuity than discovery. Too often, models and model-supported analysis suppress discussion of important uncertainties and risk, at the very time when more attention needs to be paid to such matters. Finally, we note the continuing legacy of rigid Cold War thinking rather than an emphasis on developing versatile and robust forces, forces that are operationally adaptive in many dimensions. Changes are in the wind, but will not readily be accepted.

Changing the culture must start at the top, with high-level demands for more open, competitive, comprehensive, and imaginative studies that bear a close relationship to the actual military and force-planning issues of our time. There are also implications for how major investment programs, notably for Joint Simulation Systems (JSIMS), Joint Warfare Simulation (JWARS), and Joint Modeling and Simulation Systems (JMASS) are pursued. In particular,

> we recommend against an approach that envisions **standardizing on a single model** or model familv.

Such an approach is reminiscent of Central Planning rather than a marketplace of ideas. To be sure, the community badly needs the emerging module-level technical standards that will simplify module reuse and cross-organizational comparisons (e.g., those of the High Level Architecture), but standardizing overall models, data bases, and analytical approaches is not the way to go.[4] As a last point here, there is more value in requiring the clear expression of assumptions and sensitivities (using semi-standardized forms to describe assumptions) than in requiring standardization of the tools. The tools are not nothing, but the assumptions are everything.

[4] Obviously, having common baseline data bases can be very useful. The problem, however, is that such baselines have been confused with "truth," with far too little exploration of sensitivities.

Figure S.l

Changes Needed In DoD Analysis Culture

WHAT IS	WHAT SHOULD BE
Closed processes	Open processes
--Bureaucratic review	--Peer review
--Accredited analysis	--Competitive analysis
Model orientation	Subject-matter orientation
--Mechanical	--Meaningful
--Data poor	--Data rich
--Rigid approvals	--Learning and adaptation
--Stable algorithms	--Unstable phenomena
Suppresses uncertainty	Illuminates uncertainty
Suppresses risk	Illuminates risk
Narrow, cold-war style	Oriented to now and future
--Few, accredited scenarios	--Many pol-mil scenarios
--Point assumptions	--Exploratary analysis

Exploratory Analysis Methods and Scenario-Space Testing

An important element of what we propose is for DoD to embrace an approach to analysis that seriously confronts multi-dimensional uncertainty. This is now more practical as the result of improved computer power and improved designs of models. It is now possible, in the context of a specific study with particular issues in mind, to design an "exploratory" analysis examining the consequences of alternative assumptions about factors such as threat level and capability, the sides' strategies, the qualitative competence of all forces involved, the actual weapon and force performance of all forces (function of modernization), environment, and even the algorithms and decision rules used within models. The result is to move away from efforts to optimize for point assumptions toward gaining insights about what one must believe in order to make different choices rationally. Such an approach is critical if we are to design force postures for operational adaptiveness (i.e., for versatility and robustness). It could also be quite valuable in reducing log-rolling in analysis, where the various advocates agree to accept each others' planning assumptions about weapon systems. Results would be shown as a function of those assumptions and combinations thereof.[5]

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5 The principal ideas are discussed in Davis, Gompert, and Kugler (1996) and Davis (1994), drawing on RAND work over the last decades. See also the independent and remarkably similar proposals of such methods by Vector (Bonder, 1994 and earlier references). A key theme in both is designing forces for operational adaptiveness (i.e., for versatility and robustness).

Reconceiving the Relationship Between Analysis and the Various Model Types

DoD's modeling and simulation (M&S) activities have been largely driven in recent years by technology-push. There have been dramatic advances in distributed processing, M&S technology, and applications to training. The future for simulation technology is very bright and the payoffs could be enormous (see Appendix B). There has, in contrast, been much less investment in methods and tools for analysis and sophisticated decision support. Further, serious misconceptions have arisen about how much can be accomplished with man-in-the-loop virtual and live simulations and exercises, and about what level of resolution is desirable. As discussed more fully in the text:

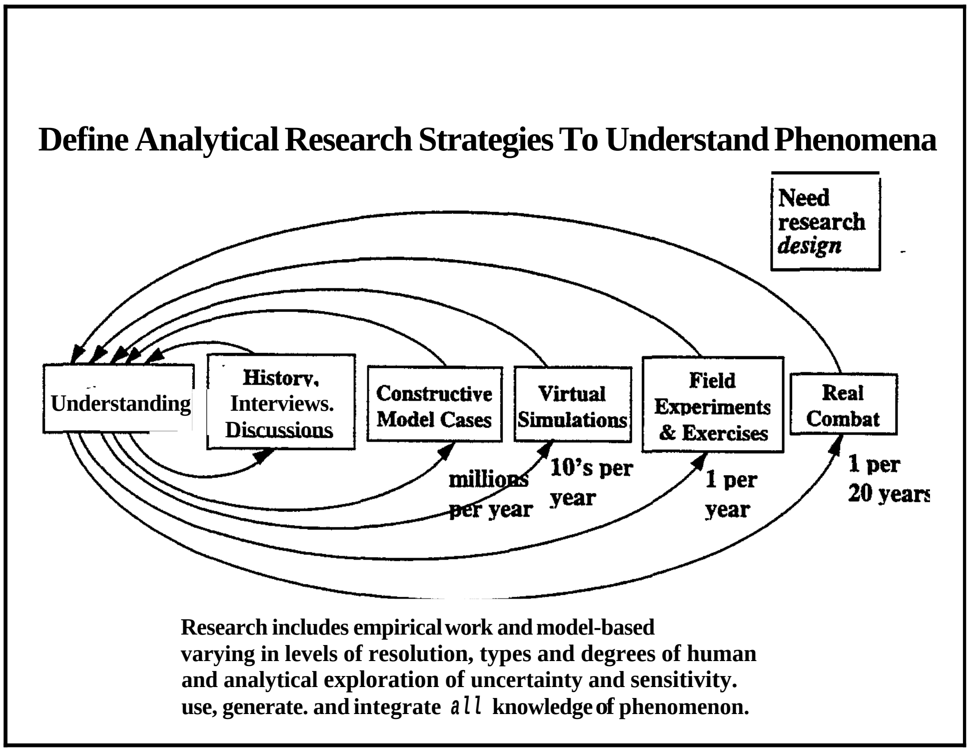
- DoD should harness more of its M&S activities in service to decision makers and analysis. Virtual and live simulations are extraordinary opportunities, but they can be ill-focused and inefficient unless they are designed with higher-level objectives in mind. Such designs require strong analytic underpinnings and an understanding of issues faced by decision makers.

- Distributed simulation should be seen more as a mechanism for exploration and experimentation than as a tool of analysis (although it will sometimes be used analytically). By and large, in-depth analysis requires (now and in the future) heavy use of constructive models (which include, in our terminology, interruptible models permitting but not requiring human play). Some of these will and should have relatively low resolution, which allow us to examin e the consequences of myriad uncertainties, to examine circumstances that could not realistically be simulated in the field, to use low-resolution information, and to conduct the many tradeoff studies needed to make sound decisions on issues ranging from doctrine to force procurement. Others will have higher resolution (e.g., Janus), but will be used with decision models to permit closed operations.

- Constructive simulations, however, should be closely tied to "real" military phenomena and the insights possible from virtual and live experiments. These insights should drive design of new constructive models and help calibrate the results. We say "help" here, because calibration should draw on information at all levels of aggregation. The notion that high-resolution models are a sufficient mechanism for calibrating low-resolution models is very often wrong. The detailed models are usually quite narrow and do not reflect critical contextual and command-control issues adequately; further, they depend on hundreds and thousands of uncertain data elements; as a result, aggregate data (including history) is often more reliable (e.g., on rates of movement, reliability in battle, and the effects of virtual attrition).

Figure S.2 illustrates the way we view the relationship among models and simulations, other forms of research, and the buildup of knowledge. The image is one of synthesizing knowledge drawing on many classes of information and analysis. There is no reason to choose among types of simulation, for example. Instead, the clear objective should be to exploit all of them appropriately.

Figure 5.2



Two further points are significant here:

- Any program to explore distributed-force concepts will badly need an infrastructure with mutually calibrated and integrated hierarchical families of models. Despite occasional claims to the contrary, these do not exist today. Perhaps they can be developed in the JSIMS, JMASS, and JWARS efforts, but the challenges involve substance, not just software technology.[6] Alternative models and families will be needed to capture all available knowledge about underlying processes, and to assure introduction of innovative methods.

- Finally, we note that future models will need to incorporate many features seldom treated well in the past. These include the representation of information warfare, high level decision making, alternative logistics concepts, the complexities of non-linear non-contiguous operations (including "emergent behaviors" seen at higher levels), and psychological and social behaviors that are not well understood presently. All of these are keys in evaluating distributed-force operations.

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6 The Panel did not discuss the very important infrastructure developments taking place, most notably those associated with the High Level Architecture (HLA) and advanced distributed simulation (ADS). It is broadly agreed, however, that the HLA and related developments are technological enablers, not research on military phenomena, nor development of integral model families. Again, then, the Panel's emphasis was the knowledge base. For an image of what technology is making feasible, however, see Appendix B.

All in all, the challenges ahead for M&S are formidable. While there is a growing belief in parts of the DOD that expenditures on the technology end of M&S can be trimmed, we believe that investments on the "knowledge" end should be increasing. So also we believe that large-scale virtual experiments would have much more payoff if guided by analysis driven from a strong and growing knowledge base.

1. Introduction

Purpose

This report has both substantive and methodological objectives. Substantively, it represents a first-cut at evaluating operational concepts developed for and in the 1996 DSB Summer Study, ***Tactics and Technology for 21st Century Military Superiority.*** It includes numerous observations, based on brief preliminary analysis, about when the concepts would be most and least applicable, about what technological and operational issues seem to be especially important to success, and where more study is most needed — especially on potential "show stopper" problems. Since the DSB is contemplating radically different concepts and operating environments, the also examines methodological issues. How well can we currently analyze the key issues? The report characterizes the baseline for such analysis and points out many shortcomings in knowledge, analytical methods, and managerial approaches to analysis. It goes on to recommend a series of DoD initiatives, some managerial and some involving specific research and analysis. Many relate to the effective combined use of constructive models, virtual war games and exercises, and live experiments and exercises. Put bluntly, we believe that relatively more emphasis should be placed on the analysis end of the problem, which implies improving constructive models that should be informed and calibrated in significant part through use of virtual simulations and live exercises, including training exercises.

Observations About Analysis and Modeling

Throughout the report we emphasize classic objectives of analysis: not proving preconceived conclusions, but rather contributing to an in-depth ***understanding*** of the problem area and supporting decision making on a wide variety of topics such as choosing among competing concepts, defining system "requirements," and making tradeoff decisions at the level of force structure. Much of the report deals with models, but they are viewed with these "analytical" objectives in mind (we use quotes here because we include synthesis or integration in our definition of analysis). Our report is not about M&S technology per se, but we have numerous suggestions about how better to harness it in support of analysis for decision makers.

The structure of the report is as follows. Section 2 provides motivation and context; Section 3 describes operational concepts; Section 4 describes a series of preliminary analytical insights about the distributed-force concepts, touching upon issues such as x leakage of penetrators and survivability of small teams, countermeasures and counter countermeasures, and high-payoff capabilities. Section 5 discusses analysis requirements and certain changes that will be needed in the DoD's approach if it is to assure that future forces are operationally adaptive (i.e., versatile and robust). It includes recommendations about research needs, because in many instances analysis is limited by the knowledge base. Appendices describe the future of simulation technology (App. B), issues and questions for analysis (App. C), and observations from supporting analysis by IDA Joint Precision Strike Demonstration Program (JPSD), and the GAMA Corporation. Results of analysis conducted by TRAC and RAND are included as separate sections in this

Volume (Appendices D, E, and F). We attach a bibliography of relevant materials, although it was impossible to provide detailed literature citations.

2. Motivation and Context

The purpose of the 1996 DSB summer study was to conceive and begin the evaluation of new information-age operational concepts that could be valuable building blocks in the tool ***kits*** of future JTF commanders. The concepts stress information dominance, long-range fire, and small initial forces that can be deployed quickly. All of them are ***distributed-force concepts.*** If successful, they could increase effectiveness and decrease vulnerability.[7]

Mid-Term Strategic Context

Why are such concepts of interest? The motivation was essentially strategic. Recent studies have increasingly emphasized that future military adversaries will have learned from the spectacle of Desert Shield and Desert Storm, and will most likely avoid giving the United States the opportunity to deploy forces in a leisurely manner and then attack on its own time table. In particular, we might expect adversaries to contemplate quick no-warning (or ambiguous-warning) armored invasions coupled with efforts to obstruct or prevent U.S. deployments into the target country. Despite U.S. programs to improve strategic mobility, including through prepositioning of equipment in Persian Gulf nations, there is no way to deploy very large traditional forces in a matter of days or a week. A key challenge, then, is developing the capability to accomplish a great deal with the small forces that could be deployed within that first critical week (DSB, 1995).

In principle, much could be accomplished with long-range bombers, and with both missiles and tactical aircraft from naval units if they were available at the outset of crisis. However, the United States would probably need to deploy ground forces and tactical aircraft to sustain the attack, secure territory, and to conduct counteroffensives. Further, without such a commitment of forces on the ground it is questionable whether intervention would be requested by the ally being defended. It follows that we should be interested in ways to improve the effectiveness of ground forces deployable into a theater within a matter of days or a week. This translates, roughly, into a "brigade-sized force," i.e., roughly 5,000 personnel, although the actual organizational character of the force might or might not bear much relationship to a normal brigade. One way to view the issue is to ask how to construct a brigade-sized joint-task force (JTF) able to accomplish key missions in the early, critical period. This JTF would probably task-organize for the specific contingency. There should be no attempt to find a one-shoe-fits-all design.

Some principles emerge quickly upon thinking about the problem. The distributed-force operational concepts should, at the joint-task-force level:

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7 There is an analogy here to computer systems. By creating distributed networks it has been possible to increase processing power (load sharing), to increase the ability of individuals to get together virtually in "ganging up on a problem," drawing on specialized expertise when necessary, to disseminate information rapidly and interactively, and to reduce vulnerability to break-down of any one node. Early efforts, however, often failed: networks were unreliable, parallel processing proved to be more narrowly applicable than originally thought, interfaces were complicated, and standards lacking. It took a decade to reach the high levels of performance we have now come to expect.

- Be truly joint and be developed with the expectation of cooperating early with the forces of the defending nation, and possibly other allies,[8] but with the capacity to act unilaterally.
- Focus on airlifting "light" forces with substantially more firepower and tactical mobility than the current 82nd Airborne.
- Allow for forced-entry capability to seize and secure critical airfields and ports, support the defended nation's government, or take on other special tasks, and to do so very early in conflict.[9]
- Achieve information dominance and bring to bear high levels of long-range precision fire — drawing upon long-range bombers, tactical aircraft (Air Force, Navy, and Marines), ship-based missiles, naval gunfire, and ground-based missiles.

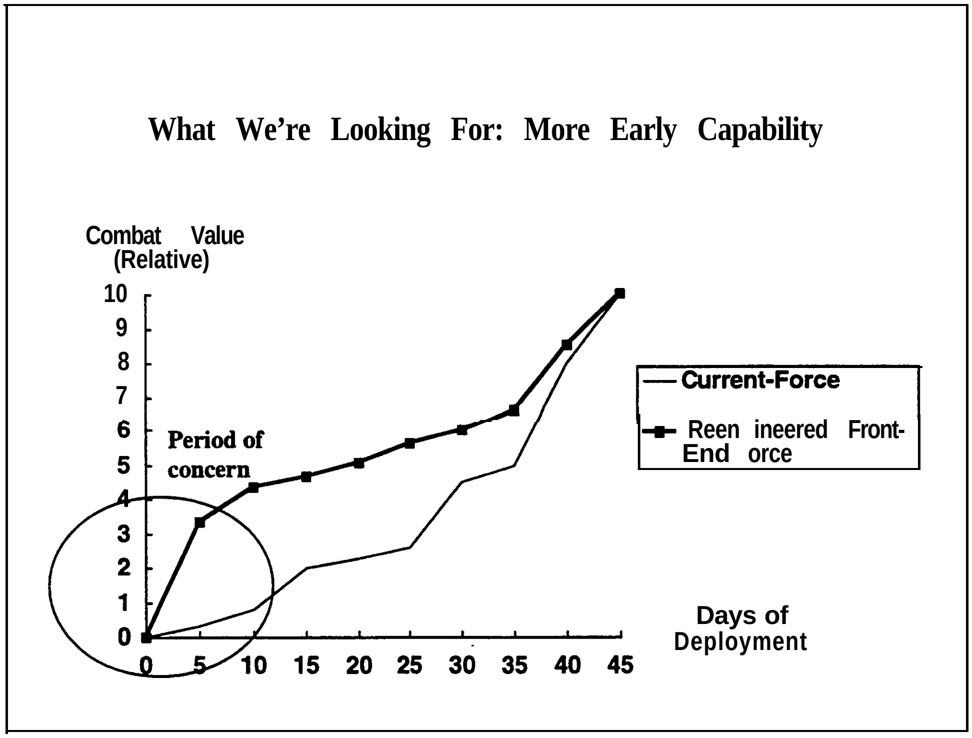
Exploiting these capabilities could greatly reduce the tonnage of equipment, munitions, and fuel to be lifted into the theater in the critical initial phase. In many cases, naval forces would be in the theater on D-Day; in all cases, long-range bombers could provide at least some capability from afar; in many cases tactical Air Forces could be in the theater early or would deploy quickly to regional air fields. In many cases, airlifted ground 'forces would include mobile-missile units (e.g., MLRS/ATACMS/BAT, along with air-defense and information-operations units). Or such units might be deployed to the theater prior to overall C-Day, in much the same way that Naval forces and Air Forces can sometimes deploy to the theater, if not to the country being defended. With precision weapons, the weight of the munitions to be airlifted would be much less than historical levels.

Qualitatively, then, the desire is to achieve a rapid build-up of usable combat power as shown in Figure 1.

8 There is understandable reluctance to "depend on allies" when planning future forces or developing contingency plans, but it would be folly to plan under the assumption that the United States will ordinarily be engaging in wars by itself. Typically, we will be attempting to support and leverage the capabilities of a defender. Further, we will often want to incorporate at least some forces of major allies from the outset. This might complicate planning, but pay very high dividends in terms of international legitimacy and both broadening and deepening support for necessary operations. It is also in the U.S. interest to build coalitions during peacetime to share some of the expected long-term burdens of maintaining stability in volatile regions (Gompert and Kugler, 1996). A consequence of this may in time be contingency plans that include some major ally forces even in early phases of war.

9 The inability to accomplish such missions today with very short warning and very fast response is a current Achilles' Heel (DSB, 1995; Davis, 1994, Ch. 3).

Figure 1



Strategic Context in the Longer Term

As we contemplate warfare in the era of 2010-2025 there are additional considerations. In particular, it is likely that:[10]

- Ground and air forces will be unacceptably vulnerable, to both conventional and mass-destruction weapons if deployed in traditional ways (large dense formations with large dense logistics bases).

This implies that there is even more reason to be interested in enhancing the power of small distributed forces supported lavishly by long-range fires. It also suggests that those who saw the DSB effort as pursuing a fairly arbitrary set of concepts based on excessive enthusiasm for “small-team” ideas may be wrong: smaller, distributed forces may be needed in any case.

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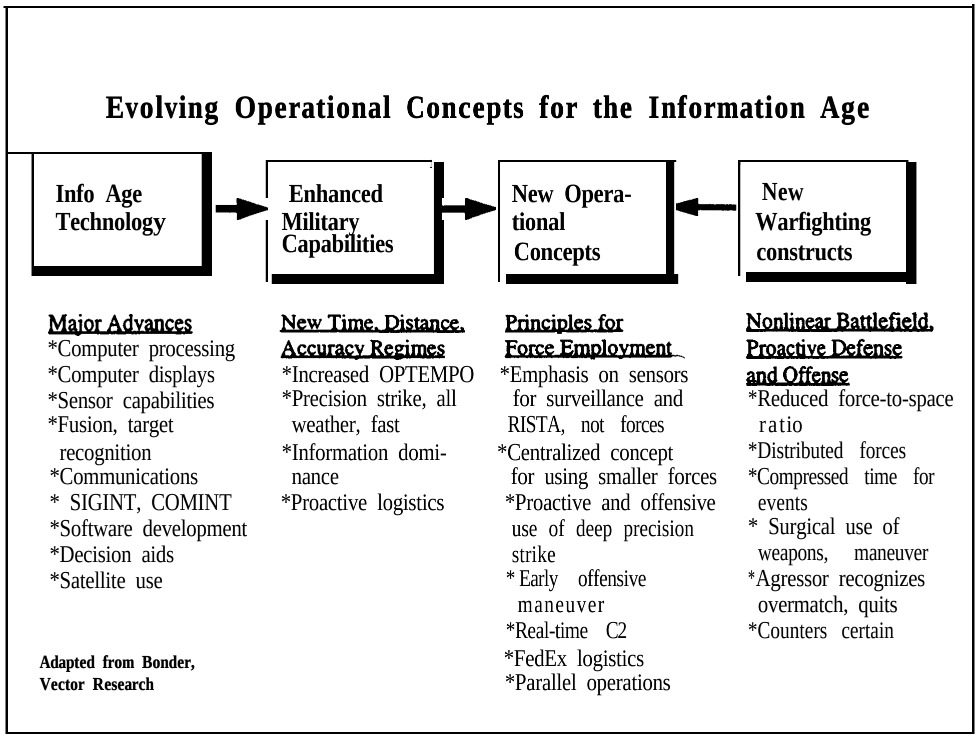
[10] In this connection, the 1995 DSB Summer Study defined a 21st-century regional threat that, while by no means a "peer competitor," has a wide variety of capabilities that could severely challenge U.S. interventions. These include diesel submarines, advanced naval mines, drones with significant detection capabilities, fairly long-range missiles with increased accuracy, mass-destruction weapons, and general-purpose-force equipment roughly comparable to 1980s U.S. weapon systems. See also Barnett (1996), which draws upon much work by the Office of Net Assessment.

Opportunities in the Information Age

Although the principal motivation for the study's scope was strategic, a comparably powerful motivation was, of course, technological, since the DSB's purpose is to help harness technology in support of military needs. In this regard, Figure 2 illustrates how strongly various factors are pointing in the direction of issues in the study. Basically, there is a confluence of influences.[11]

Figure 2



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[11] For a striking official image of the future consistent with Figure 2, see Shalikashvili (1996).

3. Alternative Operational Concepts for the Information Age

Basic Considerations

Purposes of Deployment

As described above, the focus of the DSB study was on increasing the combat capability of rapidly deployable forces required, by design or circumstances, to be dispersed and operate in small numbers. Soldiers and marines are placed upon the ground in an area of operation for a series of reasons. Among them are to:

- Demonstrate the commitment of the United States to a particular outcome,
- Provide humanitarian assistance,
- Protect or control the population,
- Seize and secure terrain,
- Preclude the enemy from accomplishing his objectives,
- Destroy enemy forces/capabilities,
- Restore order and facilitate the transition from war to peace, and perhaps
- Impart democratic values while doing so.

Although air forces and missile attacks may sometimes cause massive attrition and blunt attacks, and may be used for strategic attacks on the aggressor's homeland and logistics land forces will typically be needed to make permanent the otherwise transitory advantages achieved by such attacks. Further, in many instances, only ground forces are likely to be effective. The need to place soldiers on the ground is increased as the terrain becomes more restrictive, the enemy employs forces with reduced signatures (either in type platform or number of platforms), and the enemy increasingly disperses his force.

Increasing the combat capability of the rapidly deployable forces involves several goals.

Goals

Increasing the Combat Power of Rapidly Deployable Forces

Given the decision to employ ground forces, the first challenge is to generate combat power adequate to the mission(s). Early commitment of force is often a significant factor in deterring aggression or escalation. Rapidly placing a military force on the ground shows the ultimate commitment of the United States. The issue is balancing deployment assets against force capability. The force most strategically deployable is, by definition, a "light" force but, historically, these forces have lacked major combat power due to the weight associated with systems having overwhelming attrition capability, particularly against larger, mechanized forces. We need to do better (recall Figure l).

Part of the problem deploying significant combat power rapidly is the weight associated with indirect-fire munitions, notably "dumb" artillery, which a division can expend at the rate of, e.g., 1200 tons per day. These munitions have been designed to accommodate large target location errors (TLE) and delivery error (CEP). Studies indicate that, despite progress in reducing both TLE and CEP, volume of fires will remain important.

Additionally, light forces have had limited tactical mobility and, therefore, have been constrained by how much capability they can "carry". The first goal, then, is finding ways to increase the combat power of light forces.[12]

Equipping the Forces for Close Terrain

The second goal is to equip those forces to operate in urban and other types of rough terrain. This panel did not examine this issue significantly in the summer study.[13]

Controlling and Securing Terrain

The third goal we considered is the control/securing of terrain and the protection and support of local population. Often in this case, the total force size is such that smaller forces are called upon to perform missions/tasks which can escalate into much more threatening situations. Traditionally, the force initially confronted has not had adequate means to deal with the presented situation and the time required to reinforce that force has been unacceptably long.

Considerations in Attempting To Meet Goals

In addressing alternative solutions to these challenges, several factors must be considered. First, deployment of the entire joint force must be optimized to continuously generate the greatest combat capability. Shifting the responsibility of providing a capability from one service to another is beneficial only when considered in light of the associated strategic deployment tradeoffs. When a capability is provided in a new way, what are the changes in the *overall* joint-force capability as a function of time? This is difficult, but crucial, to assess.

Secondly, the tactical mobility of the light force determines how quickly the light force can be employed. A commander must ask "How do I get the elements of this force to their desired employment locations?"

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[12] This problem has been studied in some depth in the context of improving the capability of the 82nd Airborne's division-ready brigade (DRB). See Steeb, Matsumura, et al. (1996). These studies show, for example, the substantial potential benefit of relatively low-weight systems like the EFOG-M missile, which has a range of roughly 15 km in what may be called the "extended close battle."

[13] One conclusion from studies, however, is that with the limitations of existing aerial sensors in detecting and tracking forces in rough terrain, small defending forces can be readily overrun unless they have a ground-sensor network to detect approaching enemy forces.

Thirdly, the relationship between direct and indirect fire means must be assessed. If the combat capability of a force is increased by providing fires which are not required to be moved by this "light" force, the ability to kill the target before the target has the capability to kill the light force must be determined. "Can I find and kill the targets before they, or one of them, can kill me?" This is both a target-acquisition and an indirect-fire-system timing question and helps determine the direct-fire needs of this force.

Another question from the commander is "Can this force preclude the enemy from accomplishing its mission ? For example, if the mission of the enemy force is to stop the continued flow of friendly combat forces into the theater, can our concept keep the enemy force from occupying (or controlling) the ports ?" While a new operational concept may increase the number of kills, can it preclude the enemy from getting to the ports or closing them with long-range fires ? This issue has been referred to as "dealing with the leakers." Again from the commander's perspective:

1. "Can I sustain this force?
2. How will the force move to better/new employment locations? How will the force withdraw when that is the appropriate course of action? How will the force be extracted?
3. Related to the issue above, how will this force survive in its operational environment?"

Insights

In addressing this problem in the course of the summer study, several insights have evolved. They will be discussed more in Section 3.[14]

1. Increased situational awareness enables a force to move, reposition, and prepare for pending conflict, and to do so faster because of confidence in security.
2. Having increased situational awareness, at the appropriate resolution for target acquisition, increases the number of targets potentially engagable by indirect fire.
3. Degrading the enemy's situational awareness and ability to acquire targets greatly increases the effectiveness of U.S. and friendly forces.
4. Having increased target information must be matched by the capability to engage them. However, higher quality target information alse contributes to maneuver of friendly forces.
5. The process of engaging targets when the weapon is not within line of sight of the target (indirect fire) includes: acquiring the target at the resolution needed for engagement (detect, classify, recognize or identify), communicating the request, command-control, communicating the decision to fire, preparing the weapon, launching the weapon launch, updating target location during the time of flight, hitting the

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[14] This draws heavily on Matsumura, Steeb, Herbert, Lees, Eisenhard, and Stich (1996), work done for the summer study and included in the overall DSB report.

target, and assessing mission effectiveness (BDA). The best time from target acquisition to weapon launch is approximately three minutes (not including time of flight). More routinely this takes five times as long (15 minutes). This does not include time of flight or inter-service coordination. Reducing this time has a major effect on battle outcome.

6. Early acquisition of targets allows distributing those targets to indirect-fire systems (rather than to the direct-fire systems that otherwise might have been tasked to destroy them) and reduces losses to the friendly force.

7. This redistribution of targets from direct-fire to indirect-fire systems enables the force to engage more targets overall, if there is an abundance of targets. As a result, the force is both more effective and more survivable.

8. Reducing the number of targets engaged by direct-fire systems also reduces the quantity and weight of direct-fire munitions that must be deployed with the force.

9. However, no evidence exists that indirect fire alone can insure that the enemy will not accomplish its objective or that direct-fire engagements can be completely avoided. The ability to service all targets before a direct-fire engagement occurs is a function of acquiring all targets and killing them within the time available before the close battle begins. It appears that even with substantial indirect fire, both tactical mobility and some direct-fire capability will be needed.

10. A force with increased situational awareness, at a targeting level of resolution, and sufficient means to engage targets prior to the beginning of close battle where line of sight exists increases is more effective. Such capabilities would enhance any force and particularly those forces with limited direct-fire/close-combat attrition capability (either by force design or as a result of deployment density). This increase in force effectiveness should facilitate further dispersion of that force with the added benefit of accomplishing those tasks requiring human presence over a greater geographic area. Dispersing the force into smaller elements may also increase its survivability by reducing its signature and potential priority to the enemy. In determining potential limits in the size of the subsequently dispersed elements, enough capability must be retained to successfully deal with the residual direct-fire engagements. Further, the psychological impact of operating widely dispersed and isolated "small" teams is critical and must be assessed.

11. Tradeoffs can be made between direct and indirect means at equal effectiveness, thus potentially reducing cost and increasing deployability. while maintaining a hedge against leakers.

Alternative Distributed-Force Operational Concepts

Within this context, we considered three alternative operational concepts. These must be examined not only in light of the questions listed above, but across the wide spectrum of operational circumstances that involve differences in, e.g., terrain, enemy equipment, enemy tactical formations, and enemy modes of operation.

Certain characteristics apply to all of the alternative operational concepts:

- Increased deployability (reduced loads due to increased dependence on "external" fires)
- Enhanced tactical mobility (for similar reasons)
- Increased situational awareness (at least within the area designated for target attack) at a targeting level of resolution

Concept One: Enhancing Current Forces

The first operational concept is to enhance current, highly deployable conventional Army and Marine forces as indicated above. Because of its increased effectiveness, this force would be able to increase its dispersion and thus influence a significantly larger geographic area. This force would continue to combine both indirect- and direct-fire capability in its combat units, but would depend upon indirect fire as its primary killing system. This organization would use its ability to mass forces to facilitate movement and concentrate direct-fire capabilities when required for survivability.

Concept Two: Augment Current Forces With Reconnaissance Teams

The second concept would be to augment the conventional force with small, highly mobile target acquisition and engagement teams (TAET). These teams would be part of a larger force but would operate dispersed. Their objective would be destroying the enemy and shaping the battle space, but only with indirect-fire means. They would avoid, at all cost, engagement in direct-fire battles. These teams would change the military situation and provide more accurate and timely situational awareness to the rest of the force, which would maneuver to defeat that portion of the enemy force not defeated by the TAETs.

Concept Three: Structuring Around Autonomous Precision Strike Teams

The third concept envisions a force structured to employ small, autonomous teams throughout the battle area. These teams operate within a system of overlapping areas of increasingly higher-resolution situational awareness. The role of these teams is the acquisition of targetable information and the attrition of the enemy with indirect means. The survivability of this force is enhanced by the small signature of its teams. By virtue of their smallness, these teams would control/influence significantly larger geographic areas. The degree to which the "rest of the force" would be needed would depend on the capacity and success of the teams, which can not be predicted without substantial field experimentation and analysis.

Required Capabilities

All of these concepts require the following capabilities:

- improved munitions accuracy to reduce the weight per kill of the indirect-fire means.
- sensors with identification-level of resolution
- sensors controllable at the team level to develop targets
- reliable communications with adequate bandwidth

- enhanced sensor management and sensor data management systems
- interoperable command and control systems
- reduced sensor to damage-assessment timelines

In assessing these or alternative concepts, counters must be considered (see later section). It is reasonable to assume that these concepts are effective against large, massed formations of high signature vehicles operating in open terrain and clear weather over extended distances/time. Given this situation, an enemy will attempt to operate in other ways. These concepts are totally dependent upon high-resolution sensors and assured communications. The first counter is to operate in rough terrain in poor weather and with obscurants. The second is to also disperse into smaller formations, providing more and smaller targets, to use more dismounted infantry, and use to urban terrain or other areas where the enemy force is in close proximity to friendly people and assets. This will compel the U.S. force to identify targets, rather than being able to fire on recognition, and attack with very precise munitions to preclude fratricide and collateral damage. The third counter would be to isolate and/or force the small team(s) to move, thus negating their capability. The fourth counter would be to degrade and disrupt the communications links necessary for indirect fire, disrupt the provision of GPS data, and lastly attack and/or degrade the sensor systems.

4. Assessing New Operational Concepts: Initial Insights and the Limits of our Knowledge

Although the DSB's operational concepts only became well-defined in the course of the summer study itself, it was still possible to reach some preliminary analytical findings and conclusions — based in part on Panel discussions and prior expertise of the authors, and in part upon supporting analyses accomplished prior to and during the summer study. [15] Some of this discussion extends points made earlier.

4.1 Applicability of the Small Distributed-Force Concept

The first set of observations relate to applicability. As may be obvious to anyone who has thought more than casually about them, the operational concepts in question are far more likely to apply in some contexts than in others. By and large, they are more effective when the U.S. has information dominance, the invader is relying on classic armored/mechanized forces rather than dismounted infantry, the terrain is open (at least around the LOCs), the defender has considerable depth within which to operate, and the mission is to blunt an invasion rather than, say, conduct a counteroffensive or occupy territory with a hostile population. Table 1 shows subjectively how effectiveness would vary with some of the possible circumstances.

By contrast, there are serious problems when considering dismounted infantry attacks in rough terrain: detection and destruction of enemy forces would be more difficult, and small-team survival would be in doubt — especially if the action required of them revealed their approximate locations.

Beyond the issues shown in Table 1, there would be severe problems in attacking a mechanized formation if, for example, it were heavily laden with civilian hostages.

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[15] The supporting efforts were by TRAC, RAND, IDA, JPSD, GAMA (appendix E and F, this document), and the Joint Warfighting Center. The TRAC and RAND efforts are described in separate papers included in the overall DSB report. Appendix D describes briefly results of the IDA work on which a full paper is also available (IDA, 1996).

Table 1 — Subjective Assessment of Distributed-Force Concepts (effectiveness increases with number of bullets)

Operation	Illustrative Circumstances	Mid-Term Effectiveness	Potential Long-Term Effectiveness
Stop advancing army	Mech. invader in open terrain	•••••	•••••
	Dismounted mech. forces in closed terrain	• •	• • •?
	Broad-front minimum-logistics infantry invasion in closed terrain	••	••?
Temporarily defend point (airfield, capital)	Significant depth in which to defend	•••	••••
	Minimal depth	•	•
Temporarily defend area	Mechanized invader, mixed or rough terrain	• •	• • •
Counterattack	Open or mixed terrain	• • •	• • •
Counterattack	Urban or rough terrain	•	• •
Stabilize/occupy	In friendly territory	• •	• •
	In hostile territory	•	•

Although some might note the limited effectiveness associated with a variety of missions, if the distributed-force concept were sufficient "merely" to deter or defeat classic mechanized invasions with concentrated forces, that would be "a very good day's work:"

--It would render obsolete the forces and doctrine of many potential aggressors worldwide, who can hardly afford to buy new equipment

--It would substantially enhance the ability of defender nations to deter or defeat invasion, by forcing the invader to disperse forces and rely upon tactics likely to take more time and involve greater risks.

Looking to the more distant future, it should be possible to improve capabilities in urban and other rough terrain substantially (Vick, 1996), but we should not expect the dramatic effectiveness possible against armor in open terrain.

4.2 The Need for Personnel On the Ground

A recurring question in discussion of the new operational concepts has been why bother to have people on the ground at all? If the sensors and long-range fires are so good, then why endanger any one? This question, sometimes asked seriously, should be answered first by firmly noting that the burden of proof is on the technologists: it has never yet been possible to get along without humans in the loop when dealing with complex adversarial situations. Beyond that, however, there are many reasons for wanting people on the ground, some of which Figure 3 indicates, focusing on the potential value of small teams. Another point not mentioned in Figure 3 is that a ground-force contingent (not just small teams) may be necessary to force the attacker to concentrate forces, which greatly increases the effectiveness of attacks on those forces from aircraft and missiles. And, from a political and strategic perspective, a substantial ground-force element is likely essential if we are to expect good cooperation by the defended ally. The notion that the United States can limit its force commitments to pilots and personnel in sanctuaries far from battle is naive.

Figure 3

Potential Value of Small Teams On Ground
(in Context of Distributed-Forces Study)

- **Seizing and temporarily securing critical points**
- **Discrimination (and last-second target designation)**
  - **Enemy from friendlies**
  - **High value from decoys,...**
- **Traditional recce and surveillance in rough terrain, plus spotting for PGMs**
- **Managing C4 / ISR assets (UGS, UAVs,...)**
- **Battle-damage assessment (BDA)**
- **General-purpose hedge against technology "edges"**
- **Harassment of enemy forces**
- **Attacks on buried or otherwise protected targets**
- **Deception operations deterring or slowing enemy movements in critical periods**

4.3 Information Warfare and Dominance

In presentations to the panel, Information Warfare (IW) was a frequently mentioned subject, albeit one for which precision appears to be lacking in terms of definition and understanding even while considerable resources are being allocated to its development and execution. In this section we define the scope of this collateral campaign and present some observations from previous analyses.[16]

Following the Gulf War, the emerging significance of tactical and operational "Information Campaigns" was described by Cherry and Otis in a concept paper prepared for the Commander, U.S. Army Training and Doctrine Command. Almost simultaneously, the Toefflers published *War and Anti-War* which led to discussions of "Warfare in the Information Age," concepts of information dominance and&formation supremacy, and the allocation of resources by the Department and the services to information warfare at strategic, operational, and tactical echelons. Central to the concepts of information warfare, information operations, and information campaigns is a two (or more) sided dynamic process in which adversaries carry out operations to ***deny, disrupt, or exploit enemy information flows while concurrently protecting own force capabilities to collect, process, and use information.*** On the battlefield, information warfare will extend well beyond classic electronic warfare.

The Panel observed that, while considerable emphasis is being placed on the collection and development of information for situational awareness and targeting, and on protection of U.S. communications and information processing, little mention was made of offensive information operations. Based on analyses (but without field experimentation to support the analyses), we estimate that such operations are likely to have a very high payoff. It will require a synchronized and coordinated mix of sensors, shooters, jammers, and other resources to exploit the full scope of the information warfare concept.

Preliminary analyses suggest it is critical that strategies for conducting information warfare be developed, and that those strategies must encompass both offensive and defensive operations. In one of the analyses of offensive information warfare, more than one million alternative strategies were examined and evaluated in terms of warfighting payoffs. Figure 4 summarizes some of the results by comparing the value (in terms of warfighting payoffs) of allocating lethal resources to attack an enemy's information assets instead of using them to attack an enemy's weapon systems. The value of doing so varies by a factor of up to ten-to-one, depending on the level of attack resources used. On the offensive side, "good" strategies for information warfare typically disrupt various sets of sensor systems or particular enemy command posts. On the defense or "protection" side, it is to the enemy's advantage to disrupt U.S. sensors, command posts, and signal retransmission sites. Enemy success in these areas can have a significant impact on U.S. warfighting capability.

Critical issues that deserved more attention than the task force was able to devote include anticipated reliance on systems such as JSTARS, UAVs, and AWACS; on situational awareness and information dominance; protection of U.S. assets; and the coordinated, joint activities necessary for both offensive and defensive information operations. Information dominance can only be achieved if attention is expanded beyond bandwidth and processing power to include the critical strategies for offensive and defensive operations.

The panel believes that information warfare is extremely important, whether in the context of small unit operations or in broader warfighting contexts. While field experiments and virtual

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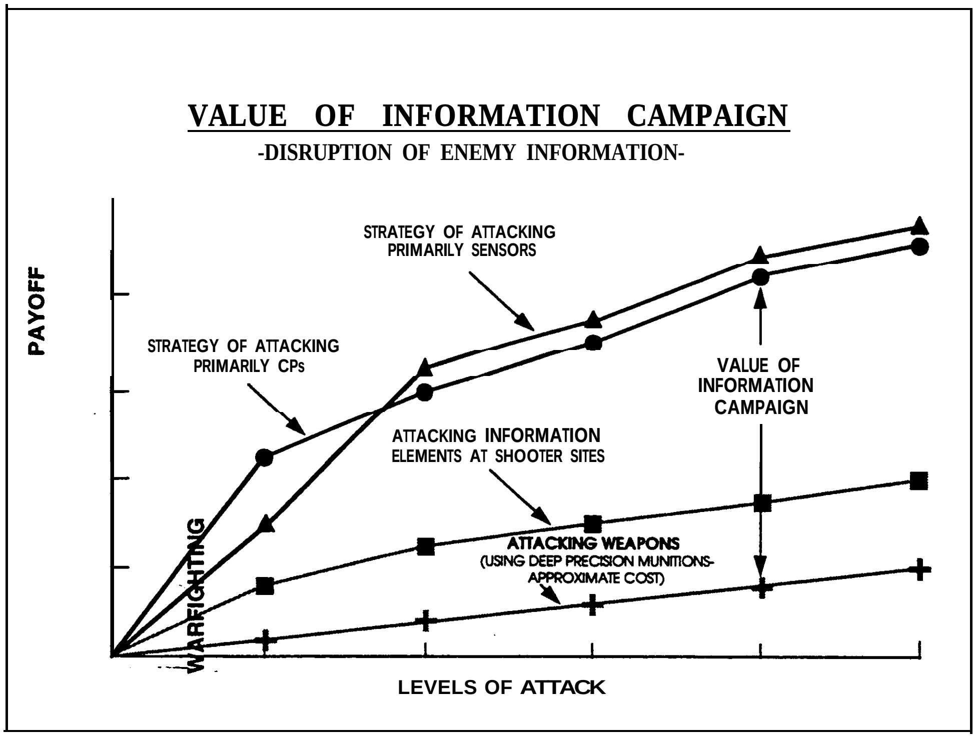
[16]This draws heavily on studies performed by Vector research during the period 1991-1995 (see special bibliography on information warfare).

exercises are necessary to develop a full understanding of the dynamics of information warfare, previous analysis clearly demonstrates that hundreds of thousands of potential information warfare strategies will need to be examined to identify those with high payoffs, and that constructive models will be required for these analyses. Given the pace of growth in technologies relevant to information warfare, issues of versatility, robustness, and adaptivity must be addressed head-on if information warfare is to be fully understood and successfully executed.

Figure 4



4.4 A System View of the Problem and the Value of Updating

The panel focused most of its system thinking on the timeline issue for long-range fire. It was apparent from the outset that the basic concept would fail unless indirect fire could be adequately responsive. This is especially the case in terrain preventing detection at long ranges. Figure 5 shows a simplified illustrative time line. By and large, the largest time increments involve: (a) decision-related delays, exacerbated substantially by layering of command (roughly 8 minutes per layer, based on virtual simulation and experience)[17]: (b) time of flight (roughly 6 minutes for missiles or 12-20 minutes for aircraft at a range of 150 km; and (c) weapon preparation. We strongly suspect that the probability distributions (probability density of per cent penetration through the long-range indirect fire) will be complex and have substantial tails, especially for long-delay weapon systems. We also suspect that adversaries will soon learn to adjust movement tactics so that the ability of

[17] See report from the Joint Precision Strike Demonstration program.

shooters to predict future locations of target clusters will be much poorer than in the past. As a related matter, Figure 6 compares target-kill results for large- and small-footprint systems as a function of "response time" (time between detection and weapon release).

Figure 5

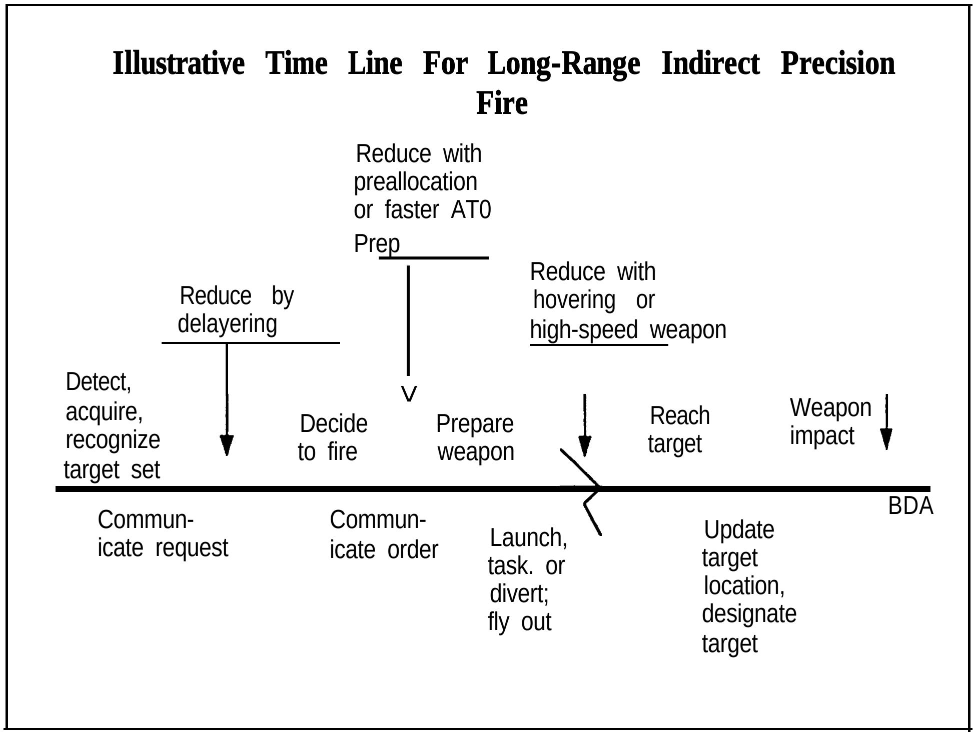
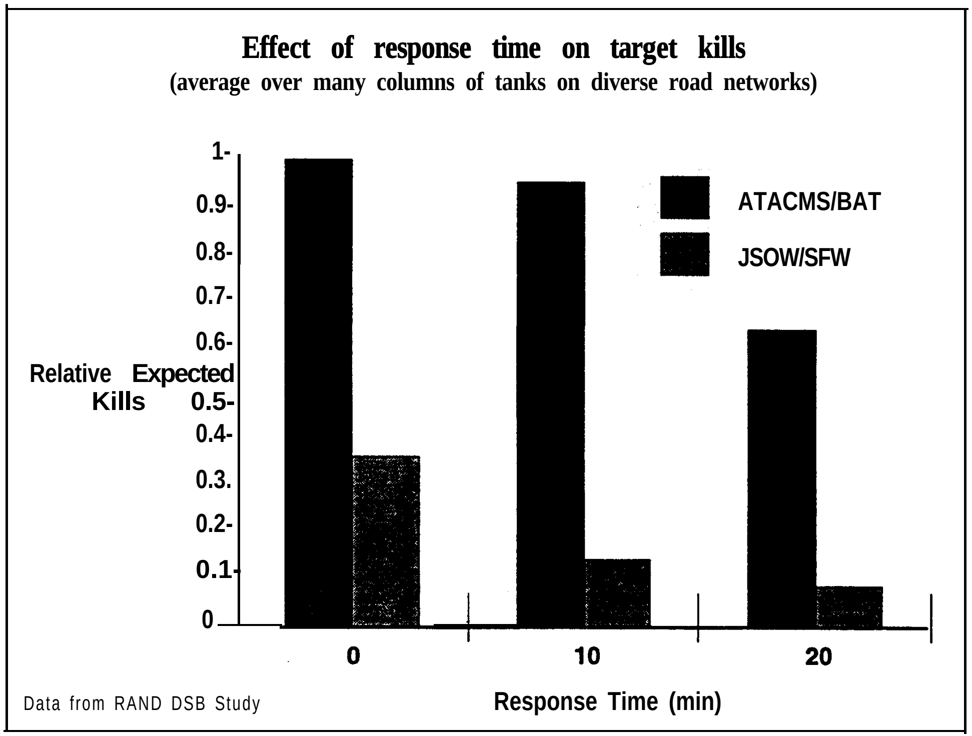


Figure 6



From these considerations and perhaps common sense it seems evident that there would be a high potential payoff from a faster missile or giving the weapon a terminal update on target location and more discriminating information to distinguish among potential targets. Obviously, this would raise costs. However, the percent increment may not be too high for expensive weapons such as Joint Standoff Weapons Systems (JSOWS) and Army Tactical Missile System (ATACMS)/Brilliant Anti-Tank (BAT).

4.5 Sensor and Weapon Management

A key element of 21st Century Tactics and Technology concepts should be an aggressive information-warfare campaign as discussed earlier. Battlefield awareness is an integral part of any such campaign. It is postulated that battlefield awareness will be achieved through a sequencing of processes that include collecting information, linking the information together into an integrated picture of the battlespace, and acting on the information through long range strikes. Managing all this is one of the most profound technical and operational charges underlying the distributed-force concepts.

High-resolution, lightweight, all/most weather, and inexpensive sensors are an enabling technology for battlefield awareness.

The envisioned process of collecting information can be broken down as follows:

a. Ground troops - Small teams of widely dispersed ground troops may scout out enemy targets and punch their locations into an information system shared by all troops. Computing devices worn on wrist or helmet could show the location of every squad and let units communicate with each other and with commanders.

b. Ships - Powerful radar will be stitched together into one enormous radar sweep, which will become part of an even larger picture of the whole theater.

c. Manned aircraft — JSTARS and its successors will continue to play a central role in long-distance detection and tracking. Manned combat aircraft such as Comanche will play a critical role in "identifying" targets and in information collection. They will have numerous sensors and will be fully connected to command and control centers.

d. Unmanned aerial vehicles (UAV) - Dozens of UAVs could form a "web" over the battlefield relaying pictures of a given area at a moment's notice. Some will be stealthy, while others will fly above the altitude of fighter jets that could shoot them down. Improved cameras will be able to see in bad weather, day or night.

e. Reconnaissance satellites - Satellites may be able to pinpoint objects with better than l-meter resolution, perhaps with large sweep areas as well (although this needs to be demonstrated operationally, rather than lightly assumed as an integral part of distributed-force concepts).

f. Remote sensors - Devices airdropped onto a battlefield should be able to detect heat, movement, sound, or even diesel fumes produced by enemy forces, provide target data, and relay data on troop movements.

Information from all sensor sources will be integrated to form a common picture of the changing situation on the battlefield. An exponential increase in the bandwidth will be needed to transmit data by satellite and will let troops at different locations, throughout the theater, receive continual updates so that all U.S. forces are looking at consistent pictures at the same time. The battlefield picture will likely be updated every few seconds, although such capability may prove to be a vulnerable weak link and should probably not be relied upon too strongly.

Stealthy aircraft, ships and ground batteries far to the rear will provide "massed effects" in concentrated barrages of bombs and missiles without the need to mass troops in large formations vulnerable to enemy attack. Computers will be able to recognize targets automatically from the data provided by sensors but humans will probably retain control over what gets attacked.

This broad construct drives sensor management as a principal concern for leaders of future warfighters. Regardless of the number of sensors that may be available on the battlefield, they become a scarce resource and will likely be vulnerable. There are functional and technical issues that require the management of the "sensor galaxy".

Functional issues arise from how sensor data is used. Applications include planning, intelligence, operations, logistics, and targeting. Each application requires a particular set of data at a certain resolution level which may require collection from more than one sensor and more than one sensor type. Applications for sensor use occur at tactical, operational, and strategic levels. The range and level of functional applications create both competitive and complementary demands. They are competitive in that different applications cause different requirements for sensors. They are complementary in that many applications depend on each other. In order to satisfy these requirements, sensors will need to be planned, allocated, and controlled for particular sensor missions. One model for future battlefield processes is to *decide, detect, deliver, and assess.* Under this model, the commander, having decided on his own course of action, wants to focus sensors on enemy assets most likely to interfere with his concepts. Planners must then decide early how sensors will be employed to best develop the related intelligence and targeting information. Then they will use deployed sensors to detect targets according to the planned logic. Using a concept of tagging and tracking of targets as a precursor of massing fires, targets will be attacked efficiently and effectively. After attack, targets will be assessed for battle damage. A comprehensive integrated architecture is the key enabler for the concept.

Technical issues include (but are not limited to) aspect, resolution, environment, revisit rates, and scalability. Aspect involves the number of attributes that can be discerned about an entity by a sensor. If, for instance, an entity looks like a tank from one direction, sensors may need to look at it from other directions to conclude that it actually is a tank and not a decoy. Additionally, for acoustic, passive infrared, and aromatic sensors, range and bearing may be a problem. Resolution involves the detail in which entities are sensed. While we may be convinced that an entity is a tank, we may need further detail to determine whether it is manned or otherwise operational, and whether it is friend or foe. Environment is important since it impacts the capability of sensors. Some sensors' capabilities may be constrained by night, weather, or foliage. Revisit rate involves how we distribute the vision of sensors over a field of interest per unit of time. For instance, if a UAV flies a pattern over a specified area, presumably it can look at only sub-areas at any given time. Scalability involves the management of detail on entities and their environmental background against varying levels of scale. The requirement for such detail is generally higher for local than global use, although selective local views may be required for some global applications (e.g. attack of specific targets that have operational or strategic value.[18]

4.6 The Problems of Leakage and Tails: External Fires Won't Stop Everyone

One of the important conclusions from our initial analysis is that it is essential to approach the evaluation of the operational concepts with the concept of leakage explicit. That is, the concepts assume that long-range indirect fire will be the killing engine, while small teams will serve primarily as sensors, discriminators, and so on. Simplistic but common calculations support this view. If, for example, an ATACMS can achieve N kills, then if M armored vehicles must be killed for success (stopping an advancing column, for example), then M./N ATACMS are necessary. End of problem, or so it would naively seem. Similarly, one can calculate the necessary number of sorties or volleys from long-range naval artillery with advanced munitions. Unfortunately, that is not the way the physics works. First, the actual effectiveness of an ATACMS varies drastically with the situation: target size and density, terrain, movement tactics, the number of volleys, the predictability of future target locations, and so on. Some targets may be attacked multiple times, while others will be attacked not at all. Weapon logic is imperfect. Leakage will occur.

It follows that in analysis the baseline should always assume and attempt to estimate some level of leakage, in which case:

- The issue is not only how much long-range fire one needs to kill most or all of the enemy vehicles but also how much organic capability the small teams will need to assure ability to deal with plausible levels of leakers — as a function of the quantity and quality of indirect fire.[19]

Figure 7 suggests notionally the kind of issues that should be addressed analytically. It highlights the importance of the leakage problem. It assumes a brigade with some level of organic fire and support from long-range fire is defending against a division-sized attack. If there were no leakage, the brigade would need no organic fires. We suspect, however, that even modest leakage would make self-defense capability very important.

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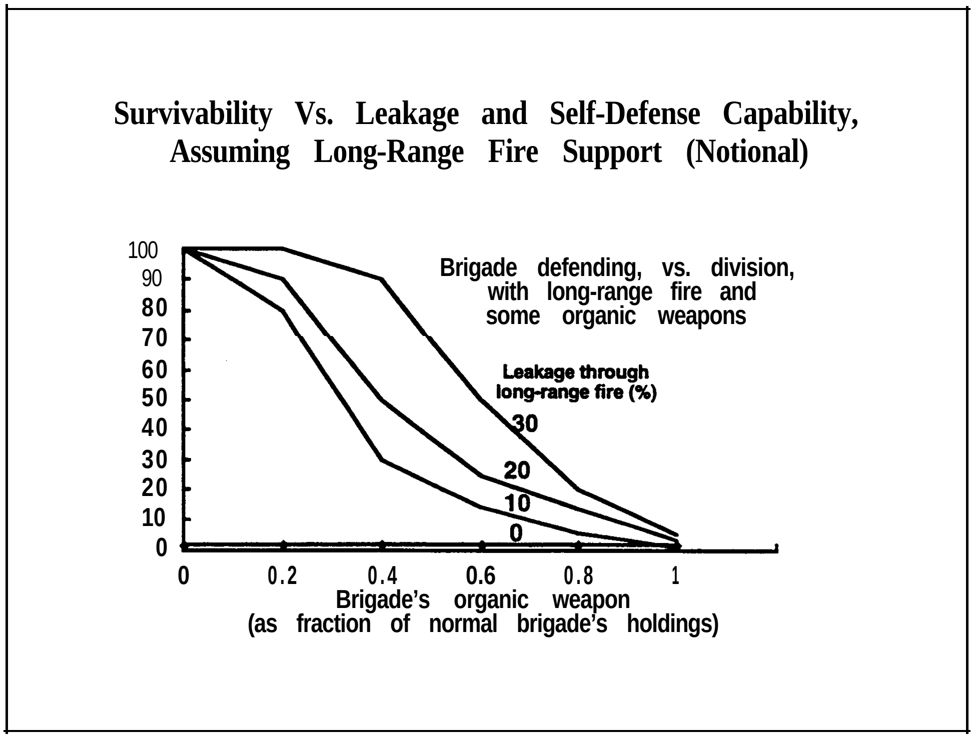
[18] Appendix D describes briefly IDA small-unit virtual analysis and illustrates the detail needed to understand the operational concepts.

[19] The organic capabilities in question could include direct-fire weapons (e.g., small arms, TOWS), short-range indirect-fire precision weapons (e.g., EFOG-M), and, in principle, traditional artillery. In practice, artillery and its heavy "dumb" weapons should be avoided to keep the unit light enough to be deployable. Readers should recognize that the short-range indirect-fire precision weapons are often included in what people refer to as "direct-fire" systems. Another phrase sometimes used is "weapons for the extended close battle," i.e., the battle out to perhaps 15 km rather than l-3 km.

Figure 7

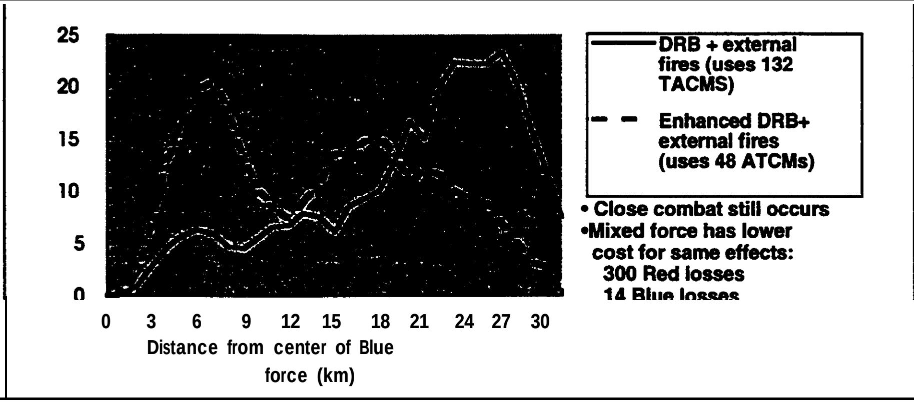


How much leakage might be anticipated? This is a complex and under-studied issue, but it now seems that key variables include: (a) depth of the indirect-fire zone, (b) maneuver tactics of the attacker (primarily degree of dispersal and predictability of future locations), (c) countermeasures, (d) terrain (including the density of places suitable for cover and of all roads that could be used), and, of course, (e) the quality and timelines of the indirect-fire system (sensors, command control, lethality, etc.). In simulations conducted at RAND, actual kills per missile for ATACMS/BAT frequently were on the order of 25% of advertised levels — even without countermeasures. That is, leakage was high and endangered the defending units — even in cases in which the analysts substantially "overused" the expensive ATACMS missile.

That work illustrates the potentially critical value of giving the teams some level of organic fire, including "extended indirect fire" such as E-FOGM. It also illustrates that for equal effectiveness — in terms of both accomplishing a mission and surviving — concepts giving the teams significant levels of organic fire (though much less than that of mechanized units) are probably a good deal more cost effective. Figure 8 illustrates this in an equal-effectiveness analysis. The force provided with some level of "extended direct-fire capability" in the form of, e.g., EFOG-M, did not need the same level of protection from external fires. Further, having more organic capability provides a substantial hedge against unmodeled failure modes of the complex external-fire system — at least, it does so if one assumes that the organic capability is less vulnerable to surprise failures. Here again we note that technical solutions are more plausible against mounted enemy forces. At this point, dismounted infantry is a serious challenge for the distributed-force concept.

Figure 8

Mix of Organic and External Fires Reduces Cost and Hedges Against Leakage



The other problem that arises here is that the probability density for numbers of penetrators is unlikely to be "normal" except in very abnormal circumstances. Based on studies in other domains (e.g., work by Horrigan Analytics (see bibliography) regarding naval mine warfare and air defense), we know that realistic distributions may be multi-modal and have large tails. This might mean that small teams would have, say, a 20% chance of seeing a large number of penetrators, even though the expected value (and even the expected value plus a standard deviation) would be much smaller. Thus, there would be a 20% chance of large casualties and mission failure. We suspect this "tail effect" would have a substantial effect on commanders' attitudes, and on the behavioral performance of small units. Again, then, some self-defense capability would seem to be essential.

4.7 Deployability of Organic Capability and Mixed Forces

A key issue here is whether the organic capability suggested in the previous section would obviate the basic concept by focusing precious lift assets on providing that capability. It is easy to fall into the trap of assuming that everything is difficult to deploy. In fact, the enhanced DRB examined in the RAND work was designed to require no more lift than the baseline force. Some data may be illuminating here. Table 2 shows C-17 sorties required for various types of unit and equipment. Note that there are big gaps in deployability between tank-carrying units and virtually everything else of interest. It follows that it is both desirable and feasible to give distributed forces both tactical mobility and some organic fire.

Table 2 — Airlift Burden of Units

Unit	C-17 Loads	C-5 Loads
Airborne Brigade Task Force (2 per division)	80	
Aviation Brigade Task Force (2 battalions)	133	
Mechanized Battalion Task Force	68	
Mech-Heavy Brigade Task Force	330	
Armored Cavalry Regiment	402	
MLRS Battalion (3 batteries and HQ)	58	
Patriot Battalion	58	
Source: Enhanced DRB (RAND study)		
MLRS Battery (9 vehicles, 114 LPCs, support vehicles) (684 missiles in the basic unit load)	18	19
HIMARS Battery		-11

Source: Ron Fuchs, McDonnell Douglas, and HQ DA for MLRS and HIMARS

4.8 Layering and Avoidance of Common-Mode Failures

Even our initial analysis suggests that leakage will be a major threat to the operational concepts. This suggests that the concept architecture should use the time-honored method of "layering." In an ideal situation, the mathematics would be simple: if one has n independent and successive mechanisms for killing penetrators, then the probability that a given entity succeeds in penetrating all n layers is the product (1-P1)(1-P2)...(1-Pn), where Pi is the probability that the nth layer will kill a given entity. Realistically, layered systems are not necessarily strictly sequential, which reduces the mathematical leverage. More serious, the layers may not be truly independent. In particular, we note that MLRS/ATACMS/BAT, ship-based ATACMS/BAT, standoff and direct-attack munitions from fighter aircraft might all depend on the same RISTA systems (e.g., the JSTARS aircraft or a critical high-altitude UAV) and the same data-fusion systems. Since even good systems fail, sometimes catastrophically, and since the adversary may be targeting critical nodes, it is important to plan for true redundancy, to test rigorously against potential common failure modes, and to exercise the ability to cope with various disasters.

4.9 Countermeasures

Obviously, we must anticipate that future adversaries will have learned from Desert Storm and be aware of U.S. moves to exploit information systems and long-range precision fire. As a consequence, we can be confident that a series of countermeasures will emerge. Discussion of some countermeasure issues is necessarily quite sensitive, but the principal ideas are not. In the summer study the panel focused on developing a taxonomy, some initial estimates of significance, and some broad conclusions about likely countermeasures. Analysis of counters should be routine if we are to have versatile and robust capabilities..

Figures 9 and 10 describe the taxonomy. Figure 9 summarizes tactical measures not requiring high technology or new forces. Many of these are passive and "obvious," such as the adversary exploiting rough terrain where both initial detection and terminal detection would be more difficult.

Figure 9

Illustrative Countermeasures (1)

- **Tactical Measures Not Requiring Hich Technology or New Forces**
- **Passive Measures**
  - Use rough terrain, poor weather, and obscurance
  - Move in spurts, confounding predictive systems and minimizing exposure time
  - Operate in urban terrain and mix with civilians
  - Disperse maximally, using minor roads and paths
  - Use smoke and decoys (e.g., towed vehicles with comer reflectors)
  - Proliferate inexpensive GPS jammers
- **Active Measures**
  - Conduct infantry sweeps to suppress or defeat small teams
  - Saturate area (e.g., ridge lines) with shoulder-fired SAMs
  - Attack critical weapons (MLRS/ATACMs), CPs with SOF
  - Attack critical sensors with rear-area troops, missiles
  - Use rear-area units to provide warning of aircraft, missiles
  - Disrupt communication links
  - Disrupt accurate target-location data (GPS)

Figure 10 completes the taxonomy by describing tactical countermeasures that would require changes in forces, doctrine, and/or advanced technology, While these lists are surely not complete, they indicate how broad the scope of countermeasures might be. The Russians, and presumably others, are actively working on a number of them, some of which are even available on the world market.

Figure 10

Illustrative Countermeasures (2)

Changes in Forces or Operations

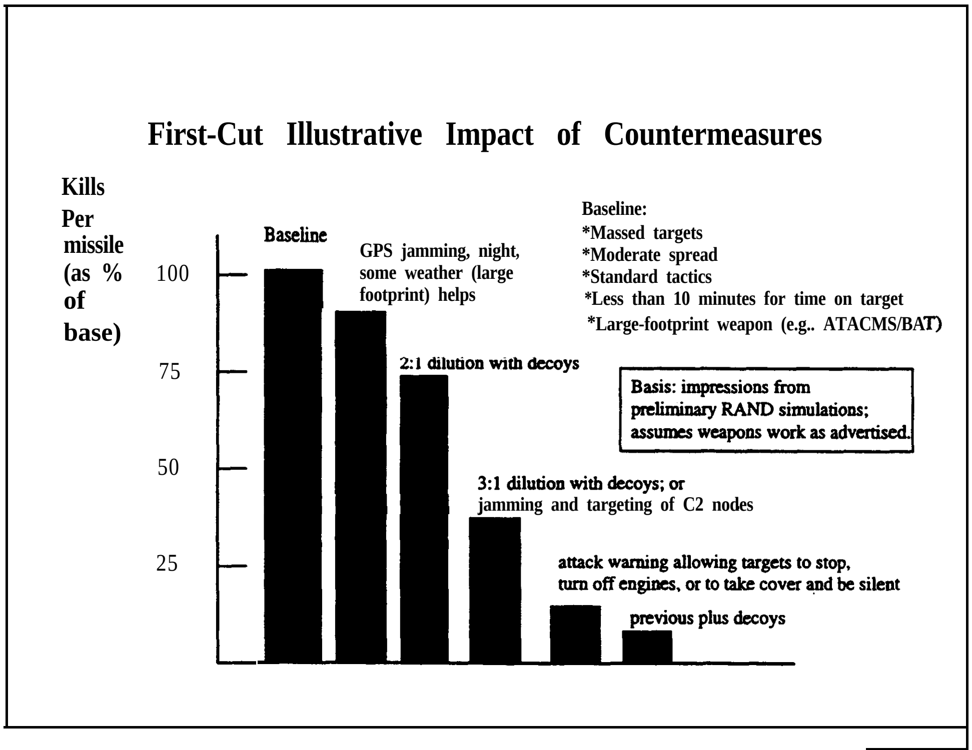
- **More emphasis on dismounted or at least dispersed infantry**
- **Old-fashioned broad-front infantry attacks**
- **Dispersed infantry attacks, depending on statistics for penetration. Concentrate at "other end" when in cities.**

More Advanced Countermeasures Requiring Technology

- **Microwave self-defense systems (counters missile sensors)**
- **Counterbattery fire**
- **Threaten ships, forcing longer standoff and reduced effectiveness (mines, UAVs / missiles)**
- **Warning systems to trigger dispersal, smoke, noise generators**
- **Large-area microwave generators and EMP generators against integrated-circuit systems**
- **Other active vehicle-protection systems**
- **More advanced, mobile SAMs -slowing SEAD and reducing sortie rates**

An important question here is whether we should expect countermeasures to have modest or large effects. Figure 11, based on informal inputs from Steeb and Matsumura, suggests that countermeasures could have factor-of-ten effects. In the case illustrated, which assumes a large-footprint weapon such as ATACMS/BAT, the significance of GPS jamming might not be large, but if decoy vehicles could be inserted in moving columns, substantial effects would be expected. The effects are sizable, but less than linear with the number of decoys, because the presence of decoys reduces the instances in which a "real" target vehicle is attacked more than once. Another counter would be some kind of warning system allowing moving vehicles to stop, turn off engines, or to take cover. If that type of counter were combined with dilution by decoys, the overall effect could be more than a factor of ten. These are merely first-cut estimates, but they are sobering nonetheless.

Figure 11



To every countermeasure there is, of course, a counter countermeasure — at least in principle. Figure 12 lists some of the responses that come readily to mind as mostly evolutionary enhancements to precision strike systems and doctrine. In-flight updating and hovering weapons to minimize warning appear especially attractive.

Figure 12

Comments and Responses

- **Some countermeasures enhance ability of allies to defend on ground**
- **Counter countermeasures (most with other purposes as well**
  - **In-flight updating (better discrimination, less specific warning time)**
  - **Hovering weapons (minimize warning)**
  - **Better, multispectral sensors**
  - **Better battle-damage assessment**
  - **Redundant targeting**
  - **Infantry-detection sensors (aerial and on-ground, including UGS)**
  - **Reduced set of activities for small teams**
  - **ROEs permitting small teams to pull back and use depth**
  - **Cluster munitions effective from high-altitude and standoff (options for JDAM, JSOWS, ...?)**
  - **High-quality counter infantry artillery / MLRS for allies**
- **Major uncertainties: microwave and EMP weapons**

Ironically, the worst "countermeasures" may not really be countermeasures per se, but rather the normal complications that befuddle complex systems in a warfare environment. Just as Saddam Hussein's primitive enhanced Scuds broke up in flight, creating a mass of debris that confused Patriot radar (as effectively as many countermeasures), so also relatively normal military operations in real-world terrain and weather might turn out to be substantially more difficult to deal with than proponents of precision strike would think based on "canonical" cases. Figure 13 illustrates these points, noting in particular that the normal calculations of precision-strike effectiveness concatenate planning factors, effectively treating correlated and nonlinear events as independent and linear. It seems likely that a more accurate treatment of the mathematics and physics will demonstrate that probability distributions for numbers of kills in a precision-weapon attack will have large "tails," of the sort that have been observed in other domains in which subtle probabilistic effects and "configuration effects" are important (e.g., mine warfare, air defense). Based on high resolution simulation it is evident that major errors can be caused by failures to model such details as the actual sensor logic used by weapons (e.g., to allocate submunitions among multiple targets).

Figure 13

Worst "Countermeasure" May Just Be Reality

- **Effectiveness calculations in models and games may be wildly exaggerated**
  - **Typical calculation merely multiplies planning factors**
  - **Independent-event calculations are likely very bad**
  - **Distributional "tails" likely to be large**
  - **Planning factors cannot be meaningful without more distinctions:**
    - **Density of minor roads, opportunities for cover in spurt movements**
    - **Sheer numbers and density of attackers and defenders**
    - **Dispersion and depth**
    - **Quality of BDA**
  - **Calculations can be very wrong if they don't model details of weapon and sensor logic, reattack of targets,.,**
- **Also, whole systems fail sometimes (JSTARS, UAVs,...?)**
- **Currently, we should not rule out order-of-magnitude errors**
- **Less optimistic calculations (and distributional tails) could greatly affect operational concepts**

Figure 14 summarizes conclusions regarding countermeasures. The principal findings here are two: countermeasures are to be expected and could, along with more realistic calculations, reduce effectiveness figures by an order of magnitude; further, probability distributions will likely be complex, with substantial tails that would be quite worrisome to a commander.

Figure 14

Conclusions

- **Countermeasures are to be expected; effects could compound**
- **Numbers of munitions needed will rise; also, fire density for "servicing"**
- **Counting on zero or extremely low leakage of penetrators through indirect fire is unwise and dangerous. Small units need some organic capabilities (including short-range indirect fire)**
- **Probability of numerous leakers may be significant (the "tail" problem)**
  - **Could greatly affect acceptability of operational concepts and psychology of small units**
- **Likelihood is high that adversaries will switch to operational concepts avoiding U.S. strengths**
- **Forces should be operationally adaptive to enemy countermeasures**

This leads to recommendations. First, we suggest that substantially more analytical effort be put into realistic — and objective — assessments, assessments accounting for real-world complications as well as countermeasures per se. This justifies high-level intervention because the centers of excellence we suggest would need to be protected from advocates and permitted (even strongly encouraged) to compare and debate their findings within the community of people with need to know.

Figure 15

Recommendations

USDA

- **Establish centers of excellence for realistic and objective effectiveness calculations with and without countermeasures** — **$5M / center-year**
  - **Detailed simulation with valid statistical analysis, configuration effects, weapon characteristics, and noise**
  - **Calibration of and guidance in use of more aggregated models**
  - **Highlighting of issues for laboratory and field experiments**
  - **Prioritization of improvment measures**
- **Protect centers from weapon-system advocates**
- **Be cautious about overclassification**
  - **Ostrich effect more dangerous than revealing semi-obvious vulnerabilities**
  - **Potential adversaries should believe many secret counter countermeasures exist**
- **Consider range of adversary strategies using terrain, infantry**

We also recommend, as shown in Figure 16, a number of policy and programmatic initiatives that could reduce vulnerability of the precision strike concepts.

Figure 16

Other Program Recommendations

- **Develop sensors to detect and track infantry**
- **Assure deployment of area counter-infantry munitions usable from high altitudes**
- **Plan export sales of counter-infantry MLRS and munitions to allies**
- **Pursue "loitering" options for all platforms**
- **Pursue improved BDA**
- **Pursue late-in-flight update options**
- **Field GPS mods with greater jammer tolerance**
- **Develop concepts for offensive and defensive IW**

4.10 Tactical Mobility

One of the recurring assumptions of many of those examining the small-team concepts was the notion that the small teams would be dismounted infantry. Upon further consideration, we conclude that such an assumption is wrong for many circumstances. To the contrary, and as evidenced by a TRAC study on "Task Force Griffin," such units would probably need tactical mobility for effectiveness, flexibility, and survival. This might be achieved by a combination of lift helicopters and light vehicles (e.g., 4-passenger) with off-road capability.

4.11 Coalition Issues

Studies suggesting a vision of the U.S. inserting a few good men into big countries, far from home, over less than truly critical issues — and without allies to boot — fail the first-order sanity test. One of the biggest legitimate criticisms of the Bottoms Up review (BUR) was its failure to discuss allies.

Further, from a cost-effectiveness viewpoint, there may be high leverage in enhancing what allies can accomplish. After all, they will provide the mass of people on the ground; whether they collapse quickly or continue fighting may dictate the entire subsequent course of war.

This said, how should we interact with several classes of allies: (a) the defender, (b) our most competent and closest allies (e.g., the UK and Germany), and (c) "others" (e.g., the Russians or Syrians)?. It seemed to us that the DSB study might reasonably comment only on (a), consistent with its emphasis on early entry.

There are several ways to think about leveraging the defending ally. One extreme would be to plan on giving allies a good approximation of the capabilities we are discussing for U.S. forces. That is *not* the approach taken here. It may also be neither feasible or desirable.

A second approach is to think about how to use our suite of information- and long-range fire capabilities to enhance the ability of the defending allies to accomplish those tasks that would be *critical,* not merely desirable, for successful mission completion overall. These might include (a) providing strategic and operational-level situational awareness to reduce their vulnerability to surprise attacks, (2) blunting invasion forces with long-range interdiction fires (not close support), (3) covering retreats with long-range fires, and (4) providing some level of missile defense early-on to avoid political surrender. The principal objectives would be to avoid early sudden collapse and to preserve as much allied capability as possible for later operations. Accomplishing these objectives would probably *not* require anything remotely like the exquisite total connectivity and jointness envisioned for U.S. forces. It would, however, require the ability to communicate effectively and to cooperate on crude but effective command and control methods that would, for example, avoid having U.S. aircraft shot down by friendly air defenses. Theater missile defense would probably also require considerable cooperation.

Recommendation: (1) Several levels of games (pol-mil seminar down to DIS-level exercises) to identify the most high-leverage low-difficulty ways to accomplish the objectives; (2) Follow-up analysis to recommend specific acquisitions, training, operations planning, and exercises; (3) Doctrine designed to accommodate combined operations.

Additional Observation. The U.S. should have alternative operational concepts for accomplishing operational objectives with and without allies participating. However, such alternatives should be consistent with a single doctrine. That is, we do not want doctrinal concepts that fall apart when we operate with an ally and we do not want to have the confusion of having to carry along multiple doctrines. This is a substantial challenge.

4.12 Task Forces Vs. Small Teams

Throughout the DSB summer study a tension existed between those who intuitively thought in terms of balanced task forces and those who were most focused on leveraging the potential power of small teams or cells. We were unable to add much to this discussion in our own panel's study, except to point out that the task-force image is unequivocally correct: further, a given commander contemplating a given mission will want to task organize. In some cases he might not want to use small teams, while in other cases they might be central to his concept of operations.

It is interesting, however, that the Army's TRAC conducted an intensive design-and-gaming effort to explore the issues. Their concept, "Task Force Griffin," involved a mix of many different types of capability, ranging from rotary-wing aviation and MLRS/ATACMS units deployed into the theater, to small precision-strike teams. We believe their analysis provided an excellent baseline for discussion, even for those who want to push to the limits the small-team approach.[20]

5. Future Analysis Requirements and Related Needs for M&S

Much more time and effort is needed to analyze all the issues associated with the development and implementation of new operational concepts (see Appendix C). The Panel discussed these matters and noted disconnects between the analytic requirements and the current approach to conducting model-based analysis in the DoD.

5.1 The Need for a New Force-Planning Approach Generally

Without elaborating in this report, let us merely observe that DoD's analytic needs are now very different than even a decade ago. During the Cold War, DoD planning was characterized as in Figure 17.[21] There was a well understood bounding threat, and the *perception* of relatively little uncertainty. Further, forces were forward deployed. By contrast, in the new era we must consider a wide range of possible future contingencies, without the simplifications of having a bounding threat. We do not know where U.S. forces will be deployed, against whom, or in what operational circumstances.

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20 See Army (1996), included in the overall SAB report.

21 For extensive discussion of these issues see Chapters 2 and 5 in Davis (1994), Bonder (1994), and Davis, Gompert, and Kugler (1996). Although developed independently, the ideas suggested by FUND and Vector studies are remarkably similar.

Figure 17

Need for a New Planning Analysis Perspective

DoD planning in the cold war:

- **Central large threat, primarily a warfighting mission**
- **Little uncertainty regarding threat location, objectives, forces, equipment, warfighting concepts, procedures, partners, etc.**
- **Little uncertainty regarding U.S. coalition partners**
- **Substantial forward-based forces**

Planning in New Global Security Environment, 1995-2025

- **Broad spectrum of potential military missions**
- **Large uncertainty as to where US forces will be employed worldwide, against whom, and for what purpose?**
- **Large uncertainty regarding aggressor objectives, forces, equipment and capabilities; operational concepts; available infrastructure; warning times, etc.**
- **Large uncertainty regarding U.S. coalition partners and competence**
- **Primarily CONUS-based forces with likelihood of delayed or even contested access**

In such an environment, then, force planning must be guided by very different principles. An important feature (Figure 18) is planning for *operational adaptiveness*, by which we mean that the forces should be able, at any point in time, to be *versatile and robust* enough to be used successfully in a wide variety of operational circumstances, some of them quite stressful and non canonical (e.g., late deployment into a region with weak and militarily ineffective allies and insecure airfields and ports).

Figure 18

The Force-Planning Perspective Needed

In very uncertain new global security environment. design of U.S. military must ensure that forces are operationally adaptive--i.e., both versatile and

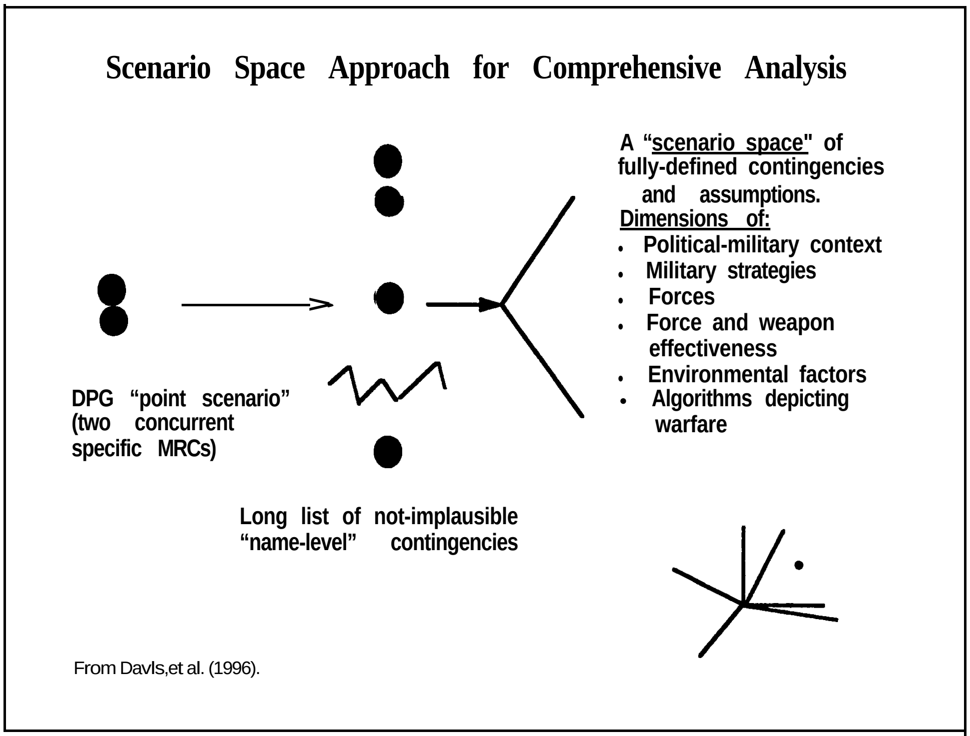
***Versatile:* Capable of achieving military objectives across broad spectrum of possible military operations (peacekeeping, peace LRC, MRC, peer war) they may be asked to undertake**

Robust: Possess sufficient capability to achieve military objectives within a particular military operation considering possible but uncertain variations aggressor force size, modernization, etc.

Defense planning and resource allocations should be based on knowledge as to in which US forces would be successful worldwide and situations where there substantial risk of failure.

One important element of force planning for the future is, as Figure 19 suggests, moving away from planning around one or two point scenarios toward an approach in which future forces are tested against a much broader set of circumstances. First, we should consider a wider range of name-level scenarios, going beyond North Korea and Iraq as the only potential threats. Some of these scenarios can and should be analytical composites. Important, however, is the second step indicated in the figure. Each name-level scenario (e.g., Iraq invades Kuwait) should be examined for a wide range of cases throughout a "scenario space." That is, we should test how well future forces would do under different assumptions about variables such as details of political-military scenario (e.g., allies, time lines), both sides' strategies (since we cannot dictate now what objectives and strategies would be adopted by a future president), the size of enemy and allied forces, the effectiveness of all the forces and their weapons (a function of modernization, training, command and control, etc.), environmental factors such as weather, and even the algorithms and related parameters we assume in our models (e.g., attrition and movement rates), since they are in fact highly uncertain. This kind of *exploratory analysis* requires a substantial experimental design using partial factorial methods and fast-running models. For such work it is possible with current computers to run hundreds of thousands of cases to better understand where (in scenario space) a proposed set of forces would and would not be effective. Much more fine-grained analysis is then necessary for special regions of interest.

Figure 19



Au early version of this approach was a classified RAND study of the Central Region balance, circa 1986-1987, which featured "multi-scenario analysis" over many hundreds of cases. An interesting application of this general approach shortly after the Cold War ended was a study for the SACEUR in 1991, which described how forces for Europe could be evaluated against cases that varied in-place forces, attacking forces, and the type of terrain (Vector, 1992). Figure 20 shows the dimensions of that study, which can be thought of as being a realization of defining scenarios from a parametric scenario space (Figure 21).

Figure 20

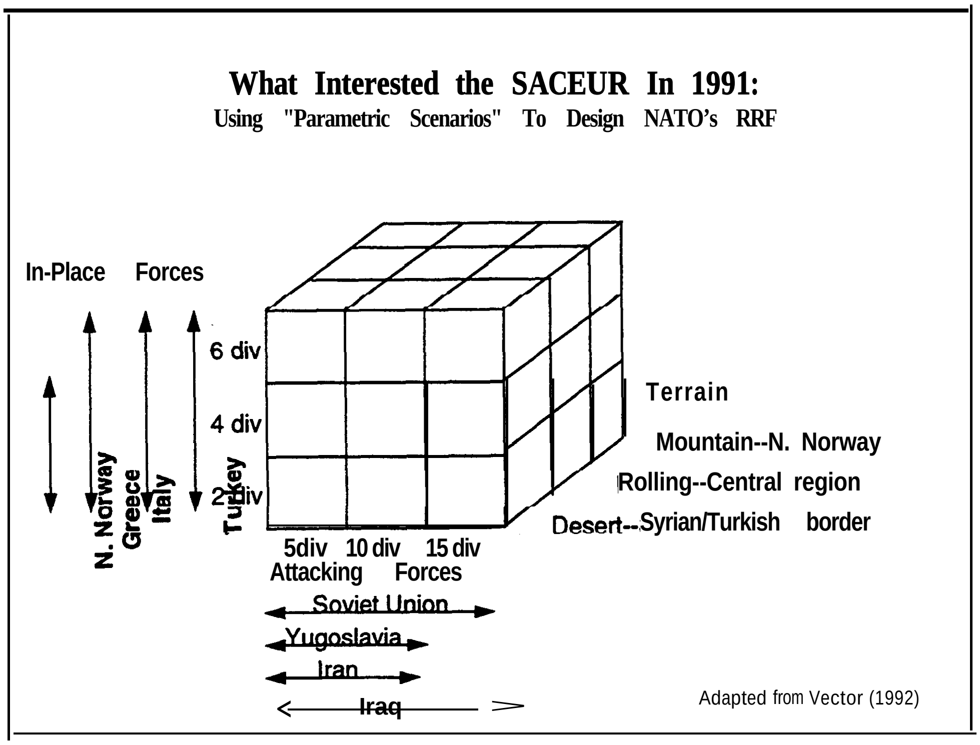
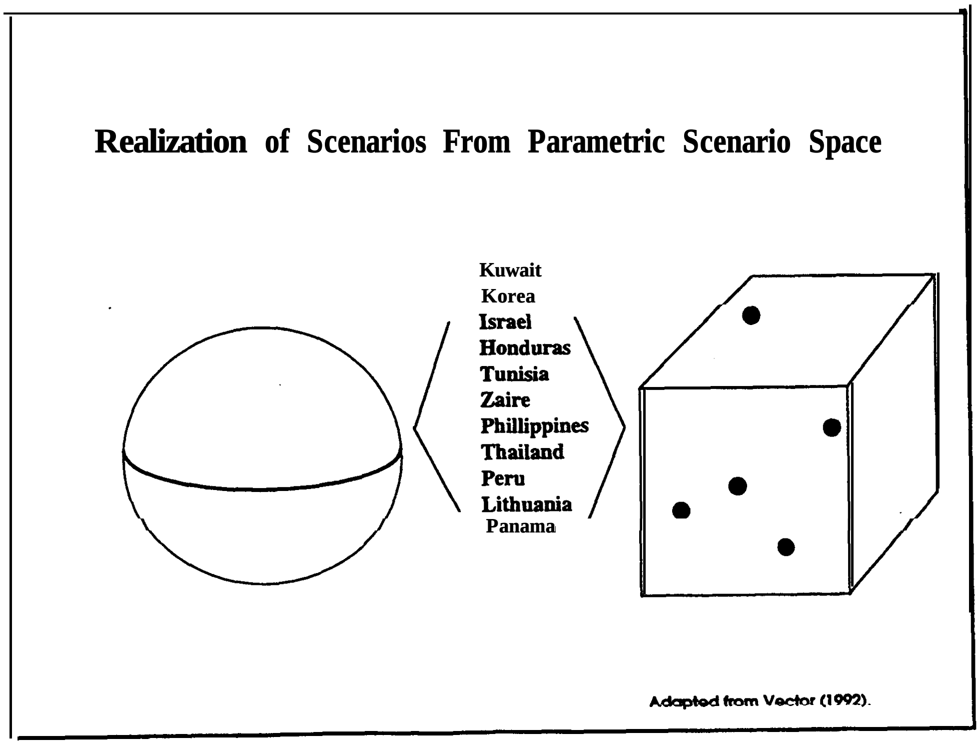
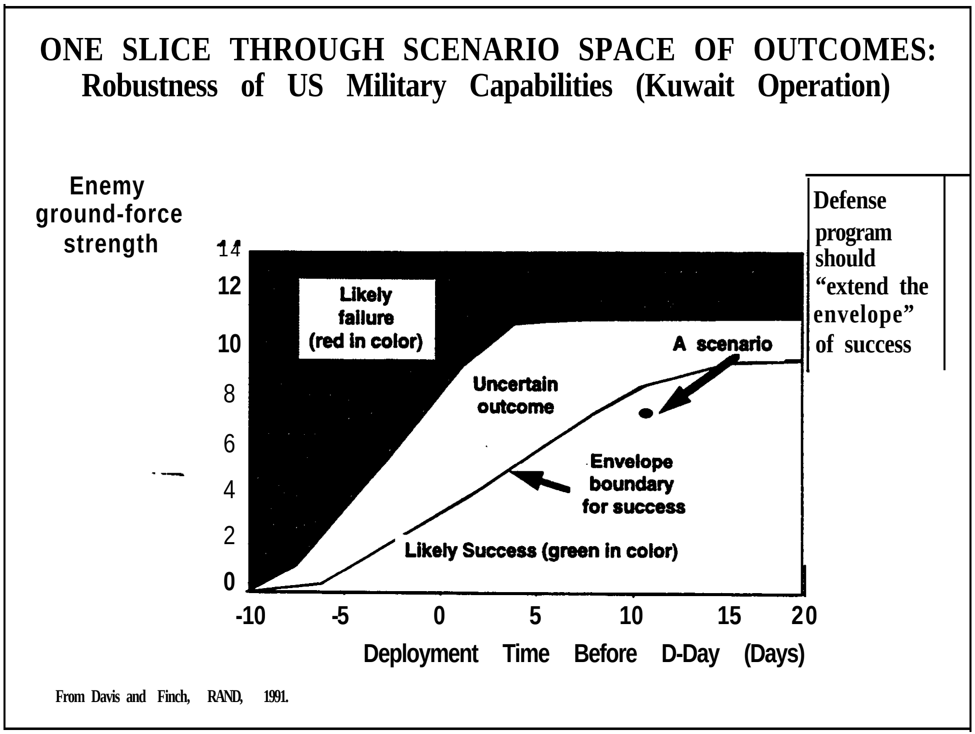


Figure 21



As an example of output, Figure 22 shows one slice through the scenario space of outcomes for wars involving Iraq vs. Kuwait (the slide is notional, but broadly representative of actual analysis). We see that that force capabilities test out as quite satisfactory given sufficient deployment time and low enough effective enemy ground-force strengths ("effective" reflects the point emphasized by the late T.N. Dupuy that many nations' forces routinely are far less effective than their equipment would permit). Note that in this depiction the emphasis is not on assessing capability for a point scenario, but in characterizing the regions in scenario space in which the forces would be expected to do well, poorly, or marginally. This helps establish priorities: instead of continuing to improve capabilities for favorable cases, it encourages us to pay more attention to addressing Achilles' Heels (e.g., the kind of difficulties that motivated the DSB Summer Study in the first place, difficulties such as deploying late into a region with insecure ports and airfields, and with allies of uncertain staying power).

Figure 22



To summarize, we see the need to transition to a new defense-planning methodology as described in Figure 23.

Figure 23

Transitioning to a New Defense Planning Methodology

- **Replace point-requirement approach (e.g., DPG scenarios) with a "scenario space" approach.**
- **Plan and allocate resources to increase the percentge of the scenario space in which operations will be successful--i.e., reduce risk**
- **Make analysis a continuous, iterative, process, not an event in support of a one-time decision**
- **Analysis of force planning should be two-tiered**
  - **Analysis of cross functional area tradeoffs to establish "capability goals" for each functional area**
  - **Analyses to "design" functional area capabilities by trading off force size, modernization, etc.**
- **Provide forum for review and debate of "competitive analyses"**

5.2 Types of Analysis Needed for Dealing With New Operational Concepts

The previous section described a number of characteristics of the new global security environment that will affect the kinds of analyses needed to support planning and resource allocation issues associated with new concepts of operations. There will be large geopolitical uncertainties regarding where U.S. forces may have to deploy, the operations they will be asked to conduct, the capabilities of aggressors they will face, and who our coalition partners will be and their capabilities. It is an environment with rapid technology development and an open marketplace for the widespread technology proliferation to many nations. Information age technologies will become integral to the performance of conflict operations, which will both enhance the capabilities of our military forces and at the same time will increase their vulnerability for rapid degradation of that capability. It is an environment which will involve more CONUS-based forces and continual reduction of resources for defense.

Analyses of new concepts of operations (CONOPS) will require the concomitant analysis of a large number of interrelated issues. Appendix A of this report lists the kinds of issues that will need to be addressed. It categorizes them into two classes: (1) those addressing the new CONOPS directly which involves capabilities of the force across many "functional areas" (e.g., precision strike, small unit operations, information operations, battle management operations, logistics operations, etc.), and (2) those which address issues within individual functional areas (design of functional capabilities, modernization, performance feasibility, procedures, affordability, etc.) This section of the report outlines a two-tiered approach for analysis of these different levels of analysis issues.

Before describing the different levels of analysis, characteristics of the new global security environment suggests a number of principles that should be considered in performing analysis at either level.

- Analyses must be conducted in a joint context and include all relevant assets from each of the military services.
- Analyses must consider not only the effectiveness of forces in highly probable contingencies (e.g., MRC-E), but their "versatility" across the broad spectrum of possible military operations worldwide that U.S. forces may be asked to undertake. This will require the use of a "scenario space" for force planning as described in section 5.1.
- In any particular military operation, analysis must consider the "robustness" of force capabilities to various uncertainties they may encounter such as variations in expected aggressor force size, aggressor modernization, aggressor counters, absence of expected coalition partners, and other surprises that could substantially degrade the planned effectiveness of U.S. forces.
- Given the move to significant basing of forces in CONUS (compared to the cold-war forward positioning), the impact of mobilization and strategic deployment of U.S. forces must be explicitly considered in analysis of issues and not just the capability of forces within an operational theater. Tradeoffs among mobilization, deployment, and employment in theater should be considered.
- Given the rapidly changing nature and complexity of the new global security environment, analysis should be a continuous process rather than an event for a particular decision problem. This will facilitate the generation of knowledge about the new complex operational phenomena and provide responsive information support to decision makers in a period of rapidly changing assumptions regarding budgets, coalition partners, aggressors, service roles, acquisition policies, and technologies.
- In the severely constrained DoD budget environment, analysis of new systems must explicitly consider their affordability through the use of "cost as an independent variable" approaches.

The remainder of this section outlines the different levels of analyses needed to address the types of CONOPS-related issues listed in Appendix A. The next section presents an overview of the two types of analyses and then each is outlined in subsequent sections.

Overview of Top-Down Iterative Process for Analysis of CONOPS Issues

As noted in Appendix B, there are a large number of planning and resource allocation issues that need to be addressed in adopting and implementing new concepts of operations. A number of issues address broad force planning design aspects of the concept of operation directly, many address more detailed questions of functional area design, and most of the issues are interdependent. Because of these interdependencies, a top-down iterative construct is needed to assure that all components of planning are integrated and consistent. An overview of such a construct is shown in Figure 24.

The structure involves two levels of analyses. The top level, referred to as force planning analyses is conducted to address the level CONOPS issues and to set the requirements for and bounds on the second level, referred to as functional area analyses. The latter are conducted to address functional area (e.g., small unit operations, precision strike operations, information operations, etc.) design issues and to provide information on functional area capabilities as input to the next iteration of force planning analyses.

Force Planning Analyses

Force planning analyses are designed to address broad issues with respect to new operational concepts and to provide guidance and input to functional area analyses. Because of its integrative role across services, it is reasonable to expect that such analyses would be conducted by the OJCS or OSD and would involve forces of all military services. As an integrative mechanism, analyses should involve simulated theater level operations that include joint services, deployment to theater and employment in theater, coalition partners, and all relevant functional areas.

An overview of information used and produced by force planning analyses is shown in Figure 25. One of the CONOPS level decision issues is selected for analysis and specific decision alternatives identified. These and a particular theater level military operation from the “scenario space” are input to the simulated military operations. Depending on the specific decision issue, analyses might examine alternative CONOPS, tradeoffs among functional capabilities to implement CONOPS, alternative roles for small units, the impact of aggressor counters, etc. for a single military situation (scenario). This process would be repeated for a large number of operational situations of the scenario space to generate the following kinds of theater level output metrics relevant to the decision issue:

- Effectiveness of each alternative (force exchange ratio, casualties, duration of the operation, window of risk, etc.) for each operational scenario.
- Robustness of the force (effectiveness of the force given larger aggressor force sizes, better modernization, counters to U.S. capabilities, etc.).
- Versatility of the force (percent of scenario space in which U.S. forces are successful).
- Risk (percent of scenario space in which U.S. forces cannot succeed).
- Affordability (life cycle cost of all forces and systems in the force).

This information is used to select “what” planning alternatives to pursue and determine resource allocations to them. This level of analysis also produces information to provide guidelines for the functional area analyses. These guidelines include:

- Capability Goals/Requirements: capabilities that need to be provided by each of the functional areas. (For example, the type of targets to be serviced, service rates, responsiveness, survivability, etc. for the family of precision strike systems.)
- Funding for each functional area.

- A set of operational and tactical vignettes taken from the theater level context to be used in performing the functional area analyses.

Force planning analyses for a single CONOPS level decision issue will of necessity involve a large number of parametric simulated military operations to generate the effectiveness, robustness, and versatility metrics for relevant decision alternatives. This will require that much of the analyses be conducted using constructive models as described in section 5.5 of this report.

Functional Area Analyses

The purpose of this level of analyses is to design each of the functional area capabilities to meet the capability goals determined via the force planning level of analyses. Depending on the degree to which multiple service assets were involved in the specific functional area under consideration, these types of analyses would be performed by either the JCS or the military services. Functional analyses is narrow in scope (single function) and higher resolution than force planning analyses which involves all functional areas. Simulation analyses are conducted using functional area operational vignettes extracted from the theater-level force planning scenarios.

An overview of information used and produced by functional areas analyses is shown in Figure 26. Inputs to analysis are specific alternatives for a decision issue and operational vignettes relevant to the functional area. Analyses would involve design tradeoffs within the functional area among modernization, force size, procedures, organization, readiness, etc. to identify functional area designs that meet capability goals within resource constraints. Depending on the particular functional area, output metrics reflect functional area capabilities (target servicing capacity, responsiveness, etc.), effectiveness (engagement, battle, or campaign outcomes), versatility (across many vignettes), robustness (to detailed enemy counters), and affordability. This information is used to identify high-leverage performance drivers, to select alternatives to pursue in designing the functional area, and allocating resources to them. Information regarding these functional area capabilities are fed back for subsequent iterations of force planning analyses.

Modeling requirements for functional area analyses are quite different from those used in force planning analyses. Models used may include force-on-force (but smaller in scope than a full theater), functional area models, and detailed system engineering simulations. They will likely involve all types of models -- constructive, interactive games, virtual, and field experiments. Subsequent sections discuss the kinds of models and methodological research needed to conduct the top-down, integrated analysis approach outlined in this section of the report.

Figure 24

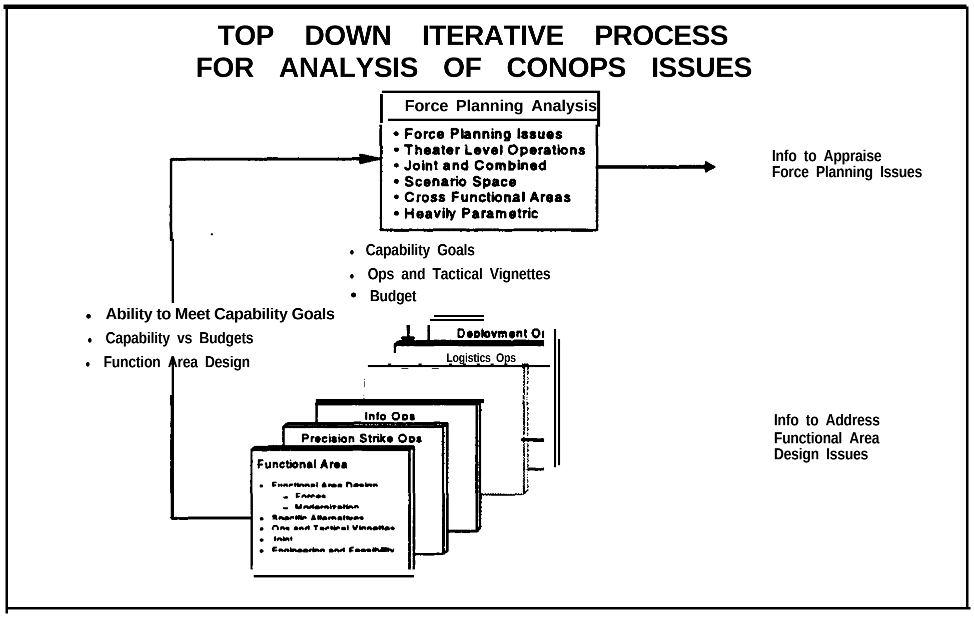


Figure 25

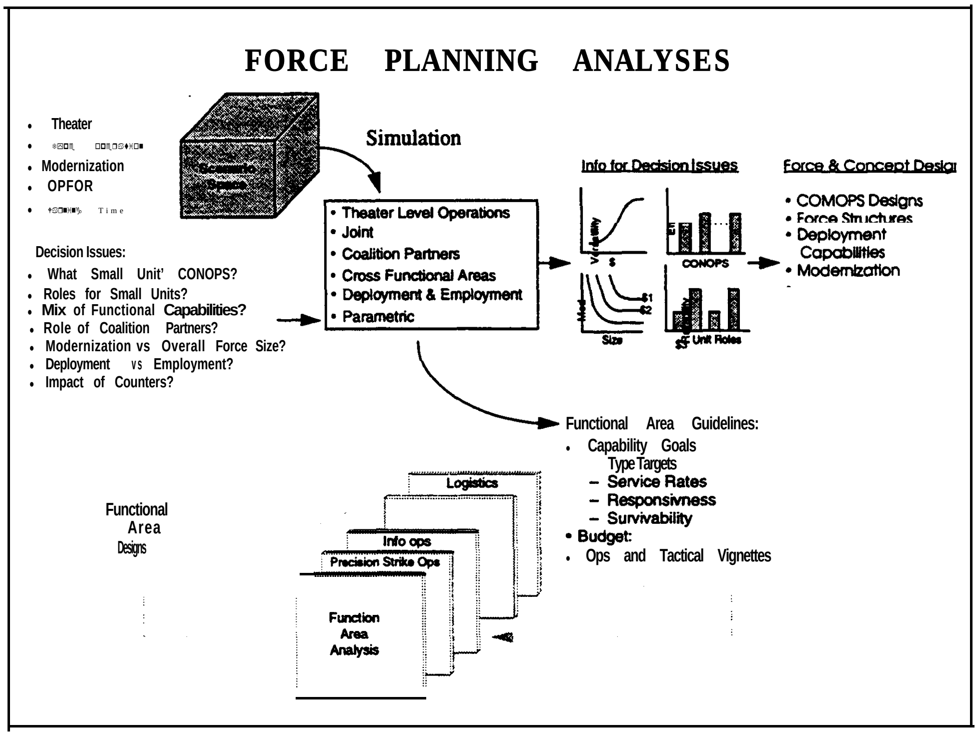
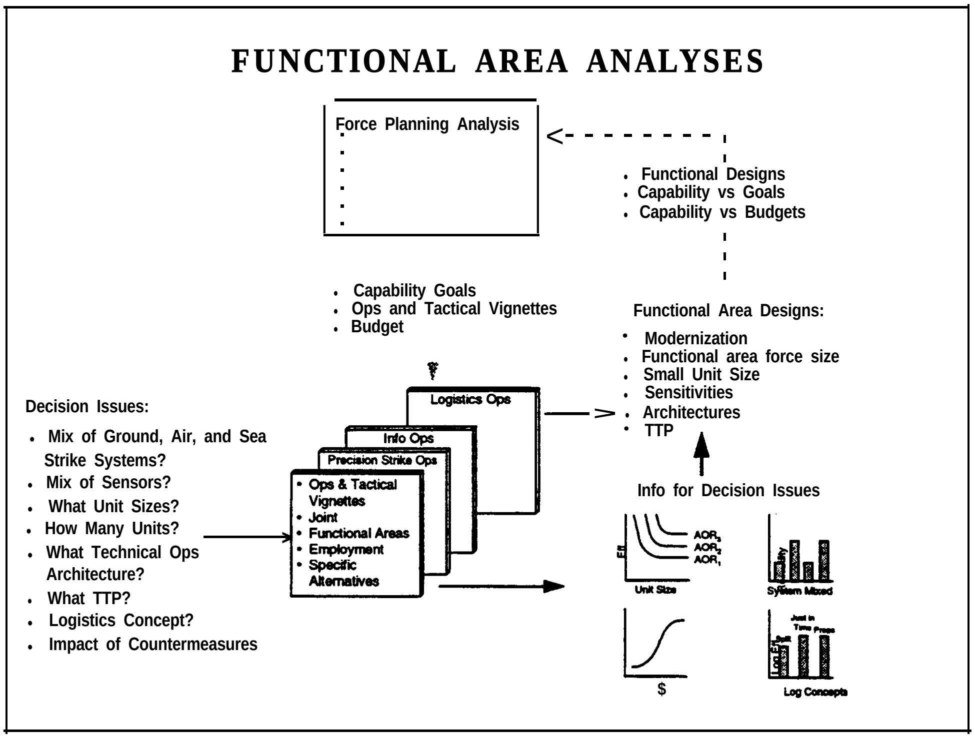


Figure 26



Appendix B describes numerous key issues at different levels of analysis.

5.3 Model Building Should Follow Building Knowledge

To accomplish the analysis needed, we obviously need models and simulations. Our panel was struck, however, by the degree to which much recent modeling and simulation (M&S) has been driven by technology and technologists rather than by questions to be answered and subjects to be illuminated. There have been remarkable and revolutionary advances as a result of the technology push, and there are already dramatic impacts in the training community, but the balance among research, analysis, and technology, including that for presenting a good show with visualization, has in our view gotten badly out of kilter.

On the Need for Humility

The United States is entering a new era of warfare and examining new operational concepts that are radically different from those they may supplant. It is a time of great opportunity, but our knowledge base — gained from decades of experience that included shooting wars — is quite inadequate: we do not even know what we do not know, nor where the most significant problems will show up. In our view, we should be approaching the new challenges with a great deal of humility and the determination to search out the knowledge we shall need. Although we were able to draw a number of tentative conclusions from our first-look analysis, our most important findings may relate to the need for organizational change and a rebalancing of approaches to analysis itself.

Need for a Dedicated Research Organization

As we contemplated the knowledge base for evaluating the new operational concepts, we were struck by the nonexistence of an appropriate *research organization*. In recent years the DoD had vigorously expanded the technological frontiers in many domains, drawing heavily on civilian technology in the process. By contrast, it has neglected research on relevant phenomenology, leaving such research to be done at low levels of effort and with great fragmentation across many programs and organizations. We believe this situation can and should be remedied. We recommend that the DDR&E establish a multi-year research program devoted to issues related to information dominance, long-range precision strike, and a wide variety of operational concepts exploiting those emerging pillars of future U.S. military capability. This would not be an aloof activity happily building models in a vacuum, but rather a program devoted to "cracking the issues" of a new subject area — perhaps analogously to how the United States cracked the issues of reentry physics in the 1950s and 1960s. It would be strongly tied to the warfighting community and could be added to the effort described in the DDR&E's new Joint Warfare Science and Technology Plan.[22]

Table 3 — Mission of a Distributed-Force Research Program

Mission Statement	Examples
• Identify analytical issues needing improvement, derived from both customer concerns and research	Countermeasures, realistic effectiveness calculations, behavioral assumptions at both small-unit and commander level
• Collect and analyze empirical data from all sources, both existing and program-generated	History, structured interviews, instrumental training exercises, virtual exercises, field tests..
• Collect and analyze results from all types of M&S both existing and program-generated, at all relevant levels of resolution	Encourage integrated hierarchical families of models, including selectable resolution; exploit data from all levels of resolution.
• Create and maintain an overall intellectual framework by engaging customers, actively guiding the research program, and	Provide strong problem definition and analytic plans to those conducting

[22] Examples of past failures to understand phenomena adequately include the government's apparent early belief that Patriot was far more effective in intercepting Scuds than it was, or the failure to understand the consequences of exploding chemical weapons and facilities.

stimulating both peer review and open debate	virtual experiments. Create subject-area forums for in-depth exchange and peer review.
• Serve the customer community by providing expert advice and advisors, making available new and better analytical modules for widespread use, and evaluating analysis at request of customers	Provide red teaming, definitive effectiveness calculations, and analytically sound modules (while recognizing uncertainty)

Illustrative Problems** for **Research

It is reasonable to ask what kinds of questions might be pursued in the kind of program we suggest. Let us mention only a few, in two groups.

Phenomenological Issues

- *Individual and Small-Unit Psychology and Behavior.* The operational concepts under study may succeed or fail depending on whether the individuals and teams are able to cope with the very unusual circumstances in which they are asked to operate and the heavy stresses placed on them by potential information overload, danger, frustration at having to depend on long-range fires with lengthy delay times, and isolation. How many of these issues can be dealt with adequately as technology improves is simply not clear. Further, it is a quintessentially empirical issue, not something to be decided by theorists or engineers operating without data.

- *Countermeasures and Counter Countermeasures.* We have already indicated the wide range of challenges in this domain. Addressing them requires in-depth research, analysis, and experimentation by top-notch scientific talent.

- *System Performance On a Dirty Battlefield.* Even the best of our current simulation-based analyses do not fully represent all the confusing "noise" of the battlefield, which may include dirt, smoke, a high density of “cultural clutter” (e.g., school buses), and military units doing unexpected things. If we are to rely on high-leverage risky military strategies that depend on a total system, then we need experiments that will stress the system in realistic circumstances, not just the circumstances normal in must-succeed experiments.

There are many other possible study topic with methodological significance; A few examples follow.

Methodological Issues

"Automated Rule Development. It may prove possible to have software observe tactics and decision criteria used in human games and exercises, and to turn those into meaningful “rules”, which could then be incorporated in or even become the basis of decision modules

Emergent Behaviors: One of the great potential shortcomings in current models may be the failure to represent adequately “emergent behaviors” that are not readily understandable in terms of the microscopic elements. Such issues become critical when we contemplate “self-organizing behaviors” among distributed forces. The language for such research comes from the field of “complexity studies.”

Non-standard behaviors and Non-linearity. A serious problem with analysis dependent on large and complex simulations is differing behaviors, sometimes approaching or involving chaos. This stems from non-linearity of many types, including what is sometimes called structural variance.[23] There is need to better understand how to eliminate artificial examples and how to deal with others. This will require new techniques for searching the outcome space and organizing results. As one example here, RAND has used a genetic algorithm to drive scenario-space analysis in search of optimum (or worst) outcomes.

Intelligent and Adaptive “Red Agents”: Develop (computer) agents which, e.g., seek out blue vulnerabilities in deciding strategies and tactics in computerized war games. This could be valuable as has research being done of the immune system.

Aggregation, Disaggregation, and Variable Resolution. This is recognized by the Defense Modeling and Simulation Office (DMSO) and DARPA as a subject needing theoretical work. It is relatively easy to establish software connections between models of different resolution, but it is very much more difficult to assure that the connections make sense substantively (Davis and Hillestad (1992). Developing meaningful and integrated hierarchical families of models will take some years of effort.

These have been mere examples, but they illustrate the need for a research component.

5.4 On the Conduct and Use of Model-Supported Analysis

General Comments

If the base of knowledge for examining distributed-force concepts is one problem, and we think it is, there is another problem with the use of models themselves. Although we can

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[23] It may happen, for example, that a simulation indicates that within some domain of values adding more capability to a side decreases its effectiveness. Often, the problem is related to non-optimal decisions(mm-optimal given perfect information about both state and the simulation). The effects may be artificial or real (as when the “real” strategy is flawed). Such effects were noted in the-early 1960s, but were discussed at more length in the early 1980s by researchers at the UK's DOAE and the SHAPE Technical Center when working with the VECTOR-2 campaign model. Since then, much work has been done by DOAE, TRAC, VECTOR, RAND, and others to understand the related issues.

offer no statistical data on the matter, the panel and many DSB colleagues have been troubled by what appears to be a trend in studies away from classic principles of good analysis and analytical discourse, and also by how resistant the DoD has sometimes been in confronting the reality of massive uncertainty. Figure 27 summarizes, in admittedly stark terms, the contrast between the current culture and what is desirable. To be sure, there are many good examples of analysis that could be cited, but we are concerned about trends with attributes such as closed processes with more attention to bureaucratically dominated accreditation than to substantive review and the search for truth through exposure and debate of ideas. At the level of models themselves, we see continuing dependence on models that can churn out results mechanically, but that require extensive data preparation, rigid approval processes, and more emphasis on continuity than discovery. Indeed, too often models and model-supported analysis suppress discussion of important uncertainties and risk at the very time when more attention needs to be paid to such matters. Finally, we note the continuing legacy of rigid Cold War thinking rather than an emphasis on developing versatile and robust forces, forces that are operationally adaptive in many dimensions.

Figure 27

Changes Needed in DoD Analysis Culture

WHAT IS	WHAT SHOULD BE
Closed processes	**Open processes**
--Bureaucratic review	--Peer review
--Accredited analysis	--Competitive analysis
Model orientation	**Subject-matter orientation**
--Mechanical	--Meaningful
--Data poor	--Data rich
--Rigid approvals	--Learning and adaptation
--Stable algorithms	--Unstable phenomena
Suppresses uncertainty	**Illuminates uncertainty**
Suppresses risk	**Illuminates risk**
Narrow, cold-war style	**Oriented to now and future**
--Few, accredited scenarios	--Many pol-mil scenarios
--Point assumptions	--Exploratory analysis

Changing the culture must start at the top, with high-level demands for more open, competitive, comprehensive, and imaginative studies that bear a close relationship to the actual military and force-planning issues of our time. There are also implications for how major investment programs, notably for JSIMS, JMASS, and JWARS are pursued. In particular, we recommend against an approach that envisions a single model or model family as accredited. We note that such an approach is more in the spirit of Central Planning than market approaches. To be sure, the community badly needs the emerging module-level standards that will simplify module reuse and cross-organizational comparisons, but standardizing overall models, data bases, and analytical approaches is not the way to go. As a last point here, there is more value in requiring the clear expression of assumptions and sensitivities (using semi-standardized forms to describe assumptions) than in requiring standardization of the tools. The tools are not nothing, but the assumptions are everything.

Exploratory Analysis Methods and Scenario-Space Testing

An important element of what we propose is for DoD to embrace an approach that confronts uncertainty as discussed in an earlier section.

5.5 Reconceiving the Relationship Among Types of Model

DoD's modeling and simulation (M&S) activities have been largely driven in recent years by technology-push. There have been dramatic advances in distributed processing, M&S technology, and applications to training. There has, in contrast, been much less investment in methods and tools for analysis and sophisticated decision support. Further, serious misconceptions have arisen about how much can be accomplished with man-in-the-loop virtual and live simulations and exercises, and about what level of resolution is desirable. Some recommendations are noted below:

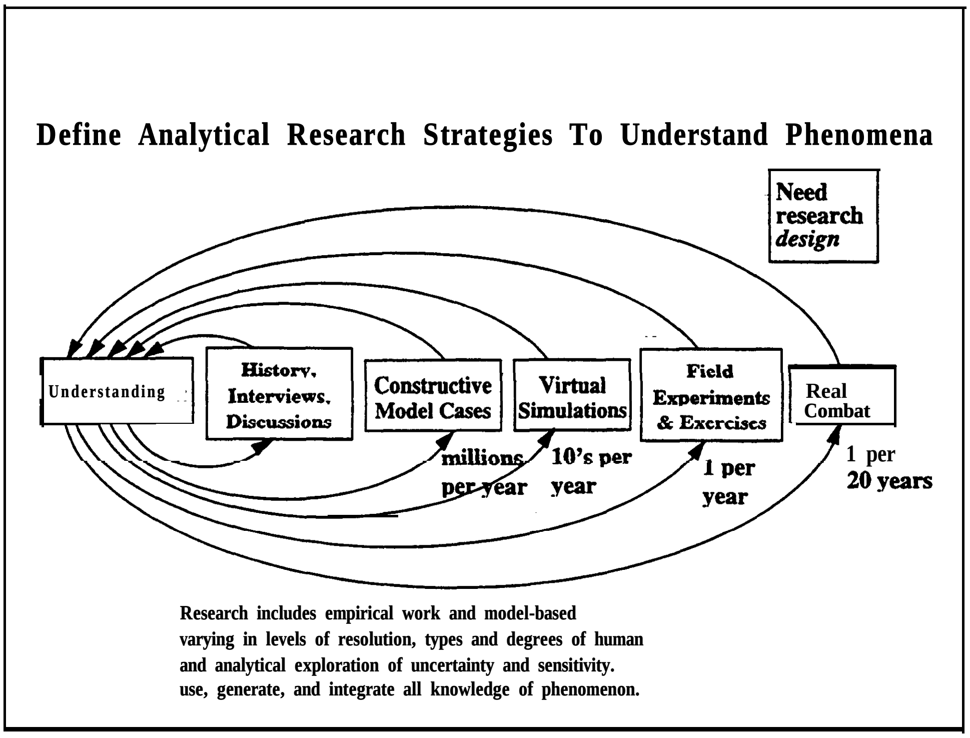
- DoD should seek to harness more of its M&S activities in service to decision makers and analysis. Virtual and live simulations are extraordinary opportunities, but they can be ill-focused and inefficient unless they are designed with higher-level objectives in mind. In our view, such designs require strong analytic underpinnings and an understanding of issues faced by decision makers.

- Distributed interactive simulation should be seen more as a mechanism for exploration and experimentation than as anything more rigorous. Analysis is and will in the future require so-called constructive models (which include, in our terminology, interruptible models permitting but not requiring human play). Many of these will be and should be relatively low-resolution models, which allow us to examine the consequences of myriad uncertainties, to examine circumstances that could not realistically be simulated in the field, and to conduct the many tradeoff studies needed to make sound decisions on issues ranging from doctrine to force procurement.

- Constructive simulations, however, should be closely tied to "real" military phenomena and the insights possible from virtual and live experiments. These insights should drive design of new constructive models and help calibrate the results. We say "help" here because calibration should draw on information at all levels of aggregation. The notion that high-resolution models are a sufficient mechanism for calibrating low-resolution models is almost always wrong — not just slightly wrong, but fundamentally wrong. The detailed models are usually quite narrow and do not reflect critical contextual and command-control issues adequately; further, they depend on hundreds and thousands of uncertain data elements; as a result, aggregate data (including history) is often much more reliable (e.g., on rates of movement, reliability in battle, and the effects of virtual attrition).

Figure 28 illustrates the way we view the relationship among models and simulations, other forms of research, and the buildup of knowledge.

Figure 28



- Any program to explore distributed-force concepts will badly need an infrastructure with mutually calibrated and integrated hierarchical families of models. Despite occasional claims to the contrary, these do not exist today. Perhaps they can be developed in the JSIMS, JMASS, and JWARS efforts, but the challenges involve substance, not just software technology.

- The models needed for the future will need to represent information war, high level decision making, alternative logistics concepts, and the complexities of non-linear non-contiguous operations, including complexities related to psychology and behavior that are not well understood presently.

5.6 Question Driven Use of M&S

General Observations

A part of the credo for analysts is that use of models and simulations should be driven by problems and questions (including, to be sure, "soft questions such as "What the heck is going on in this system?", which may require a period of relatively unfocused exploration before better questions can be posed).

An Example of Question-Driven M&S Supported Analysis

To illustrate what we mean by question-driven use of M&S, suppose that we were interested in reducing time-to-target, for reasons discussed in Section 4. This would imply that we need "cache" of weapons able to kill targets within minutes. There are numerous possibilities:

- Late-in-flight diversion of weapons to best targets, perhaps with loiter-capable weapons (seconds of loiter)
- Fixed or rotary CAP aircraft (hours)
- Loitering armed UAVs (hours)

We would then have numerous questions about, e.g., the size and nature of the "cache" that would be needed, the tradeoffs among approaches, and the overall value of the concept. Even getting started on an analysis would require an understanding of tactics, technology, and — important — the possible theater-level contexts. This higher-level understanding of context might come from a combination of war games and . Then, as indicated below, a combination of live, virtual, and constructive models could be assembled and used to investigate the problem. about value

Figure 29

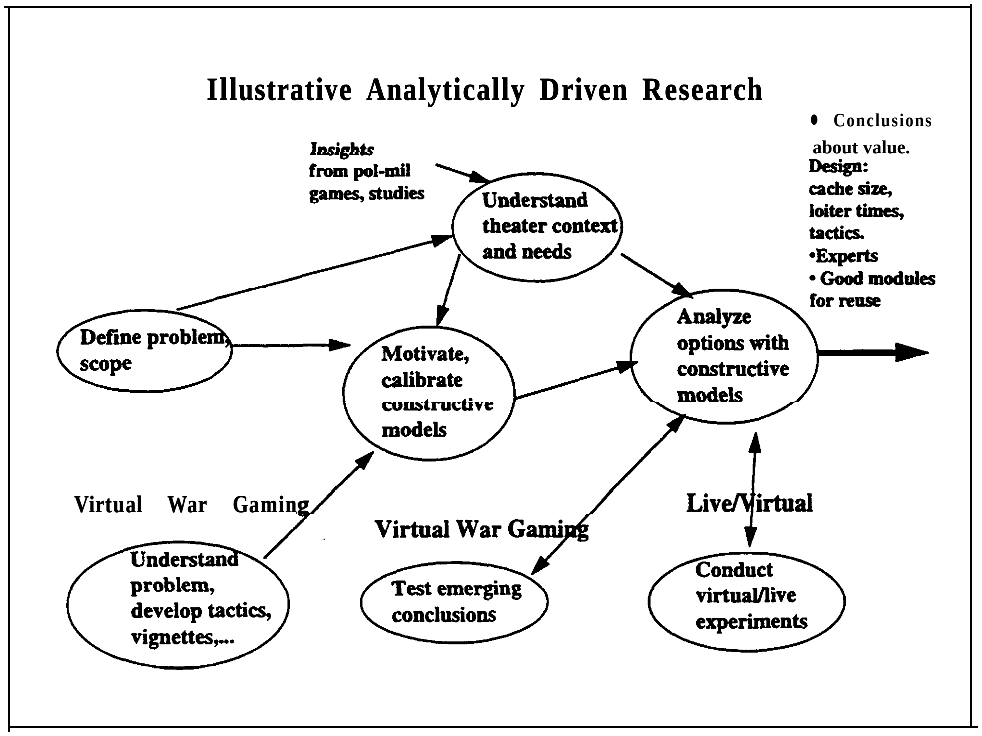
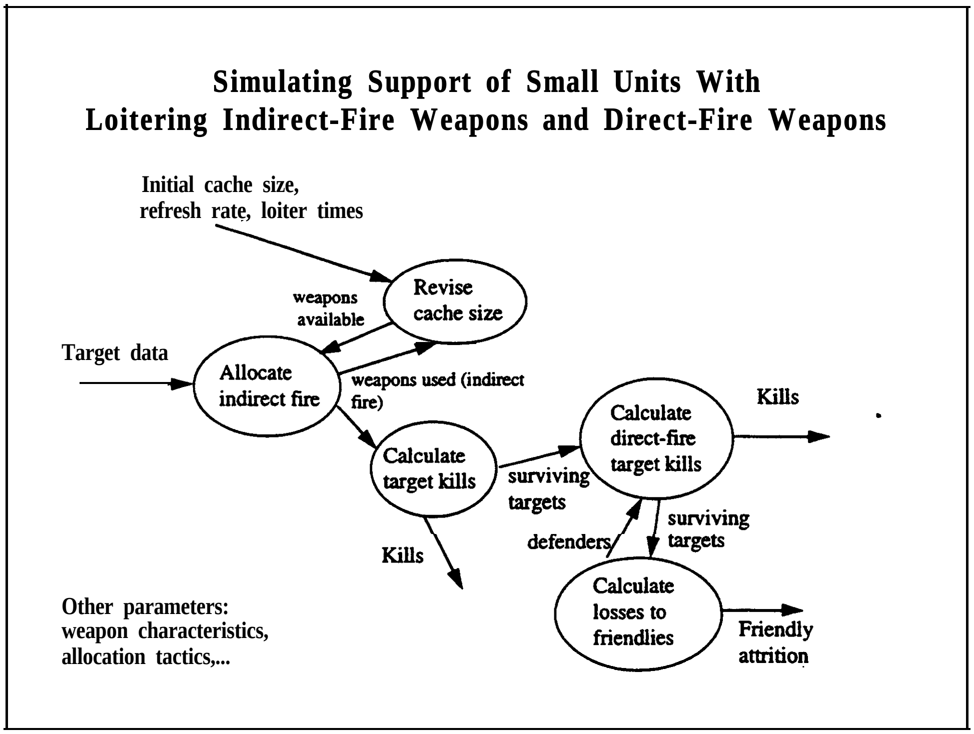


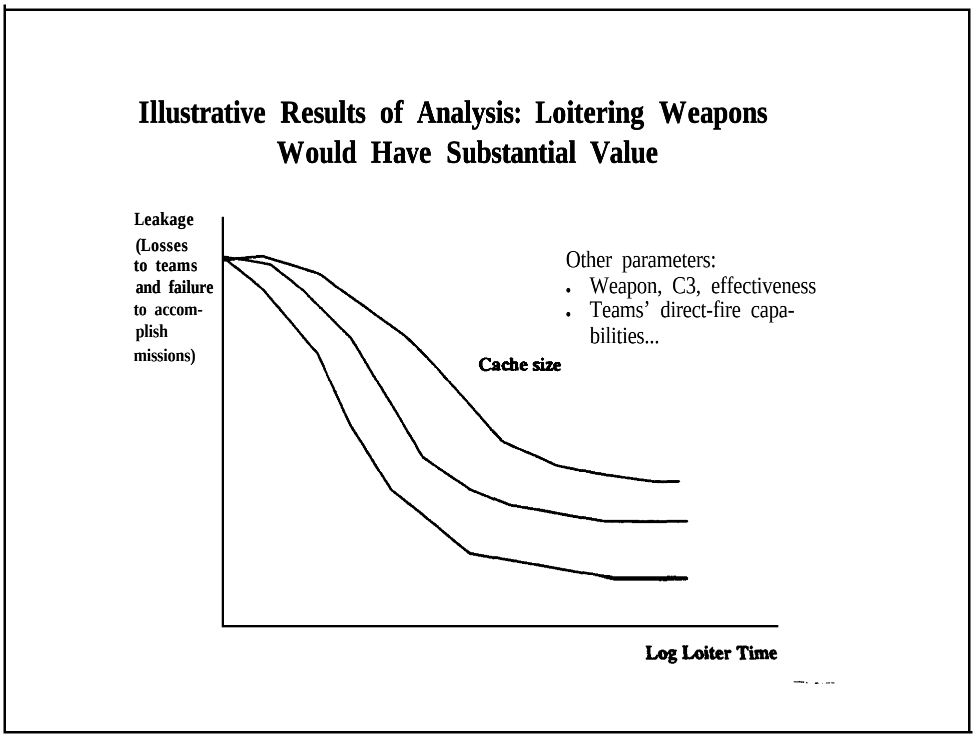
Figure 30 sketches what a constructive simulation might be expected to do in this case. It envisions input as data on when and in what numbers targets appear. The size of the cache and the loiter time of the cache weapons would also be input, as would the characteristics of the ground unit being supported. The simulation would then model how the overall system would decide when to attack targets with indirect fire, how effective the attacks would be, how the weapons in the cache would decrease as they were used or time went on, and so on. Output would include data on attrition to enemy targets, friendly attrition due to some of the enemy targets leaking through, and the efficiency of indirect-fire weapons.

Figure 30



The results of such an analysis might be as indicated in the Figure 31, which shows losses to the small teams (and failure to accomplish mission) as a function of the loiter time and cache size. Although notional, the figure is intended to suggest (through use of the log scale) that substantial loiter times may be necessary.

Figure 31



5.7 Correcting Misconceptions About Analysis and Modeling

There are many reasons for difficulties in model-supported analysis and its interpretation. The panel believes that a number of them are due to what we regard as misconceptions. The following illustrate these.

Accreditation

Organizations and officials often act as though models can be meaningfully accredited. The analytic community, by contrast, has consistently been vociferous in noting that models cannot be evaluated outside of specific contexts. Even efforts to accredit a model for a class of applications is suspect, because details of application matter down to the level of what model-derived conclusions will appear on summary view graphs. "Good" models can be used very badly and relatively crude models — developed for different purposes — can be used very well. Further, models are data and assumptions-driven, and those change with context. The bottom line here is that it makes sense to review analytical methodology for a specific study or exercise, but not more generally. Further, organizations that accredit models more generally are begging for trouble because this tends to stifle creativity, lock analysts in to using models inappropriately, and operate against the normal evolution. Although additional funding to improve the quality of models and test their validity — within the limits of what kind of validity is meaningful — is strongly desirable, we believe that model accreditation should be de-emphasized: in practice, its effects have too often been pernicious.[24] A program to improve the quality of analysis and the supply of highly talented analysts would be significantly more useful.

Resolution

It is commonly believed in parts of the M&S community that more resolution is good and that the goal in M&S should be to build the "correct" model from the entity level up. This same view is sometimes expressed by very senior military officers and officials. They sometimes go on to assert that all functions from force-planning analysis to training the troops for war could then be done with the same model. This notion is simply wrong. The key to success is using models of varied resolution, preferably designed to feed each other, and to develop calibrated families using all the information available. Which model should then be used should depend on the application.

Object Oriented Programming and Variable Resolution

Some enthusiasts of object-oriented programming give the impression that it makes it easy to design variable-resolution models. The reality is very different: OOP simplifies carrying along hierarchically related objects (e.g., division/brigade/battalion), and simplifies model reuse, but it does not address the hard part of the problem, which is understanding how aggregate *processes* relate in the real world to lower level processes (e.g., division-level versus battalion-level attrition). That issue depends on military phenomenology and cannot be solved by mere programming methods.

Cross-Use of Models

It is certainly the case that some models used for training can be used for analysis and vice versa. However, the models are typically designed quite differently (for good reason). It is not straightforward to cross the gap between these two. Nor is either depiction "right." While cross-use may be desirable in some instances, it is not something that should be established as a general goal because trying to force cross-use can unnecessarily burden all the workers involved (forcing them to deal with data and choices that are irrelevant to their applications) and create considerable confusion.

Optimization

Operations researchers tend to like optimization. Strategists tend to cringe when they hear the word, since they have learned to expect that whatever is being optimized is a

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24 This said, it is reasonable and useful to have "standard cases" for different groups to run so that face-validity judgments can be made and some standardization achieved. Even here, however, these standard cases tend to be treated as best estimates of reality when they are not,

simplistic representation of the real problem. Optimization methods are very powerful at certain levels of analysis and decision support, but they must be used with great care and limited to functions in which they make sense.

Appendices

Appendix A. Panel Members and Contributors

The Analysis and Modeling Panel of the DSB study on *Tactics and Technology for 21st Century Superiority* consisted of

Jasper Welch (Maj Gen, USAF-retired), chairman

Paul K. Davis

Seth Bonder

David Maddox (GENERAL USA-retired)

Ron Fuchs

All contributed to the current report.

Efforts of the panel were assisted by contributions from a number of individuals, including Albert Brandstein, Gary Coe, John Matsumura, Randy Steeb, and Rick Wright.

Appendix B. Simulation Technology for the 21st Century

The Panel did not have the opportunity to spend much time discussing model and simulation technology per se because of other priorities. It seemed appropriate, however, to include a brief discussion because there are revolutionary changes taking place that will have a major impact on analysis, including analysis of distributed-force concepts. What follows was provided as input to the Panel. It was prepared in May 1996 by the following.

COL Robert P. Reddy, Defense Advanced Research Projects Agency

Mr. Bennett Dickson, Institute for Defense Analyses

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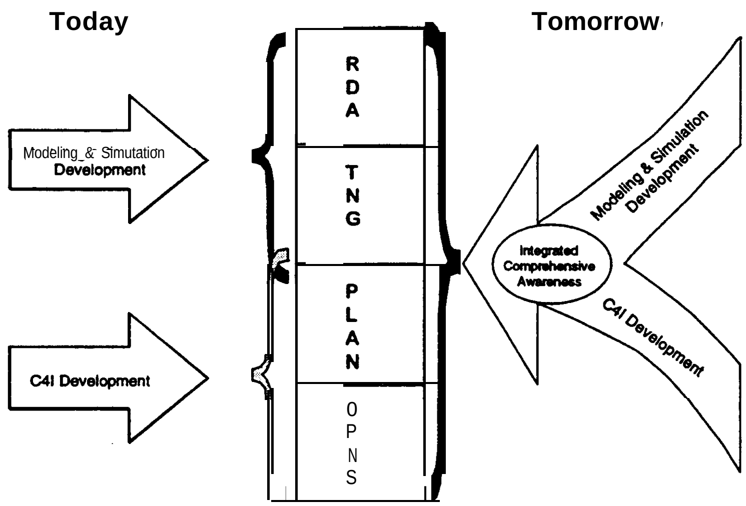
Simulation Technology for the 21st Century

Warfighting in the 21st Century will be fought on a battlefield dominated by information age technologies. Emerging weapons, sensor, and communications systems will generate, communicate, and interpret massive amounts of data that will represent real time comprehensive awareness of the battlefield. Commanders will make decisions based on a real time visualization of the battlefield that closely replicates ground truth. Individual soldiers and small teams will be able to control terrain and enjoy freedom of maneuver through a comprehensive awareness of their environment and an ability to quickly bring remote weapons to bear against any threat.

Tactical and strategic success will depend on the use of electronic tools to employ precision weapons in carefully measured increments at the decisive time and place on the battlefield. Mounted and dismounted ground forces will be highly dispersed, small in number, and thoroughly integrated into an array of ground, sea, air, and space based sensors and weapons. Fratricide and collateral damage will be greatly reduced while increasing the probability of destroying enemy targets. Small units will require direct and immediate access to detailed and localized command and control information.

This 21st Century battlefield will be significantly different and considerably more complex from any battlefield we know today. Achieving this vision for the 21st Century battlefield represents a significant technological challenge for information sciences including communications, networking and data management technologies, and modeling and simulation. The purpose of this paper is to outline the future for modeling and simulation requirements to support information age warfare, especially as it applies to support for smaller, more capable formations that will operate on a joint and combined battlefield.

Technology developments to support future C^4I systems and those required for future modeling and simulation address the same problems. Integration of these emerging technologies will be the key to information age battlefield domination. Future C^4I systems should fuse communication, sensor, and simulation systems to enhance human reasoning and real time decision making. Current systems represent an emphasis on hardware development, while future enhancements should focus on software development to build and interpret a complete and relevant picture of the battlefield. Modeling and simulation technologies should be an integral component of future C^4I systems. M&S capabilities should be imbedded in the C^4I systems to provide commanders, staffs, and individuals with an on-demand capability for training, mission rehearsal, and mission analysis. Modeled synthetic forces and terrain and associated reasoning tools should interact with C^4I entities to provide informed and logical extensions of known information to fill in the picture of the battlefield.



From a modeling and simulation perspective, the good news is that the technology for processing and displaying this information in a training, mission rehearsal, or system development context is quite congruent with the technology required for processing and displaying the same information in an operational context. Because of this congruence, it makes sense to begin prototyping the required system components in simulation from the outset. This is more than an engineering effort, we are faced with several unknowns and need new technologies to support this information age war-fighting. Fusing the synthetic environment with the command and control environment requires that we develop technology for dealing with massive throughput of data and the inevitable loss of data packets or source data. Packet and data loss need a compensation mechanism such as the consistency protocol being developed for High Level Architecture. Publication and subscription mechanisms for data sources and recipients used in modeling and simulation can also apply to operational systems. Dynamic multi-casting mechanisms will be required to deal with complex multipoint-to-multipoint communications.

Wireless communications and geolocation systems provide excellent connectivity for air and sea borne platforms and for stationary command posts. Future development should focus on extending a digital, wide bandwidth capability to the small unit and individual combatant operating in close and restrictive terrain. We need better miniaturization and the development of lightweight, continuous power sources to provide individuals with required communications and computing tools. Mobile, ground-based command posts require real-time continuous digital communications with other command posts, sensor platforms, and combatants. Geolocation systems are currently degraded when a clear view of the satellite array is blocked by foliage, buildings, etc. This problem should be solved so that individual combatants can be continuously tracked by the C^4I system. The soldier and small unit leader's C^4I system requires careful engineering to minimize the load carried, while technological breakthroughs are required for display devices that are suited for dismounted soldiers.

The design of the user display interfaces for small unit commanders is an issue of particular importance. It is all too easy to overwhelm users with information, especially in tactical environments where the lives of the commander and his troops depend on maintaining real-time situational awareness. An essential capability is to be able to input information (spot reports, etc.) quickly and easily, and to extract information that is most relevant to their current needs without having to execute complex command sequences. Enhanced situational awareness requires the representation of terrain and forces on a variety of 2-D and 3-D graphical displays. Integration of the synthetic environment into C^4I systems will greatly enhance commanders' abilities to conceptualize, plan, and control operations.

These information systems should be prototyped and then driven with realistic data in virtual environments. Algorithms for information fusion (e.g. do two reports represent two independent sightings of the same unit, or two different units?) can be driven by simulated data as easily as they can by live sensor data; and the decision-making processes of the small unit commander can be monitored, recorded, and analyzed in realistic contexts. Virtual prototyping of emerging C^4I systems is essential for developing both the software and hardware functionality that is required for optimizing the man-machine interfaces with emerging technology.

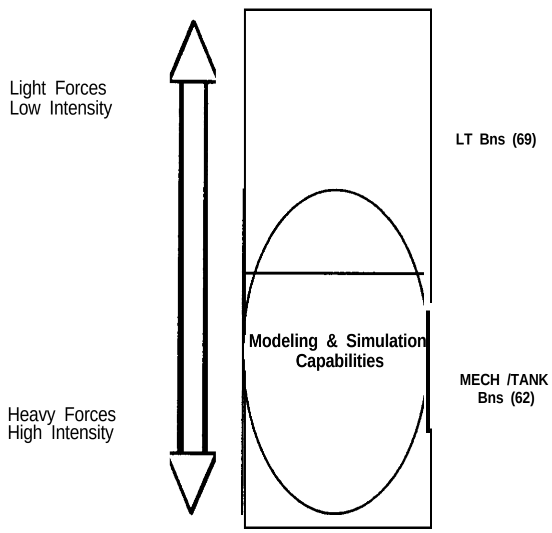
Modeling and simulation is required to support the development of new and emerging capabilities of the 21st Century battlefield. This development will require concentrated efforts to fill several critical gaps. Key among these are:

- Representation of individual combatants
- Dynamic modeling of the synthetic environment
- Integration of live and virtual entities
- Improved modeling of C^4I systems
- Modeling of multiple forces
- Integration of C^4I and M&S technologies

REPRESENTATION OF INDIVIDUAL COMBATANTS

Current individual soldier modeling capabilities do not extend far beyond the ability to model rote, crew drill behaviors at the small unit and individual soldier levels. Currently we cannot train or rehearse in environments where the computer generated light forces are indistinguishable from human participants. This represents a serious shortfall when considering the proportion of light forces fielded today. As the chart below shows, M&S development is much more mature in the heavy force/ cold war environment. The science of modeling weapons systems is well understood, but the same cannot be said for modeling individual soldier and commander behaviors in a wide variety of environments and tactical situations.

US Army and USMC Maneuver Battalions



Future systems should model human behaviors beyond the level currently achieved for weapons and platforms. Unsolved problems remain in the areas of computer learning, modeling intuition and context dependent reasoning, the specification and use of "common-sense" reasoning, use of uncertain or partially-specified information, and identification of the most favorable demarcation between calculating rationality and bounded optimality for Computer Generated Force (CGF) deliberations. Moreover, we should begin to model behaviors that do not conform to the traditional American norms; e.g. the cultural values of peoples from foreign countries that have behaviors which run counter to those of a rational actor with our heritage.

Progress on such problem areas is required to improve Command Forces (CFOR)/ CGF capabilities for situation assessment, to include the intelligence preparation of the battlefield (IPB), plan generation and modification, plan evaluation, course of action selection, and situation exploitation. Representation of human perceptual behaviors, including the use of various sensors under a wide range of environmental conditions: day, night, dusk, rain, snow, fog, smoke, heat, cold, etc., each of which has different effects on different types of sensors is critical to modeling the tactical implications of forces operating with these capabilities.

Current models of human behavior on the battlefield focus primarily on activities that are measurable, well-defined, and algorithmic in nature. In general, these activities reflect the behavior of individuals, combat vehicle crews, and small units as they execute actions for which formal tactical descriptions and performance measures have been developed. Few useful models exist for more complex cognitive activities such as situation assessment, plan generation, evaluation of alternative courses of action, monitoring of the current status of an action with respect to the original plan, modification of plans in progress, etc. These are critical and essential activities for battlefield commanders and their staffs. Efforts are currently under way, in STOW and other programs, to model and represent these higher-level functions in computer-generated CFOR, but much more basic and applied research is required. Commander and staff officer behaviors should be included in future models. This will provide semi-automated forces at the entity level of detail capable of being controlled by computer generated command entities. Modeling of detailed human behaviors will be critical to replicating the information age battlefield and will provide an essential component for a future integrated mission planning, training, mission rehearsal, and mission execution C^4I system.

DYNAMIC MODELING OF THE SYNTHETIC ENVIRONMENT

Current representation of the synthetic battlefield depends on time consuming development of relevant terrain databases. Current limitations in computational power limit the fidelity of terrain databases. This has proved satisfactory for training purposes and for use by aerial and armored platforms, but is inadequate for operational use by individual combatants. Rapid generation of terrain databases that are highly accurate in both horizontal and vertical dimension is essential for operations and training. One of the salient issues is in determining the most appropriate resolution for the terrain data because there is a polynomial relation between the data resolution and the time and space requirements imposed by the resulting data. If three meter horizontal data is sufficient, we do not want to incur the significant overhead of creating, storing, and processing one meter data which is at least an order of magnitude more expensive in each of these categories. A non-trivial issue that should be resolved in this regard pertains to the discovery of suitable metrics useful in adjudging resolution sufficiency; how do we determine that a specific resolution is adequate for an intended purpose?

We should develop technologies that allow data capture in a more robust manner. Current capabilities do not allow us to create high resolution elevation data sets when we cannot "see through the trees" from above. Also, data set creation is a highly labor intensive process and we need progress in the construction of automated tools to amplify human abilities. We need terrain analysis tools that can help the cartographer recognize tactically significant terrain features so that these features can be most accurately modeled. We need further advances-in the process of constructing polygonal representations of the lattice data used to represent terrestrial elevations as well as methods to better integrate cultural features into these polygon sets. Finally, hardware advances are required to permit real-time use of very dense polygonal representations of the environment. .

Current terrain databases represent highly compiled raw data. This limits dynamic changes to those objects such as bridges, buildings, and trees that can be treated as objects and assigned various operational states to represent anticipated damage, removal etc. Representing other, real time changes to terrain such as earth moving, cratering, and fortifications as well as seasonal and other weather phenomena will require development of tool sets to permit real time recompiling of such effects and efficient integration with existing data sets. We need progress in basic computer science issues related to parallel and distributed access to very large databases.

INTEGRATION OF LIVE AND VIRTUAL ENTITIES

In training as well as concept evaluation applications, it will rarely be feasible to fully populate a scenario with "live" players representing all friendly and hostile forces, and non-combatants. It will be important to be able to employ virtual (computer-generated) entities in some of these roles, and ensure that they exhibit sufficiently realistic behavior, so it will not be immediately obvious to the live players which ones are virtual and which are live. Even in simulations in which all the principal participants are "live," it will be essential to populate the surrounding environment with hundreds or thousands of computer-generated "extras" playing a variety of roles. The very essence of the challenge in many small unit operational scenarios is to detect and identify a relatively small number of adversaries in a complex, dynamic environment that includes a large number of noncombatants.

IMPROVED MODELING OF C⁴I SYSTEMS

Current models and simulations are rudimentary in their representation of C^4I systems. Perfect command and control is assumed in many models, or is modeled outside the simulation by real or emulated C^4I devices. More realistic representation of command and control involves improvements in two areas. The first involves physics-based models of how C^4I signals are propagated and how they are interrupted, degraded, or modified by natural or man-made phenomena. These models can be used to determine whether or not a given transmission arrives at its intended destination. The second involves cognitive processing models of how the sender composes the content of the message and the meaning he intends it to convey, and how the receiver interprets the message and the meaning he extracts from it. Both of these areas should be addressed to generate more realistic representations of C^4I systems, which play a growing role in the employment and effectiveness of weapons systems.

MODELING OF MULTIPLE FORCES

Future models should incorporate the growing role that worldwide C^4I systems play in the employment and effectiveness of weapons systems. Modeling of individual combatants and weapons systems should replicate the synergistic effects of comprehensive awareness. Operational requirements are significantly more complex than most of the combat situations our forces have faced in recent decades. Demands for comprehensive awareness will go well beyond simply locating and identifying "our forces" and "their forces." There will be many small, dispersed friendly units in a given geographic area, along with several kinds of adversaries, multiple coalition partners, and noncombatants. Battlefield IFF will require a clear picture of the battlefield. Real time awareness of all friendly unit and individual positions can be used to prevent inadvertent fires into areas occupied by friendly forces. Unidentified vehicles or forces can be compared with sensor inputs and information flowing on C^4I networks. Reasoning tools can provide best guesses against templates and decision models to further aid in identification of potential threats.

INTEGRATION OF C⁴I AND SIMULATION SYSTEMS

Future C^4I systems will provide multiple, real time inputs from sensor systems, weapons systems, and individual combatants. Integration of these inputs into a common and relevant picture of the battlefield will require multiple software tools to augment and interact with human reasoning.- Simulation can provide model-based semantic objects that can interact with the inputs from sensor systems to create anticipated values and fill in the gaps in sensor coverage. These tools should go beyond the mechanical/algorithmic mechanisms into the incorporation of automated higher reasoning functions. Information age commanders risk drowning in a sea of data while unable to stand on any islands of knowledge. Modem sensor and communication systems provide voluminous data that must be filtered to find information and synthesized to create knowledge. The computer is facile at processing large amounts of data but not without guidance. However, relating disparate data often involves a creative, intuitive process that has to date defied automation. Simulation offers a mechanism to sift through the data, compute interactions, and present resulting situations in a manner that amplifies human reasoning abilities by making important aspects readily apparent. Progress is required in automating creativity, data interrelation schemes, and attention focusing mechanisms.

Faster than real time interaction between simulations and C^4I systems can provide important what ifs and aid commanders in anticipating enemy action and reaction. The fusion of synthetic environments and the C^4I environment will shorten the decision cycle and permit dominance of the information age battlefield. Faster than real-time simulation capability should be improved to permit better CFOR planning as well as human analysis of operational alternatives. This basic problem has been attacked in several past efforts, but remains as an impediment to further progress in militarily significant computer applications. Advances in heuristic estimation capabilities are required to exclude automated consideration of least-likely but possible branches and sequels that could impact tactical analyses. Further advances in attention focusing and game playing techniques are required as well.

Integrated C^4I and simulation systems should be capable of interacting in real time with massive, dissimilar databases maintained and located at multiple remote locations. Database updates from multiple sensor inputs will provide commanders and small units with essential information necessary to complete the comprehensive awareness picture of the battlefield. Modeling and simulation can provide for the graphic representation and visualization of multiple sensor inputs. We should devise more robust inter-visibility representations and calculations. Our current capability assumes that we have a perfect knowledge of the world and relies on pure algorithmic methods. Line of sight does not now consider any probabilistic effects. As an example, a stationary object is more difficult for humans to detect than one that is in motion. Line-of-sight algorithms consider all objects to be stationary and either completely detectable or not. Similarly, the effects of foliage, backgrounds, camouflage patterns, sun angle, and many other phenomena are not considered in these calculations. In general, we should devise a meaningful method of incorporating probability of visibility into the current purely "yes-no" analyses.

Multispectral representation of synthetic environments are also needed, as well as studies to calibrate human visual perception of computer generated images. An accurate representation of these phenomena is essential for modeling the detection and identification of individual entities, which in turn drives the problem of fusing this information into a coherent depiction of the appropriate battlespace for each participant.

Current rules and methods for software development are inadequate to construct the complex information tools envisioned. Improved protocol standards to permit interoperability of different simulation systems, C^4I systems, and weapons systems should be developed. An improved communications network architecture is necessary to efficiently transfer the massive amounts of data required to support this system. Increases in computational power to control real time interactions of up to 100,000 entities is essential. Data and information filtering techniques should be developed to avoid information overload of commanders, staffs, and small unit leaders.

Developing an integrated C^4I and modeling and simulation environment to support information age warfare involves much more than an engineering effort to extend and expand current capabilities. Several key technological challenges should be solved through basic and applied research. Simulation, as developed within the last 15 years, has become a core enabling technology whose potential has only been narrowly exploited. This technology provides a unifying mechanism and framework for the development and support of diverse research areas. It provides a proving ground where research results can be studied in complex settings, a vast improvement over isolated examinations. There are also novel applications of simulation technologies that are as yet unexplored. Above, we mention its potential use as a data fusion mechanism. Simulations might also serve as personal assistants, where each soldier can own and access immediate planning, analysis, and prediction capabilities in their own context of operations. Fusion of modeling and simulation with C^4I, starting with the individual combatant and working up to the theater and national level should be a priority. Developing the enabling technologies and building the integration tools should begin today.

Appendix C. Issues for Analysis

Introduction

A.1 Purpose

The purpose of this Appendix is to identify the planning and resource allocation issues that need to be addressed by DoD leadership before committing to and implementing new Information Age concepts of operations (CONOPS). Section 5.2 of the report describes the types analysis needed to address these issues. Although the focus of this section is on operational concepts, decisions regarding these issues impact related decisions on many DoD resource areas such as modernization, structure, service roles, training, personnel, readiness, etc.

In the context of the complex global security environment discussed in Section 5.1, the analysis issues must explicitly consider:

- “versatility" of U.S. military capability
- “robustness” of U.S. military capability
- “competitive strategy” thinking in designing an enduring military capability
- affordability in light of continual pressures to reduce defense budgets

The types of issues that need to be addressed include:

(1) Concept of operations (CONOPS) level issues involving cross-functional, analysis of which generates “capability requirements” for each of them. Six principal functional areas are considered:

Precision strike operations

Information operations

Battle management operations (C^3)

Small unit operations

Logistics operations

Strategic deployment

(2) Functional level issues which address the design of “capabilities” or determination of requirements for individual functional areas

(3) Functional level issues which address the “engineering feasibility" of performing each of the functions and interactions among them

Each of these types of issues will likely be addressed iteratively and continually in order to account for the complex interactions between the functional areas and the CONOPS. A two-tiered approach involving *"force planning analyses"* and *"functional area analyses"* is presented in Section 5.2 of the report.

A.2 Concepts of Operations-Level Issues

These are planning and resource allocation issues that must be addressed by senior leadership — JCS and OSD. The issues involve multiple functional areas and they generally cross military service boundaries. The analyses must be top-down, integrated and not stovepiped. CONOPS-related issues, by necessity, involve issues of modernization, force structure, organizations, service roles, and readiness. Decisions regarding these issues determine requirements for and establish future U.S. military capabilities in many functional areas. This section of the Appendix lists some of the principal and interrelated CONOPS-level issues that need to be addressed:

- Should a radical new CONOPS involving "small units" be adopted? Will it be effective for a range of operational situations that may require U.S. involvement?
- What is the role of the "small units" in each situation?
- What are the key determinants of the concept's effectiveness? The technologies? The organization? The force size? The doctrine?
- Which tactics should be employed by the small units?
- When and where should these small units be used in lieu of conventional units?
- What mix of functional capabilities are required? How much of each? What capabilities (requirements) must they have? How do they interact with each other? How do budget constraints affect these functional capabilities?
- What is the associated DoD-wide RDA strategy to equip the force to implement the CONOPS?
- What roles should each of the Services perform?
- What are the institutional implications to implement the new CONOPS?
- What are the transition implications — doctrine, training, organizations, etc.?
- What role should be assumed for coalition partners? What are the implications for coalition warfare? For training and equipping coalition partners?
- What level of strategic deployment capability is needed to support the CONOPS? What is an appropriate mix/balance between deployment capability and capability of employed forces in theater? What are the implications for prepositioning of equipment?
- What aggressor "counters" could effectively negate the efficacy of the CONOPS? What means could be used to defeat these enemy counters?

- Can modernization reduce the force size needed to implement the concept? What is an effective resource allocation between modernization and force size given constrained resources?

- Does the concept make efficient use of resources to maintain readiness?

A.3 Functional Area Level Issues

CONOPS-level issues and associated analyses will determine what capability goals each of the functional areas must achieve to make the concept effective. This section highlights some of the key issues that need to be addressed to determine "how" the capability goals are to be achieved — the functional capabilities needed to achieve the goals. There are three inter-related classes of issues:

- Determining the means of providing the capabilities — quantity and quality of systems, forces, procedures, etc.

- Assessing the system engineering feasibility which may include interactions with other functional areas

- Understanding the impact of costs and budgets on system requirements

These planning and resource allocation issues would be under the purview of the joint staff and the services. CONOPS-level analyses will indicate the nature (types, numbers, timing, physical and operational environment, desired effects, etc.) of the capability goals. The following questions are common to each of the functional areas noted above:

- What affordable mix of ground, air, and sea platforms provides. the greatest effectiveness, versatility, robustness, and survivability?

- What affordable mix of systems allows achievement of military objectives over the broadest range of likely scenarios?

- What are the capacity, accuracy, timeliness, lethality, range, vulnerability, survivability, etc., requirements for the systems?

- What mix and capabilities of systems are required? How does this mix vary with cost in a budget constrained environment?

- What communications and computer support is necessary?

- What connectivity and information are required on the systems?

- What susceptibilities might these forces have? How can these be mitigated?

- What battle management procedures and materials are needed?

- What are effective tactics, techniques, and procedures?

- What means might an aggressor employ to counter the effectiveness of individual components and the integrated system? How can these counters be mitigated?

- What are logistics support requirements, including deployment of support systems?
- What are the costs of each of the components and their integration into the system?
- What are the R&D performance, cost, and schedule risks?
- What training is required? How should this be accomplished?
- What is the feasibility of integrating all of the components into a functional area (e.g., precision strike, information operations, BM/C3, etc.) system?

Some functional area specific issues are noted below:

Precision Strike Operations

Precision strike operations are concerned with the surgical delivery of precision munitions in a timely fashion against a spectrum of aggressor targets throughout the theater of operation. COMOPS-level analyses will indicate the nature of the capability requirements for the area (e.g. types, timing, physical and operational environment, desired effects, etc.). Some issues unique to this functional area include:

- What are the accuracy, timeliness, and lethality capabilities for each of the platforms, munitions, and sensors?
- What terminal sensor capabilities are required?

Information Operations

Information operations are concerned with:

(1) Providing information for:

- Movement of forces and materials for effective employment
- Targeting
- Effective guidance and homing of precision munitions
- ID (IFFN)
- Effective strategic and tactical psyops

(2) Proactively controlling an aggressor's information so he is at an information disadvantage

Some analysis issues unique to this functional area include:

- What are the accuracy, timeliness, capacity, power, sensitivity, etc. capabilities for information operations systems?

- How should resources (forces, modernization, etc.) be allocated to collecting and providing information to U.S. forces and to proactively degrading an aggressor's . ability to do so?
- What are appropriate targets for proactive (offensive) information operations?
- How dependent are the component systems on pre-hostility technical and operational intelligence?

Battle Management/C3

Battle management/C^3 is concerned with the development, processing, storage, and transport of information and the planning and decision making in support of each of the functional areas and their integration. Some issues unique to this functional area include:

- What are appropriate technical, system, and operational architectures to support the concept of operations?
- What is the appropriate assignment of functions to man and machine for BM/C3?

Small Unit Operations

Small unit operations are concerned with the conduct of activities/tasks of small maneuver units on a distributed battlefield. Some issues unique to this functional area include:

- What types of small units are needed?
- What size should each type of unit be? What should be its AOR?
- How many small units are needed?
- How should they be organized? What skills are needed in the personnel?
- Which assets are needed to perform assigned tasks?
- What are the BM/C^3I requirements?
  - For autonomous ops?
  - For collective ops?
- What are the small units mobility requirements? What mobility assets should be pursued?
- How survivable are small units on the battlefield? How can their survivability be enhanced?
  - During task performance?
  - Between tasks?
- How long can small units operate effectively?

- What are insertion and evacuation requirements? What materiel assets should be pursued?
- What are the small units sustainability requirements?
- What are the small units medical support requirements?
- What are the personnel leadership requirements?

Logistics Operations

Logistics operations are concerned with the acquisition, distribution, maintenance and repair of systems and services; and the deployment and transport of personnel, units, and materiel on any battlefields/theaters. Some issues unique to this functional area include:

- What concepts should be pursued, e.g., split based, prepositioning stocks, forward deployments, "just in time", "just in case", push or pull, ... ?
- What are the particular requirements for logistics support of small units on the distributed battlefield, including medical support?
- What equipment/organizations/procedures are needed to insert and evacuate small units and to resupply them?

Strategic Deployment

Strategic deployment is concerned with the acquisition and employment of systems for the deployment of personnel, units, materiel to the battlefields/theaters. Some issues unique to this functional area include:

- What arrival rate is required for each type equipment
- What are the cost and effectiveness tradeoffs among faster deployment, prepositioning on land, prepositioning afloat, etc.?

Appendix D. The IDA Small-Unit Virtual Analysis

VIRTUAL SIMULATION SUMMARY

1.0 INTRODUCTION.

The Virtual Simulation Excursion was conducted at the Institute for Defense Analysis (IDA) Simulation Center. The purpose of these excursions was to investigate the efficacy of the Small Team Concept on a 2015 battlefield for the 1996 Defense Science Board.

1.1 SIMULATION EXERCISE.

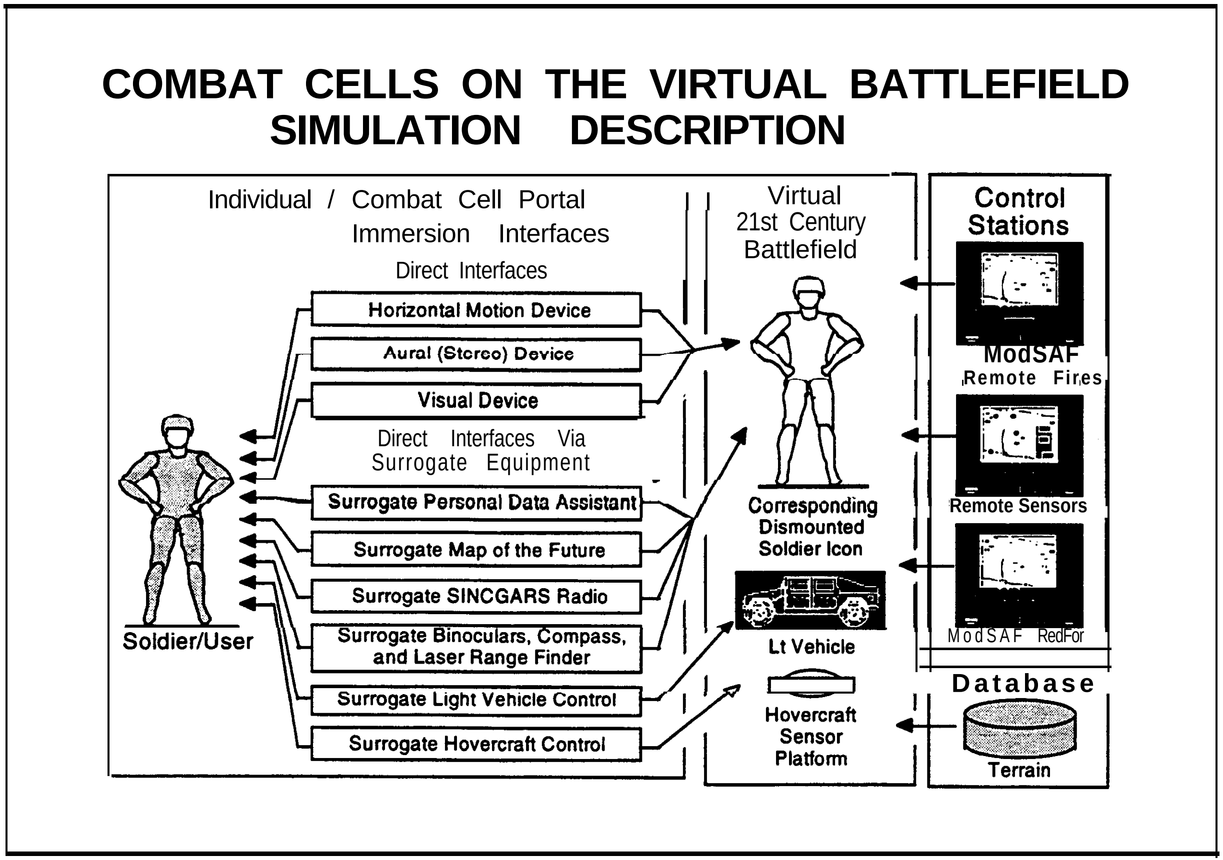
The Virtual Simulation excursions addressed a slice of a battlefield portraying only the targeting elements of two small teams (2-3 men, each) plus an intermediate headquarters and a task force headquarters. The exercise was divided into trials designed to investigate parametric variations in small team size and composition, mission, organic sensor capabilities, and remote sensor suites. Active Duty and Reserve Component Army and Marine officers served as the live subjects in these trials. The composition included a team with the intermediate leader serving as a team member and other cases where the team leader was independent. Teams were assigned missions to control an area of 5 km radius in several trials. In other trials both teams were told to operate together in one control area, effectively halving the size of their mission. Sensor capabilities varied from rudimentary to ground truth. In addition to the small team variations, trials were run on two different types ofgeography. The Ft Hunter-Liggett Terrain Database (TDB) provided a desert-like environment and the STOW-E TDB area around Hohenfels, Germany provided a European (mixed) environment with numerous tree lines and rolling hills. The trials were observed by tactical and behavioral experts. They monitored participant activity and evaluated how they performed their missions. In addition, a voice and digital data logger was captured information about the simulation events for subsequent analysis.

1.2 PHYSICAL DESIGN included three each player and exercise control interfaces

- **Player interaction** was designed through (1) a vehicular mounted portal, (2) a foot mounted portal (treadport), and (3) an intermediate leader station. Each interface included a ModSAF simulation large screen display of the synthetic battlefield and integrated interaction with communications devices (voice and text), sensors (binocular integrated with a laser range finder and a tethered aerial sensor platform (COVER)), and an electronic map of the future (MOF).

- **Exercise control** was implemented through four interfaces: (1) Fire direction center (FDC) consisting of a three person cell complemented with an automated fire support emulator to process fire requests , (2) Sensor management station consisting of one person, (3) Blue commander and exercise control station and (4) OPFOR station. The ModSAF constructive simulation and MOF integrated inputs from these stations and the player interactions.

1.3 SIMULATION RUNS. A series of simulation runs that varied players, terrain, OPFOR, and sensor capability. Player performance was observed, interviews were conducted, and combat results were measured, particularly fire support time lines. Data collection sources included the ModSAF data logger that tracked simulated events, observer observations and interviews, voice logger, a fire direction center emulator that tracked fire support time lines, and after action reviews.

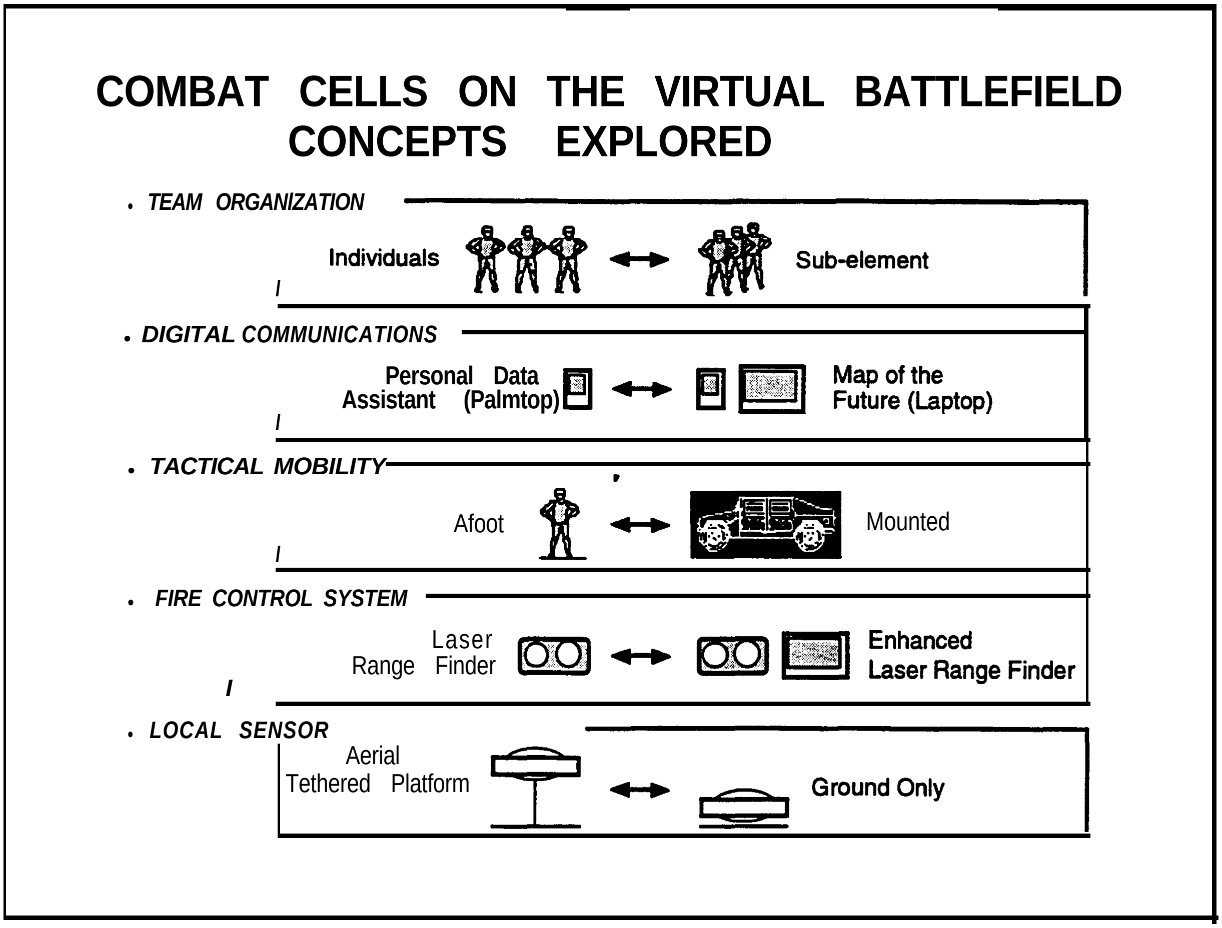


The virtual simulation portrayed the targeting and situation understanding elements of two combat cells, plus higher headquarters. The simulation was used to examine variations in environment, cell composition, and equipment. Army and Marine officers served as the live subjects (players) in these trials. Cells were assigned missions to control an area (size varied up to 5 km radius).

The geophysical aspects of this battlefield were created from digital terrain databases. Two different environments were explored: a desert and a European type with numerous tree lines and rolling hills. Modified synthetic automated forces and adjunct models were employed to provide remote fires and sensors, and enemy forces that included tank, armored vehicle, truck-mounted, and dismounted platoons.

Members of the cell were placed in portals that provided interfaces with the virtual environment and virtual equipment. The individual(s) could walk, run, crawl, see, hear, and talk on the virtual battlefield.

The cells conducted 7 combat operations, ranging in duration from 1 to 3 hours. During these battles the cells received over 200 sensor reports and requested over 150 remote fire missions. Throughout the approximately 14 hours the cells were engaged in combat, they were confronted by about 175 enemy platoons (tank, BMP, truck, or dismounted). The trials were observed by tactical and behavioral experts who monitored and recorded participant activity.



The alternative concepts depicted above were explored during the combat cell virtual battles. These included alternative allocation of tasks among members of the cell as 'well as equipment options.

For example, the relative effectiveness of a laser range finder (incorporating binoculars and an electronic compass) was compared with a similar device integrated with a data entry device/radio and software which predicted the targets location at the projected time of impact of indirect fire. Alternative fire request and fire control procedures between the cell and the task force headquarters were also explored.

Following each combat operation, each member of the cell filled out a questionnaire and participated in an After Action Review (AAR) together with the observers, subject matter experts, and the software designers. Based on these AARs, cell doctrine was modified and, periodically, the Personal Data Assistant (PDA) and Maps of the Future (MOF) functionality were modified.

2.0 FINDINGS

COMBAT CELLS ON THE VIRTUAL BATTLEFIELD

OBSERVATIONS AND INSIGHTS FROM THE DSB-SPONSORED TRIALS

(All are subject to further analysis)

General

--Combat effectiveness is strongly dependent on the apportionment of the roles and responsibilities between the cells and task force headquarters.

--While individual situational awareness should be enhanced, combat power is derived through teamwork.

--A dismounted combat cell was not nearly as effective as one that had an agile vehicle.

- **Sensor Management**

--The major functions performed by the cells were to detect and classify enemy forces not observable by other sensor systems and to help determine enemy intent and options.

--Battle Damage Assessment was not an effective task for the cells.

- **Data Management**

--Distributed databases and a multicast communications system would enhance situational awareness and C2 by providing the right information when needed.

--The cells could validate a target and request fires, but the "system" should track and complete the engagement at the most appropriate time.

- **Weapons Management**

--Cells need confidence in the fire support system. Without feedback, they clog the C2 system with redundant requests for fire and information.

-If targets are not tagged and tracked, weapons must engage within 2-5 minutes of the fire request, or the predicted target location may no longer be accurate.

-The cells had difficulty handling more than two targets at the same time.

- **Data Presentation**

--Palmtop size map displays were much less useful than laptop size.

--Control of large areas requires digital, scaleable maps of appropriate size that can perform distributed automated battle management and terrain analysis.

--Three different data entry and display devices were needed to produce a full capability for acquisition and engagement of targets. These capabilities need consolidation into one device, optimized to support the conceptual doctrine.

GENERAL — The combat cell was made responsible for most aspects of requesting and controlling indirect fires; employing organic sensors; determining areas for remote sensor refocus; and battle damage assessment (BDA). These responsibilities overloaded the cell and overall mission would be more successful if some portion of these tasks were handled by the task force headquarters.

Initially, considerable attention was given to empowering the individual combatant, but it was found that more focus should be on empowering the cells. Forming the cells into sub-elements, assigning distinct tasks to each member of a sub-element and equipping each cell with respect to its collective mission was more effective than when each member was assigned a wide range of tasks and the same equipment.

The cell's combat effectiveness was enhanced when it had transportation to move about the battlefield. The dismounted infantrymen could not move fast enough to accomplish some assigned missions and assure their survivability. With many cells widely dispersed, and large areas for each to control, they should be capable of moving rapidly and stealthily in a vehicle that is easily deployable by helicopter.

SENSOR MANAGEMENT — The cells were able to gather and provide unique information including characteristics of enemy targets and intent. Positive identification of dismounted enemy or enemy using civilian-type transport was often possible only by visual means. Further, the exercises illustrated that cells functioned as sensors that were effective where other sensors were not.

The cells could detect targets out to 5 km, with an elevated, tethered video sensor platform, but still had difficulty detecting targets in restrictive terrain beyond 2 km because line of sight was blocked. A taskable tactical UAV (the Lower Tier Bubble) that could look in difficult places from a favorable angle would enhance situational understanding for both the combat cell and task force.

BDA was not an effective mission for cells since it detracted from more effective primary tasks mentioned above. This is especially true if the weapon time-on-target is uncertain (to the cell) and the cell must therefore continue to follow the target for an extended period. The "macro sensor system" should be capable of performing most BDA, with the cells contributing only when the remote sensors are incapable of performing that task.

DATA MANAGEMENT — Items of equipment should be combined and integrated to expedite transmitting information. For example, a remote sensor sighting could automatically slue the hovercraft sensor platform to the location of the sighting, without requiring the operator to scan for the target.

Once the cell has requested fires on a target, the "fire control system" should determine when to strike. The task force commander can make this determination better than the combat cell because of additional resources and information. However, it is also important for the team to know what action is being taken, in order to have confidence that a target is no longer its concern.

WEAPONS MANAGEMENT — The cells occasionally submitted multiple fire requests for the same target because they received no feedback on what action was being taken to track or engage the target. This detracted from their ability to continue locating and validating additional targets.

The concepts employed required the cell to monitor target engagement from start to finish. This was possible if the target could be engaged within 2-5 minutes. However, most engagements that used long range, indirect precision fires required about 20 minutes. Therefore, the cells needed to stop locating and evaluating other targets in order to provide location updates and terminal guidance for previous target requests. The total system should be capable of tagging, tracking, engaging, and conducting BDA without constant attention from the cell.

DATA PRESENTATION — Improvements of display and message formats will permit the cells to have better situation understanding and expedite processing and dissemination of information. It is not sufficient to automate current manual message formats. Software designers should work closely with the equipment developer and user to optimize data presentation.

Scaleable Maps of the Future were much more effective than the map on the Personal Data Assistant (PDA) that only presented a small size 3x3 km map. The user of the smaller presentation had difficulty orienting himself on the battlefield and understanding the tactical situation. Digital maps and information manipulated by voice, touch pad, etc., rather than a key pad would facilitate use. A built-in terrain profiling capability would facilitate mission analysis and planning.

Appendix E. Lessons Learned and Insights Examples From JPSD 94' and 95' Exercises and Demonstrations

Sensor Management

The joint sensor suite required to attack High Payoff Targets in Corps and Divisions AOs normally requires focusing theater and Army sensor systems on specific areas of interest. Current joint procedures are lengthy, manpower intensive and inadequate for attacking multiple targets rapidly.

JPSD experiments have demonstrated the benefits of precise synchronization of service and theater sensors and potential to be gained with automated collection management tools.

- The JSTARS offers a potential source of cueing data for Critical Mobile Targets but in certain scenarios is hindered by masking problems and countermeasures.

  JPSD demonstrated the benefits of alternative and complementary sources of cueing data to include artillery Firefinder, to cue UAV systems to threat launch point locations.

- The Tactical UAV offers a critical source of proactive targeting data for attack of both SCUD and MRL type targets.

  Reactive targeting by Firefinder systems reduces the target window of vulnerability to counter-fire systems. The Tactical UAV may acquire targets as soon as they leave concealed area and offers minutes of additional targeting time.

- Dense concentrations of High Value Targets require rapid target detection to permit timely attack. UAV with EO/IR systems have limited fields of view and require manual target identification.

  JPSD experiments with varying numbers of UAVs and revisit times will provide recommended system densities for specific targets. Dense concentrations may require as many as one UAV per 100 sq. km.

- The artillery's counter-battery radar (Firefinder) has very limited tracking and discrimination capabilities and provides immediate targeting only to the artillery force.

  JPSD experiments to provide Firefinder data to corps artillery and intelligence nodes resulted in a new source of cueing G2 ACE and targeting data for Air Force CAS.

- Current procedures for selecting sensor area of interest for targeting Critical Mobile Targets are manual and time consuming.

Information Management

- Coordination of sensors and weapons for attack of a Critical Mobile Target may require as many as 10 separate communications to detect, cue, identify, target, attack, and assess damage against SCUD-like targets.

  JPSD experiments to expedite this process indicate the benefits of targeting team with preallocated systems, abbreviated TIP, and specialized software.

- A corps sensor to shooter loop may entail as many as 8 processing nodes in the loop to include intelligence and artillery systems.

  JPSD•III Corps experiments to reduce this loop to the lowest possible numbers resulted in increased numbers of timely and accurate attack on time sensitive targets.

- The coordination of fires between Army Fire Support Elements and supporting Air Force CAS and Naval Fire Support and manual and slow.

  Experiments with the 2d Infantry Division to automate the joint fire support process are anticipated to permit synchronization of artillery and supporting service fires within the FSCL and beyond.

- Current concepts for the corps and division targeting nodes envision few targeting workstations.

  JPSD•III Corps experiments against dense, protected, and agile threats such as the North Korean Multiple Rocket Launcher force indicate the need for 4 or more to produce the required number of targets.

Weapons Management

- Existing procedures for employment of the MLRS are inadequate to respond to immediate missions against Critical Mobile Targets.

  Innovative experiments by the Field Artillery School and III Corps indicate the significant potential for mission success using weapon target pairing software that reduces weapons selection from minutes to seconds.

Appendix F. TACTICAL TRAINING TOOL, Simulations of Combat Cells Calling in Fires for: Defense Science Board's Summer Study on Tactics & Technology in the 21st Century

TACTICAL TRAINING TOOL

Simulations of Combat Cells Calling In Fires

for: DSB Tactics & Technology in the 21st Century

Sponsor:
Commandant's Warfighting Lab
Marine Corps Combat Development Command
Quantico, VA

Developer: GAMA Corporation
5205 Leesburg Pike
Falls Church, VA 220141
703 578 1700
attn: F.J. Bing West

F-l

This appendix covers the work of GAMA Corporation in support of the DSB Summer Study. It first sets the stage by establishing a framework of analysis of combat cell operation and the concept of massing fires rather than forces. It then offers observations based on both simulations of combat cell operations and historical experience. The analysis, using the Tactical Training Tool (a PC-based simulation), considered several different environments (open and close terrain) and missions (dealing with dispersed infantry/commandos, halting mechanized convoys, neutralizing mobile missiles). The model was designed to simulate calls for fire and is being used in training at the small unit level.

Concept of Combat Cells: Mass the Effects of Fires

- small (6 to 12 men), highly-trained units, called combat cells, which operate by stealth and employ indirect fires rather than direct fires to destroy the enemy
- in Desert Storm, US forces were massed and maneuvered with skill and speed
- in the next war, we should be able to mass fires as we can now mass forces
- this adds to our warfighting repertoire

F-2

The infantry division was designed by Napoleon 200 years ago. It was based on three principles. The first was mass - deploying a large number of riflemen in close proximity to each other. Today's weapons have invalidated Napoleon's need to mass men in order to mass aimed fires. Infantry mass is still needed to break an entrenched opposing army. But that is a tactic which must be used sparingly, given the nation's aversion to casualties. It is not done because, as in Napoleon's day, many muskets are needed at 100 paces.

The second principle was a chain of command with spans of control based upon voice communications in battle. Communications continue to limit the flexibility of maneuver units. Division fire support centers have evolved due to communications architectures and the governing limitation has been the short range of battlefield FM. Take away that communications limitation, as cellular has taken it away for consumers and commercial business, and the structure and process for indirect fire support must be revisited.

The third Napoleonic principle was a narrow span of control for each leader. When shouting over the din of battle was the only way to communicate. Today, the smallest independent units can be supported in ways not possible even during Desert Storm. With the proper equipment, they can reach directly back for relevant information (or up to a satellite) or communicate with each other in order to fill in the battle picture.

Framework for Analyzing
Combat Cells (Small Units)

1. Specify Setting (Context, Objective, Rationale, Expected Value-added)
2. State Mission & Forces in standard military terms
3. Insertion, extraction, emergency extraction
4. Patrol style, parameters & detection systems
5. Commununications
6. Command & Control
7. Fires
8. Mission accomplishment & MoEs

F-3

Let us walk through the actions which should be analyzed and gamed or simulated in order to better understand the application of indirect fires.

1. Specify Settings

- US current doctrine of Combined Arms Maneuver is excellent & battle-proven
- but also heavy & works best in open terrain,
- plus, fewer direct firefights save US lives
- there are missions where light, fast, stand-off forces are needed (specify examples)

F-4

There are two national security conditions under which the small units might be employed. The first is as the early entry force, first on the scene, in essence buying time until the Combined Arms force can be built up and inserted. Virtue from necessity. The second is when small units with indirect fires become a desirable battle concept in themselves. This will take ten years. The DSB can only be a forerunner, indicating what is evolving.

Broadly speaking, there are two kinds of future battlefields. The first is linear warfare, front lines delineated by trench lines or units tied in physically one to the next. US maneuver doctrine is designed to defeat the linear opponent by identifying his centers of gravity and maneuvering against them.

The second in non-contiguous battle. Acknowledging our air and overhead surveillance superiority, the enemy fragments his forces to deny us clear centers of gravity, converging them only at times and places of his choosing. Understanding he must elude in order to survive, the enemy disperses to negate our deep strikes and synchronized mounted maneuver. On this battlefield, there is a high probability we will have to disperse our forces.

The combat cells operate best on nonlinear battlefields, where there are large gaps among forces on both sides.

2. State Mission in Military Terms

- why? put everyone of same sheet of music

1. Mission
2. Enemy forces, intent & style
3. Terrain & weather
4. Friendly forces
5. Time to accomplish objective
6. Supporting arms & equipment
7. Logistics

F-5

Distinguishing among battlefields/crises settings would be helpful because it would provide the 'context' some say has been missing. Mission is probably best stated in the standard military phraseology of METT-TSL (Mission, Enemy order of battle, Terrain, Time to accomplish the mission, Friendly order of battle, Logistics and Supporting arms). In one page of text, METT sets the scene.

The DSB, by seeking the analysis of different cases, has implicitly endorsed Mission Definition as the first step in analysis. METT-TSL is simply a militarily-established means of quickly putting down the essential information about each case. It has the great advantage that the military in all services will then at a glance understand the context.

3. Insertion & Emergency Extraction

- needs work; we have overlooked this component
- most dangerous time is when rotary-wing is inside shoulder-held SAM envelope
- no front lines = no safe areas for rotary-wing descent

F-6

Assuming this is primarily by rotary-wing, the DSB needs to provide some quantitative parameters pertaining to air defenses, especially shoulder-held. Some warn that air defenses would improve relative to the current net condition. That is bad news for insert, extract and emergency pull-out. This is when the small unit is most vulnerable. We have discussed means of protecting the teams if engaged on the ground; we have not addressed the ingress/egress vulnerability.

4. Patrol Style, Parameters & Detection Systems

- analysis and simulation break into near & longer term pieces
- near-term, troops need basic gear & can do the job; longer-term, radical style of fighting is possible
- patrol style is stealth; requires precise location, target designation, training & cell leadership
- we have good field data on quantitative parameters - movement speed, terrain coverage, etc..
- detections - we have identified the issue: multiple fragmetary detections are the norm; ***how to infer patterns & associate fragments with the whole is the technical challenge with high payoff***

F-7

This can be modeled well, and the parameters can be quickly changed, and runs done again and again. We have a base of 8,000 patrols. We know movement rates (generally .7 km/hr and contact (firefight) rates (under 10%) against a trained enemy in covered terrain. We know patrol endurance, how thoroughly terrain can be searched over time, and can model fairly well the probabilities of detecting various size enemy units on the march and in base camps.

Today, the sensors are the troops. For close-in (within audible and visual range) work, the human being is an extraordinary sensor. We know that on average in Vietnam, the patrol sensed only in daylight, and sighted two enemy groups per day, with 7 to 8 troops in a sighting. If night vision is added today, the reasonable number of sightings will be on the order of three per 24 hours in close terrain against a trained enemy, and more and larger sightings if the enemy is not as well trained or is not up a learning curve and unaware that the teams are in the vicinity.

To improve the situation awareness bubble, the focus should be upon enemy infantry; they are the hardest to find. JSTARS et al are doing a good job against platforms. Airborne microwave Moving Target Indicators were suggested as possible, even in close terrain.

As other detectors are added, the model can change the detection ranges. But lacking exercise or test data, we have to be careful about promises about future systems.

5. Communications

- combat cells cannot operate today - VHF FM 10 kms
- Army/Marines have just invested > $500 million in FM
- need a work-around for cells which doesn't require whole force to change
- e.g., equip Army light divisions & Marine divisions
- run risks with security to hold down costs, because std communication provides backup (after a fashion)
- what is the work-around? (must be digital)

F-8

The FM from 1938 is the backbone of Marine and Army tactical communication and it will not support the small unit concept. It cannot be done with FM. Communication gaps are too numerous. Relays are necessary every ten kilometers. Long-range is not possible. The system is not designed for the concept the DSB is analyzing. It is designed for Combined Arms Maneuver, when the tactical units will be in close proximity to each other and when vehicular radio relays will be plentiful.

This raises the question whether a work-around can be developed for the small units, or whether the entire tactical communication must be overhauled. If the latter, then the small unit concept is probably stopped dead in its tracks because the services are still procuring FM and do not have the resources or the plans for divesting and starting over.

6. Command & Control

- DSB focus is small teams calling in indirect fires
- in Vietnam, this operation was highly decentralized
- each team was on its own & decided when to call fires
- some centralized orchestration might be in order, -- if the system for connecting sightings improves
- DSB working on that, but not there yet
- technically premature to change operational C2
- best left to military judgment on case-by-case basis

F-9

There are two military models used for allocating artillery: TACFIRE and AFATDS. In exercises, commanders have been turning off TACFIRE and going with their instinct, based on 20 years experience. Models are good for keeping track of data, but not (yet) for battlefield decision making.

We know all small units want the reassurance they are being taken care of and watched over. This a good leader will convey instinctively. The colonel or general and his staff, removed from the physical and psychological pressures of the battlefield, will often see patterns and opportunities the teams, being bone tired, will overlook. The senior staff will have access to more information and can put together the pieces.

These are obvious observations. They may not need to be said at all. It is not clear how analysis can illuminate this area at this juncture. The DSB wisely has stayed away from this aspect in analyzing small units. It is best left to the military professionals. Artificial intelligence may someday have a role, but right now the small unit concept needs nurturing and clarity, not automatic decision. rules. One commander may decide to fight the battle and employ the units one way, and another commander may choose another way.

7. Fires

- artillery, the backbone of Combined Arms Maneuver, may be too short range & too heavy in theater logistics
- if so, DSB is suggesting *radical* long-term changes
- one TACAIR squadron per combat cell battalion is a first approximation
- munitions must hit targets in l-2 minutes from call for fires; solutions? can munitions loiter?
- UAVs seem to have merit both as sensors & to deliver suppressive fires if a cell is under fire

F-10

If each cell in close terrain averages three sightings of enemy per 24 hours, and we have ample data to indicate this is the ball park if the enemy is numerous, then the question is how to match 90 sensings/detections per 24 hours to adequate response fires. Assume the battlefield is 100 miles from the airfield or carrier, permitting 75 minutes on station with two external tanks and 450 knots transit time there and back. An F16 or F18 can be refueled, rearmed and maintained in two hours after a sortie. Two are needed on CAP at all times. Each can attack three separate targets. Or a maximum potential of 144 targets per 24 hours compared to an expected average of 90 calls for fires, if the cells are operating under 'hit all you detect' rules, which are the least restrictive. Two constant CAPs require two aircraft and crews launched every 90 minutes. If each crew flies two sorties a day, then the requirement is for 18 crews and 12 aircraft.

Helicopter gunships 100 miles from launch point can remain on station for less than half an hour. At that range, they probably need a designated target or mission before launch. They like to use nap-of-the-earth tactics and pounce on their targets. But they are used to lurking on the safe side of the FLOT. In the nonlinear battlefield, there is no FLOT; all territory belongs to the enemy, requiring revision of tactics. At this point, it is not clear what the role of the attack helicopter would be, except as escort in inserts and evacuations.

In the past, artillery has averaged about 8 rounds per mission; AFATDS is a good tool for adjusting volume based on the value of the target.

8. Mission Accomplishment & MoEs

- are combat cells a tactic or can they be decisive?
- they may need an exploitation back-up force to finish off enemy units, once chewed up by fires
- MoEs are easy to construct, but they tend to be input-driven; that is, the enemy does not cooperate by confirming the data & we have no war precedent
- we know targets are acquired; we are unsure whether a thinking enemy can disperse to avoid catastrophic loss
- we need field data, & the judgment of teams which call in fires (e.g., 1st Recon is 30 minutes from Irvine)

F-11

Using field data about. movement rates and dimensions of units, models such as the TTT can deploy and move (at up to 10:1 speed) the friendly and enemy forces. Such runs have yielded slightly more than three fire missions called per day per team in close terrain. These are not evenly distributed. Some units make no interaction with the enemy; others make multiple calls when they encounter a large unit and acquire multiple sightings over an hour or so.

Seeing (detecting) the enemy is commonplace. Correlating the sighting with a particular size enemy unit is not (yet) done. There are many targets to shoot at; most are small and fleeting. If fires are applied as targets appear, the enemy will be kept under pressure. If the enemy is mounted, the crossover point between attrition and damage sufficient to prevent the unit's mission can probably be determined. If the enemy is infantry, the teams will quickly develop a sense for when they have encountered a large unit (or when they have approached a hornet's nest). But this will be a judgment call with scant quantitative parameters. Over time, say, two days to a week, patterns will emerge which the Combat Operations Center should be able, with expert military judgment, to analyze.

Description of Tactical Training Tool

- TTT is a PC-based, C++ language simulation at the strike team level, accommodating up to 70 teams & dozens of enemy units.
- Animated movement and size dimensions result in detections and calls for fire, which may be accommodated by air, artillery or naval guns.
- Video of targets is shown so the user can determine what types and amounts of fire to call

F-12

TTT focuses upon small unit mission performance across the battlefield - the interactions of dozens of small units with the enemy, and the C3 and supporting fires. Over the past two years, many officers with combat experience have contributed recommendations for identifying the variables most critical to small unit mission success, TTT has a combat experience base - the records of 8,000 patrols of Operation Stingray and the Army Long Range Patrols (LRPS), direct precursors of this DSB.

Military users can change the values assigned to those variables most critical to small unit performance, if the model default settings are judged wide of the mark for the particular terrain and expected enemy CONOPS.

Data on fire missions and engagement zones are reviewed on an ongoing basis by 1st Recon Bn (CA) and 5th Force (WESTPAC); in their deployments worldwide, they are close to the realities of terrain, movement and fire support. They also are providing the field video footage, such as shown in the brief to the DSB on the nature of a firefight.

General Observations from Simulations and Historical Experience

- Basic characteristics of a battlefield: a) Terrain, Open or Close(wooded or urban); b) Formations, Linear or Nonlinear; c) Forces, Platform-intensive or Non-platform.
- US. optimized for Open, Linear, Non-platform warfare. We are well prepared to destroy platforms.
- Strike Teams or Combat Cells major added-value may be in Close/Urban, Non-linear, Non-Platform warfare.
- We cannot prepare only for the type of wars we prefer to fight. In two of the past three wars - Korea & Vietnam - platforms were not the problem.

F-13

Confronting scattered forces in urban or covered terrain offers no opportunity to synchronize divisions and sweep forward. General Shalikasvili, Chief, Joint Chiefs of Staff, envisions US ground units operating independently on the contiguous battlefield. The size of our independent units will depend on density, terrain and mission; there is no reason to send battalions or companies in tight formations if the enemy offers elusive or non-existent centers of gravity.

Combining technology with self-confidence and training, we have to prevail rapidly and with few losses, sending our units against forces of larger size which are hiding, striking and hiding again. To support our units, we must fires as we maneuvered forces in Desert Storm.

Observations (continued)

- In Close Terrain Simulation, of the 70 Strike Teams deployed (vs. 6,500 dispersed troops) 49 reported sightings averaging 10 enemy. (Vietnam average Stingray Call For Fire -CFF- was against 8 enemy troops.) TTT responded with 20 rounds to the average CFF, less than the Joint Munitions Effectiveness Manual suggests. Nonetheless, this resulted in 248 artillery missions. How to service a multitude of Non-Platform targets, especially troops , if artillery is not on the battlefield, is a tough issue.
- Strike Teams survive by stealth & average 700 meters/hour when enemy nearby. TTT did not model vehicular mobility. If the battlefield becomes more transparent to opposition forces through IR detections etc., the teams will come under added pressure.
- Training, team confidence & team leadership cannot be exaggerated. A 3-day patrol equals running 3 marathons, with an 80 LB.. pack, under stress, sometimes in fear.

War in the air or at sea stresses detecting the opposing platform, and killing with precision shots. In the air and on the sea there are few targets and fewer places to hide. The maxim is: What is seen, can be hit. Hence DoD emphasizes the fusion of sensors and precision strike from the air throughout a 200 kilometer 'transparent battlefield'.

Unlike air or sea combat, land war features many targets and innumerable obstacles. Earth, trees and buildings are not currently transparent. When the battalion is the core maneuver unit used to uncover the enemy, the troops are exposed. While the compensation is superior firepower at the point of attack, the first blow often rests with the opponent. On land infantry survive despite being seen frequently for short periods - seconds to minutes - because they take cover before rounds are brought to bear. If indirect fires could better supplement hand-held weapons, in many situations the troops would not to provide a firing line or a base of fire which draws return fire and return casualties.

Observations (Continued)
Cell Survival: Stingray Patrol Experience in Vietnam

- Of 8,000 Vietnam patrols, only about 10% were compromised & engaged in firefights
- That experience yielded basic rules:
  - First, stealth is key to survival; stealth works
  - Second, carry enough firepower, smoke & gas for a ferocious, short-term self-defense
  - Third, pre-plan extraction (fires, helicopters & troops)
  - Fourth, after extraction retaliate massively against the zone; it deters future attacks. Never fight fairly.

Casualties in Recon were lower than in the infantry.

F-15

Cell survival depends heavily upon the terrain, enemy density & aggressiveness. The precedent of 8,000 Stingray patrols in Vietnam is illustrative. The jungle provided such cover that less than 10% of Stingray patrols were compromised. (But Recon was not sent into absurd situations, either. For instance, at Khe Sanh, the enemy were so thick Recon couldn't get beyond the wire. So commonsense has to dictate where one sends small teams. But on a non-linear battlefield in Close Terrain - as distinct from the open desert - a well-trained team should be able to move and not be compromised.)

So the first rule is stealth. This requires arduous training and goes against the basic American fighting style of massing & employing devastating direct fires. One cannot move, say, a battalion with stealth. It is simply too large. So there is a tradeoff in training time, in doctrine, in SOPs, in mind-sets between tactics which rely upon battalion-sized maneuver & the Combat Cell concept.

The second rule of survival is to carry enough organic firepower & obscurants (smoke) & impediments (gas) to - if engaged - lay down a heavy volume of fire while running away. Usually the enemy is not expecting to find a team, and is disorganized, allowing escape from the immediate area.

Third, it goes without saying that pre-planned Final Protective Fires, helicopters & troops are standing by for an emergency extraction.

Lastly, smashing up the locale after the extraction gradually convinced - at least in the Vietnam case- some enemy that it was better not to press a Recon team, even if spotted, too closely, because the bombs came after the team left.

Observations (continued)

- 3 sightings of enemy units per 24 hrs. not uncommon.
- With proper Intelligence Preparation of the Battlefield, the essential quantitative parameters for TTT simulation (# of Teams, patrol boxes, projected Calls For Fires (CFFs), fire support systems, TRAP & exploitation forces) can be reasonably projected.
- For instance, in the 15-25 July GLOBAL game, 40 officers organized as a JTF staff. Using the TTT, they deployed 30 Strike Teams, joined by UAVs & helicopters in Open Terrain in a 100 x 100 km box. Mission: find & destroy mobile missiles dispersed among 2 mechanized divisions. Of the first 33 CFFs, the CJTF decided to place fires on three Hi Payoff Targets.
- The point is observed CFFs will easily be 5 to 10 times more numerous on a per unit basis than in past battles. **F-16**

The preeminent military historian, John Keegan, believes the era of linear warfare with draftee armies began with Napoleon and ended with Desert Storm a short period in military history. Pitted against modem technology, the Iraqi army was fodder. Manpower in trenches and platforms without air defenses counted for almost nothing, quite different from World War I, World War II and Korea.

At the same time, the West has done away with the draft and eschews casualties. What does this mean? To Keegan, it signals a return to what he calls "warriordom". The enemies the US has to beware of are:

"warrior peoples - Somalis, Chechans, Serbs - who live in harsh surroundings almost inaccessible to outsiders...Hardness makes for hardness of spirit and cruelty - neither asking for nor giving quarter - and contempt for the world beyond... With the West disarming and the young not wanting to serve, the of mass warfare is over. Small nations with a large military opinion of themselves take on a new significance.

"To defeat them, the West must depend on selectively-recruited units that cultivate a strong warrior spirit themselves, exclusive, proud, fierce. To prevail they must be flexible, adapting to modem technology."

Observations (continued)

- Difficult to specify the full dimensions of enemy units. Team usually reports only a portion of an enemy unit. Managing CFFs by writing a list of "priority targets" may not suffice because targets are not that distinctive.
- Teams, like fighter pilots, vary substantially. Digital CFFs give no clue who are Team "aces". Deciding which CFFs deserve expensive fires will be as much art as science.
- Prior combat suggests exploitation forces to finish an enemy unit after it has been hit hard by the Teams & before it can regain cohesion. Massing fires must be tied to decisive operations.
- If a Forward Operating Base is nearby (<50 km), heavy, inexpensive volumes of arty can respond to most CFFs.
- If fire support comes from > 100 km, times of one minute to decide, one minute for fire systems adjustments and time of flight of 3 to 5 minutes should be goals attained before 2010.

Where Analytical Work Needed at Tactical Level

We need to be careful about inferring too much from simulations like the TTT. We need more real field data, as cited below:

1. Movement rates without compromise in different terrain (ask Recon, SF, & SEAL Teams to provide these data)

2. Typical fields of observation found in those terrain

3. Enemy tactics as reflected in movement parameters

4. Actual times from Call For Fire to rounds on target for different weapon systems

5. Actual dispersal and lethality patterns (Aberdeen), and how location accuracy of an Forward Observer (FO) with GPS changes the recommended number of rounds for a given target set.

Tactics & Techniques of Combat Cell

What We Have Learned

- Team tactics for survival work
- Teams achieve high fire accuracy with new technologies: GPS, rangefinders, fast communication, night & laser designators
- We can mass fires, not forces

What We Need to Learn

- Merging Combat Cells into CJTF CONOPS - contingencies where they are -& where are not - applicable
- Managing fire support when hundreds of CFFs pour in
- If long-range (>100 km) fires can provide timely support without artillery & associated logistics on the battlefield

Technology now enables the infantry to stand off & strike. That fundamentally changes the basic imperative to close with the enemy.

The DSB has heard and seen enough data to be assured that the Cell or team can survive. Stealth does work in most terrain, and there are ample precedents and ongoing operations.

Similarly, high accuracy is being achieved - first round Fire For Effects. This is the major difference technology has brought. No longer are indirect fires area weapons only.

With training and thought, we can mass fires as we now mass forces; indeed, we can mass the fires with fewer forces exposed.

This concept, however, has yet to be merged with Joint Task Force (JTF) or CINC contingency planning, except on a Special Operations level. We are looking at a broader application, and that will take time to work out.

How fires are allocated when there are hundreds of Calls For Fire and the targets are moving and not fully identified as to type and size will be a challenge. This is compounded because the battlefield is non-linear and may not be divided into geographic sectors, which has been a prime way of dividing fires.

Lastly, if artillery is on the battlefield, it requires large logistics and leads to a large footprint. But if arty is not on the battlefield, it is not clear whether long-range fires will be adequate and timely enough to be an acceptable substitute.

On balance, technology does enable our infantry to stand off and accurately strike. We must take full advantage of this basic change.

ENEMY COUNTERS

- MAY TAKE 30 DAYS OF WAR BEFORE AN ENEMY LEARNS HOW TO REACT
- PRECISION NAVIGATION & LOCAL-AREA CONNECTIVITY FOR SITUATIONAL UNDERSTANDING ARE THE TECHNICAL KEYS TO THIS CONCEPT
- NAVIGATION COUNTERS, ESP. GPS, ARE BEING WELL ADDRESSED ELSEWHERE
- CONNECTIVITY WILL BE DEBATED IN TERMS OF SECURITY VS. COST
- THAT IS THE SUBJECT FOR ANOTHER FORUM

ON BALANCE, THE US. CAN EMPLOY COMBAT CELLS; NO ENEMY CAN, & NO ALLY CAN. WORKING WITH ALLIES WILL BE AS GREAT A CHALLENGE AS COUNTERING ENEMY TACTICS.

F-19

Learning curves in war take time. This Combat Cell concept so changes our style from Desert Storm that it would probably take the next adversary by surprise. It is not unreasonable that 30 days of fighting would pass before the enemy had digested what was happening and devised counters.

The Combat Cells cannot mass fires without precision navigation. GPS is the key. Fortunately, that is widely recognized and there are adequate working groups addressing that subject.

Connectivity is a different story. We are focused on local connectivity - among and from the teams up and back to the supporting infrastructure of UAVs, intelligence, C3 centers and fires. There will be a debate about the degree of security needed vs. the costs. A separate working group is needed to address that broad subject.

On balance, there appears no adversary could fight in this style, nor adequately counter us. However, by the same token, it appears no ally or coalition partner has the wherewithal to equip and train its forces to share such a non-linear battlefield with us on equal and fully coordinated terms. We will have to come to grips with this. It may not be particularly difficult tactically; (in Desert Storm, it was handled by allocating separate geographic sectors.) But it will be a problem in alliances such as NATO, with joint exercises & a stress on interoperability. We just have to recognize that fact.

Technologies Needed for Dismounted Combat Cell

- INSERT Low Observable Rotary, 150 mi. range, 300 knots
- NAVIGATE 1 meter location in jungle or urban
- SURVIVE Stealth for man (cloth armor, infrared shield, etc.)
- UNDERSTAND SITUATION Sensors & UAVs at cell level
- CONNECT Long-range, 10 lb. voice & text radio & computer
- DECIDE (C2) A procedural issue, not technology
- TARGETING Suite of designators for cells
- FIRES >100 mi. range, <8 min to target, especially anti-personnel.

MOUNTED CELL ADD-ON

- MOBILITY 1500 lb. payload, 100 mi. range vehicle

URBAN ADD-ON

F-20

- SURVIVE Robots, direct blast weapons & robust non-lethals

Lists such as cited above reasonably reflect what those who specialize in this form of warfare are requesting.

INDIRECT FIRE EQUIPMENT SUITE
PROVEN & AVAILABLE TODAY

- COMM - PRC 117 VHF/HF/UHF/SATCOM Delta Harris Corp. $34,100
- DESIGNATORS - SOFLAM laser sparkler day/night McDonnell Douglas $18,000
- TORCH infrared $3,000
- Laser rangefinder COTS $4,000
- GPS units (2) COTS $1,000
- SELF-DEFENSE - Thermal detector hand held $2,000
- Other --Silencer $1,000; caseless ammo $1,000; inter-team VHF COTS communication $1,000; smoke & CS $1,000; individual load bearing $1,000
- TOTAL $67,100

F-21

Currently, the infantry does not have the equipment for multiple, simultaneous stand-off attacks. A battalion may have three Forward Air Controllers (FAC) and four FOs qualified and equipped. These numbers have not changed appreciably in 50 years. Instead, every unit capable of independent patrolling - at least 40 squads in a typical battalion - should be trained to call in fires immediately - within two minutes - and should be equipped with a laser rangefinder and target designator, thermal scope, night vision scopes, GPS and light, reliable communications which can reach all supporting arms, including air.

The cost of the target designation equipment cited above is $50,000 and $75,000 per unit - $100 to $200 million in all - equivalent to three modem aircraft. The price is low because the US has only 1,900 non-mechanized infantry squads.

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Section V
"Task Force Griffin Final Briefing Report?,
September 1996
TRADOC Analysis Center, Fort Leavenworth KS

Volume 2, Part 1,
Task Force Griffin

TRADOC ANALYSIS CENTER SUPPORT OF THE 1996 DEFENSE SCIENCE BOARD SUMMER STUDY

TASK FORCE GRIFFIN
Final Report

September 1996

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TASK FORCE GRIFFIN

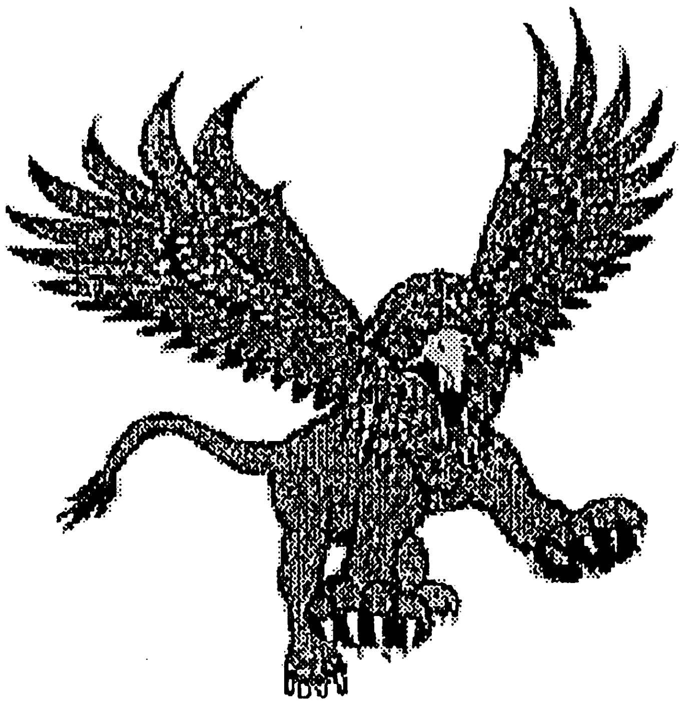
This scripted briefing describes the analysis conducted by the TRADOC Analysis enter (TRAC) in support of the Defense Science Board (DSB) 1996 Summer Study which focused on tactics and techniques for military superiority in the 21st Century. Specifically, TRAC examined the concept of a relatively small force that is rapidly deployable, specially equipped, trained and supported by a suite of remote sensors and precision weapons and able to accomplish missions that have been previously possible only with larger massed forces.

TRAC developed a relatively small, potentially lethal unit concept that was titled "Task Force Griffin." Exploiting stealth, speed and strike capabilities, this unit was designed to provide a rapid reaction, early entry, area denial force to the 21st Century Army and serve as the "tip of the spear" for more conventional forces. As is portrayed in subsequent slides, Task Force Griffin is organized around rapidly-insertable teams that can employ a redundant suite of sensors to gain unprecedented situational awareness and that can access a suite of remote weapons to indirectly attack enemy targets with precision. The capabilities of this force are further enhanced by the presence of an integrated aerial sensor-shooter platform that can both detect and engage enemy targets.

The Griffin was selected as a symbol for the force, an analytical rally-point. A mythological creature that is half lion and half eagle, the Griffin embodies certain key design characteristics intended for the force. Keen sensors, rapid air and ground mobility and the ability to strike both on the ground and from the air not only define the Griffin, but are also essential to the success of the Task Force.

TASK FORCE GRIFFIN

An analysis of a small, potentially lethal unit that exploits stealth, speed-and-strike capabilities to provide a rapid reaction, early entry, 'tip-of-the-spear' to the 21st Century Army, circa 2015 and beyond.



"The eyes and wings of an eagle, the speed and strike of a lion"

TRAC STUDY EFFORT

The Study and Team represented a combined effort by analysts and Janus garners from TRAC-Ft Leavenworth and TRAC-WSMR. LTG John Miller, the TRADOC Deputy Commanding General, not only served as the study sponsor, but also provided a commander's perspective for many of the operational concepts examined in the analysis.

The analysis was a short-term, quick-response effort. TRAC was advised of the concept for analysis in late June and immediately initiated several concurrent efforts. Certain study team members began to develop the concept of the force to be examined and the scenario in which to exercise that force while others began to review and modify the existing Anti-armor Requirements and Resource (A2R2) Study database to serve as a baseline for the analytical effort. This particular database was selected because it modeled a force in the year 2015 and, hence, already captured many relevant future force capabilities. As is defined in subsequent slides, three versions of the proposed force were examined in order to gain a full appreciation for the capabilities and limitations of the force. It is critical to recognize, however, that operational insights concerning this force were derived not only from the Janus gaming effort but also from the qualitative analytical effort of every team member and the professional insights and thoughts generated during the series of in-progress reviews (IPRs) conducted with GEN (R) Maddox, LTG Miller, MG Scales, the TRADOC Deputy Chief of Staff for Doctrine (DCSDOC), and other members of the TRADOC staff.

A final briefing was presented to the Defense Science Board on 9 August. Selected slides from the briefing were then incorporated into the Defense Science Board's brief to the Secretary of Defense on 16 August. Those selected slides are contained in Appendix A.

TRAC STUDY EFFORT

LTG John Miller - TRADOC Deputy Commanding General and Study Sponsor

TRAC Study Team

Fort Leavenworth, KS
- COL Steve Kirin, Study Director
- Mr. David Fuller
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- Mr. Barney Watson, Gaming Support
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  - Mr. Ronald Saylor
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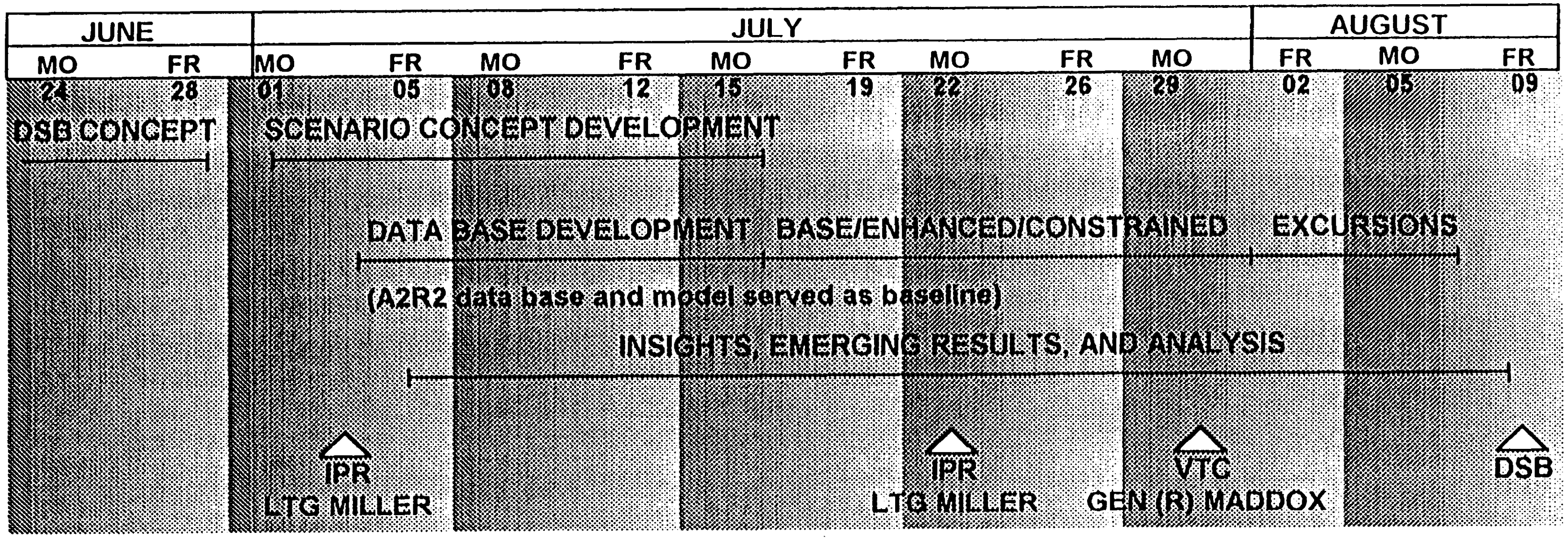
  - Mr. James Wittwer
  - Mr. Scott Huskey
  - Mrs. Susan Galloway
  - SSG Chris Augustine

Milestones/Schedule



AGENDA

The briefing is organized into three sections. First, a traditional G2 brief is presented that discusses the enemy, terrain and other conditions that define the situation.

Second, a G3 brief is provided in which we discuss Task Force Griffin's organizational and operational concepts. In this section, we detail the structure of Task Force Griffin as well as the tactics and techniques employed by that force. The mission statement and commander's intent that defines the expectations for Task Force Griffin in this particular scenario are also defined.

Finally, the scenario, its underlying assumptions, and the results of the analysis are examined in greater detail. The briefing concludes with a presentation of certain analytical and operational insights.

AGENDA

Situation

a. Terrain Orientation
b. Road to War
c. Enemy Operational and Organizational Concept

Task Force Griffin Organizational and Operational Concepts

a. Task Force Structure
b. Operational Concept

Analytical Effort

a. Scenario
b. Assumptions
c. Base-Case Results
d. Comparative Analysis
e. Pink "Audible"
f. Emerging Operational Insights

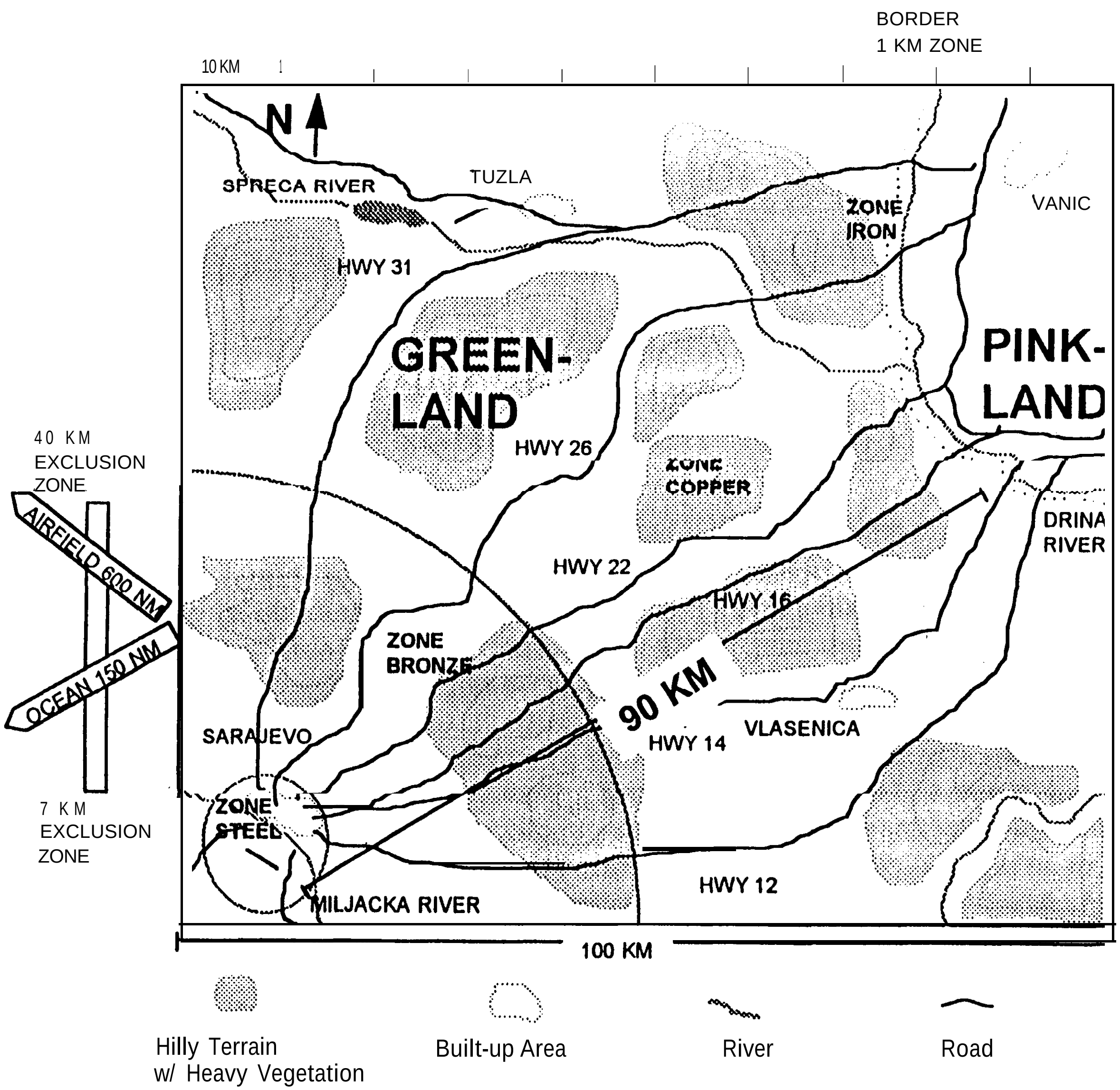
TERRAIN ORIENTATION

The terrain selected for the scenario is based in a fictitious country Greenland, represented by the hilly, heavily-forested terrain of Bosnia.

Several operational considerations are apparent. First, the area of operations is within striking distance of both naval and air assets that may be located in the Adriatic Ocean and from air bases in neighboring allied countries. Second, the area of operations is quite large, measuring 100 KM by 100 KM. This provides an appreciation for the capabilities expected of Task Force Griffin. Third, the rugged terrain creates certain disadvantages for a heavy mechanized force as it offers only limited, distinct avenues of approach with clearly defined engagement areas. On the other hand, this terrain presents significant advantages to a dismounted or insurgent force.

Several "zones" are depicted on the map that actually support friendly force operations, but also serve as a means for orienting the reader to the terrain. Zone Steel, with a radius of 7 KM, includes the area immediately surrounding the airstrip. Zone Bronze, with a radius of 40 KM, is an exclusion zone that, once cleared, would prevent attack on the airfield by indirect fire. Zone Iron is a 1 KM no-movement, exclusion zone along the Green-Pinkland border that is designed to eliminate unauthorized traffic within this critical region. This border region is approximately 90 KM from Zone Steel. Lastly, Zone Copper encompasses the remaining portion of the area of operations.

TERRAIN ORIENTATION



WEATHER

January, European, early morning with 5 KM visibility.

TERRAIN

- All rivers are fordable except the Drina River. Six crossing sites currently span the Drina River.
- Main roads run northeast to southwest. Highways 12, 14, 16, 22, 26 and 31 are high-speed avenues of approach from Pinkland to Sarajevo.
- Off-road trafficability supports heavy vehicles.
- Airport in Sarajevo can support C-130 and C-17 operations. Small airstrip vicinity Tuzla can not support military transport aircraft.
- Terrain is extremely hilly with heavy vegetation. This significantly limits line-of-sight.

ROAD TO WAR

The next two slides capture the key events that lead to conflict within the region. It is important to recognize that there are several potential protagonists. First, Greenland is the host nation that is attempting to establish an independent government but does not have adequate military forces to impose control over the entire country. Second, the Red faction within Greenland is dissatisfied with the actions of the Greenland government and is intent on undermining that organization. The Red faction, which is primarily a poorly equipped, low tech insurgent force that is active only in the vicinity of Sarajevo and the countryside to the northeast of Sarajevo, has initiated aggressive, subversive actions against the Greenland government and has ignored several UN peace initiatives. Third, Blue responds to a request from the UN and deploys Task Force Griffin as the lead element of a Joint Task Force. It also initiates the deployment of the remainder of the Joint Task Force to include both naval and air assets. Finally, Pinkland desires to reassert itself as the regional hegemonic power and seems to be looking for potential opportunities to exploit the instability in Greenland. Pinkland's military consists of heavy mechanized forces and, in fact, one heavy mechanized division is currently staged approximately 40 KM from the Green-Pinkland border.

ROAD TO WAR

- As Pinkland hegemony eroded, Greenland achieved independence and elected a majority Green government.

- The Red faction within Greenland disputed the elections and initiated subversive actions to discredit the elected government. The majority of Red's support is concentrated in the Northeast and Sarajevo regions. Up to 25 percent of the population in those areas support Red. There has been no observed Red activity in the other regions.

- Red has ignored UN diplomatic initiatives, continued aggressive actions and repeatedly crossed the Pinkland border to steal supplies.

- Greenland has no standing military and its internal police force is only capable of maintaining order in the capital. Greenland has requested UN support in reestablishing order.

ROAD TO WAR (cont.)

Text on previous slide.

ROAD TO WAR (cont.)

- Red has recently taken credit for a rocket attack on a Sarajevo market place that killed six civilians. They have also openly publicized a recent attack on two Greenland police vehicles.

- The UN has requested Blue to take the lead to reestablish order. Blue has deployed Task Force Griffin to Greenland and has initiated the deployment of the remaining elements in the Joint Task Force, to include air assets to bases in neighboring countries. A Carrier Battle Group (CVBG) is on station approximately 150 NM from Sarajevo.

- Pinkland desires to regain regional hegemony, deny Blue a larger regional role and reestablish Greenland as a buffer. Pinkland has threatened to invade Greenland if incursions continue and has positioned forces in the vicinity of the Greenland border.

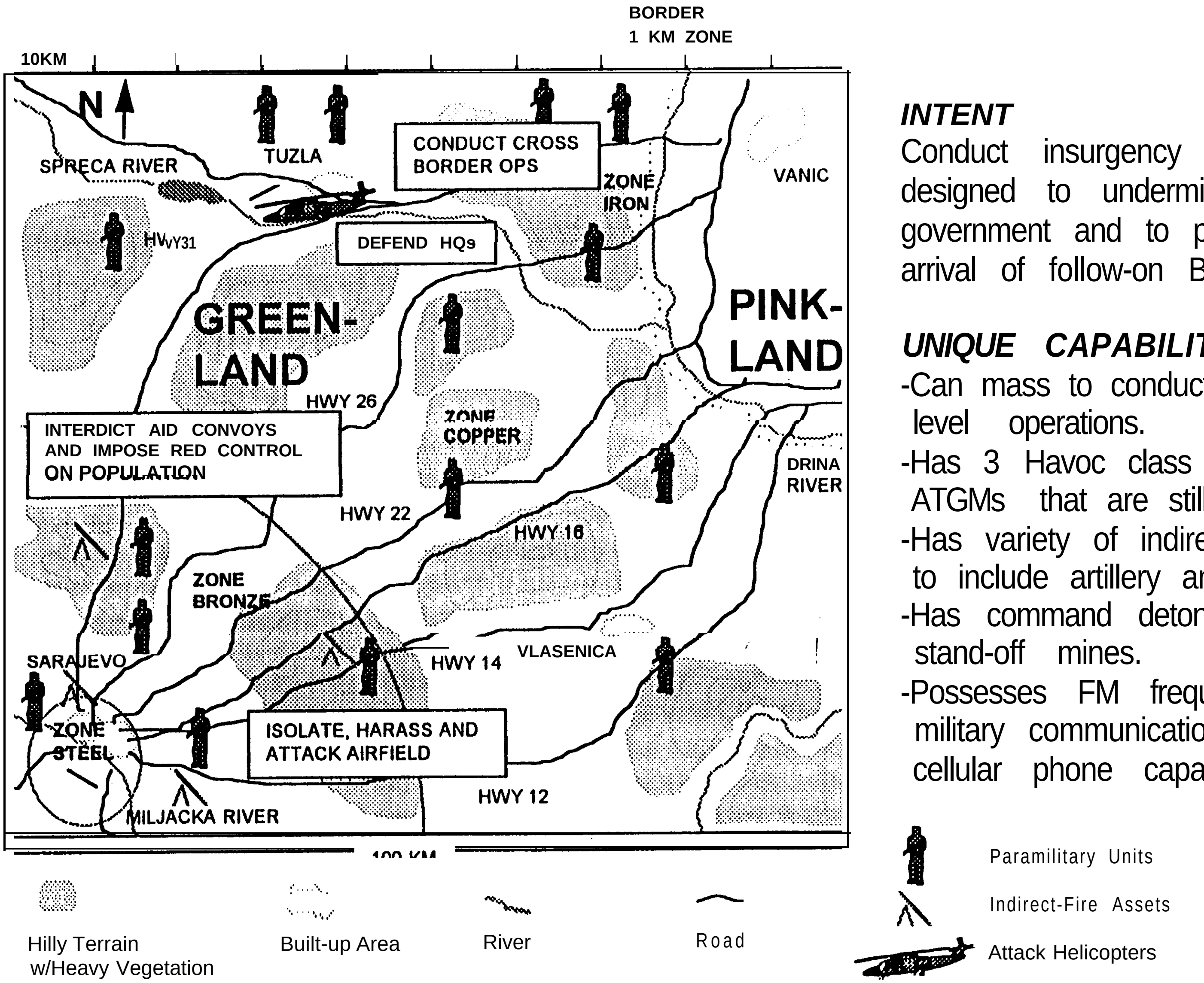
- Pinkland has closed all border crossings with Greenland.

RED PARAMILITARY OPERATIONAL CONCEPT

The next set of slides defines the Red and Pink force structures and operational concepts. As already mentioned, Red is intent on undermining the Greenland government and there are several typical Red activities to achieve that intent. These activities include isolating and harassing the airfield at Sarajevo, attempting to impose control on the Greenland populace, and conducting cross-border operations into Pinkland. These latter operations are designed to obtain supplies and logistical support for the insurgents operating throughout the Greenland countryside. These cross border operations are a significant threat to stability in the region. Pinkland has on several occasions publicly announced that they will not tolerate continued raiding operations.

Although primarily low-tech and poorly equipped, the Red insurgents do have several unique capabilities. First, they have three Havoc class helicopters which are known to exist by Blue but remain undetected posing a potentially significant threat to any organization executing a peace enforcement mission. Although undetected, those helicopters are suspected to be based in the Tuzla area. Second, they have relatively sophisticated communications capabilities which include military-type, frequency-hopping radios and cellular telephones. Finally, they have a variety of indirect fire assets, to include rockets with portable launchers, that are difficult to locate in the hilly, forested terrain.

RED PARAMILITARY OPERATIONAL CONCEPT



INTENT

Conduct insurgency operations designed to undermine Greenland's government and to preclude the arrival of follow-on Blue Forces.

UNIQUE CAPABILITIES

-Can mass to conduct company-level operations.
-Has 3 Havoc class helicopters with ATGMs that are still undetected.
-Has variety of indirect-fire systems to include artillery and rockets.
-Has command detonated and stand-off mines.
-Possesses FM frequency hopping military communications and a cellular phone capability.

RED PARAMILITARY ORGANIZATION

The total Red insurgent force includes approximately 720 active guerrillas, approximately 10,000 sympathizers who provide an excellent intelligence network but who are not expected to bear arms, and some 1,200 militia supporters who provide logistical support and who would participate in defensive operations to protect their villages. These forces are active primarily in the Sarajevo region and the Northeast region and, in fact, there has been no organized Red activities detected outside these two regions. These figures represent the expected strength of the Red insurgents as Blue forces begin to arrive in country. The Red insurgent effort has already suffered some losses, particularly in the Sarajevo region, as the Greenland police force continues to attempt to maintain peace in the region.

The slide highlights typical equipment that might be found in a Red platoon although there are no formal tables of organization for these units. It is interesting to note that there is a chain of command available which would facilitate the coordinated massing of subordinate Red units in order to conduct company level operations.

RED PARAMILITARY ORGANIZATION

Red Land Liberation Front

- **Sarajevo Region**
  - 140 Men
  - 30 Men
  - . . .
  - 9 Men
- **Northeast Region**
  - 220 Men
  - 50 Men
  - . . .
  - 15 Men
- **Southwest Region**
- **Northwest Region**
- **Southeast Region**

NO ORGANIZED RED GUERRILLA ACTIVITY IN THESE THREE REGIONS

TOTAL ACTIVE RED GUERRILLA FORCE IS ABOUT 720

EQUIPMENT/BN

18 Howitzers
22 122 mm Rockets
4 Stand-off Mines
3 Havoc class helicopters with ATGMs

EQUIPMENT/PLT

2 Trucks
1 SA-XX w/FLIR and 2 RDS
1 RPG W/ 2 RDS
1 SVD with TWS
1 Command Detonated Mine
1 RPK
1 82mm MTR
3-9 AK-74
7-13 PVS-5

-Approximately 10,000 Sympathizers in Both Regions
-Sympathizers Are Unarmed Supporters Who Serve As an Intelligence Network for the Red Paramilitary

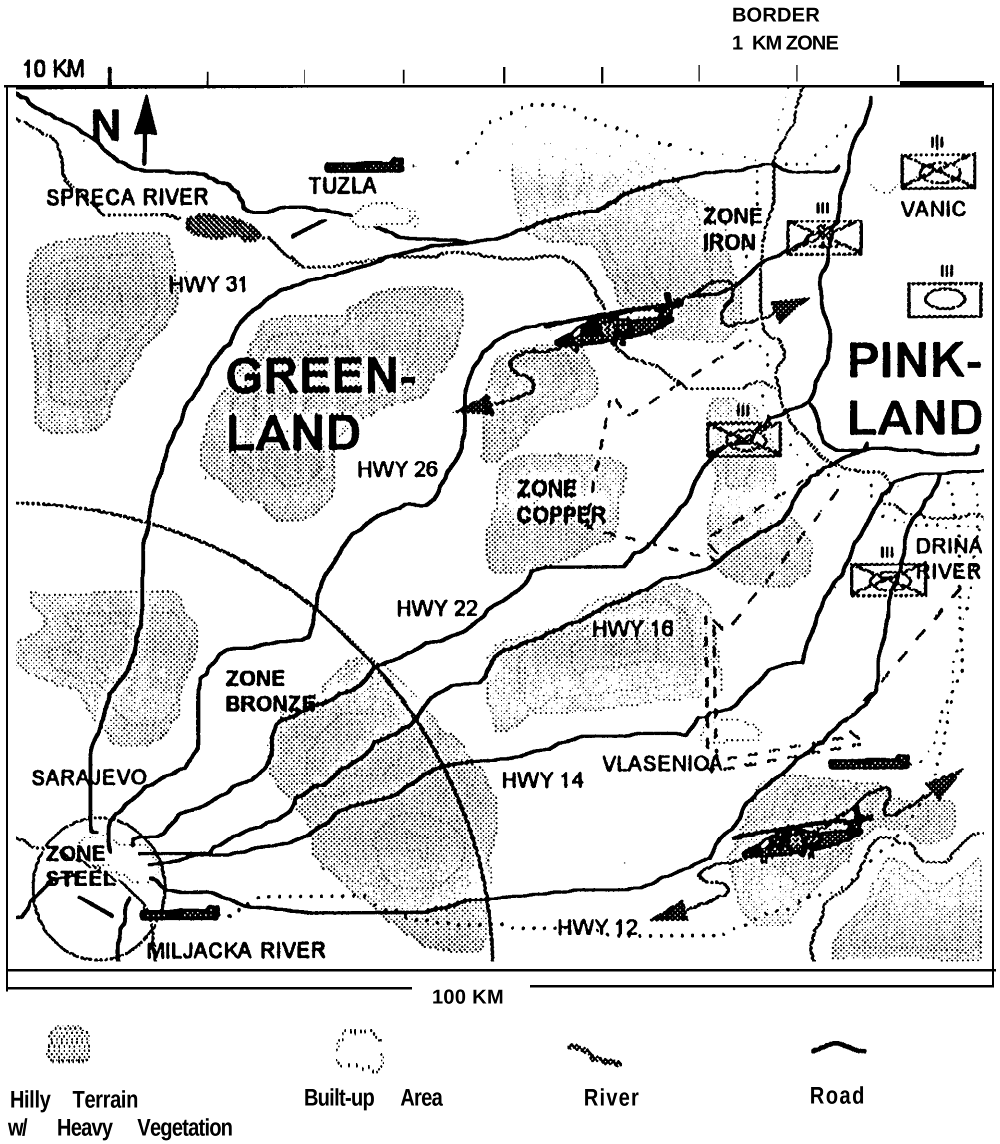
-Approximately 1,200 Militia Support Sarajevo and the Northeast Region
-Militia Are Armed Supporters of Red Paramilitary Who Will Actively Provide Logistic Support and Limited Defensive Operations

PINK OPERATIONAL CONCEPT

Pinkland is equipped with heavy mechanized forces and, in fact, has a division positioned approximately 40 KM from the Green-Pinkland border while other forces are moving to the border region. Pinkland also has certain unique capabilities. They have invested in relatively low cost cruise missile technology and have 11 missiles available to support potential operations into Greenland. They have also invested in the ability to jam the linkage between airborne UAVs and their attendant ground stations. These capabilities are of significant concern to a Blue force that is heavily reliant on relatively vulnerable indirect fire systems and UAVs for sensor information and situational awareness.

It is suspected that if Pinkland attacks, the main effort will proceed along Highways 12 and 14 since these provide the most direct, rapid routes to Sarajevo. The supporting effort is expected along Highways 16 and 22. A motorized rifle regiment would lead both the main and supporting attacks, while available aviation assets would attempt to provide protection to those lead elements. A third motorized regiment is expected to follow the main effort with a tank regiment remaining poised to exploit success along either avenue of approach.

PINK OPERATIONAL CONCEPT



INTENT

- Pinkland has positioned forces 40 KM east of the border. They will attack if they:
  a. Suspect stronger Green-Blue diplomatic ties.
  b. Can exploit continued instability in Greenland.
- Pinkland may use continued Red cross-border incursions as an excuse for offensive operations.

UNIQUE CAPABILITIES

- Modified heavy OPFOR w/T-90s, BMP-2s BM-22s 2S19s, 16 Havoc class helicopters with ATGMs.
- Has invested in certain niche technologies to include cruise missiles and anti-UAV capability.

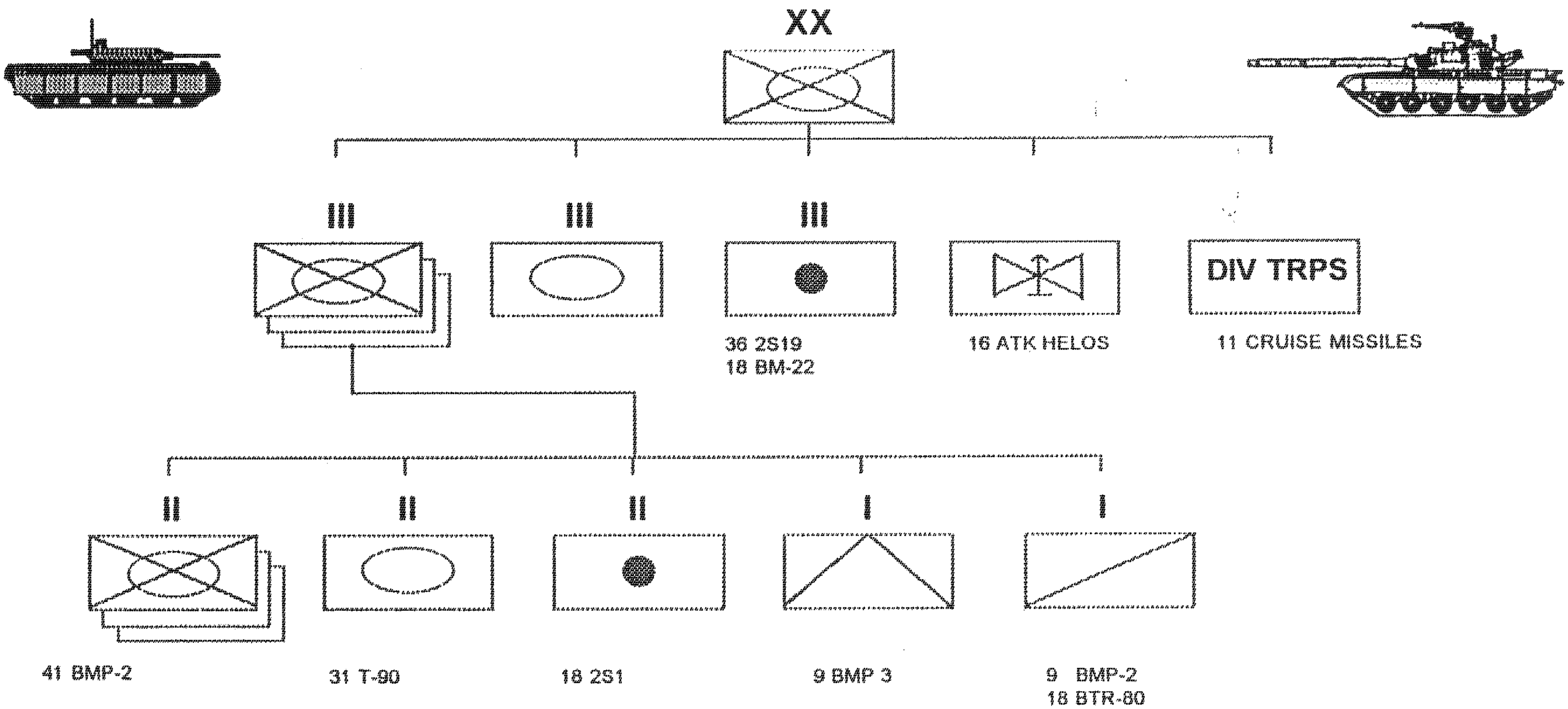
PINKLAND MILITARY FORCE

As already mentioned, the Pink force that is immediately posed along the border consists of a motorized rifle division with three motorized rifle regiments, one tank regiment, and supporting artillery and aviation assets.

The specific combat assets available to the regiments within the division are shown in the following chart.

	MRR	MRR Recon	TR	RAG	ADA	Atk Helos
T-90	31		94			
BMP-2	123	9				
BMP-3	9					
2S1	18		18			
2S19				36		
2S6	12		6		6	
Havoc						16
BTR-80		18				
BM-22				18		

PINKLAND MILITARY FORCE



AGENDA

Given this situation, we will now review the organizational and operational concepts of Task Force Griffin.

AGENDA

Situation

a. Terrain Orientation
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TASK FORCE GRIFFIN
A Force for 2015 and Bevond

The charter of the Defense Science Board was to examine how to make rapidly deployable forces that exploited "theater-wide situation awareness, effective remote fires and a robust interconnected information infrastructure" more potent: Task Force Griffin was designed to embody these qualities and to achieve the desired potency.

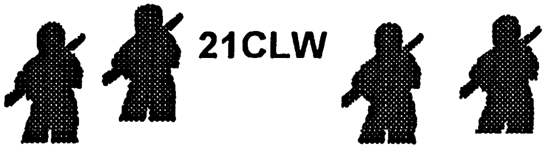
We built the Task Force from the ground up, starting with an organizational structure that permitted the unit to field dispersed combat teams that could rapidly move around the battlefield but retained the necessary hierarchy to mass when necessary. These teams could respond to a variety of missions to include both peace enforcement and peacekeeping operations as well as certain combat operations. As we developed this concept it became clear that such a force would not be able to eliminate the need for other conventional forces but, rather, what we developed was a complementary capability that could be used as the "tip-of-the-spear" in situations that required more conventional forces. In fact, we examine just such a case as we continue through the analysis.

There are three essential enablers underpinning the potency of Task Force Griffin. First, the force relies on a 'living internet' to provide each member of the force with an unprecedented level of situational awareness. Each combat team is linked to that internet through a redundant suite of sensors that increase in capability from a micro-UAV with short range and limited loiter time at the team level to those national assets that can be made available to support the Task Force's operations. Within the Task Force, there is a Battlefield Integration Cell that insures that the fused intelligence is constantly available to every member of the Task Force.

Second, the Task Force is dependent on long-range precision fires to attack identified targets. Those teams that are dispersed on the battlefield are not expected to become engaged in a direct fire battle but, instead, rely on remote fires to eliminate the enemy threat. Each team is expected to exploit its organic mobility to stay 'at arm's distance' away from the enemy force, to move as necessary to retain surveillance of the enemy and to always be in position to direct precision munitions on identified targets. Numerous sources, to include land, air, sea and space assets can conceivably provide the precision indirect fires required by these teams. We, in fact, examine the utility of an armed UAV as a potential source of such support. The key to the potency of the force is not the source of the fires but the responsiveness of the fires provided.

The last enabler is the utilization of alternative power sources that provide several benefits. It reduces the logistical infrastructure needed to support the force and we can focus on deploying more tooth than tail into the area of operations. The dispersed teams can remain hidden in forward deployed positions for a longer period of time without requiring resupply. As teams move around the battlespace, they are no longer constrained by a tether to a logistical support train.

TASK FORCE GRIFFIN
A Force for 2015 and Beyond

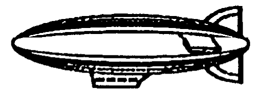


21CLW

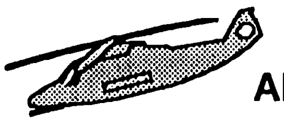
Versatile force that can respond to all missions along the operational continuum. Designed to operate with ***widely dispersed teams*** but ***capable of massing*** when necessary to execute missions including show of force, crowd control, etc. As an ***ear/y-entry*** force it can demonstrate US resolve but it is also capable of ***shaping the battlespace*** for follow-on general purpose forces.

MICRO, MACRO, HAE UAV

Digitized force that employs a ***redundant suite of sensors*** to achieve information dominance and ***situational* awareness.** Employ ***battlefield integration ce//*** at appropriate headquarters to coordinate sensor suite and attack systems.

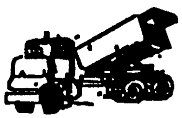


AEROSTAT

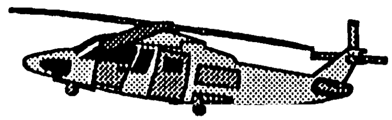


AP-15

Lethal force that ***avoids direct-fire engagements.*** Employs advanced sensors, organic mobility and enhanced indirect-fire systems to identify and destroy the enemy.

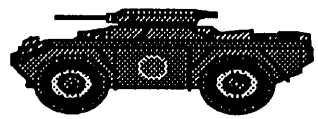


HIMARS



ELH

Smaller force that ***employs alternative power*** sources to ***reduce logistical tail*** and infrastructure requirements.



FRV

KEY SYSTEMS OF TASK FORCE GRIFFIN

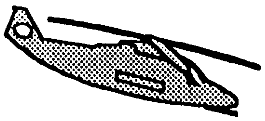
Several notional systems provided Task Force Griffin with the capabilities identified in the previous slide. The Aerial Platform 2015 (AP-15) served as an integrated sensor and shooter that not only detected targets but also engaged those targets at extended ranges as necessary.

The Future Reconnaissance Vehicle (FRV) provided protection and ground mobility to the displacing combat cells or teams and allowed them to move rapidly around the battlespace, avoiding direct fire engagements. The assumption that the vehicle had an alternative power source not only reduced the requirement for resupply but also enhanced the safety of the crew by minimizing their reliance on external support mechanisms.

The Enhanced Lift Helicopter (ELH) was designed to supplement the ground mobility of the combat cells by air lifting those teams over extended distances. The ELH was designed to carry one complete PST or one FRV with assigned crew.

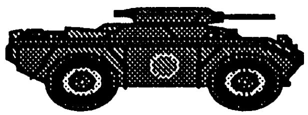
The force was supported by a redundant suite of sensors that were assigned at every level of command. Task Force Griffin controlled the high altitude long endurance UAVs; intermediate headquarters controlled the macro UAVs while each PST had its own hand launched, short endurance UAV.

KEY SYSTEMS OF TASK FORCE GRIFFIN



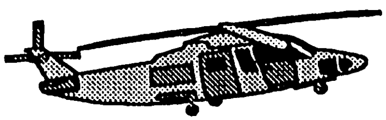
AP-15

Aerial Platform 2015: 3rd generation FLIR, enhanced radar, carries 14 Hellfire II missiles. Includes stealth and low-observable technologies which reduce EO, IR and acoustic signatures. Maximum speed 120 KTS with 2.2 hours endurance. Sensor range 8 KM.



FRV

Future Recon Vehicle: A stealthy ground vehicle that provides protection of M113 at 1/3 the detectability. Carries 4-man crew over extended range of 500 miles. Will be replaced by Electric Wheeled Combat Vehicle. Armed with a Javelin or follow on to TOW (FOTT) and the objective crew-served weapon (OCSW). Maximum speed 90 KPH with 500-mile endurance. Sensor range 6 KM.



ELH

Enhanced Lift Helicopter: All weather, capable of carrying FRV with crew or entire dismounted PST. Has greater range and better avionics than current MH-60. Maximum speed 130 KTS with 2.2 hours endurance. Sensor range 6 KM.

MICRO, MACRO, HAE UAV

Micro, Macro, High Altitude Endurance UAVs: Micro UAVs are hand-launched VTOL capable, has a 30 minute endurance, with a maximum altitude of 1 KM and range of 15 KM. Sensor range is 3.5 KM and video linked to PST. The Macro UAVs are ground launched and has TV and FLIR sensors, has a 6-hour endurance, with a maximum altitude of 3 KM and range of 200 KM. Sensor range is 5.5 KM. There are 2 Macro UAVs per ground station. The HAE UAV are ground launched and has EO, FLIR and SAR sensors, has a 72-hour endurance, with a maximum altitude of 15 KM and range of 500 KM. Sensors range is 20 KM. All UAVs maximum speed 120 KTS.

KEY SYSTEMS OF TASK FORCE GRIFFIN (cont.)

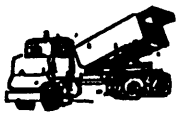
Other systems also played key roles in Task Force Griffin. The Aerostat is designed to hover at high altitude and detect incoming cruise missiles. The High Mobility Artillery Rocket System (HIMARS) provides the force with an indirect fire asset that can attack targets at extended ranges. It should be noted, however, that many other systems, to include air assets, arsenal ships, or armed UAVs with lengthy loiter times could provide the indirect fires required by the Task Force. The Enhanced Fiber Optic Guided Missile (EFOGM) system provides the force with a relatively short range, precision munition that can also serve as a source of target detection. The counterfire radar is capable of detecting both cannon and mortar fire at extended ranges and, consequently, provides significant force protection.

Finally, the 21st Century Land Warrior (21CLW), capable of relatively independent operations over extended distances, is the key to this force. While an analysis of the training, specific doctrine and leadership skills necessary to train such a soldier is beyond the purview of this study, it is clear that the equipping and training of these soldiers is essential to the success of this force.

KEY SYSTEMS OF TASK FORCE GRIFFIN (cont.)

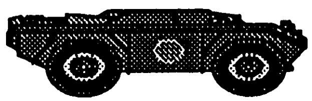
AEROSTAT

AEROSTAT: Operates with a look-down type surveillance radar capable of detecting and tracking cruise missiles and aircraft. Is capable of fire-control solutions, interceptor fly-out acquisition, and seeker acquisition. Sensor range 50 KM. Can serve as a surrogate satellite and provide MTI capability.



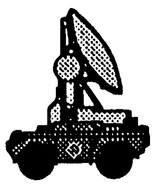
HIMARS

High-Mobility Artillery Rocket System: Fires MLRS rockets with DPICM and a range of 45KM. Also fires ATACMS BLK I with APAM warhead and BLK II with 13 BAT submunitions at a range of 100+ KM.



EFOGM

Enhanced Fiber Optic-Guided Missile: FRV with 8 ready missiles that strike with pinpoint accuracy up to a range of 15 KM. Maximum missile speed is 250 KTS. Two missiles can be tracked in flight simultaneously.



CFR

Counterfire Radar: Locates enemy indirect-fire systems to within 10 meters of their firing location. Range is 100 KM.

21CLW

21st Century Land Warrior: Armed with the objective individual combat weapon (OICW), advanced body-armor protection, micro-climate cooling (MCC) system and digitized communication links with other team members.

TASK FORCE GRIFFIN

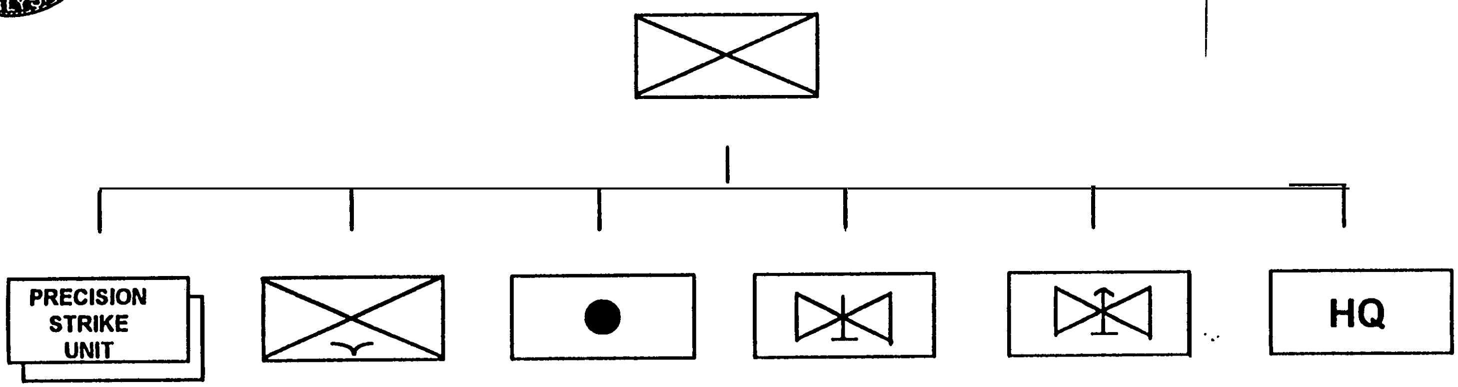
This slide depicts the organizational structure of Task Force Griffin. Subsequent slides will develop the details of several of the subordinate units, but certain key considerations should be recognized.

First, the force was not developed to the table of organization and equipment level of detail nor were other factors, to include the final logistical support structure, specifically defined. Consequently, it is inappropriate to specify an precise unit end-strength, however, our estimates indicte that Task Force Griffin is between 3200 and 3500 soldiers.

Second, the unit is task organized for the mission at hand and could, depending on the situation, deploy with a different mix of indirect fire systems or with either PSYOPS or Civil Affairs units. As depicted, the Task Force headquarters contains many elements that are mission specific, to include an Engineer unit with airfield repair capability, a Military Police unit, certain Air Defense elements that include Avenger type launchers and an advanced, deployable theater missile defense element.

Finally, the Task Force is clearly a combination of conventional forces and non-conventional precision strike units. The precision strike units are a complementary asset to more conventional forces, and this combination is critical to the success of Task Force Griffin.

TASK FORCE GRIFFIN ORGANIZATION



PER PSU
69 FRV
- 34 JAVELIN
- 35 FOTT
- 69 OCSW

6 EFOGM HMMWV
3 MACRO UAV CONTROL STATIONS WITH 6 UAVs
15 MICRO UAVs
1 WAM MINEFIELD
INTEL CELL

16 JAVELIN
12 FOTT HMMWV
12 OCSW
4 120mm MTR

16 ATCAS (155 mm)
9 HIMARS
4 CTR FIRE RADAR

38 ELH

26 AP-15
3 MACRO UAV CONTROL STATIONS WITH 6 UAVs
INTEL CELL

HHC
EN UNIT w/AIRFIELD REPAIR TEAM
ADA UNIT
TMD UNIT
FSU
MP UNIT
4 HAE UAV CONTROL STATIONS WITH 8 UAVs
BATTLEFIELD INTEGRATION CELL
1 AEROSTAT

Actual size of Task Force Griffin will vary based on a variety of factors, for example, logistical support structure, which is beyond the purview of this analysis.

PRECISION STRIKE UNIT ORGANIZATION

Task Force Griffin has two Precision Strike Units (PSUs), each of which is composed of three Precision Strike Force (PSF) units, a Headquarters Unit and a Support Unit. The intermediate headquarters plays an important role by permitting the teams to be massed to conduct company level operations. The Support Unit provides organic indirect fire support and manages the macro-UAVs that are assigned to each PSU.

Each PSF is composed of five Precision Strike Teams (PSTs). These teams comprise the combat cells that previous slides have discussed and are organized into Precision Strike Sections (PSS). Each section has eight soldiers and two FRVs, for a total of sixteen soldiers and four Future Reconnaissance Vehicles (FRVs) in each PSF. Obviously, each section or team can also operate in a dismounted mode if METT-T conditions dictate. This analysis assumes that all soldiers in the PSTs are airborne qualified and all equipment can be heavy-dropped. The capabilities of the soldiers within the teams are designed to permit independent operations and to ensure redundancy between sections.

PRECISION STRIKE UNIT ORGANIZATION

PSU

HHC

EQUIPMENT
3 FRV
3 OCSW
2 C2 FRV
INTEL CELL

PSF SPT

PSF

UAV

EQUIPMENT
3 MACRO UAV
CONTROL
STATIONS
WITH 6 UAVs

EFOGM

EQUIPMENT
6 EFOGM

SPT

EQUIPMENT
11 CARGO HMMWV

PSF HQ

EQUIPMENT
2 FRV
1 JAVELIN
1 FOTT
2 OCSW
2 CARGO FRV

PST

PST

PSS

EQUIPMENT
2 FRV
1 JAVELIN
1 FOLLOW-ON TO TOW
2 OCSW

-8 MEN
- FRV1 FOTT/OCSW
CDR
TGT/FO SGT
MED SGT
AA SGT W/JAVELIN
-FRV2 JAVELIN/OCSW
ASST O/I SGT
ENGR SGT
COMMO SGT
AA SGT W/FOTT

PSS

EQUIPMENT
2 FRV
1 JAVELIN
1 FOLLOW-ON TO TOW
2 OCSW

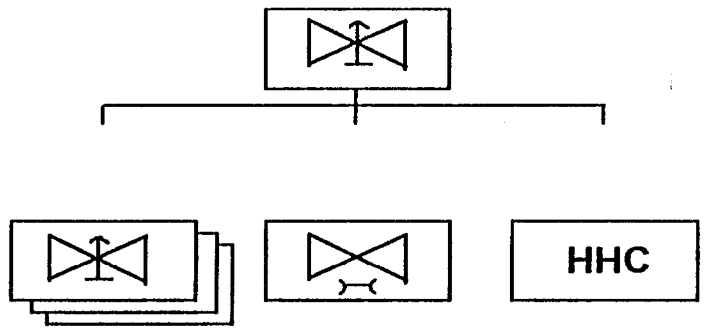
-8 MEN
-FRV3 JAVELIN/OCSW
O/I SGT W/M4 TWS
ENGR SGT
COMMO SGT
AA SGT W/JAVELIN
- FRV4 FOTT/OCSW
PST TECH
TGT/FO SGT
MED SGT
AA SGT W/FOTT

PSU - Precision Strike Unit
PSF - Precision Strike Force
PST - Precision Strike Team
PSS - Precision Strike Section

AP-15 ORGANIZATION

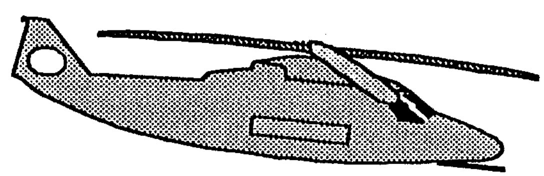
The AP-15 organization was designed to facilitate command and control and to allow the AP-15 to be task organized as necessary to support the PSUs. With its organic macro-UAVs, the AP-15 unit can also conduct independent operations.

AP-15 ORGANIZATION



PER UNIT
8 AP-15

2 AP-15
3 MACRO UAV CONTROL
STATIONS WITH 6 UAVs
INTEL CELL

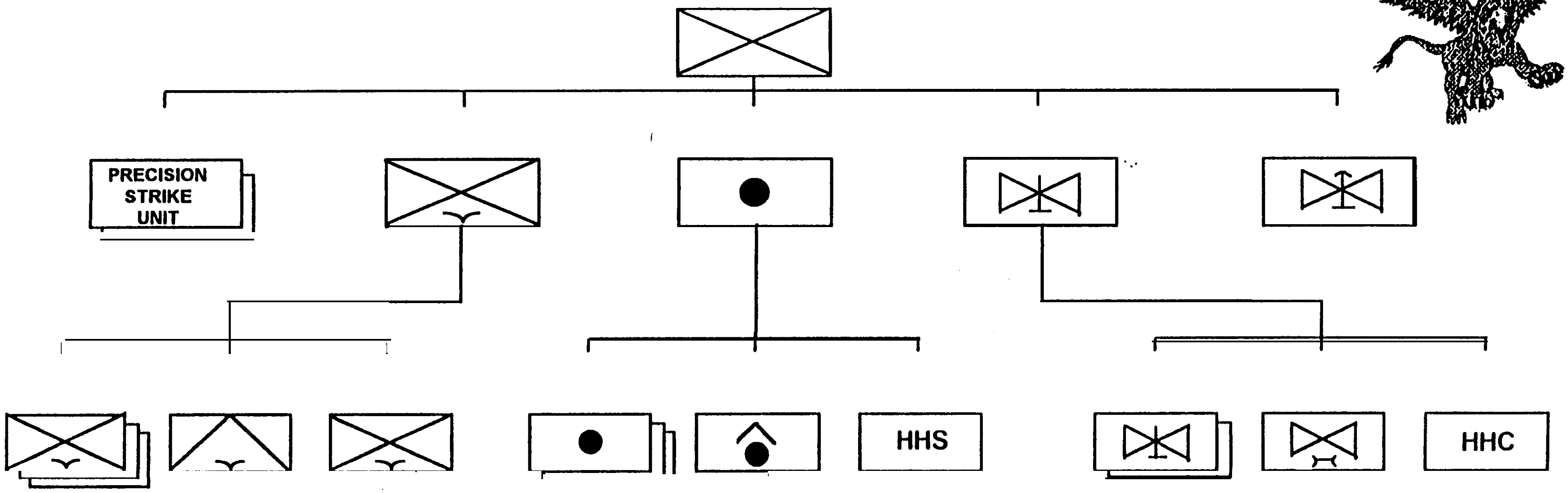


OTHER ELEMENTS OF TASK FORCE GRIFFIN

Two other elements of Task Force Griffin should be highlighted. First, a conventional airborne infantry element with three subordinate airborne infantry units is included to conduct those missions perhaps more appropriate for massed dismounted infantry. These missions include security missions, crowd control, demonstration of force, etc. This element is supported by an antitank unit that fields 12 follow-on-to-TOW (FOTT) systems.

The indirect fire unit assigned to Task Force Griffin contains 18 Advanced Towed Cannon Artillery System (ATCAS), nine HIMARS launchers and four counter-fire radars. This organization is especially flexible and warrants further analysis. In operations analyzed in this study, the range of the ATCAS, for example, precluded it from making any significant contribution, while the HIMARS was routinely the major killer on the battlefield, suggesting the need for additional HIMARS and less ATCAS If, however, air or naval assets are within range and can provide the responsive fires demanded by the Task Force, then a less robust indirect fire unit may be deployed, thereby reducing the deployment and logistical requirements.

OTHER ELEMENTS OF TASK FORCE GRIFFIN



PER UNIT
6 JAVELIN
2 60mm MTR

SUB UNITS
-3 PLT/CO
-CO MTR SEC

12 FOTT HMMWV
12 OCSW

SUB UNITS
-3 PLT/CO

4 120MM MTR
11 CARGO HMMWV

SUB UNITS
-MTR PLT
-SPT PLT
-RECON PLT
-HQs ELEMENT

PER UNIT
6 ATCAS (155 mm)

SUB UNITS
-2 PLT/BTRY

9 HIMARS

SUB UNITS
-3 PLT/BTRY

4 CTR FIRE RADAR

30 ELH

8 ELH

ADA ELEMENTS TASK ORGANIZED TO TASK FORCE GRIFFIN INCLUDE:

AVENGER UNIT
(12 AVENGERS/8 MANPADS)
THEATER MISSILE DEFENSE UNIT
(8 PATRIOT LAUNCHERS)

TASK FORCE GRIFFIN'S MISSION AND INTENT

The mission of Task Force Griffin, as the lead element of a Joint Task Force (JTF), is as stated. The Commander's intent has three critical elements.

First, both the 40 KM exclusion zone established around the airfield and the border zone must be rapidly sealed while some risk is assumed in the remainder of the region.

Second, safety of the deployed PSTs is a paramount concern. If any team becomes isolated, that is, it loses its linkage to the situational awareness grid or the support of the indirect fire assets, it must reposition to reestablish that linkage. The commander will not accept PSTs becoming involved in direct fire engagements with heavy conventional forces.

Finally, success is defined as eliminating the threat to the airfield so that follow-on forces of the JTF can be airlanded. If Pinkland attacks, that attack must be stopped outside the 40 KM exclusion zone, again so that enemy indirect fire systems cannot interfere with APOD operations. If possible, Task Force Griffin should be able to set the conditions for the successful employment of these follow-on forces.

TASK FORCE GRIFFIN'S MISSION AND INTENT

Mission

Task Force Griffin secures APOD, disarms the paramilitary forces within the 40 KM exclusion zone, and assists local authorities in restoring order. On order, defeats the Pinkland forces allowing no penetration of the 40 KM exclusion zone.

Commander's Intent

I intend to rapidly restore and maintain order within the sector. We will accomplish this by securing the airfield, reducing pockets of insurgency, and disarming paramilitary forces within the expanding series of exclusion zones. Precision Strike Teams (PST) will rapidly deploy to positions within the 40 KM exclusion zone to locate and neutralize rockets and artillery that can range the airfield. Other reinforced teams will move to the Pinkland border to enforce the 1 KM 'no-movement' zone, provide early warning and direct deep-strike assets against invading Pink forces. We will accept some risk outside the 40 KM exclusion zone as we focus our initial efforts on sealing the border and protecting the airfield.

Red's center of gravity is his ability to maintain the support of the local populace. We must convince the Greenland citizens that we can eliminate the danger posed by the Red guerrilla force and that we can ensure the safety of Greenland citizens and the security of their property. By rapidly eliminating the Red threat, we reduce the potential for a Pinkland attack.

Throughout this operation, survivability of the PST and all supporting elements is a paramount concern. To accomplish this, we must ensure that an effective situational awareness grid is in place and that the teams have immediate access to indirect-fire assets. Those teams that become isolated, that is, lose access to the situational awareness grid or indirect-fire systems, are considered to be at risk and will reposition as necessary to reestablish these critical linkages. In addition, I am not willing to accept the risk of PSTs in direct-fire engagements with heavy conventional forces.

Success is achieved once the airfield is no longer threatened, aid flows unimpeded, and, if Pinkland attacks, that force is stopped prior to the 40 KM exclusion zone to set conditions for follow-on force operations.

BLUE RULES OF ENGAGEMENT

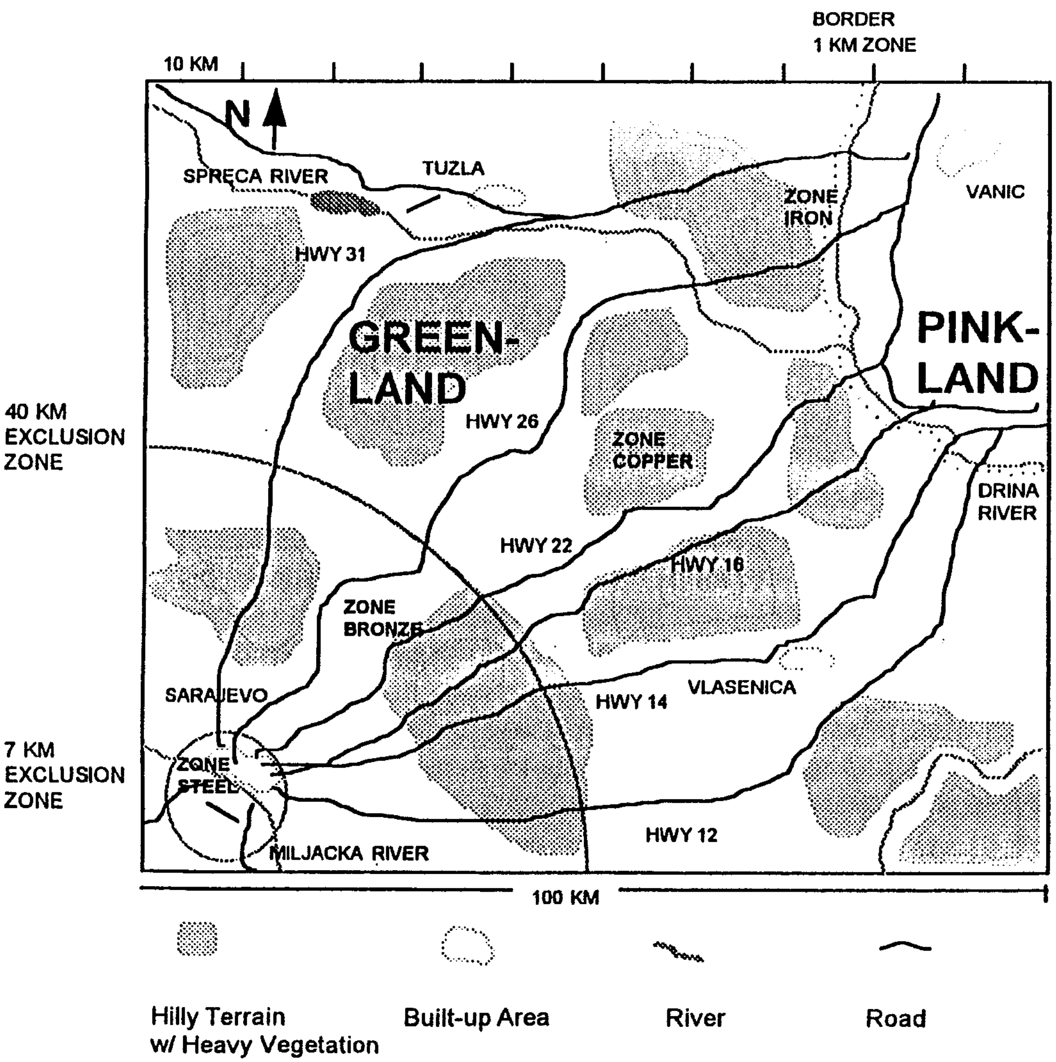
The JTF commander has proposed and secured approval for rules of engagement (ROE) that will define its options against potential enemy operations.

Against the Pink force, should they attack, Task Force Griffin is restricted only by typical wartime ROE. However, against the Red insurgent, the ROE defiring Blue force options vary based on the zone within which the insurgent is operating.

These ROE become significant because they impose certain restrictions on the Task Force. For example, in several instances, the Task Force is required to apprehend Red insurgents and await the arrival of Greenland police. This can distract several teams who could otherwise be detecting or attacking other targets. The Task Force cannot indiscriminately employ prepositioned minefields against a potential Pink attack because of the threat these systems present to the civilian population of Greenland.

An unclassified version of these ROE, many of which are very restrictive, has been publicized to the Greenland populace in order to facilitate Blue force operalions.

BLUE RULES OF ENGAGEMENT



AGAINST PINK

-Blue will not conduct cross border operations without permission from JTF CDR.
-If Pinkland invades, typical "wartime ROE" apply.

AGAINST RED

-The right of self-defense is guaranteed.
-Appropriate force will be employed to complete the mission and minimize collateral damage.
-Surface-to-air missiles are considered a threat to Blue forces and may be engaged without provocation.
-Individuals participating in potentially hostile activities will be detained and turned over to Greenland police.

AGAINST RED WITHIN ZONE STEEL

-Display of any weapon is considered a hostile act.

AGAINST RED WITHIN ZONE BRONZE

-Crew served weapons are considered a threat whether or not crew demonstrates hostile intent.

AGAINST RED WITHIN ZONE COPPER

-Blue is authorized to use all necessary force to confiscate and demilitarize crew served weapons.

AGAINST RED WITHIN ZONE IRON

-Unauthorized entry into 1 KM zone is considered a hostile act and deadly force is authorized to prevent crossing border.

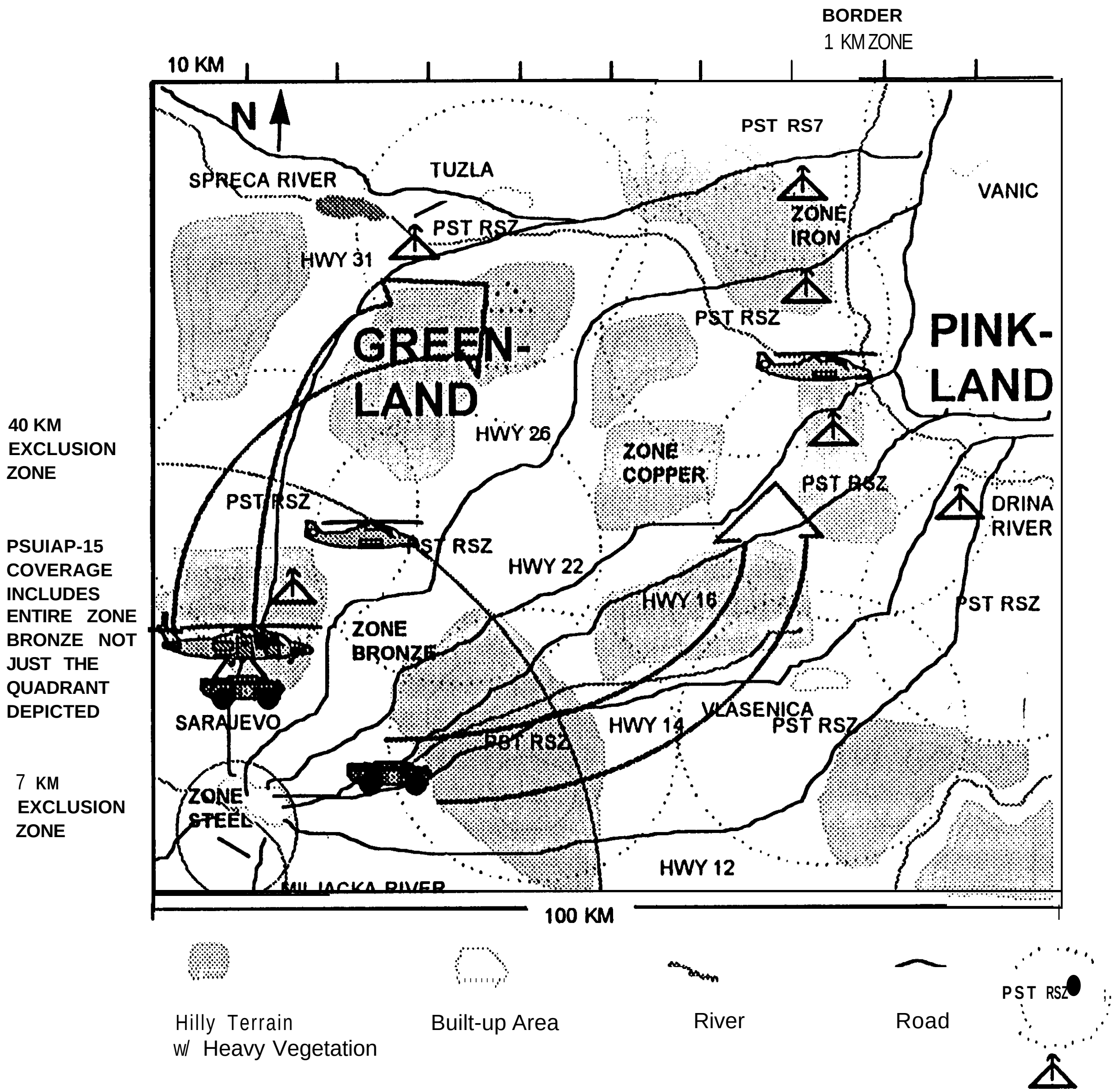
OPERATIONAL "SNAPSHOT"
PHASE 1- DEPLOYMENT

The next three slides capture the operational techniques employed by Task Force Griffin during three expected phases of the operation.

During Phase 1, the main focus of the Task Force is to rapidly deploy to operational position areas and clear Zone Bronze of any indirect fire threat. PSTs deploy by ground throughout the entirety of Zone Bronze and receive immediate support from an AP-15 unit. These teams either occupy overwatch strike positions from which they monitor and observe specific target areas or they assume responsibility for a recon strike zone in which they conduct mobile operations to locate enemy targets. It should be noted that even though there was no suspected threat from the south or west, teams were deployed in that portion of Zone Bronze that is off the map as a necessary safety precaution. Four teams immediately deploy to seal the border in Zone Iron and are supported by a section of two AP-15s. Finally, an AP-15 unit is on patrol within Zone Copper to identify and eliminate any potential threat in that zone.

As the ground teams begin to deploy to Zone Copper, two different techniques are examined. Five of the deploying teams deployed by ground using organic FRVs. Five other teams deployed by air with four ELHs required to emplace one PST with vehicles. This phase would last several hours as teams moved into position.

OPERATIONAL "SNAPSHOT"
PHASE 1 - DEPLOYMENT



OBJECTIVES

-Enhance force protection by rapidly deploying to operational position areas.

-Demonstrate "show-of-force" and threat of action.

-Clear Zone Bronze of indirect fire threat.

"SNAPSHOT" STATUS BY ZONE

-Zone Steel - Airborne battalion has secured airfield. 1 AP-15 company(-) is on strip alert.

-Zone Bronze - 9 PSTs in overwatch strike positions, 6 PSTs in recon strike zones, 1 AP-15 company providing immediate support.

-Zone Copper - 1 PSTs in overwatch strike position, 5 PSTs being deployed by ELH, 5 PSTs self-deploying, 1 AP-15 company conducting recon/security missions.

-Zone Iron - 4 PSTs in overwatch strike positions, 1 AP-15 section providing immediate support.

PST RECON STRIKE ZONE (RSZ)

PST OVERWATCH STRIKE POSITIONS (OSP)

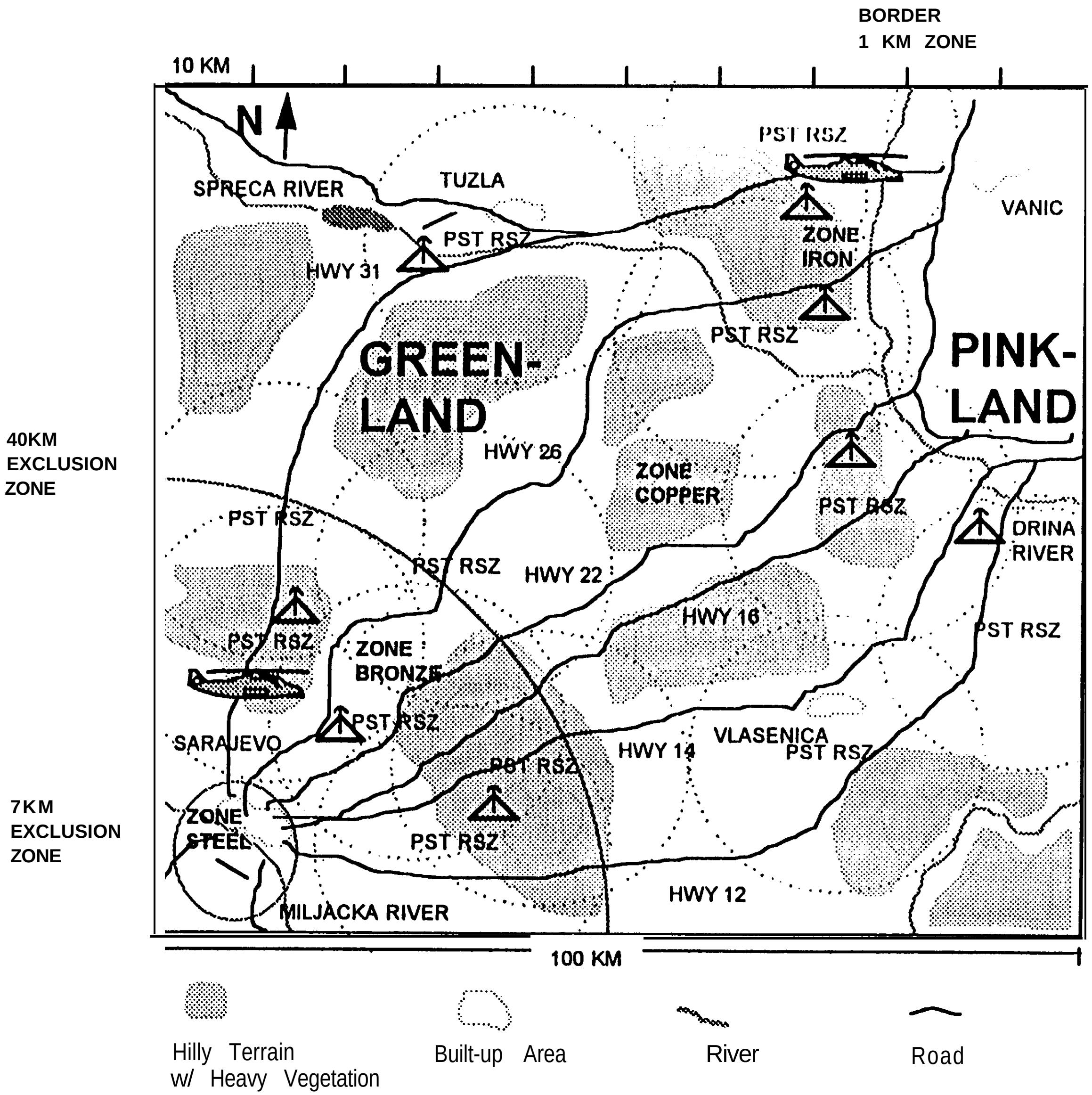
OPERATIONAL "SNAPSHOT"
Phase 2 - PEACE ENFORCEMENT

During the Peace Enforcement Phase, the task force is focused on eliminating the armed threat in Zone Bronze, preparing the airfield for the arrival of follow-on forces, continuing to seal the border and controlling the armed threat in Zone Copper.

The duration of this phase is certainly undefined. It was not assumed, for example, that the follow-on forces would immediately begin to flow into theater and, in fact, it was recognized that there would be some undefined time when Task Force Griffin would be conducting relatively independent operations. Consequently, there is a need to consider resupply requirements and the need to relieve deployed teams. The AP-15 units initiate a rotational pattern from the airfield with each of the three units at different stages of deployment, alert or rest. Ground teams are all deployed at the start of the phase, but at some point, possibly after an initial extended period of operations, these teams would have to be relieved. Certainly, there would be a requirement to deliver supplies to the deployed teams. The Task Force accomplished this by dispatching an ELH at staggered intervals along various routes to airdrop supplies at predetermined linkup points for each team.

OPERATIONAL "SNAPSHOT"

Phase 2 - PEACE ENFORCEMENT



OBJECTIVES

- Do not seek combat but force Red compliance through threat of action.
- Seal Pinkland border (Zone Iron).
- Secure and prepare airfield for follow-on forces.
- Eliminate armed threat in Zone Bronze.
- Control armed threat in Zone Copper.

"SNAPSHOT" STATUS BY ZONE

- **Zone Steel** - Airborne battalion continues security mission, indirect-fire systems in position, ADA units operational, 1 AP-15 company on 10 minute strip alert, 1 AP-15 Company (-) on 1 hour response.
- **Zone Bronze** - 9 PSTs in overwatch strike positions, 6 PSTs in recon strike zones, 1 AP-15 company providing immediate support.
- **Zone Copper** - 1 PST in overmatch strike positions, 10 PSTs in recon strike zones.
- **Zone Iron** - 4 PSTs in overwatch strike positions, 1 AP-15 section in support.

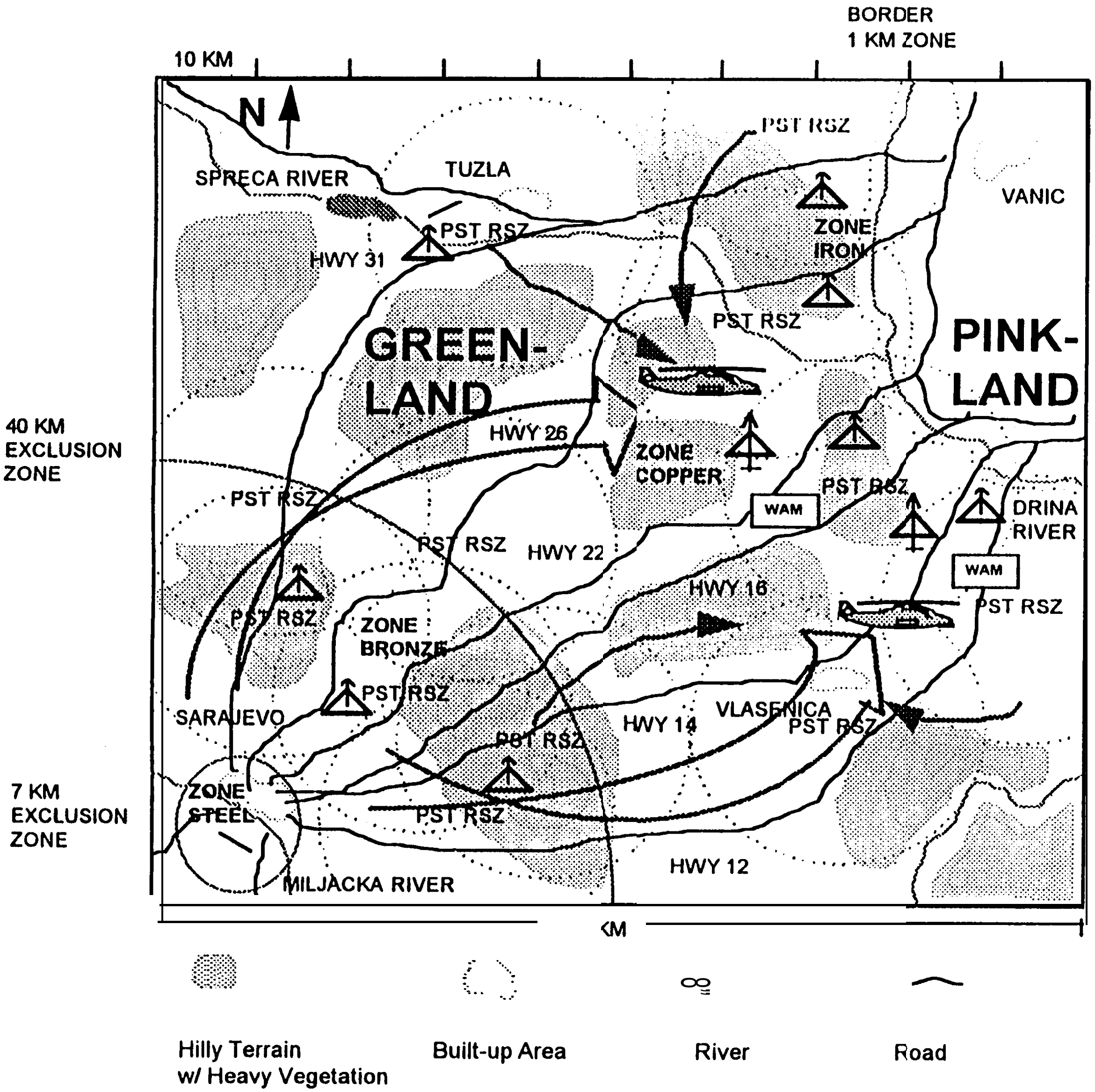
OPERATIONAL "SNAPSHOT"
Phase 3 - HALTING PINKLAND ADVANCE

During the third phase, the objective of the Task Force is to halt the Pinkland attack outside the 40 KM exclusion zone. During this operation, selected PSTs reposition to alternate overwatch strike positions, while some simply go to ground and remain in place to observe the attacking force. The WAM minefields are emplaced along the likely enemy avenues of approach in order to slow the advancing forces and shape the battlespace. Finally, AP-15 units begin to rotate to forward overwatch strike positions from which they could observe and report on the advancing enemy.

Several alternative techniques for the employment of the AP-15 are possible. In one technique, the AP-15's role as a sensor and shooter is emphasized and there are no restrictions placed on the use of its on-board missile systems. Once all ammunition has been consumed, the AP-1 5 would rotate back to the FARP for resupply and be replaced on station by another AP-15 with a full load of ordnance. In a second technique, the AP-15's role as a sensor is emphasized. The AP-15's capability to rapidly move around the battlefield and provide focused observation of enemy formations allows it to complement the suite of sensors already deployed in support of Task Force Griffin. Using this employment technique, the AP-15 only fires for self-protection or, in this scenario, if the advancing enemy force is about to penetrate the 40 KM exclusion zone.

Several considerations drive the technique chosen. For example, if the FARP is at a great distance and significant time is required to rearm the aircraft, then the second technique may be more appropriate. On the other hand, if there are limited indirect assets available or if minimal collateral damage around the target is required, then the precision fires of the AP-15 may play a critical role. Perhaps the most important conclusion is that such an integrated system provides the commander with tremendous flexibility in how he employs the force,

OPERATIONAL "SNAPSHOT"
Phase 3 - HALTING PINKLAND ADVANCE



OBJECTIVES

- Maintain security of airfield.
- Continue to conduct peace enforcement operations.
- Halt Pink attack and allow no penetration of Zone Bronze.

"SNAPSHOT" STATUS BY ZONE

- **Zone Steel** - Airborne battalion continues security mission, Task Force Griffin reserve (AT company) moves to initial battle position.
- **Zone Bronze** - 9 PSTs in overwatch strike positions, 6 PSTs in recon strike zones.
- **Zone Copper** - selected PSTs displace to alternate position, AP-15 battalion rotates companies to forward overwatch strike positions.
- **Zone Iron** - on order 4 PSTs collapse back to alternate positions.

BLUE RECON AND SURVEILLANCE COVERAGE

This slide is intended to portray the redundant suite of sensors supporting Task Force Griffin. Depicted in the schematic are:

a. National assets.

b. The four HAE UAVs, Aerostat and four counterfire radars controlled at Task Force level.

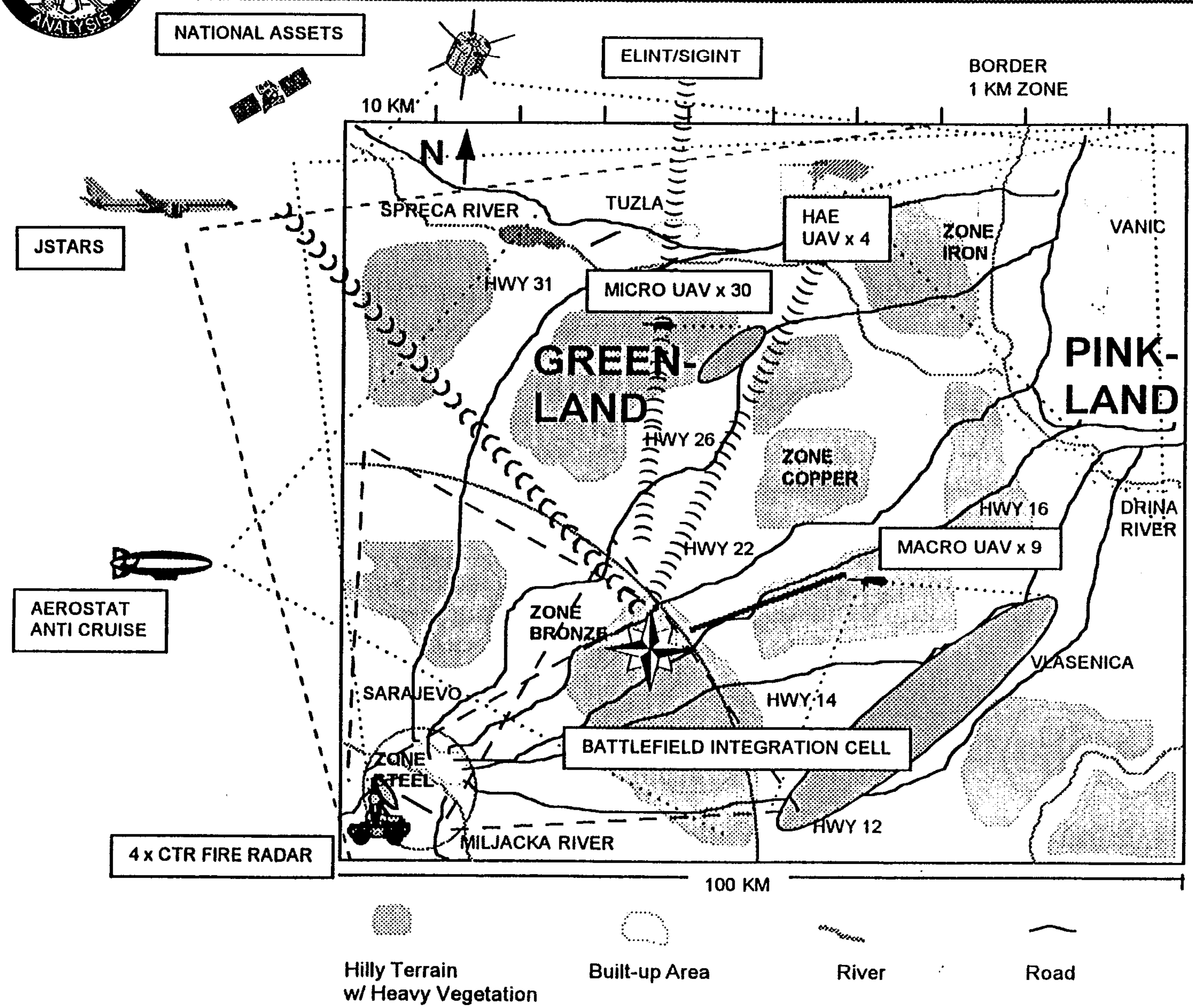
c. The nine macro-UAVs managed by the PSUs and AP-15 unit.

d. The thirty micro-UAVs available to the deployed teams

Two considerations became obvious. As the coverage for this suite of sensors was overlayed on the battlespace it became clear that some mechanism is necessary to coordinate these assets and to create a comprehensive, integrated picture of the battlespace. For the purposes of this study, we labeled that mechanism a Battlefield Integration Cell (BIC), and assumed that it would function at Task Force level and would be heavily reliant on automated assets. This cell would provide the force'with a capability similar to the cooperative engagement capability which currently supports naval air assets. Clearly, this is an area deserving significant additional consideration and analysis. In subsequent slides, several expected tasks for this organization are highlighted.

Second, even such a remarkably redundant coverage pattern does not eliminate the need for the human sensor who can explicitly confirm target data, and can discriminate between friend, foe, or impartial bystander.

BLUE RECON AND SURVEILLANCE COVERAGE



Task Force Griffin sensor suite ensures overlapping coverage and constant situational awareness.

Sensor spottings are transmitted to the Battlefield Integration Cell (BIC) which determines and deploys most appropriate system. Passes appropriate intelligence on to other systems.

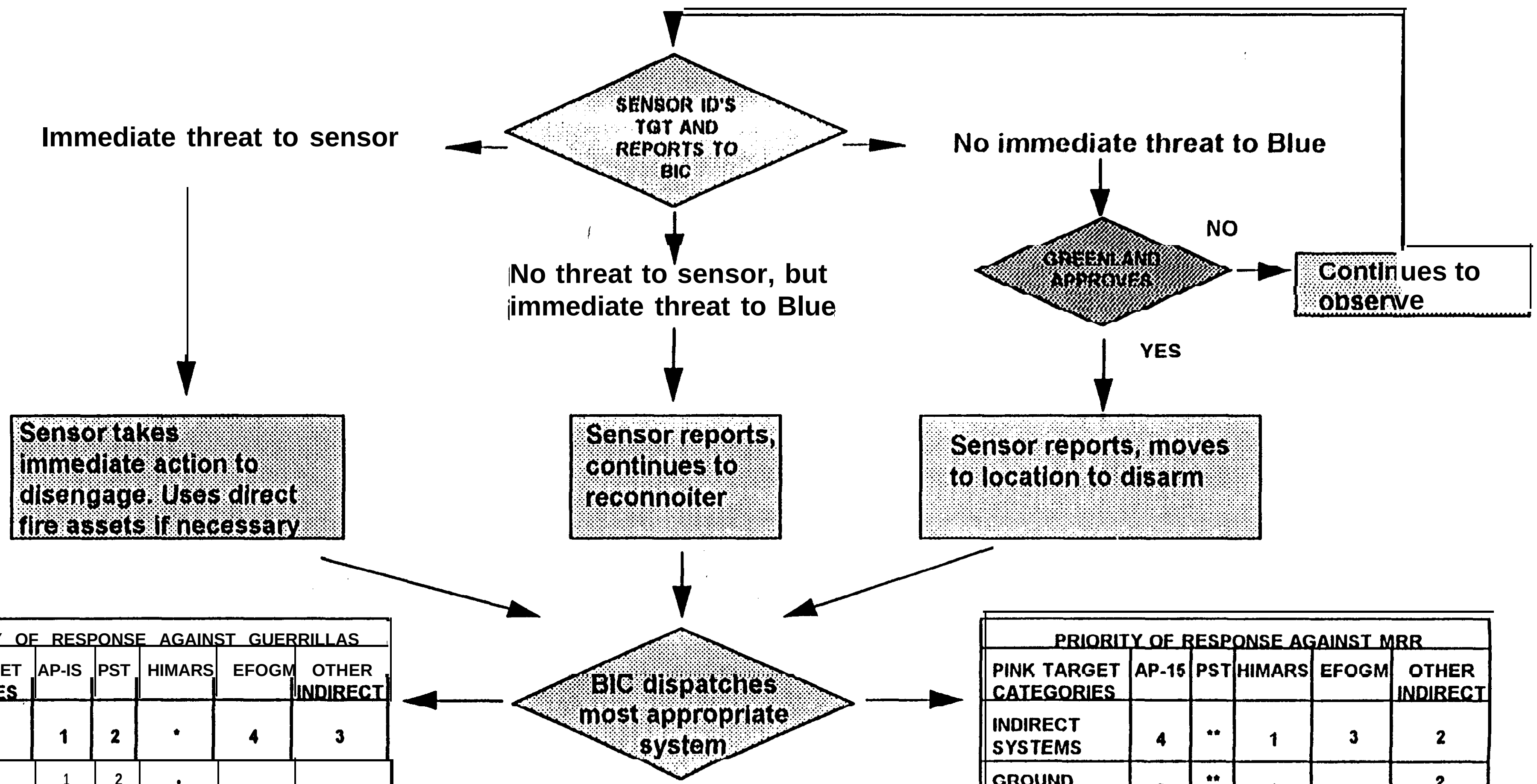
TARGET ENGAGEMENT TECHNIQUES

Finally, we attempted to define how the force should react to a variety of targets. This flow chart links available attack mechanisms to each of three potential target types: those that pose an immediate threat to the sensor, those that pose no threat to the sensor but are a threat to other elements of Blue force and those that pose no immediate threat to any Blue element. In the latter case, interaction with Greenland authorities is required and, as a result, Blue forces may be consumed arresting or apprehending a target when, in fact, a more dangerous target may be identified by another system.

Once the target information is transmitted to the Battlefield Integration Cell, that mechanism confirms the selection of attack mechanism. These attack procedures would be incorporated as standard operational procedure throughout the force in order to insure rapid response and to reduce sensor-shooter timelines. The role of the BIC would be to confirm attack, incorporate target information into the overall picture of the battlespace, alert other systems, monitor battlefield damage assessment (BDA) but not to impose itself as an additional step in the sensor-shooter linkage. The two tables were generated based on the recognition that different conditions drive the selection of different attack mechanisms. If the proposed target requires pin-point accuracy, prompt response and minimal collateral damage, as in the case of an identified insurgent rocket launcher, then the AP-15 is the response mechanism of choice. On the other hand, if the target covers a larger area and collateral damage is less of a concern, as in the case of a Pink artillery unit, then the AP-15 is the least preferred system and some other indirect fire mechanism, such as HIMARS, is selected.

Against Red insurgent targets, the PST is considered a potential response mechanism. Against Pink targets, however, the PST is not even considered. This reflects the commander's guidance that the PSTs will not become engaged in direct fire contact with heavy mechanized forces.

TARGET ENGAGEMENT TECHNIQUES



PRIORITY OF RESPONSE AGAINST GUERRILLAS

RED TARGET CATEGORIES	AP-IS	PST	HIMARS	EFOGM	OTHER INDIRECT
INDIRECT SYSTEMS	1	2	*	4	3
GROUND TROOPS	1	2	*		
VEHICLES	1	3		2	4
HELICOPTERS	2				1 (ADA)

'ONLY WITH JTF APPROVAL

PRIORITY OF RESPONSE AGAINST MRR

PINK TARGET CATEGORIES	AP-15	PST	HIMARS	EFOGM	OTHER INDIRECT
INDIRECT SYSTEMS	4	**	1	3	2
GROUND TROOPS	3	**	1		2
VEHICLES	4	•ı	1	3	3
HELICOPTERS	2				1

"SELF-DEFENSE ONLY

AGENDA

Finally, we turn our attention to the analysis of Task Force Griffin and the operational insights achieved.

AGENDA

Situation

a. Terrain Orientation
b. Road to War
c. Enemy Operational and Organizational Concept

Task Force Griffin Organizational and Operational Concepts

a. Task Force Structure
b. Operational Concept

Analytical Effort

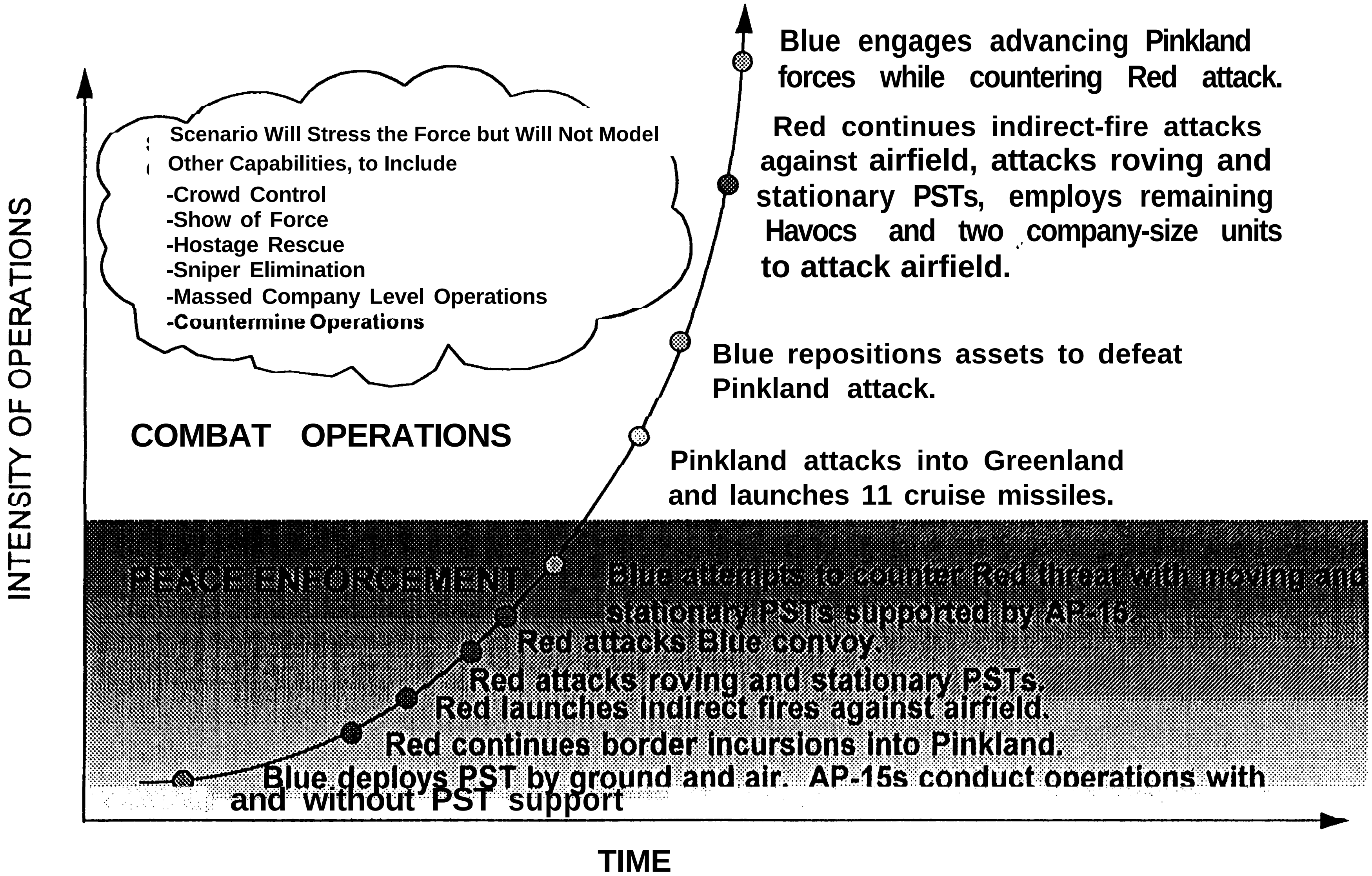
a. Scenario
b. Assumptions
c. Base-Case Results
d. Comparative Analysis
e. Pink "Audible"
f. Emerging Operational Insights

“STRESSING THE FORCE”

The scenario is designed to stress and challenge the force across the spectrum of operations. Two points must be highlighted. First, at some point, Pinkland does attack and the intensity of operations significantly increases from peace enforcement to full combat operations. However, Red does not cease their activities and, in fact, takes advantage of Blue’s preoccupation with Pink by attempting to launch a company sized attack on the APOD.

Second, certain operations were not included in the scenario even though they are, based on our analysis, clearly within Task Force Griffin’s range of capabilities. As we suggested earlier, for example, the PSUs are structured to conduct massed company level operations. Each team, especially if it were equipped with certain robotic devices, could effectively eliminate a sniper or rescue a hostage.

"STRESSING THE FORCE"



ASSUMPTIONS

We have attempted to capture and organize our assumptions into several main categories and some of those need to be highlighted.

First, sufficient air assets are available to protect the Blue Force and to assist in the defeat of the Pink mechanized forces, if Pink should choose to attack.

Second, as the scenario begins, it is assumed that the entire Task Force Griffin is on the ground in Greenland. We assume that the Task Force can deploy within five days, based on our analysis of the equipment and personnel organic to the Task Force and a review of deployment requirements for a heavy brigade and a light division package of the 82d Airborne Division,

Obviously the actual deployment profile and number of days required for deployment variables are sensitive to a number of considerations, to include the distances involved from APOE to APOD, the number and type of transport aircraft available; the operational Maximum-on-Ground (MOG) capability of the selected APOD; and the determination of which loads would be heavy-dropped as opposed to air-landed.

ASSUMPTIONS

- WARFIGHTING.
  - There are no other LRCs or MRCs underway at this time.
  - US Air Force is enforcing a No-fly Zone over Greenland.
  - CAS is required and available to assist in the defeat of the Pinkland force.
  - US Air Force maintains air superiority when Pinkland attacks.
  - Blue national assets provide approximately 60 percent of the Pink and Red order of battle and at least 6 hours warning of Pinkland attack.
- DEPLOYMENT.
  - APOD can support C-130 and C-17 operations.
  - Task Force Griffin is able to deploy in 5 days.
  - The proposed deployment capacity as defined by the Mobility Requirement Study has been achieved.
  - Entire Task Force Griffin is fully deployed before Pinkland attacks and is preparing for the arrival of follow-on forces.

BASE CASE RESULTS - PEACE ENFORCEMENT PHASE

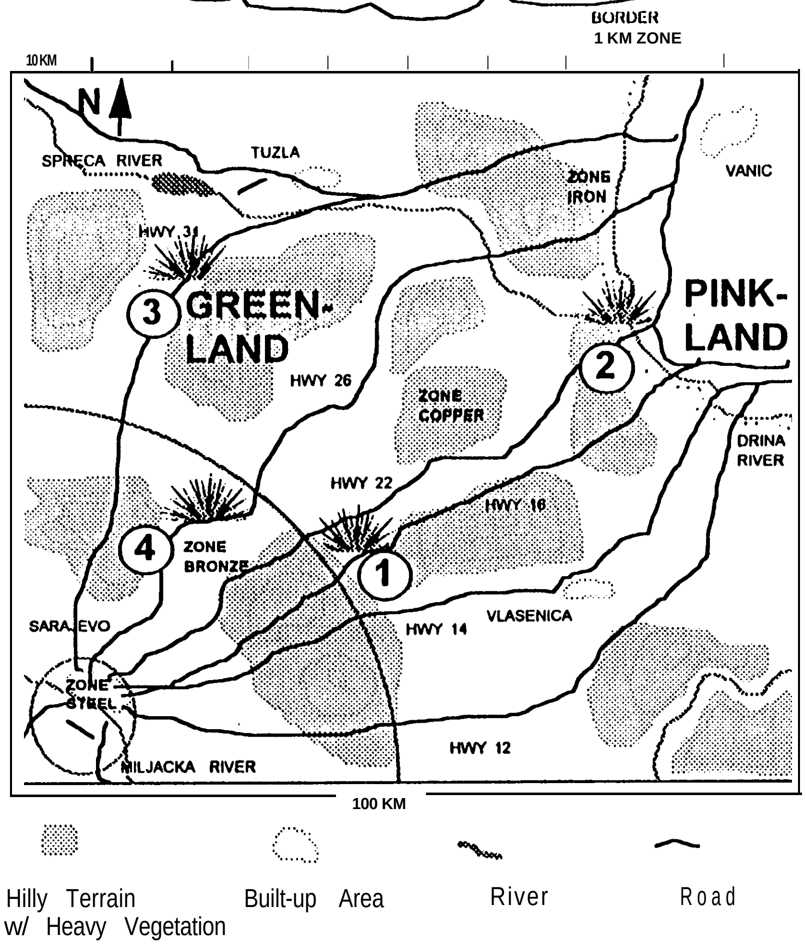
The results achieved when Task Force Griffin, as defined in earlier slides, conducts the peace enforcement and combat operations phase will now be reviewed. During the Peace Enforcement Phase, Task Force Griffin successfully secured the APOD and had dramatically reduced the insurgent's capability to employ indirect fire assets in Zone Bronze. Thoughout this phase the Task Force was, however, vulnerable to the activities of a relatively low tech force.

The aid convoy was ambushed in a small built up area by an enemy RPG gunner who was operating out of a garage and who was also able to trigger some command detonated mines. These results suggest other possible options that the force might have employed to counter low tech threats in this risky mission. These options include the use of conventional forces that can dismount and clear the route more effectively or the employment of some robotic devices that might be able to nullify the ambush.

One ELH was shot down by a gunner armed with an enhanced antiaircraft system. While it can be argued that future helicopters will have on-board protective systems to preclude such an attack, it was not assumed, within this study, that rotary-winged aircraft would be able to fly with impunity throughout the area of operations. It was postulated for analysis purposes that some relatively inexpensive system would be available even in the year 2015 that could pose a threat to rotary-winged aircraft,

BASE CASE RESULTS - PEACE ENFORCEMENT PHASE

BLUE SUCCESSFULLY SECURED APOD BUT WAS STILL DISARMING THE PARAMILITARY WITHIN EXCLUSION ZONE WHEN PINK ATTACKED.



KEY EVENTS AND INSIGHTS

1 ESCORTING AID CONVOY

- Convoy was ambushed in built-up area, low-tech systems (RPG, remotely-detonated mines) successfully negated the high-tech characteristics of the PST.
- Mission maybe more appropriate for conventional forces that dismount and clear route.
- Suggested potential for:
  - -Robotics or nonlethal systems to nullify ambushers.
  - -Enhanced sensors to identify land mines, hidden weapons.

2 SEALING PINKLAND BORDER

- Supported by strict ROE, Blue successfully employed a combination of UAVs, PSTs, and AP-15s to achieve complete coverage of border and halt red infiltrators.

3 CONDUCTING ELH SUPPORT MISSIONS

- Five teams self deployed while five teams deployed by air via ELH, two ELHs were destroyed by rogue SA-XX gunner.
- Resupply conducted using ELH was successful but robotic resupply may be less risky.

4 CLEARING ZONE BRONZE

- Primary focus within zone bronze was to eliminate the indirect-fire threat to the airfield that was posed by rockets and artillery.

LOW-TECH INSURGENTS REMAIN A CHALLENGE FOR EVEN A HIGH-TECH FUTURE FORCE.

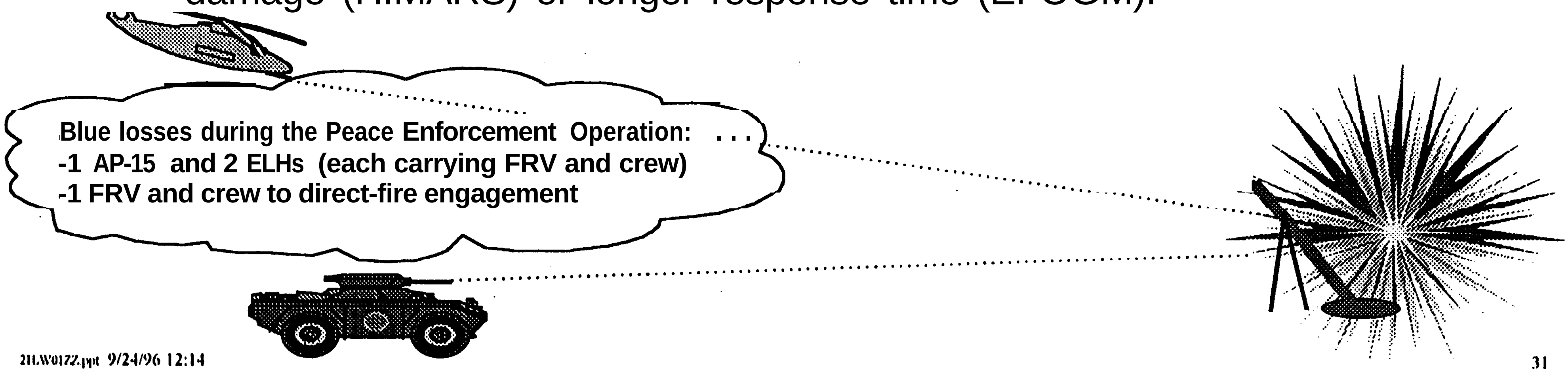
CLEARING ZONE BRONZE - OPERATIONAL INSIGHTS

The efforts to clear Zone Bronze of indirect fire systems reveal certain key considerations. First, the majority of insurgent systems were not detected until after they had fired. This reinforces the need for a counter-fire system that rapidly identifies and locates such targets - unfortunately, it also translates into an increased risk for those forces guarding the APOD. The vast majority of systems that are detected are, in fact, eliminated.

Second, once these indirect fire systems are detected, the AP-15, with its speed, mobility and capability to provide precise attack with minimal collateral damage, emerges as the most efficient response mechanism. However, while PSTs were hampered by the demanding terrain, there were no weather conditions imposed that might have limited the AP-15's ability to respond. If the Red insurgents had more aggressively used his air defense systems to protect his limited indirect assets, this would have created a greater risk for the AP-15 and might have caused the Task Force to employ other assets to eliminate these threats.

CLEARING ZONE BRONZE - OPERATIONAL INSIGHTS

- Red guerrillas had 30 rocket/artillery systems available.
  - 23 deployed within Zone Bronze.
  - 7 hidden in Northeast sector for later employment.
- Blue successfully identified all 23 systems within Zone Bronze.
  - 65% located by counterfire radars after system fires.
  - 35% identified by UAVs, PSTs or AP-15s before system fires.
  - 22 systems destroyed or captured.
- AP-15 had quickest response time once system was identified.
  - AP-15s killed 67% of the systems that were destroyed.
  - PSTs killed remaining systems reacting to contact or to eliminate an immediate threat to the airfield because the AP-15's could not respond.
  - Other indirect-fire systems were not employed due to threat of collateral damage (HIMARS) or longer response time (EFOGM).



CLEARING ZONE BRONZE - OPERATIONAL INSIGHTS (cont.)

As mentioned on an earlier slide, the need for some mechanism to synchronize sensors and shooters and to conduct the other tasks outlined on this slide quickly became obvious. Target handover becomes a particular challenge, especially in light of the fleeting nature of the targets and the vulnerabilities of each system.

This is an area that is especially fertile for further analysis. How these processes are managed, what automation support should be expected, at what command level such a mechanism should exist, and how other services address this requirement are just a sampling of questions that require further analysis.

CLEARING ZONE BRONZE - OPERATIONAL INSIGHTS (cont.)

- Battlefield Integration Cell was needed to synchronize effort by:
  - Coordinating employment pattern of available sensors.
  - Cross-cueing sensors to ensure continuous coverage once a critical target is detected.
  - Analyzing massive available information and creating fused intelligence.
  - Collecting and analyzing battlefield damage assessments (BDA).
  - Determining criteria for rapid target handover, based on several considerations, to include:
    - -- Insurgents presented fleeting targets that disappeared before some systems could respond.
    - -- AP-15 provided most rapid response, PST response time was dependent on terrain conditions.
    - -- PST was not vulnerable to Red tactic of co-locating SA-XX gunner with an indirect-fire system; but, PST was vulnerable on road.
    - -- 'Closest' team may be preoccupied with another target.

BASE CASE RESULTS - COMBAT OPERATIONS PHASE

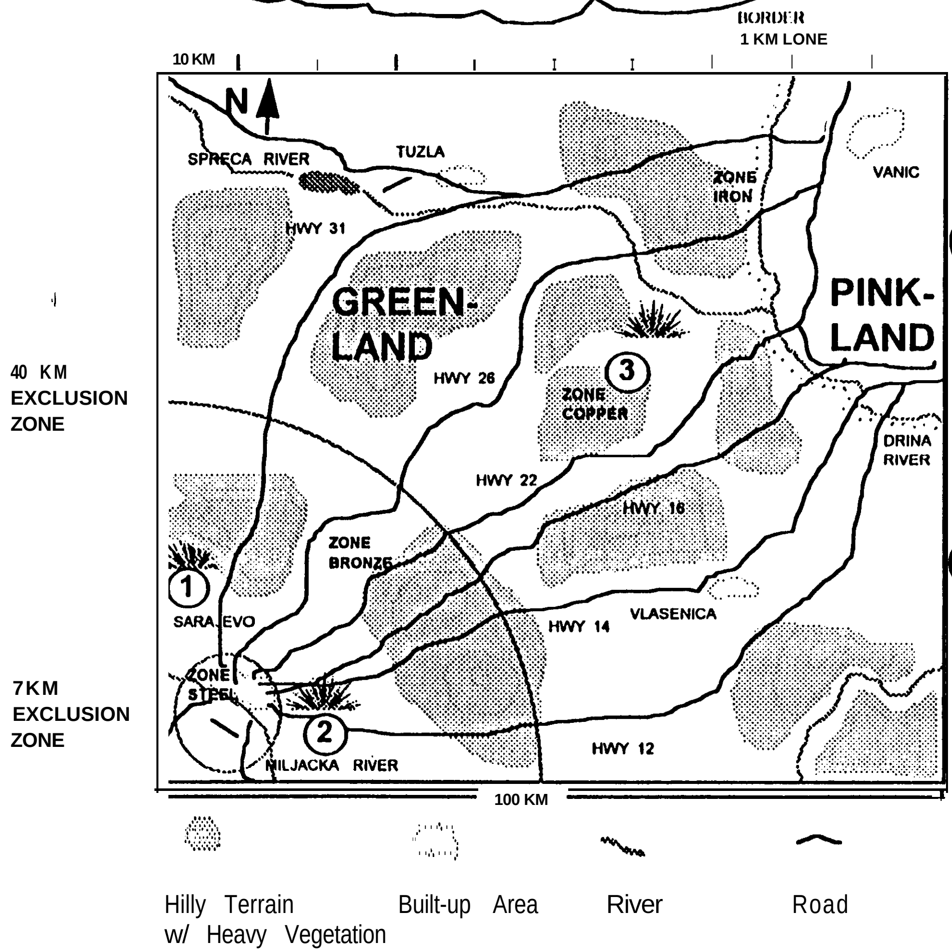
The ability of the Blue Force to defeat the Pink cruise missile threat ensures the safety of the long range indirect fire systems that support the Blue operation. The defense against the cruise missile attack is successful primarily because of the few numbers and the slow speed of the attacking missiles,, as they transit the extended detection range of the Aerostat, insures that they are subject to multiple engagements by Task Force Griffin's systems. Had the Pink force been able to launch a sufficiently large number of missiles, they might have overwhelmed the defensive systems, and some would have successfully penetrated to the APOD.

The Red attack on the airfield is defeated, but it is important to recognize the critical role that the conventional forces played. These conventional forces, which are appropriately structured for such a security mission, were able to defeat this threat without forcing the PSTs to abandon their overwatch strike missions against the attacking Pink force,

The Pinkland mechanized attack is halted approximately 60 KM from Sarajevo, outside Zone Bronze. It was assumed that once the lead elements of the Pink forces were attrited to 30% strength that the invading forces would go to ground. As shown in subsequent slides, the key Blue killers on the battlefield were the long-range precision munitions. Quite interestingly, the expectation that the enemy would attack along the southern routes proved incorrect. The Pinkland's main effort, in fact, attacked along Highways 22 and 26 with the supporting effort in the south. This discussion reflects the Pink commander's assessment that the cover and concealment provided by the northern routes was more beneficial than the high speed avenues of approach provided by the southern routes.

BASE CASE RESULTS - COMBAT OPERATIONS PHASE

BLUE SUCCESSFULLY HALTED THE PINK-LAND ATTACK AND PREVENTED PINKLAND FROM PENETRATING THE 40 KM ZONE



KEY EVENTS AND INSIGHTS

① DEFEATING CRUISE MISSILES

- Ten cruise missiles launched at Sarajevo, ten destroyed. One launched at powerplant at Tuzla, outside Aerostat range fan, and was successful.
- Aerostat coverage extended out to 50 KM. this range, coupled with the slow speed of incoming missiles, allowed multiple engagements by blue TMD.

② COUNTERING RED ATTACK ON AIRFIELD

- Two companies conducted coordinated ground attacks supported by three Havocs.
- Three Havocs were killed by Avengers.
- Blue sensors provided conventional forces with accurate insurgent location.
- Conventional forces were able to engage dismounts at extended ranges using improved infantry weapons.

③ HALTING PINKLAND ATTACK

- Limit of advance is as depicted. Pink forces "went to ground" 60 KM from Sarajevo once they were reduced to 30 percent strength.
- 63 percent of Pinkland combat vehicles were destroyed by indirect-precision munitions.

HALTING PINKLAND ATTACK OPERATIONAL INSIGHTS

As this slide indicates, the primary killer was the HIMARS, accounting for 60% of the Pinkland combat vehicles killed. HIMARS engagements were carefully planned in subsequent engagement areas to maximize the effectiveness of the missile and to preclude the attack of dead targets by the submunitions.

The WAM proved to be an efficient system even though its utility in this scenario was minimized because of the restrictive nature of the ROE. It is important to note that the WAM provided several other contributions, which we were unable to measure directly, that may be significant. These include disrupting and slowing the enemy advance, providing sensor information on enemy locations and interfering with the enemy's C2 functions.

The 15 KM range of the EFOGM limited its role in this phase. On this extended battlespace, the positioning of the EFOGM was critical if it was to contribute to the defeat of the Pink forces.

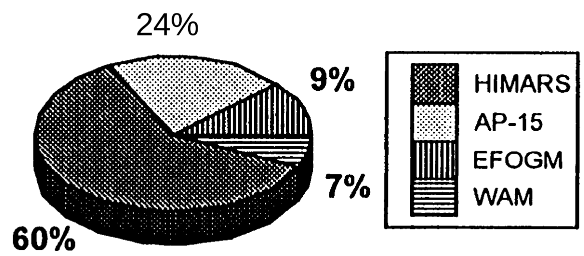
In this base case, the AP-15 was allowed to act as both a sensor and a shooter. There were, in fact, only loose restraints placed on that system's ability to engage identified targets, although the intent was for the AP-15 to complement the HIMARS by attacking those enemy systems that successfully escaped from each engagement area. The AP-15 is especially successful against the Pink Havocs because of the range of the onboard sensors and comparative speed advantage.

Pink artillery is an ineffective player for two reasons. First, the extended range of the battlespace precludes Pink artillery systems from ranging high payoff targets from their initial positions. Second, the dispersed manner in which the PSTs deploy eliminate massed targets that are appropriate for the Pink artillery.

The concept of operations for the PSTs insured that they did not become involved in direct fire engagements. Exploiting their organic mobility, PSTs were able to reposition as necessary and continue to direct precision fires on the invading force. No PSTs are lost to Pink combat vehicles.

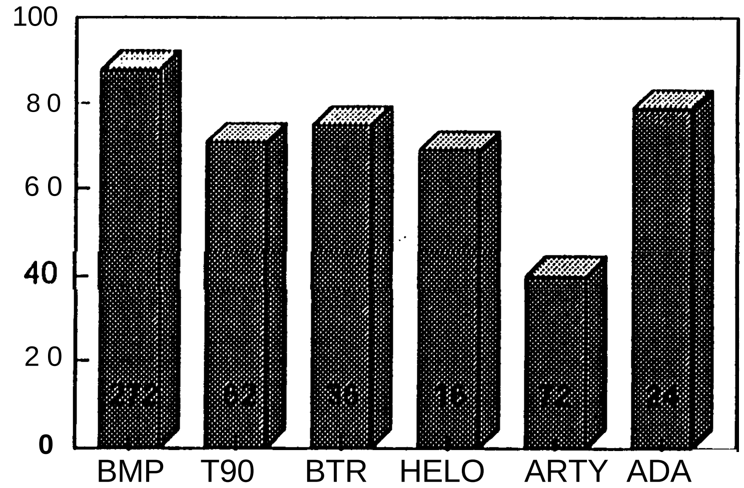
HALTING PINKLAND ATTACK OPERATIONAL INSIGHTS

% of Pink Combat Vehicles Killed by Blue Systems



- Indirect precision munitions, from multiple possible sources, were clearly the dominant killer.
- Limited range of EFOGM (15 KM) caused AP-15 to attack more targets.
- PSTs successfully avoided direct fire engagements.

% of Pink Systems Killed



Number of available systems indicated on each bar

- Overall Pink strength down to 30%.
- Pink artillery posed minor threat due to range limitations.
- AP-15 account for all Pink helicopter losses.

Blue losses minimal - 5 FRV with crews to 'chance' artillery engagement.
- 5 UAV and 2 AP-15 to ADA.

HALTING PINKLAND ATTACK OPERATIONAL INSIGHTS

Several reasons contributed to Task Force Griffin's success. These reasons are highlighted on this slide.

It is an interesting analytical exercise, therefore, to attempt to define what Pink might have done differently to change the battle dynamics. Clearly, Pink needs to be able to influence Task Force Griffin's indirect precision fire support systems. That may be a significant challenge. In this scenario it would require fielding some system, for example, an overwhelming suite of cruise missiles, or Special Operations forces, that can destroy the HIMARS launchers. In another scenario, however, Task Force Griffin's support may not be limited to what is brought into the area of operations, but could include air and/or naval assets, to provide the long range precision fire capabilities. These systems would probably prove even more difficult for Pink to interdict. A dismounted attack would also prove more difficult for Task Force Griffin to target and defeat with the available long-range precision systems and might require the PSTs to accept greater risk and become involved in direct fire engagements. Greater interaction between the Red and Pink belligerents might allow the Red insurgents to serve as an intelligence network for the invading force and allow Pink to impose greater casualties on the Precision Strike Units.

Finally, and perhaps most interesting, is the option of seizing a limited objective. This is an option that we will explore in more detail in a subsequent excursion to the base case.

HALTING PINKLAND ATTACK OPERATIONAL INSIGHTS

- Blue success can be traced to several factors:
  - Available terrain channelized Pink into clearly defined indirect-fire engagement areas (EAs). Pink could not generate sufficient speed to overcome terrain disadvantage or escape EAs.
  - Blue never presented a massed target within range of Pink artillery.
  - Pink had limited ability to influence Blue's key enabler - its long-range, indirect-precision munition delivery systems.
  - Pink's ability to jam selected UAVs had little impact on Blue's redundant sensor suite.
- Pink options that might change battle dynamics.
  - Invest in and employ some systems (i.e. improved cruise missiles that achieve greater speed and can overwhelm Blue sensors, SOF to destroy ground based long-range precision munition delivery systems).
  - Employ dismounted infantry in an infiltration attack.
  - EnlistRed assistance in locating PSTs to cause them to displace.
  - Seize a limited objective from which Pink would have to be ejected.

RUN MATRIX

This run matrix highlights the differences in the three different cases that were examined in this analysis. HIMARS is present in all three variants with the same capabilities, so that system is not listed on the chart,

The base case captures the structure of Task Force Griffin as has been described in previous slides. The enhanced case is a variant of the base case in which the sensors available to the Task Force have a greater range, the Task Force has access to an armed high altitude endurance UAV, and the EFOGM system supporting the Task Force has a dramatically improved range.

In the constrained case, several significant changes are introduced. First, the PSTs lose their organic mobility and must move around the battlespace either on foot or via lift assets. Without their organic FRV, the teams also lose their micro UAVs. Finally, the EFOGM is removed from the force structure.

There are also two excursions to the base case that were examined. The first, as the previous slide suggested, allows the Pink commander to alter his intent and limit his attack to the seizure of a limited objective. The second imposes more restraints on the AP-15 and requires it to focus on its role as a sensor.

Finally, there are numerous other capabilities that are envisioned for the force but which were not addressed in this analysis. For example, it is appealing that robotics could potentially play a major role in such a force, to include providing unmanned resupply missions and clearing routes to be used by friendly forces. Nonlethal devices would provide the Task Force with a unique means to respond to certain crises especially during Peace Enforcement operations. These are certainly worthy of additional analysis,

RUN MATRIX

	Base Case	Enhanced Case	Constrained Case
AP 15	3 Gen FLIR w/8 KM range	**5 Gen FLIR w/16** KM **range** SAR **30% signature reduction (T/O)** Enhanced wpn (12KM) LOAL	3 Gen FLIR w/8 KM range
PST Mobility Organic Firepower Sustainability Force Protection	 FRV M4/SAW TWS 3 Gen **OCSW** 120 HRS ELH Resupply 21 CLW Protection	 EWCV OICW **TWS 5 Gen** 25mm gun 120 HRS Drone resupply 21 CLW Protection (+)	 **No organic vehicle** M4/SAW **TWS** 72 HRS ELH resupply BDU
Sensor Suite	AEROSTAT UAV HAE 4/4 Tactical Macro 9/9 Micro 30	**Enhanced** AEROSTAT UAV HAE **Armed 4/4** Tactical Macro 9/9 Micro 30	**Constrained** AEROSTAT UAV HAE (Predator) 4/4 Tactical Macro 9/9 Micro 0
Indirect Fires	EFOGM (15KM)	EFOGM (40KM)	No EFOGM

21CLW Protection	21 Century Land Warrior Body Armor
HAE	High-Altitude Endurance
LOAL	Lock On After Launch
OCSW	Objective Crew Served Weapon
OICW	Objective Individual Combat Weapon

Base-case excursion limited the role of the AP-15 as a direct-fire system except in selected situations.

Other capabilities are envisioned for the force, to include robotics, nonlethal devices and enhanced commo systems, but were not addressed.

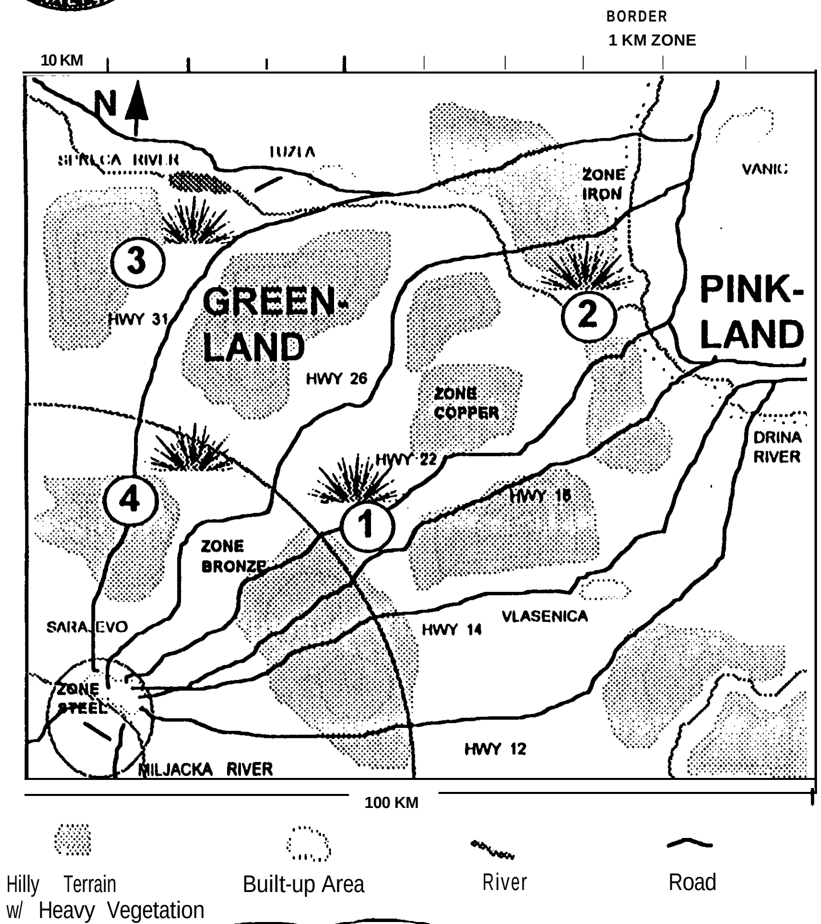
COMPARATIVE RESULTS - PEACE ENFORCEMENT PHASE

In both the enhanced and constrained cases, there is little difference in the outcomes of the convoy security mission or the ELH support missions. In both cases, the changes in the for e capabilities are not sufficient to eliminate the low-tech, rogue threat that often exists in an insurgency e vironment.

The ability to seal the Pinkland border changes as the structure of the force varies. In the base and enhanced cases, the PSTs are able to seal Zone Iron. Once the PSTs lose their organic mobility and, more importantly, their ability to control a dedicated, focused UAV, they are unable to identify all the potential border crossers and, as a result, are unable to seal the border with the assigned teams.

Several interesting observations are noted as the various forces attempt to clear Zone Bronze. First, in the enhanced case only, the force is able to identify a majority of the Red indirect fire systems before they fire on the APOD. This has obvious benefits for the Task Force in that it reduces the threat to the forces guarding the APOD. Second, the AP-15 continues to be the most effective tool against the fleeing Red targets although in the enhanced case we also begin to see the potential contribution of an armed UAV. Finally, it is only in the enhanced case that the full suite of Red indirect fire systems are found. In the other cases, there are several systems that continue to avoid detection.

COMPARATIVE RESULTS - PEACE ENFORCEMENT PHASE



IN THE CONSTRAINED CASE, THE LACK OF MOBILITY FOR THE PST SIGNIFICANTLY DEGRADED THEIR ROLE IN IDENTIFYING, APPREHENDING OR ELIMINATING RED THREATS.

KEY EVENTS AND INSIGHTS

1. **ESCORTING AID CONVOY**
   - In all cases, convoy is susceptible to the low-technology techniques of the insurgent force and sustains some losses in Red ambush in built-up area.

2. **SEALING PINKLAND BORDER**
   - With the inherent mobility and detection capability in the base and enhanced cases, Blue successfully seals the border and eliminates all border crossings.
   - In the constrained case, without the mobility of the PST or the focused detection capability of the micro UAV, Blue cannot seal the border and almost all of the Red attempts to cross the border are successful.

3. **CONDUCTING ELH SUPPORT MISSIONS**
   Relative success of ELH support missions remains a constant in all cases.

4. **CLEARING ZONE BRONZE**
   - All Red artillery and rocket systems in Zone Bronze are detected and eliminated in the enhanced case only. Some systems remain undetected in other cases.
   - In the enhanced case, as opposed to the base or constrained case, more Red systems are detected and eliminated before they are able to fire.
   - In the enhanced case, the armed UAV is employed to eliminate two Red systems instead of "handing off" the target to another Blue system.

COMPARATIVE RESULTS - COMBAT OPERATIONS PHASE

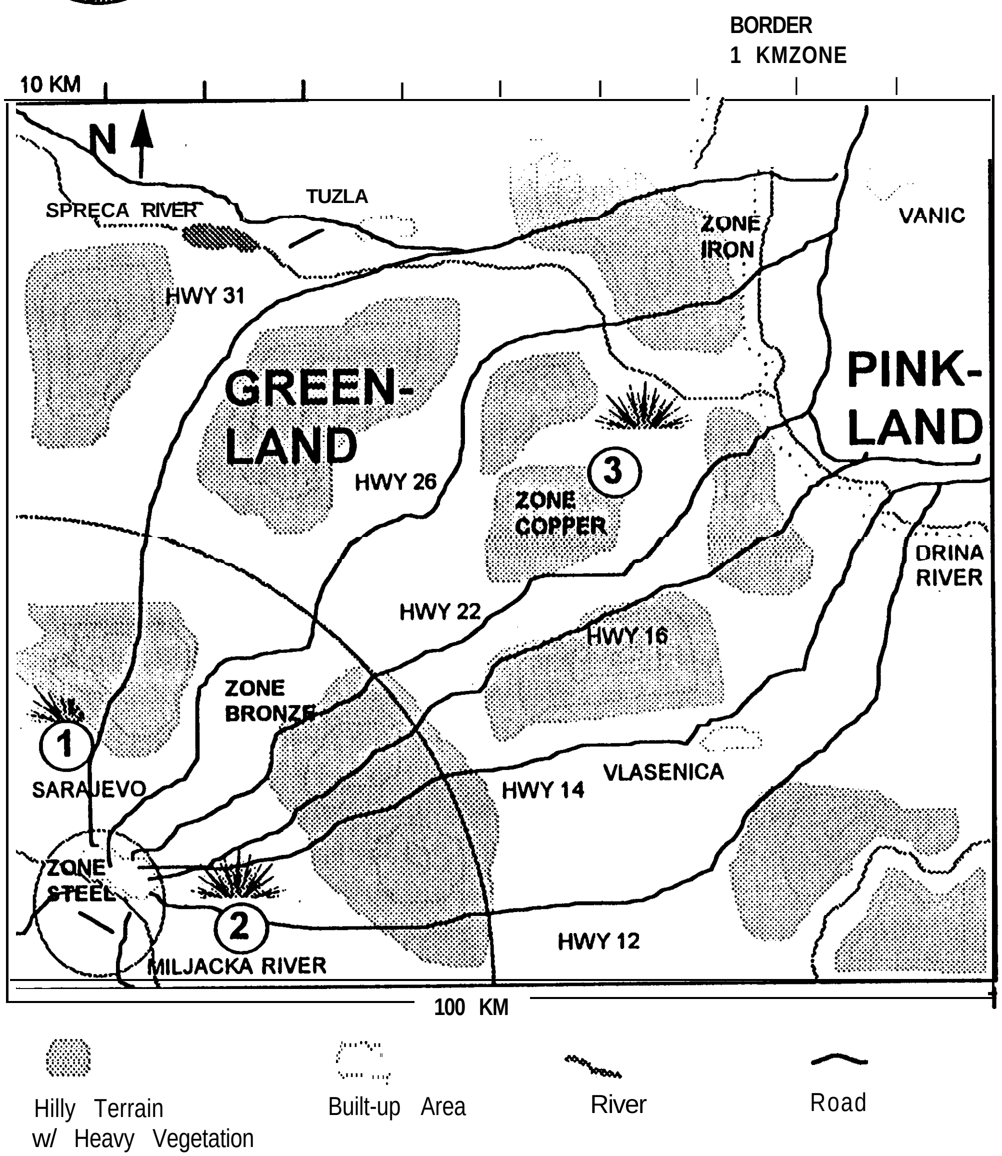
In all three cases, there is little difference in the outcome of the Red attack on the airfield. Again, the significant conclusion is that in all cases the Task Force relies on its conventional arm to eliminate this threat.

Against the cruise missile threat, the enhanced case achieves the same level of success as the base case. In the constrained case, with a reduced detection range for the Aerostat and a reduced probability of kill for the supporting air defense system, one missile avoids detection and is able to destroy one HIMARS launcher.

Finally, in all three cases, the Pink force is stopped before they penetrate the 40 KM exclusion zone. They are halted almost 80 KM from the APOD in the enhanced case. In the constrained case, lead vehicles of the lead regiments reach the boundary of the exclusion zone before the attack is halted.

The differences in force capabilities between the base, enhanced and constrained cases are simply not dramatic enough to significantly mitigate those conditions that ensure Task Force Griffin's success. The ability to conduct long range, precision attacks, the situational awareness provided by the redundant suite of sensors and the level of force protection provided by the Task Force's dispersed method of operation, assure the ability of Task Force Griffin to defeat this mechanized threat.

COMPARATIVE RESULTS - COMBAT OPERATIONS PHASE



KEY EVENTS AND INSIGHTS

1 DEFEATING CRUISE MISSILES

- In the base and enhanced cases, all cruise missiles targeted at Sarajevo are eliminated. in the enhanced case, these missiles are engaged at a significantly extended range.
- In the constrained case, due to reduced probabilities of intercept and kill, one missile avoids engagement and impacts, causing the loss of up to two HIMARS.

2 COUNTERING RED ATTACK ON AIRFIELD

- Blue successfully defeats ground attacks in all cases with no significant differences.

3 HALTING PINKLAND ATTACK

- In all cases, blue successfully halts Pinkland attack and prevents penetration of the 40 KM zone.
- Pink is most successful against the constrained force, penetrating to within 50 KM of Sarajevo.
- Restricting the AP-15 to primarily a sensor role increases reliance on HIMARS and its engagement time and allows Pink to penetrate further.

HALTING PINKLAND ATTACK - COMPARATIVE RESULTS

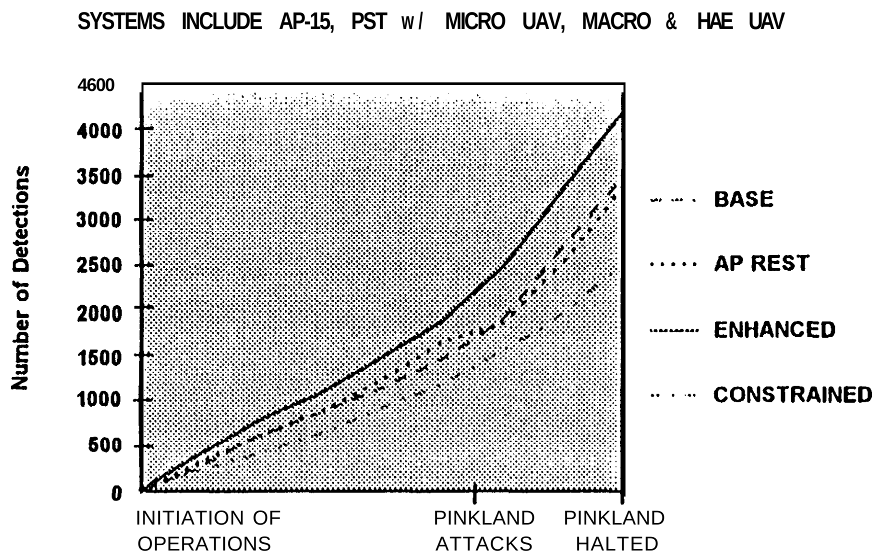
The comparison of the combat operations leads to some of the more interesting conclusions about this force. First, in all cases, the PSTs are the major contributors of initial, unique detections. That contribution is degraded when the force is only foot-mobile, but, even in that case, the contribution is approximately 40% of the total detections. The ability of the PSTs to blanket the battlespace, to discern friend from foe in an insurgent environment, to focus their organic UAV, and to provide continuous coverage permits dramatic contribution.

Second, the indirect fire system, whatever its source, is the dominant killer. In this scenario, the compartmentalized terrain, coupled with extended distances allowed multiple attacks on the enemy in successive engagement areas. Had the range from the Pinkland border to the APOD been reduced, Task Force Griffin would have had to employ different techniques, to include synchronized attacks by several indirect fire systems to attrit the enemy and, perhaps, more direct fire engagements between PSTs and Pink forces. In another scenario, if the range had been limited and if the country of Greenland did not offer terrain well suited to Task Force Griffin's concept of operation and capabilite, conventional forces may have had to be introduced earlier.

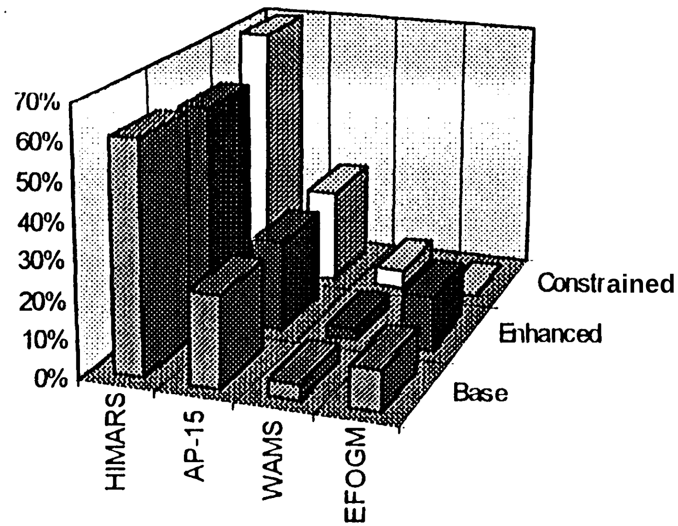
Finally, when the role of the AP-15 is restricted to primarily a sensor platform, the number of kills credited to that systems drops from approximately twenty-five percent to approximately eight percent. There is not, however, a corresponding significant increase in the number of detections logged by the AP-15 primarily because in this scenario the PSTs remain the dominant observers. In addition, Pink penetrates further because additional HIMARS and EFOGM attacks are required in subsequent engagement areas. This suggest that perhaps METT-T conditions should define the appropriate role for the AP-15, but highlights its flexibility to act as either a sensor or a shooter.

HALTING PINKLAND ATTACK - COMPARATIVE RESULTS

Totai Detections over Time By Blue Organic Systems



Pink Combat Vehicle Kills by Blue Systems



- **Results confirm expectations**
  - **in enhanced case, Task Force detected more, quicker, and at greater range.**
  - **in constrained case, Task Force cannot achieve same number of detections.**
- **FRV equipped PSTs, armed with their micro UAVs, provide almost continuous coverage of the battlefield and account for approximately 55% of the unique detections.**

- **HIMARS remains the dominant killer in all cases.**
- **In an alternative case the AP-15 is restricted to a sensor role, its contribution is reduced from 25% to 8% of total kills.**

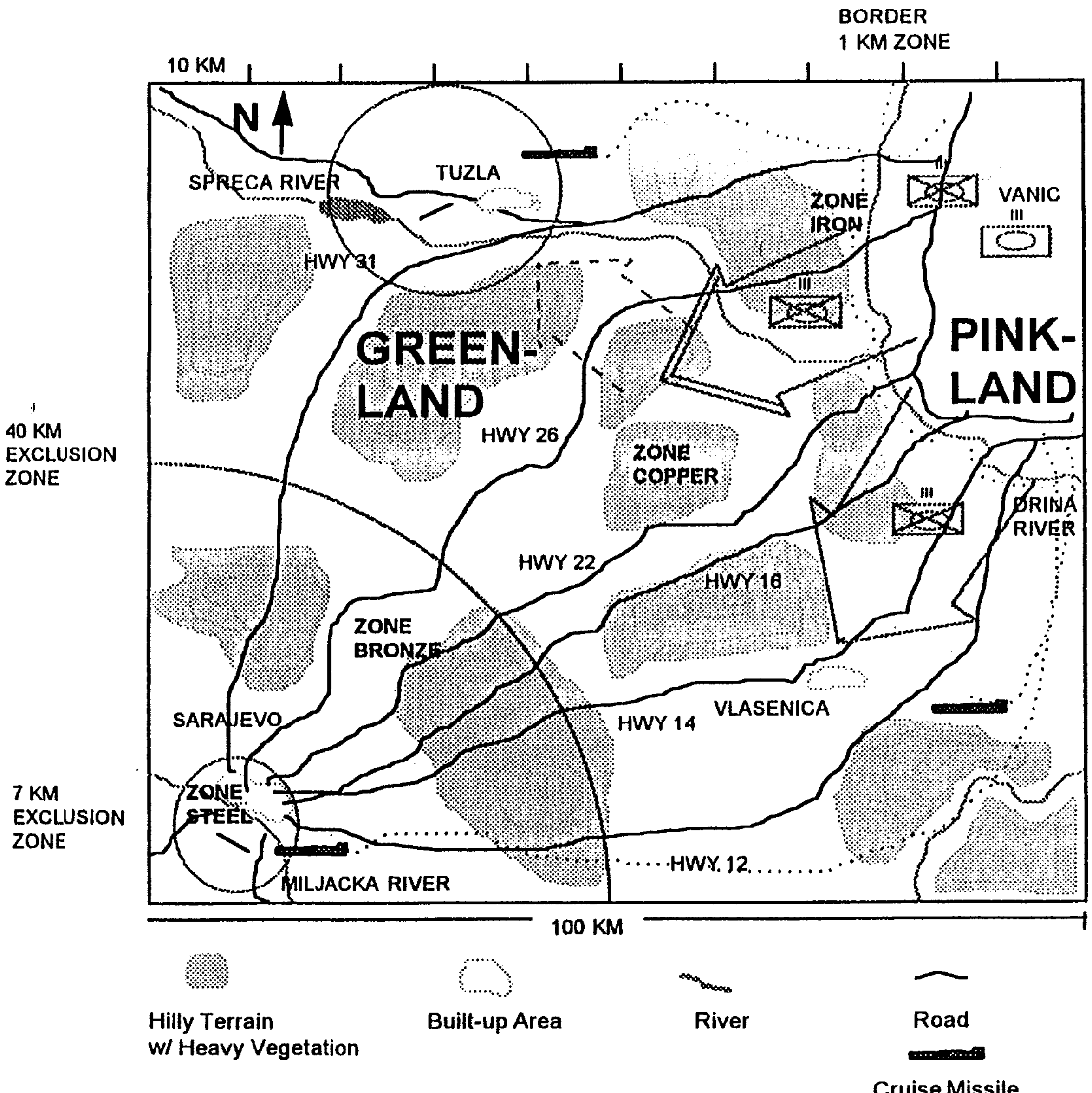
Task Force Griffin is designed to operate in an extended battlespace. It is dependent upon the distances inherent in that battlespace to allow the organic redundant suite of sensors to focus indirect precision munitions on the attacking enemy and effectively shape the battlespace.

PINK LIMITED OBJECTIVE "AUDIBLE"

The next three slides set the conditions and highlight the outcome if, in fact, the Pink Commander redefines his mission and attempts to seize a limited objective.

This slide outlines that change of intent and the actions that the enemy commander would take. This enemy commander recognizes that he is unable to achieve his mission of securing the Sarajevo APOD, that he is unable to eliminate the PSTs and aerial platforms that are fighting from dispersed positions while directing precision indirect fire, and that he cannot afford to continue to insert follow-on forces if they will be subject to the same level of attrition.

PINK LIMITED OBJECTIVE "AUDIBLE"



CONCEPT

- Pink initiates its attack along two axes with main effort in the north.
- Due to losses incurred after crossing the Drina River, Pink commander determines he cannot seize Sarajevo and turns to seize Tuzla as a base of operations and to await follow-on forces. He initiates contact with the Red insurgents in Tuzla to facilitate occupation.
  - -- Lead Motorized Rifle Regiment in the north will seize Tuzla and surrounding defensible terrain.
  - -- Lead MRR in the south goes to ground to avoid further attrition.
  - -- Trail MRR in the north continues movement east on HWY 31 to support force that is attempting to occupy Tuzla.
  - -- Reserve Tank Regiment moves to positions along Pinkland border and prepares to reinforce forces in Tuzla.
- A second Pink division is moving to support.

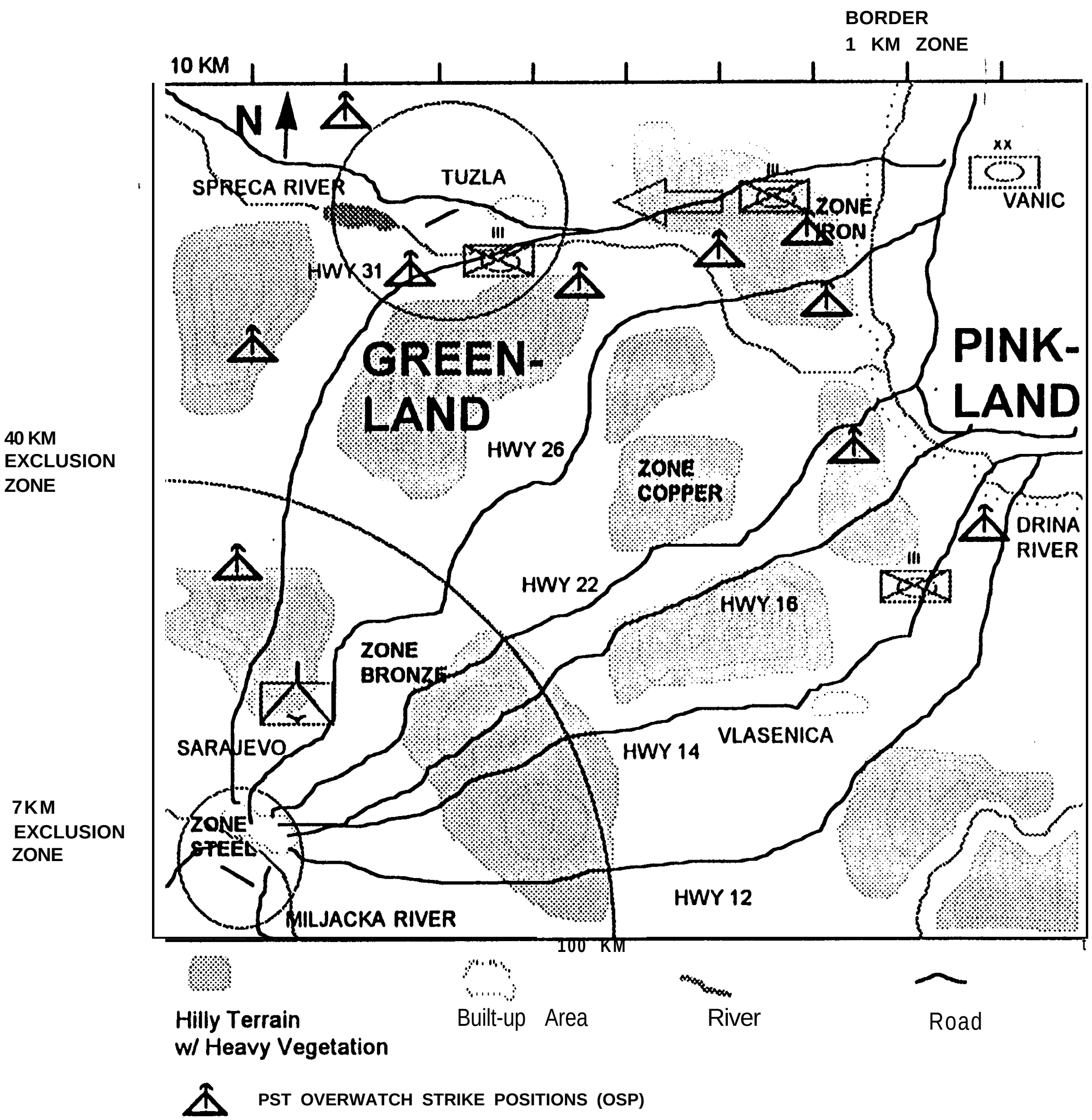
BLUE CONCEPT TO ISOLATE TUZLA

Recognizing the Pink commander's change of intent, the Task Force Griffin commander executes a branch plan to isolate the town of Tuzla and set the conditions for the successful employment of follow-on forces.

The critical observation is that once the enemy chooses this option, the utility of Task Force Griffin is somewhat limited. It can continue to attrit those forces that attempt to secure Tuzla and it can prevent additional forces from transiting from Pinkland to Tuzla. It cannot, however, force the enemy forces out of the urban area nor can it eject those forces in the south that take advantage of the highly defensible terrain and "go to ground."

At this point more conventional dismounted forces are needed to dislodge the enemy from Tuzla. Such an environment requires the commitment of more troops for a given frontage, perhaps several times greater than that expected in combat on open terrain. The danger of excessive collateral damage within such an area limits the utility of those precision weapons available to the Task Force. In addition, the very nature of built-up areas tends to minimize the effectiveness of indirect fires. Consequently, the Task Force's ability to strike at extended ranges is mitigated and the Task Force cannot, even if it masses the PSTs to form company size PSUs, generate the density required to secure a foothold within Tuzla and clear the Pink force from that town.

BLUE CONCEPT TO ISOLATE TUZLA



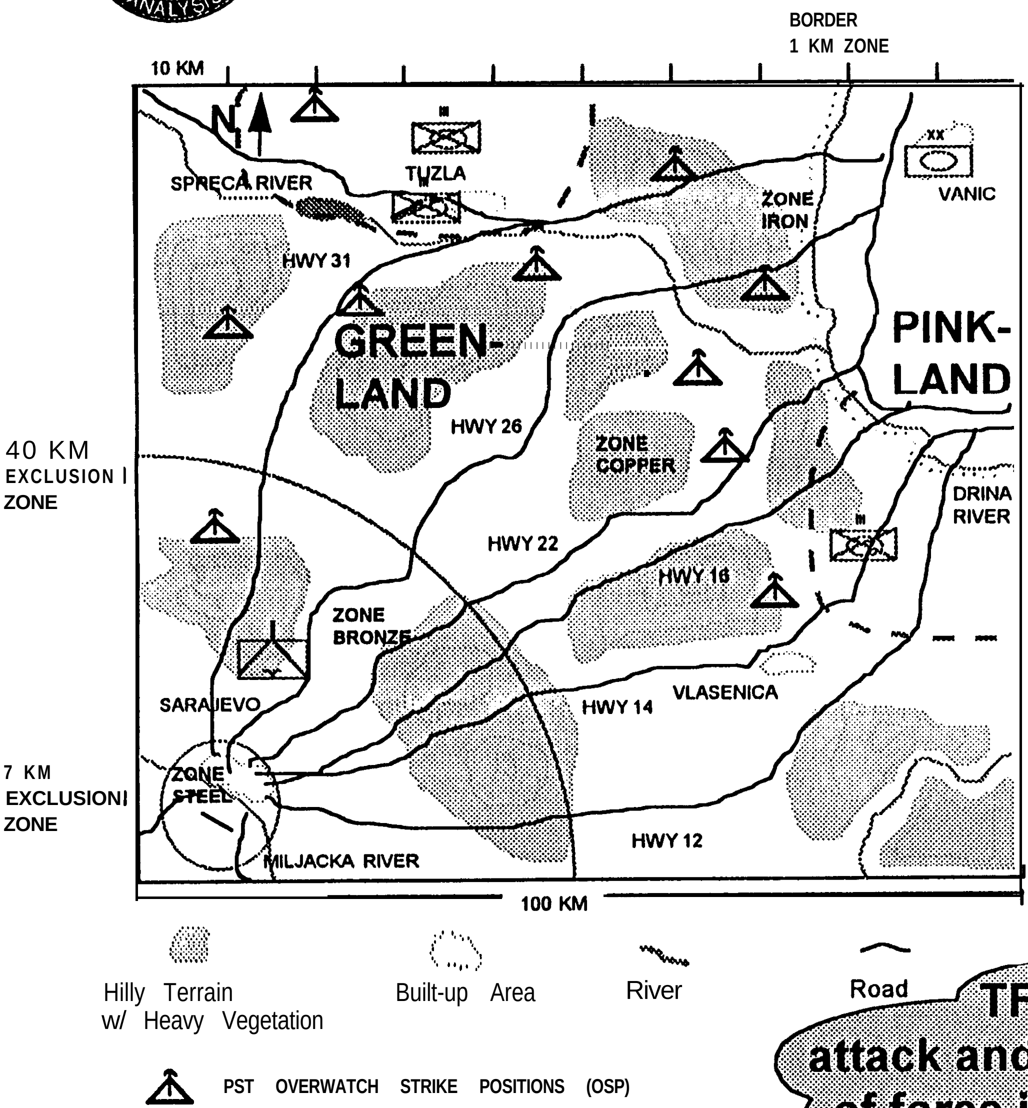
CDR's INTENT

- I intend to isolate and shape the battlefield to allow follow-on forces to eject the i invading Pink force. We must minimize collateral damage to facilities in Tuzla.
- We will continue to attrit the regiment that is turning towards Tuzla and we will attack the follow-on motorized regiment with DA-WAM and deep-strike fires to attrit that force before it closes on Tuzla.
- We will destroy the Drina crossing sites in the north with joint precision strikes; establish OSPs with EFOGM along the border and HWY 31, as well as north and south of Tuzla . AP-15s will assist the PSTs especially north and east of Tuzla. We must prevent the uncommitted tank regiment and the reinforcing Division from moving to Tuzla.
- I will accept risk in the south and move the AT CO to blocking positions north of Sarajevo. AP-15s and PSTs will not engage on their own except in self-defense.
- Success is achieved when follow-on forces are prevented from reaching Tuzla and Blue heavy follow-on forces begin the destruction of the Tuzla position.

THE ISOLATION OF TUZLA

This slide reflects the disposition of forces once the Pink units have moved into Tuzla. At this point there are two MRBs (+) in the vicinity of Tuzla and a MRB (+) in the southern sector. Pink units in Tuzla are now supported by Red insurgents. The Blue Force is faced with a non-linear battlespace that will require follow-on forces to eliminate the threat.

THE ISOLATION OF TUZLA



DISPOSITION OF FORCES

- The lead motorized regiment, originally traveled along HWY 26, turned north and moved to Tuzla, occupying that location at about 30% strength. This unit has linked up with the Red insurgents.
- The trailing motorized regiment continued to advance along HWY 31 and came under HIMARS fires and encountered several WAM minefields. That force closed at Tuzla at about 60% strength.
- The regiment in the south goes to ground and established defensive positions northeast of Vlasenica. That force was attrited to about 33% and is preparing to move back into Pinkland.
- The battlefield is now nonlinear and extends along the Spreca River in the north and along defensible terrain in the south.
- Blue forces have destroyed the northern Drina River crossing sites and are in position to attack any Pink forces attempting to reinforce the units in Tuzla. PSTs and AP-15s have established Overwatch Strike Positions to isolate Tuzla.

TF Griffin has halted the Pinkland attack and can now isolate and monitor activities of force in Tuzla. Conditions have been set for employment of follow-on forces.

ANALYTICAL INSIGHTS

These five bullets highlight many of the insights that were generated throughout the course of the study and that are discussed on previous slides.

The organic mobility inherent in the force paid several dividends. First, the PSTs were able to enhance their survival by avoiding direct fire engagements with the invading enemy force. Our results indicate that no PSTs are lost to Pink combat vehicles. Second, those PSTs that were portrayed as possessing organic mobility also controlled a micro-UAV which added to the sensor coverage of the Task Force. Third, the AP-15 proved most effective in quickly reacting to the fleeting insurgent targets during the Peace Enforcement phase of the scenario. This mobility allowed them to account for the majority of the Red indirect fire systems eliminated in that phase. Finally, the mobility inherent in both the AP-15 and the PST allowed the Task Force to rapidly respond to the Pink commander's decision to occupy Tuzla and to move to positions that would further attrit the invading Pink units and prevent reinforcement by follow-on forces.

The Task Force successfully massed the effects of its various supporting elements without massing those elements directing the precision fires. As a result, the indirect fire assets of the Task Force were able to remain outside the range of the Pink systems, while the forward-deployed PSTs, operating out of dispersed recon-strike zones or overwatch strike positions, failed to present an appropriately massed target for Pink to engage.

The mechanism needed to synchronize sensors and shooters flows from the analysis that suggests the need for a Battlefield Integration Cell. The requirement for that cell became apparent during the Peace Enforcement Phase. and, in previous slides, we have outlined several considerations for the development and implementation of such a cell.

In every case examined, the long range precision munitions that attacked the invading Pink force in a series of sequential engagement areas, were the dominant killers on the battlefield, Clearly, the suite of sensors were key to the identification of the targets and could pass those targets to the long-range precision munitions that were unhampered in their ability to repeatedly engage the advancing enemy force. The AP-15 played an important role, as we suggest earlier, in its ability to not only support the force as an airborne sensor but also by its ability to attack pinpoint targets and to eliminate those vehicles that may have escaped the repeated volleys of the indirect precision systems.

Finally, throughout the analysis, it is clear that the Task Force benefits from the conventional forces that are included in the unit's structure. The conventional forces are able to defeat the attack on the airfield but could have been used to support the aid convoys, and are now necessary to support operations to eject the Pink forces from Tuzla.

ANALYTICAL INSIGHTS

- **Organic mobility** allowed the Task Force to avoid direct fire engagements with heavy, conventional forces, ensure greater sensor coverage, engage fleeting targets when appropriate, and respond to a radical change in enemy intent.

- The ability to **mass the effects of multiple dispersed systems** enhanced the effectiveness and survivability of the Task Force.

- **A mechanism is needed to synchronize sensors and shooters,** optimize sensor employment patterns, ensure sensor cross-cueing, facilitate rapid target handover, and rapidly fuse intelligence.

- The **ability to attack throughout the depth of the battlespace,** enabled by a redundant suite of sensors, precision long-range munitions, and an integrated sensor-shooter platform allowed Task Force Griffin to halt a heavy, conventional force.

- A **balanced integration of dispersed teams and conventional forces** was necessary to counter insurgent operations, minimize vulnerability to low-tech systems, and eject the heavy force.

CONCLUSION

Task Force Griffin is, indeed, a capable, early-entry force that can be used as the “tip of the spear” for conventional forces. It is a future force, perhaps an integral part of that Army that follows the currently proposed Force XXI. It is a force that enjoys significant benefits from an integrated sensor-shooter platform and the flexibility to access several sources of indirect fire systems. It is a force that may reduce the logistical footprint and suffer fewer casualties because of its dispersed method of fighting.

It is, however, a force that works in conjunction with and complements conventional forces. In this scenario, Task Force Griffin was able to successfully shape the battlespace and set the conditions for follow-on forces. In other scenarios, the balance between this force and other conventional forces may be varied or those other forces might have to be introduced earlier.

The analysis does suggest, however, that this concept certainly deserves continued investigation, for it has demonstrated a very clear and appealing potential.

CONCLUSION

In this situation:

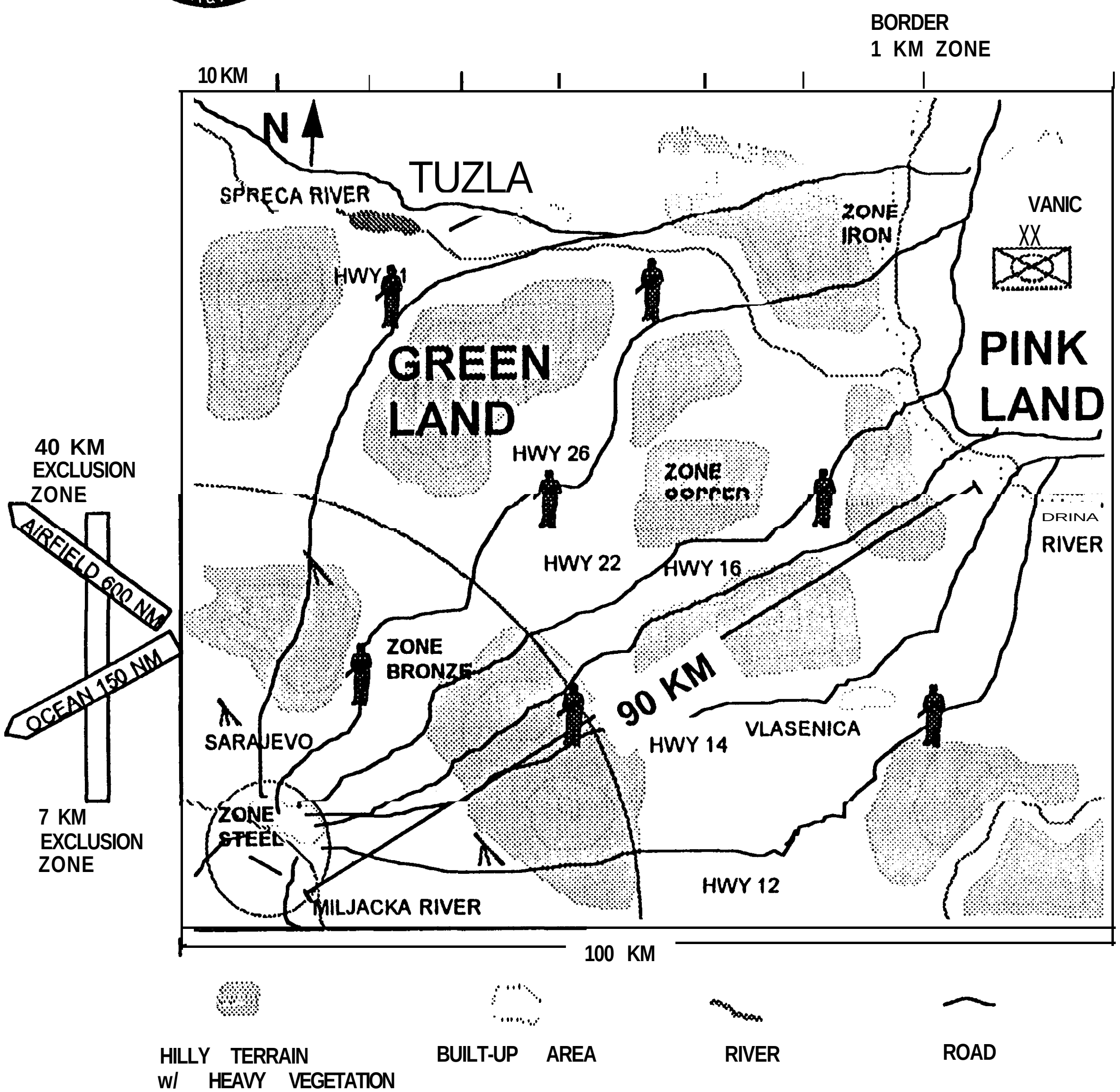
****Task Force Griffin is a capable, early-entry force that successfully denied the enemy his operational objective.***

- ***It is an effective "tip of the spear" for conventional forces, but:***
  - conventional follow-on forces are required to conduct extensive offensive operations, dominate the enemy, sustain battlefield victory, etc.
  - the conventional element within Task Force Griffin is necessary for certain missions, such as seizure of the APOD, crowd control, security operations, military operation in urbanized terrain, or defeating enemy ground forces where collateral damage should be minimized.
  - the balance between conventional forces and dispersed teams may vary as the operational situation changes.

Appendix A

A final briefing was presented by TRAC to the Defense Science Board on 9 August. Selected slides from that briefing were then incorporated into the Defense Science Board's presentation to the Secretary of Defense on 16 August. The following slides were briefed by GEN (R) Maddox.

SITUATION



RED PARAMILITARY INTENT

Conduct insurgency operations designed to undermine Greenland's government and to preclude the arrival of follow-on Blue Forces.

PINK INTENT

-Pinkland has positioned forces 40 KM east of the border and will attack if they:

a. Suspect stronger Green-Blue diplomatic ties.
b. Can exploit continued instability in Greenland.

-Pinkland may use continued Red cross border incursions as an excuse for offensive operations.

FRIENDLY FORCES

- Greenland has no standing military. Internal police force only capable of maintaining order in Sarajevo.
- UN has requested Blue take the lead in restoring order. ***Blue deploys Task Force Griffin as the leading element of a JTF.***

TASK FORCE GRIFFIN

Versatile, Digitized, Dispersed - a Force for 2015 and Beyond

PRECISION STRIKE UNIT

PSU

- HHC
- PSF SPT
- PSF
  - PSF HQ
  - PST
    - PST
      - PSS
      - PSS

PER PSU
69 FRV ARMED WITH JAVELIN OR FOTT
6 EFOGM HMMWV
3 MACRO UAV SYSTEMS
16 MICRO UAVs
1 WAM MINEFIELD
INTEL CELL

18 JAVELIN
12 FOTT HMMWV
4 120mm MTR

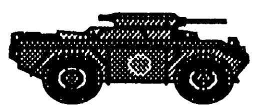
18 ATCAS (155 mm)
9 HIMARS
4 CTR FIRE RADAR

38 ENHANCED LIFT HELICOPTERS

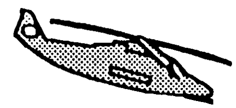
26 AP-16
3 MACRO UAV SYSTEMS
INTEL CELL

HQ

HHC
BATTLEFIELD INTEGRATION CELL
1 AEROSTAT w/TMD UNIT
4 HAE UAV SYSTEMS
ADA UNIT
FSU
MP UNIT
EN UNIT w/ AIRFIELD REPAIR TEAM



FUTURE RECON VEHICLE
FRV



AERIAL PLATFORM 2015
AP-15

EQUIPMENT	EQUIPMENT
2 FRV	2 FRV
1 JAVELIN	1 JAVELIN
1 TOW FOLLOW ON	1 TOW FOLLOW ON
•8 MEN	•8 MEN
•FRV1	•FRV3
CDR	O/I SGT
TGT/FO SGT	ENGR SGT
MED SGT	COMMO SGT
AA SGT	AA SGT
•FRV2	•FRV4
ASST O/I SGT	PST TECH
ENGR SGT	TGT/FO SGT
COMMO SGT	MED SGT
AA SGT	AA SGT

PSU - Precision Strike Unit
PSF - Precision Strike Force
PST - Precision Strike Team
PSS - Precision Strike Section

TASK FORCE GRIFFIN'S MISSION AND INTENT

Mission

Task Force Griffin secures APOD, disarms the paramilitary forces within the 40 KM exclusion zone, and assists local authorities in restoring order. O/O, defeats the Pinkland forces allowing no penetration of the 40 KM exclusion zone.

Commander's Intent

- Initially rapidly deploy Precision Strike Teams (PST) and Aerial Platforms 2015 (AP-15) to clear Zone Bronze and seal the border. Assume some risk outside 40 KM zone.

Survivability of PSTs and supporting elements is a paramount concern.

- -Insure teams have access to indirect fire assets and situational awareness grid. Isolated teams will reposition to reestablish linkages.
- -PSTs will not become engaged in direct fire engagements with heavy conventional forces.

Success is defined as eliminating threat to airfield, halting Pinkland forces outside 40 KM exclusion zone and setting conditions for follow-on forces.

ANALYTICAL INSIGHTS

- **Organic mobility** allowed the Task Force to avoid direct fire engagements with heavy, conventional forces, insure greater sensor coverage, engage fleeting targets when appropriate & respond to a radical change in enemy intent

- The ability to **mass the effects of multiple, dispersed systems** enhanced the effectiveness & survivability of the Task Force

- A **mechanism is needed to synchronize sensors and shooters,** optimize sensor employment patterns, insure sensor cross-cueing, facilitate rapid target handover and rapidly fuse intelligence

- The **ability to attack throughout the depth of the battlespace,** enabled by a redundant suite of sensors, precision long range munitions and an integrated sensor-shooter platform, allowed TF Griffin to halt a heavy, conventional force

- A **balanced integration of dispersed teams & conventional forces** was necessary to counter insurgent operations, minimize vulnerability to low-tech systems and eject the heavy force

OPERATIONAL INSIGHTS

In this situation:

- ***Task Force Griffin is a capable, early-entry force that successfully denied the enemy his operational objective***
- ***It is an effective "tip of the spear" for conventional forces, but***
  - conventional follow-on forces are required to conduct extensive offensive operations, dominate the enemy, sustain battlefield victory, etc.
  - the conventional element within Task Force Griffin is necessary for certain missions, such as seizure of the APOD, crowd control, security operations, military operation in urbanized terrain, or defeating enemy ground forces where collateral damage should be minimized.
  - the balance between conventional forces and dispersed teams may vary as the operational situation changes

Section VI
"Analytical Support to the Defense Science Board - Tactics and Technology for 21st Century Military Superiority"

John Matsumura, Randall Steeb, Tom Herbert, Mark Lees, Scot Eisenhard, Angela Stich,
RAND Corporation

Volume 2, Part 1,
RAND Study

DOCUMENTED BRIEFING

RAND

Analytic Support to the Defense Science Board

Tactics and Technology for 21st Century Military Superiority

John Matsumura, Randall Steeb, Tom Herbert, LTC Mark Lees, Scot Eisenhard, Angela Stich

DB-198-A

November 1996

Prepared for the United States Army

Arroyo Center

PREFACE

This draft annotated briefing summarizes a fast response (one month) research effort that directly supported the Defense Science Board Summer Study Task Force on Tactics and Technology for 21st Century Military Superiority. This research examined the effectiveness of small dispersed force concepts, defined by the Defense Science Board, as they might be employed on a future battlefield. RAND, through the Arroyo Center, was one of several organizations to provide analytic support to this study. RAND's primary contribution focused on the higher end of the threat spectrum--small dispersed forces against attacking armor--representative of an early entry phase of a larger conflict. A fairly extensive simulation environment was employed to provide analytic-based assessments. Our work in this area continues to evolve as the research provides new insights and raises new questions.

The research was sponsored by the Deputy Assistant Secretary for Research and Technology--Chief Scientist in the Office of the Assistant Secretary of the Army for Research, Development, and Acquisition and was conducted in the Arroyo Center's Force Development and Technology Program. The Arroyo Center is a federally funded research and development center sponsored by the United States Army.

CONTENTS

SUMMARY

MAKING SMALLER FORCES MORE CAPABLE

The Defense Science Board (DSB) Task Force on Tactics and Technology for 21st Century Military Superiority was formed by the Office of the Secretary of Defense to explore new concepts for making a relatively small and rapidly deployable force capable for accomplishing missions that would otherwise require a large, massed force. As part of the concept development phase of the study, the DSB identified two different means of achieving a capable small dispersed force. The first concept represents an evolutionary change from current small forces such as the division ready brigade (DRB) of the 82nd Airborne. Here the force is envisioned to remain as a small, mostly self-contained unit such as a DRB, but it is given the mission and capability of a larger unit such as a division. This may be accomplished by augmenting many of the current components of a DRB with advanced RSTA, C2, and weapon systems, much as envisioned in the Rapid Force Project Initiative (RFPI) and the U.S. Army's Force XXI concept. The DSB builds on these concepts by emphasizing joint non-organic or "external" RSTA and fire support system technologies.

The second DSB concept is more revolutionary, removing the notion of an area control by ground forces almost entirely. Here, long range fires are called by small, virtually independent dismounted teams moving around the region. This concept is close to that espoused in the USMC Sea Dragon proposal. The DSB concept builds on Sea Dragon by extending it to include a larger range of external RSTA and weapons and possibly giving it a more substantial level of team mobility.

While our simulation effort focuses on the first concept, the two have many aspects in common, and some merging of ideas is expected. Both concepts emphasize joint operations and coordination among many geographically remote systems. The common question between both concepts is how much of a ground presence is needed to accomplish the many missions envisioned for the force.

ASSESSING TEE SMALL FORCE CONCEPT

Breaking up the Concept into Components

Given its many dimensions, assessing the effectiveness of the DSB small force concept can be a complex process. To address this concept, we broke it up into its fundamental components and systematically "built up" a base DRB into a notional DSB small force.

The first component examined was improved RSTA. We augmented the base DRB with a COVER-like system (similar to the commander's observation vehicle for elevated reconnaissance), in which scout vehicles are given a small tethered UAV that gives a largely unobstructed overhead view. We then added two RFPI technology RSTA systems--acoustic sensor arrays and remote sentries. The last RSTA system added was a generic high-altitude UAV with foliage-penetrating SAR and GMTI radar.

The next components to be examined were the external weapons and associated C2 options. Notionally, these could include different forms of ground, air, and naval long-range systems. The impact of two representative weapon systems were examined in conjunction with the three aforementioned levels of RSTA, using standard tactics, techniques, and procedures (TTPs). We also conducted sensitivity analysis to determine whether the effectiveness of these weapons could be improved. Assuming near-perfect intelligence, TTPs were changed, volume of fire was increased, and time-over-target timelines were reduced.

The final component examined was force dispersion. The base DRB force was broken up into battalion-sized units and spread out over an area 5-6 times as large as before. This force was attacked with two different levels of enemy artillery prep fires.

Scenario Used for the Analysis

Given the limited timeframe for our study, we used a variant of the LANTCOM High-Resolution 33.7, an already-existing scenario, originally developed by TRAC and modified for previous analysis. This scenario puts a partially attrited (forced entry) DRB in a hasty defense against a large armor attack (division minus) in mixed terrain. Perhaps uncharacteristic of the scenarios motivating the DSB vision, there is limited battlespace in this scenario, and thus limited time to conduct the enhanced RSTA and fire support phase of the defensive operation.

RESEARCH INSIGHTS

Our research evolved around answering four main questions. These questions are somewhat sequential in form, and they tend to parallel the analysis plan.

- How do more comprehensive and varied RSTA levels impact DRB performance?
- For the different levels of RSTA, how do advanced external fires affect the battle outcome?
- Given near-perfect RSTA, can external long-range weapons themselves stop an attacking force, or will units need organic capability?
- Will dispersing the force make it more or less vulnerable, and will it still be able to carry out a defensive mission?

Our initial responses to these four questions are provided in the following subsections.

How Did More RSTA Change DRB Performance?

Augmenting the base DRB with a COVER-like system offered the potential for more target acquisitions at range; however, benefit was seen mostly when the system was kept in stationary, hide positions. Using the COVER-like system on-the-move in mixed terrain yielded only a few more acquisitions than the base RSTA because the system was not able to maintain standoff *and* acquire targets (i.e., too many chance encounters from the attacking Red force). Addition of two types of RFPI unmanned sensors--acoustic arrays and remote sentries--provided considerable improvement in target acquisition. Working in conjunction with the COVER-like system, the two RFPI sensors could acquire deep targets nearly as well as close ones. Finally, the addition of a generic high-altitude endurance UAV using GMTI radar has the potential to offer a much more complete picture of the battlefield. However, we note that this type of information (from GMTI) may come with relatively large target location errors and limited ability to discriminate or identify vehicles.[1]

The successive levels of RSTA improvement systematically increased situational awareness, but this alone did not result in improved battle outcomes. The already "dug-in" DRB was postured to handle a multiple-axis Red attack, and any subsequent adjustment to the defensive laydown would be expected to yield only limited benefit. More importantly, increased target acquisitions with improved RSTA did not translate to improved force performance because the long-range weapons currently associated with the base DRB, cannon artillery with conventional rounds, were generally not effective against moving armor.

How Does Advanced External Fire Support Change DRB Performance?

When the above RSTA was accompanied by advanced external fire support, the DRB effectiveness was seen to improve notably. We assessed two different external "area" weapon system options that could be made available to the DRB in the future: an air-delivered standoff weapon with relatively small-footprint submunitions and a missile-delivered weapon with large-footprint submunitions. Without any RSTA improvements to the DRB, the relatively sparse, incomplete intelligence generally did not allow for such external weapons usage (assuming standard TTP guidance). *However, as RSTA was added, target opportunities rose, resulting in deep enemy attrition. Generally, as more RSTA was added, more engagement opportunities appeared and more weapons were fired, resulting in greater percentage of enemy vehicles being attrited before closing to the direct fire battle. Consequently, the direct fire battle intensity decreased, and overall force effectiveness improved (as*

[1]Assumes GMTI radar without the benefit of rotation around the targets.

expressed in loss-exchange-ratio). This effect was-more evident for the large-footprint submunition than for the small-footprint one.[2]

Can External RSTA and Fire Support Do It All?

To address this question, we performed a parametric analysis which systematically "improved" the application of the external fire support. Assuming the best RSTA case (near-perfect intelligence), we decreased the time to target to the point where weapons were delivered instantaneously. We also increased the volume of fire up to an order of magnitude higher than what standard TTPs might suggest. We next examined the effect of imposing battle damage assessment (BDA) between subsequent missions (i.e., are the weapons ripple fired, or is there an intermediate step to assess the effect before follow-on fires are committed?).

Generally, we found that shorter timelines led to higher overall weapon effectiveness, but this occurred only up to a point. Both weapons considered had some ability to compensate for target location error (TLE) and target movement error, and so both could be used effectively with some level of time delay. As expected, the weapon with small-footprint submunitions tended to perform best with very short timelines and when targets were moving predictably. In all other cases, the submunition effectiveness was seen to drop off significantly. In contrast, the large-footprint submunitions were generally much more forgiving. That is, reducing time over target from 20 minutes to 10 minutes produced some improvement; however, shortening the timeline further to zero yielded only minor improvements over the 10 minute time. This effect can be attributed directly to the ability of the footprint to compensate for the time delay.

With regard to volume of fires, for both weapons we observed significant "diminishing marginal returns" effects. That is, as more munitions were committed, the efficiency (kills per weapon fired) decreased, with the last targets becoming the hardest to hit.

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[2]Both weapon systems were assumed to originate from some distance away. Platforms that loiter or weapon systems that can be updated while in flight will probably yield different results.

We also varied the requirement for BDA. Because these weapons are considered precision weapons, there is normally some BDA imposed after a volley lands and prior to re-engaging the same set of targets. (That is, before committing subsequent fires, one should determine the outcome of the current fire mission.) This allows for appropriate scaling of effect for the subsequent volley. For our parametric analysis, we generally assumed optimistic levels of BDA--either it was almost instantaneous after the munitions landed or there was no requirement for BDA whatsoever. No requirement for BDA led to rounds being "ripple fired" at a set of targets.

Interestingly enough, even with the best of all cases (near-perfect intelligence, instantaneous time over target, high volume of fires, and no requirement for BDA), not all targets were killed. *This suggests that at least some level of organic weapons is needed to achieve the objective (e.g., to protect the airfield).*

What Happens with Dispersion of the Force?

We have only started to address the value of dispersion. What we have seen so far suggests that merely dispersing the base DRB will yield mixed effects. On the positive side, the indirect fire battle outcome improves for the DRB because enemy artillery fire becomes much more "diluted" given the larger area it must cover. However, on the negative side, the direct fire battle for the DRB degrades somewhat because its defense occurs around a much longer perimeter, resulting in a reduction of interlocking, mutually supporting fires. This outcome may change, though, with added DRB precision indirect fires, external fires, or more effective dispersion into mutually supporting "defensive pockets."

CONCLUSIONS

In general, the DSB concept for enhancing small dispersed forces with external RSTA and weapons offers tremendous potential for improving the outcome of battle. However, we note the concept relys on many steps to operate effectively--acquiring targets, passing information, assigning weapons, dispensing munitions, performing BDA, and many others. Each of these steps must function well for the concept to succeed.

Up to a point, we found that adding layers of ground-based and overhead RSTA could significantly improve situational awareness and enhance the application of external fires. The situation estimate can seldom be both complete and accurate, though, and different types of sensors contribute different inputs to the overall picture. In those cases where overlap of coverage was present, additional value was still observed in the form of commander confidence in committing rounds.

The notion of "if you can see it, you can kill it" was not demonstrated here. External fire support may exhibit long flyout and cycle times, and may not be able to engage targets as decisively as organic weapons. This can be especially true if the enemy uses deliberate countermeasures, such as dispersion, jamming, or decoys.

In view of such uncertainties, a force equipped with organic firepower appears to be essential, especially so when either an objective must be protected or an area denied to the enemy. Although our research does suggest that the amount of organic capability can be reduced given a significant presence of effective external RSTA and fire support, the most attractive and robust solution for enhancing the capability of small forces was a mix between advanced organic systems *and* external systems.

ACKNOWLEDGMENTS

Many people took the time and made the effort to contribute to the development of this quick-response research. To these people, the authors owe a debt of gratitude. At RAND, Dr. Bernard Schweitzer generously provided information on advanced radar technologies, Dr. Eugene Gritton provided high-level information on emerging small force concepts and technologies, and Dr. Paul Davis provided a highly constructive and timely technical review of this document.

Dr. John Parmentola and Dr. Fenner Milton at the Office of the Secretary of the Army for Research, Development, and Acquisition sponsored this research. Dr. Theodore Gold and Dr. Donald Latham, co-chairman of the Defense Science Board Study on Tactics and Technology for 21st Century Military Superiority provided high-level direction for this research. Maj. Gen Jasper Welch (USAF Ret.) and GEN David Maddox USA Ret.), leaders of the simulation support to the Defense Science Board, provided critical guidance throughout the research process.

This work was conducted in the Force Development and Technology Program within the Arroyo Center, under the management of Dr. Kenneth Horn and Mr. James Quinlivan.

The authors, alone, are responsible for the information contained in this documented briefing.

GLOSSARY

ABN	Airborne
ACTD	Advanced Concept Technology Demonstration
AD	Air Defense
AGS	Armor Gun System
APC	Armored Personnel Carrier
ASP	Acoustic Sensor Program
ATACMS	Army Tactical Missile System
ATGM	Anti-Tank Guided Missile
BDA	Battle Damage Assessment
C2	Command and Control
CAGIS	Cartographic Analysis Geographic Information System
COVER	Commander's Observation Vehicle for Elevated Reconnaissance
CM	Countermeasure
CR	Close Range
DPICM	Dual Purpose Improved Conventional Munition
DRB	Division Ready Brigade
DSB	Defense Science Board
EFOG-M	Enhanced Fiber Optic Guided Missile
FLIR	Forward-Looking Infrared
FO	Forward Observer
GMTI	Ground Moving Target Indicator
HAE	High Altitude Endurance
HE	High Explosive
HIMARS	High Mobility Artillery Rocket System
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
ICM	Improved Conventional Munition
IFV	Infantry Fighting Vehicle

IR	Infrared
JSOW	Joint Standoff Weapon
LER	Loss-Exchange-Ratio
LOS	Line-of-Sight
MADAM	Model to Assess Damage to Armor with Munitions
MLRS	Multiple Launch Rocket System
MOUT	Military Operations on Urban Terrain
MRL	Multiple Rocket Launcher
MTI	Moving Target Indicator
PGMM	Precision Guided Mortar Munition
RFPI	Rapid Force Projection Initiative
RJARS	RAND's Jamming Aircraft and Radar Simulation
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RTAM	RAND's Target Acquisition Model
SAR	Synthetic Aperature Radar
SEMINT	Seamless Model Integration
SOF	Special Operations Forces
SPH	Self-Propelled Howitzer
TACAIR	Tactical Aircraft
TLE	Target Location Error
TOC	Tactical Operations Center
TOW	Tube-Launched, Optically-Tracked, Wire-Guided (Missile)
TOT	Time Over Target
TRADOC	Training and Doctrine Command
TRAC	TRADOC Analysis Center
TTP	Tactics, Techniques, and Procedures.
UAV	Unmanned Aerial Vehicle
USMC	United States Marine Corps

1. Introduction

ANALYTIC SUPPORT TO THE DEFENSE SCIENCE BOARD

Tactics and Technology for 21st Century Military Superiority

In July 1996, RAND was asked to provide a quick response analysis to the Defense Science Board on the military utility of options for small, dispersed forces. This annotated briefing summarizes our examination and simulation of selected systems (reconnaissance, surveillance, target acquisition, command and control, and weapons systems) and new tactics and doctrine.

Project Objective

- **Explore the potential contributions of small dispersed force concepts on a future battlefield**
  - **Early entry phase of major contingency**
  - **-- U.S. defends against attacking armor**

The primary objective of the work is to use high-resolution simulation to explore and quantify the potential contributions of light force concepts in a specific set of circumstances--the early entry phase of a major contingency, when only light forces are in place. These light forces are required to defend a high-value area against a large attacking armor force.

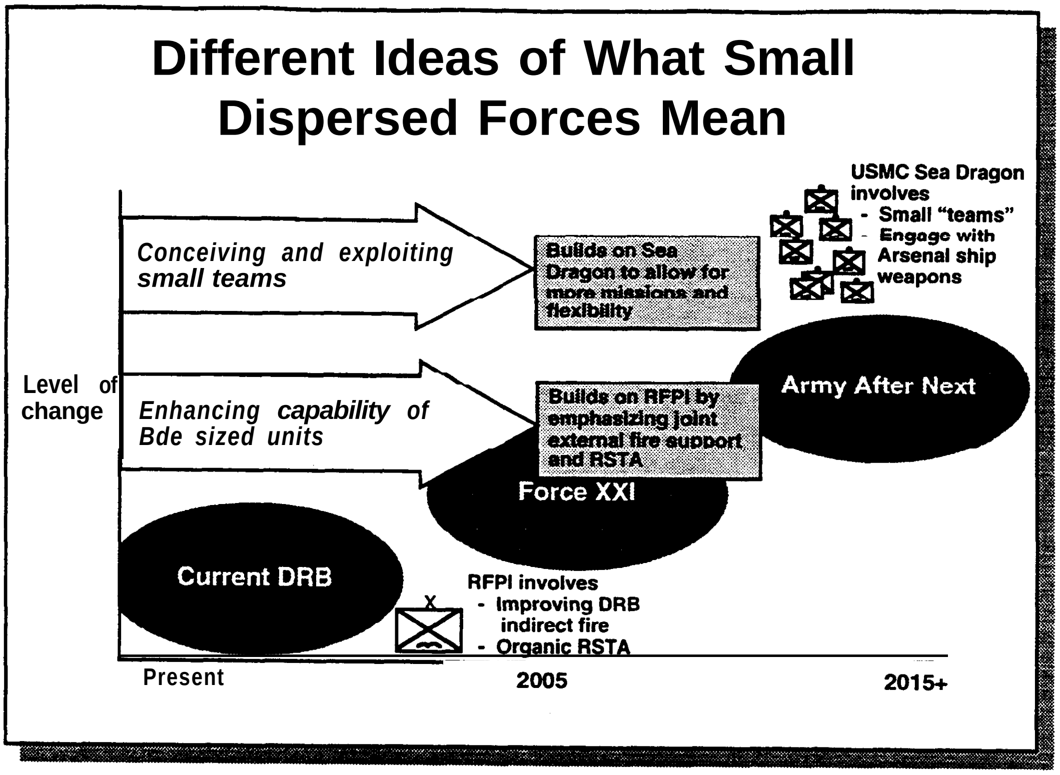
Other circumstances of interest to the DSB, such as use of small dispersed forces performing in infantry operations, MOUT, and low intensity conflict, are being examined by other simulation and modeling groups. Our work should have some applicability to these other areas, but our emphasis is on the anti-armor battle in a major contingency.

Small Dispersed Force Concept May Involve Dramatic Changes

Conventional force	Small dispersed force	Possible solutions
Overwhelming force	Minimize force, casualties	- Standoff, stealth, unmanned systems
Massed troops	Dispersed troops	- Improved C2 network - New logistics concept
Direct fire battle	NLOS battle	- Rapid, indirect fires
Massed firepower	Precision fires	- Efficient, discriminating weapons
Hold ground	Defend/deny ground	- Detect, deliver, scoot
Close & destroy	Destroy at stand-off	- RSTA/C2/long-range fires
Threat distinct	Threat intermingled w/friendly forces	- Robust IFF systems - Precision fires

The small dispersed force concept can be quite revolutionary in form, with many implications for the conduct of future warfare. For example, traditional or conventional conflicts, including Desert Storm, have emphasized positional warfare in which massed forces and firepower have been used to take and hold ground using primarily direct fire weapons. Use of small dispersed forces may change this by minimizing the presence and vulnerability of U.S. troops, and enabling small forces to take on the missions of much larger units. These forces will rely on non-line-of-sight systems to destroy much of the enemy force and avoid the high-attrition line-of-sight battle. While the light dispersed forces will not be as able to hold ground as conventional heavy forces, they should still be able to inflict substantial losses on the enemy and deny him the ability to maneuver, occupy ground, or otherwise affect Blue operations.

The types of systems and technologies needed to achieve these goals include deep, survivable RSTA systems, agile and robust C2 architectures, and precision, discriminating weapon systems. Some very sophisticated technologies, such as stealth, robotics, and automated IFF, may also be required for key missions.



The DSB has identified two different means of achieving a capable small dispersed force. The first is an evolutionary change from current small forces such as the division ready brigade (DRB) of the 82nd Airborne. Here the force remains as a small, mostly self-contained unit, but it is given the capability and mission of a larger unit. This is done by replacing many of the current components with advanced RSTA, C2, and weapon systems, much as is envisioned in the Rapid Force Project Initiative (RFPI). The DSB concept builds on the RFPI plan by emphasizing long-range, joint external RSTA and fire support.

The second DSB concept is more revolutionary, removing the notion of an area control by ground forces almost entirely. Here, long-range fires are called by small, virtually independent dismounted teams moving around the region. This concept is close to that espoused in the USMC Sea Dragon proposal. The DSB concept builds on Sea Dragon by extending it to include a larger range of external RSTA and weapons, and possibly giving it a more substantial level of team mobility.

Although our simulation effort focuses on the first concept, the two directions have many aspects in common, and some merging of ideas is expected. Both concepts emphasize joint operations and coordination among many geographically remote systems. The main question is how much of a ground presence is needed to accomplish the many missions envisioned for the force.

Key Research Questions

How might DSB small force concept improve brigade-sized unit performance?

- **What kinds of opportunities do different RSTA concepts provide?**
- **How do different levels of *target acquisition* affect long-range weapon performance?**
- **Given best RSTA, can *external long-range weapons* defeat armor attack, or will units need organic capability?**
- **How does *dispersion* affect the indirect and direct fire engagement dynamics?**

There are four main research questions we attempt to answer in our work on enhancing the capability of brigade-sized units. These questions are somewhat sequential in form, and they tend to focus on one issue at a time. First, how do more comprehensive and varied RSTA levels impact situation awareness and target acquisition? Second, for a given type of precision long-range weapon, how do different levels of target acquisition quality affect battle outcomes? Third, we ask a force composition question-given near-perfect RSTA from a variety of sources, are there circumstances in which external long-range weapons can themselves stop an attacking force, or will units need organic direct and indirect fire capabilities? In effect, can small semi-independent teams and external weapons alone do the job? The last question focuses on the effect of spreading out the Blue light force to cover more area--will the force be more or less vulnerable, and will it be able to better carry out a defensive mission?

Mission and Scenario Examined Is Only a Starting Point for Answering Questions

- **Specific conditions may not permit generalizations**
  - **Focus on engagement of moving armor**
  - **Relatively small area of battlespace available to conduct long-range attack operation**
- **"Benefit of doubt" given to technology**
  - **Assume near-perfect communication connectivity**
  - **Future RSTA and weapon systems perform as expected**

To begin to answer these research questions, we are using a specific scenario, with Red armor attacking a Blue light force in a hasty defense. We consider this scenario to be a good starting point, as it addresses many key issues for the light force concepts, such as surveillance and targeting of mobile and stationary units in several different formations and in several types of terrain. Other scenarios should also be examined to provide more complete insights about the force options, and the concepts themselves should be evaluated in degraded conditions. For example, blocked communications, unreliable and flawed RSTA inputs, and stressing environmental and battlefield conditions should all be represented in future work.

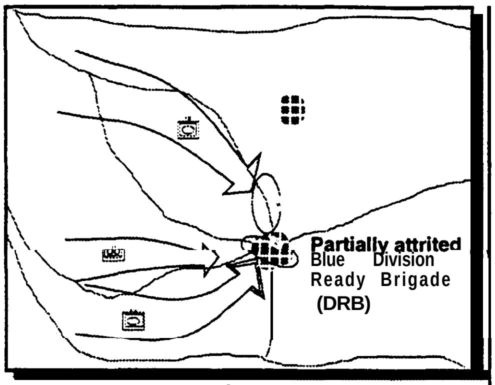
2. Background

Outline

- **Background**
- **Research plan**
- **Findings**
- **Conclusions**

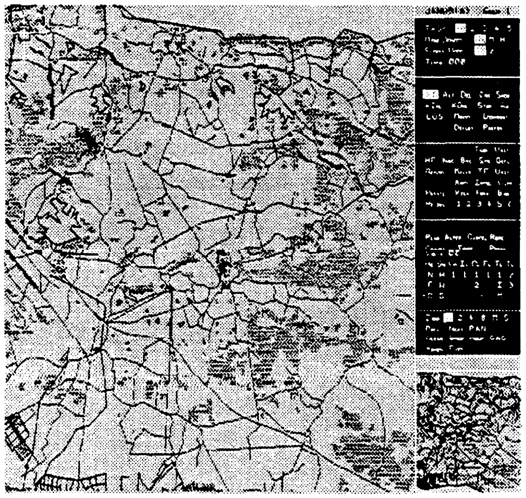
The annotated briefing is divided into four parts, with the great majority of attention given to the findings section. The first section describes the scenario and methodology used in our work.

LANTCOM: Light Infantry in Hasty Defense Against Heavy Division(-) in Mixed Terrain



1998 Force	Red	Current DRB
Tank	131 T-72S	4 AGS
ATGM	0	24 Javelin
APC/IFV	143 BMP	34 HMMWV-TOW
Rocket artillery	6 MRL	0
Cannon artillery	12 2S3+	26 105/155 (towed)
Helicopters	6 Havoc	6 Apache
Air defense	40 2S6	6 Stinger teams

+152mm SPH



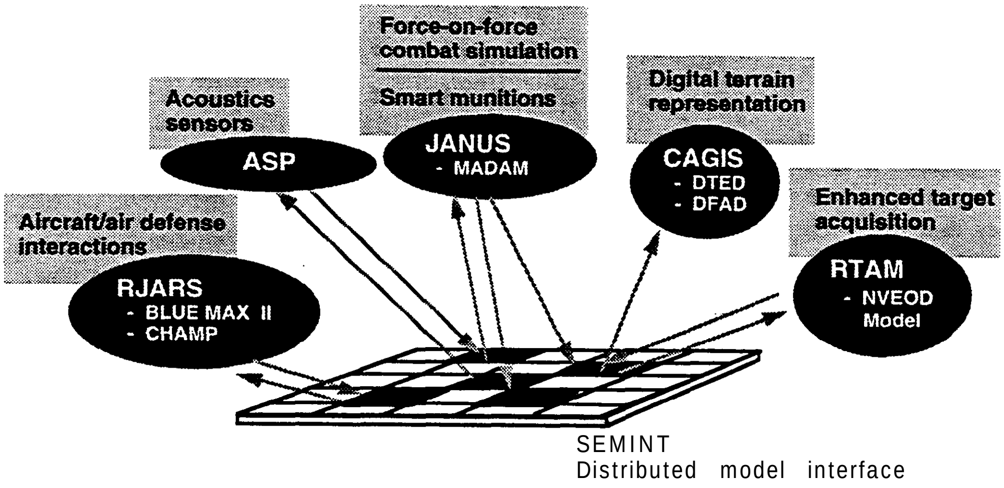
Simulation screen image (modified TRAC HRS 33.7)

The scenario we used for the analysis is a high-stress variation of the TRAC High Resolution Scenario 33.7 in LANTCOM. In this scenario, a partially attrited Blue DRB (following forced entry) faces a substantially larger Red force, a division (-) attacking along three primary avenues of approach. The Red force contains some sophisticated weapons, including: T-72S with AT-11 (fire on move) missiles, BMP-2s and BTR-60s with AT/P-6 missiles, self-propelled 120mm MRLs and 152mm (2S3) howitzers, which are considered to be medium to hard targets, and mobile air defense units (2S6) with radar track 30mm guns and (SA-19) missiles. Red does not have sophisticated RSTA and must rely on commander FLIRs and visual recognition for the direct fire engagements.

The Blueforce objective is to hold the key strategic point (an airstrip), until heavy reinforcements, now en route, can arrive. The Red objective is to destroy the Blue force as fast as possible before reinforcements can engage. Preparatory fires from Red self-propelled artillery--firing improved conventional munitions (ICM) and high explosive (HE) rounds--support the deliberate Red armor attack.

The partially-attrited DRB is assumed to have enough time to set up a defensive position, complete with extensive ground-based RSTA--prior to the Red attack. The simulation screen image above shows the main body of the Blue force positioned in the high ground around a town. Forward of this (to the west) are RSTA systems spread over the likely Red areas of advance. The area shown is approximately 60 by 60 kilometers.

Modeling Effort Integrates Different High-Resolution Models Locally

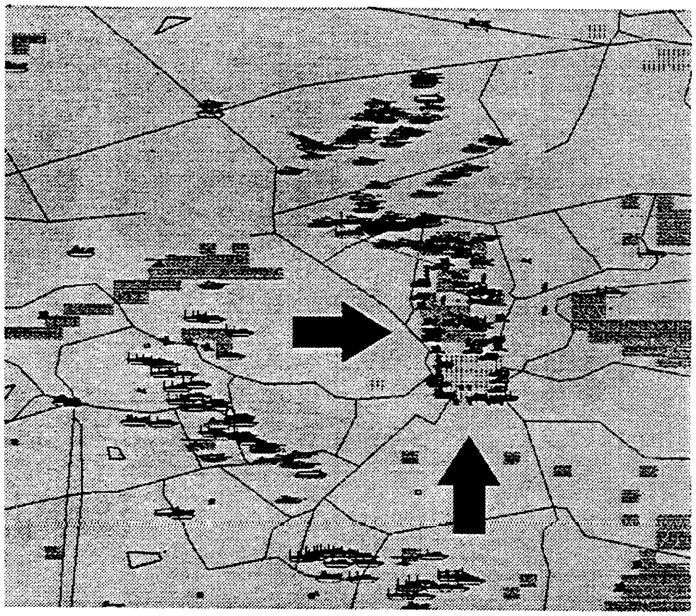


Over the last half-dozen years, we have developed a locally-distributed interactive simulation system to support analytical studies on advanced land combat. Although the work is usually conducted entirely within RAND, it involves connecting a number of separate models and simulations as shown above. Janus provides the overall force-on-force ground combat context, where the RAND version can represent up to 1200 distinct entities on a side.

Generally, the other models and simulations allow us to examine other combat dynamics in greater detail or fidelity than available in Janus. RTAM and CAGIS, for example, allow us to represent acquisition of reduced signature vehicles on the battlefield. RJARS models the detection, tracking, flyout and fusing of air defense missiles. MADAM and CAGIS simulate the effects of smart munitions, including multiple hits, hulks, unreliable submunitions, etc. ASP models acoustic sensing by such systems as unattended ground sensors and smart mines. SEMINT, finally, allows all of these simulations to communicate during a simulation. The integrated set of models can be run interactively (with Red and Blue garners), or the system can be run in batch mode with plans and behaviors input beforehand.

Simulation Shows Base DRB Does Not Survive Against Large Armor Force Attack

- Virtually all engagements occur in the direct fire (LOS) battle
- Blue direct fire systems achieve good LER=3 to 1
- However, Red massed attack eventually overwhelms Blue
- Primary direct fire vehicles are attrited
- Then, dismounts and towed artillery become vulnerable



Red force overruns Blue defense

Simulation in the LANTCOM scenario shows that the base DRB is unable to attrit the attacking Red force at range, because its only indirect fire assets--towed 105 and 155mm howitzers firing DPICM and HE--are relatively ineffective against moving armor. Only 3% of kills by Blue are attributable to artillery, while 30% of kills by Red are from artillery firing (preparatory fires) on the fixed Blue positions.

The Apaches provide some extended-close (out to 15 km or so) lethal fire, but this is not significant enough to halt the attack. The battle moves quickly to a ground-based direct fire engagement, which favors the defenders initially, with an observed 3-4:1 loss exchange ratio.[1] However, Red's superior numbers, heavier firepower (including a fire-on-the-move missile), and greater armor protection soon overwhelm Blue. In particular, Red directs massed fires on the Blue vehicles that exhibit firing signatures. Red then penetrates the defensive lines and defeats Blue in detail. We typically examine the simulation outcome at 58 minutes into the battle, because this is the time when Red first breaches Blue's defense.

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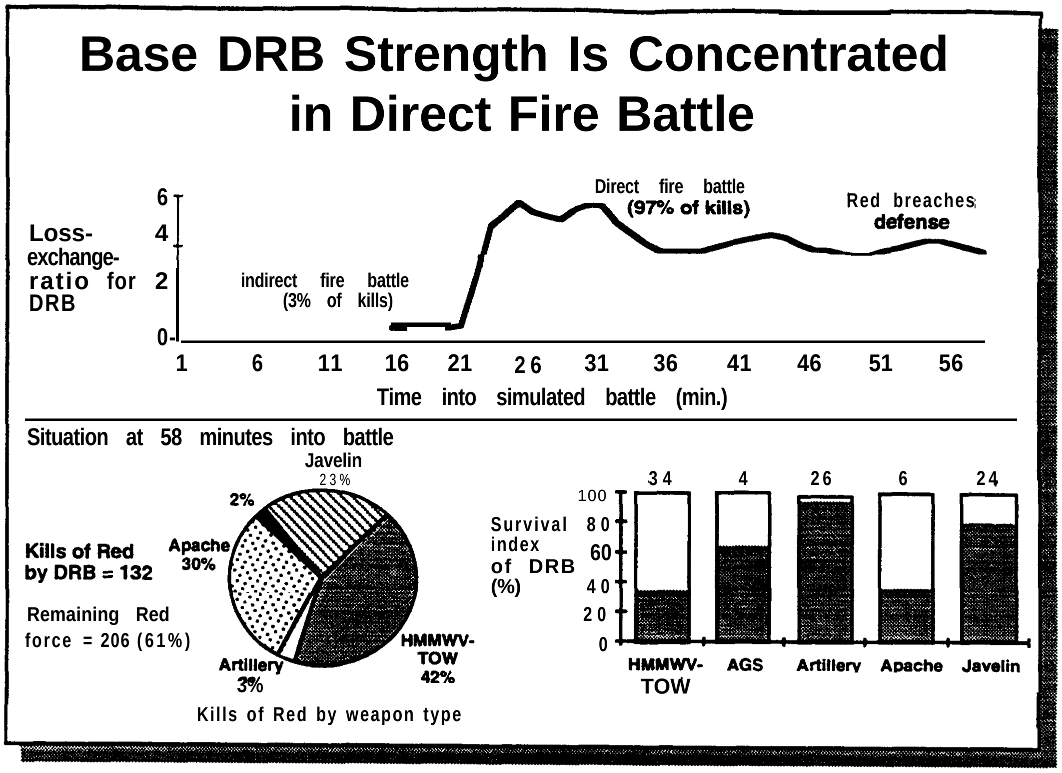
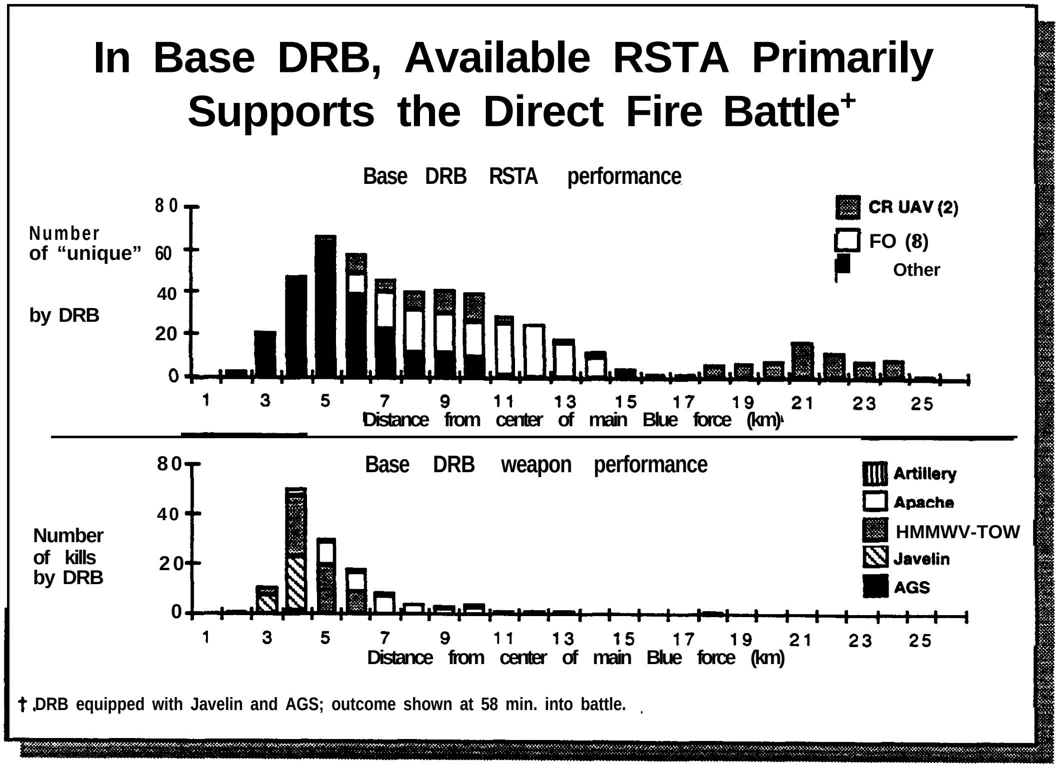
[1] Because of the initial force ratio of about 6:l in favor of Red, and the heavy vs. light composition of the two forces, we observed that a decisive win for Blue required a loss exchange ratio on the order of 10:1 or better.



The 58 minute snapshot look on the previous slide provided only a limited picture of the dynamics and outcome of the simulated battle. In the LANTCOM scenario, the base Blue DRB shows a very low LER for the first twenty minutes of battle. In effect, it is losing the indirect fire battle against the overmatching Red long-range artillery. The LER increases as the engagement moves into the direct fire phase, but Blue is still penetrated and overrun. Most of Blue's kills of Red are due to Apache, HMMWV-TOW, and Javelin. Survival of Blue's mobile systems--HMMWV-TOW, AGS, and Apache--is very limited, dropping to about 50% at the stopping point.



These figures show that Blue target acquisition primarily supported the direct fire battle, because the indirect fire systems--105 and 155 mm towed howitzers--were able to kill only a few Red armored systems. Most of the Blue direct fire systems were self-cued anyway, as they directed their fires at targets they themselves identified. The deeper acquisitions, at 18-24 km, were provided by two tactical UAVs flying at approximately 1000 meters over the battlefield. These Close Range UAVs were flown to maintain some level of stand-off from the attacking force (no overflight) and, thus, were assumed to be survivable in this analysis.

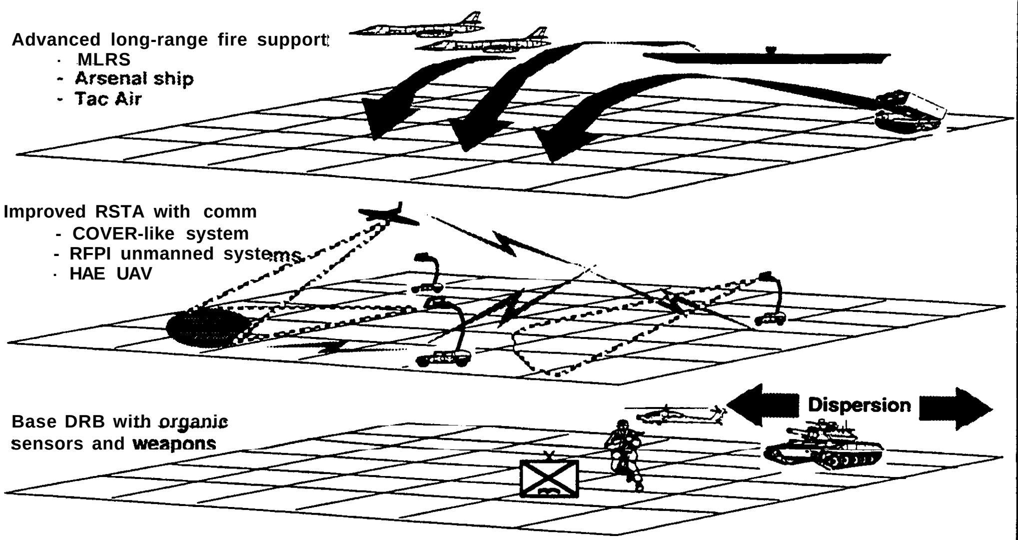
3. Research Plan

Outline

- **Background**
- **Research plan**
- **Findings**
- **Conclusions**

We now describe the research plan for investigating the potential benefits of improved RSTA, external fire support, and dispersion to the DRB force.

Analysis Involves Starting with Base DRB and "Building Up" to Alternative Force



Our analysis was designed to examine different parts of the DSB concept in sequential form, building up a picture of the significant issues.

The first series of runs examined RSTA performance. We augmented the base DRB with a COVER-like system, in which scout vehicles are given a small tethered UAV that gives a largely unobstructed overhead view. We then added two RFPI systems--acoustic sensor arrays and remote sentries. The last RSTA system added was a stand-off high-altitude (based loosely on Tier II+) UAV with foliage-penetrating SAR and MTI radar.

The second set of runs examined application of joint external weapons options, including ground, air, and naval long-range systems. These last excursions were made under conditions of near-perfect RSTA.

The final set of runs looked at force dispersion. The base DRB force was spread out over an area 5-6 times as large as before. This force was attacked with two different levels of enemy artillery prep fires.

4. Findings

Outline

- Background
- Research plan
- **Findings**
- Conclusions

Next we summarize our results.

Findings

- **What kinds of opportunities do different RSTA concepts provide?**
- How do different levels of target acquisition affect long-range weapon performance?
- Given best RSTA, can external long-range weapons defeat armor attack, or will units need organic capability?
- How does dispersion affect indirect and direct fire engagement dynamics?

- **Ground-based RSTA gives accurate but limited coverage, overhead systems complete the picture**

First, we look at the level of situational awareness provided by several different possible combinations of future RSTA systems. The systems were found to be complementary in nature, giving a good overall picture of Red position, status, and composition.

RSTA Systems Examined Have Very Different Characteristics

- FO--2 man team deploy on foot; optical sensor with 4 km max range with GLLD
- UAV--employ with standoff tactics at 1000 meter alt.; equipped with advanced FLIR 6 km max range

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- COVER-like-hovering UAV tethered to HMMWV; equipped with either 3 or 6 km max range FLIR
- Acoustic sensor--8 microphone, non-LOS system; nominal 3 km range against loud target (e.g., tank)
- Remote sentry--unattended ground sensor with mast mounted FLIR cued by acoustics; 3 km max range on FLIR
- Generic HAE UAV--GMTI radar with $P_A = 0.9$ in open, $P_A = 0.45$ in intermittent foliage (not explicitly modeled)

The base types of RSTA systems currently in the DRB are shown at the top of the chart, and future additions contemplated for this study are shown below the line.

The base DRB has forward observer teams with laser rangefinder and designators, and tactical UAVs with stabilized FLIRs.

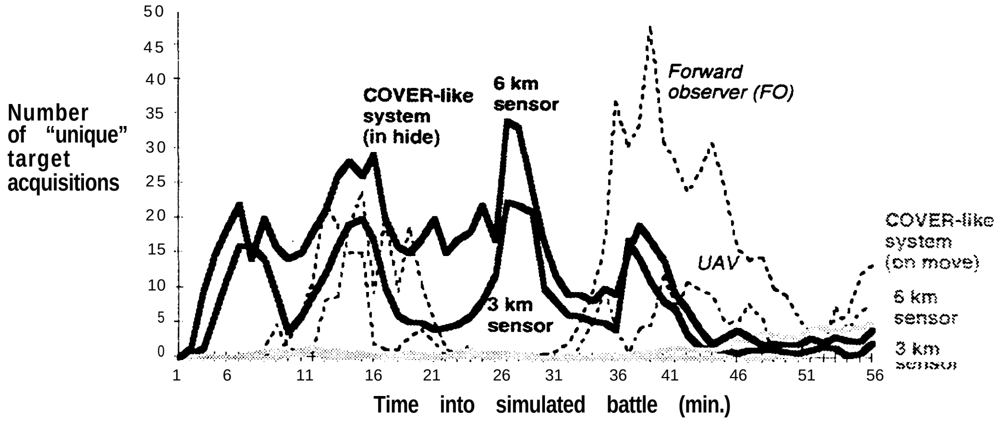
The future systems include COVER (a small tethered UAV 200 feet above its associated scout vehicle), arrays of eight microphone acoustic sensors, acoustic/imaging remote sentry, and high-altitude endurance UAVs. All except HAE UAV are modeled explicitly. Acoustic phenomena such as non-LOS sensing, triangulation among sensors, and target loudness levels are all represented in the model. Imaging system sensitivity is similarly captured, using modifications of the NVEOL algorithms. The HAE UAV with ground moving target indicator (GMTI) radar, on the other hand, is represented statistically. A standoff system should be able to perform GMTI across the entire region quickly. In foliage penetration mode, it should be able to penetrate brush easily and trees with some difficulty. The resulting picture should show most moving targets, but with limited location accuracy and type discrimination.

We Augmented FOs with COVER-Like System in LANTCOM Scenario

- **Initial parameters examined**
  - **Range of sensor (3 km vs. 6 km FLIR)**
  - **Tactics (on-the-move vs. stationary)**
- **Results from simulation**
  - **System operating with on-the-move tactics did not survive or provided minimal acquisitions**
    - **Multi-axis target attack did not allow for comprehensive acquisition (w/limited FOV sensor)**
    - **Speed of attack did not allow system to maintain safe stand-off**
  - **In stationary hide positions, 6 km FLIR provided about 40% more acquisitions than 3 km FLIR**

We performed several excursions to determine the effectiveness of COVER, a HMMWV-based scout vehicle with a tethered UAV (since the COVER system is still not yet fully defined, we refer to it as a "COVER-like" system in this report). The UAV was given a basic FLIR (3 km max range against ground targets) and a very good FLIR (6 km max range). The scout platform itself, a HMMWV, was commanded to move in some excursions (maintain standoff with the enemy and return to the DRB main body) and to remain stationary and be bypassed in other excursions. We found that movement compromised performance heavily, even with the very good sensor. Movement typically resulted in platform losses and any attempt to maintain standoff with Red reduced the number of acquisitions by the COVER-like system to almost zero. A stationary set of scout/COVER-like systems in forested hide positions, on the other hand, provided substantial numbers of detections, especially with the longer-range sensor.

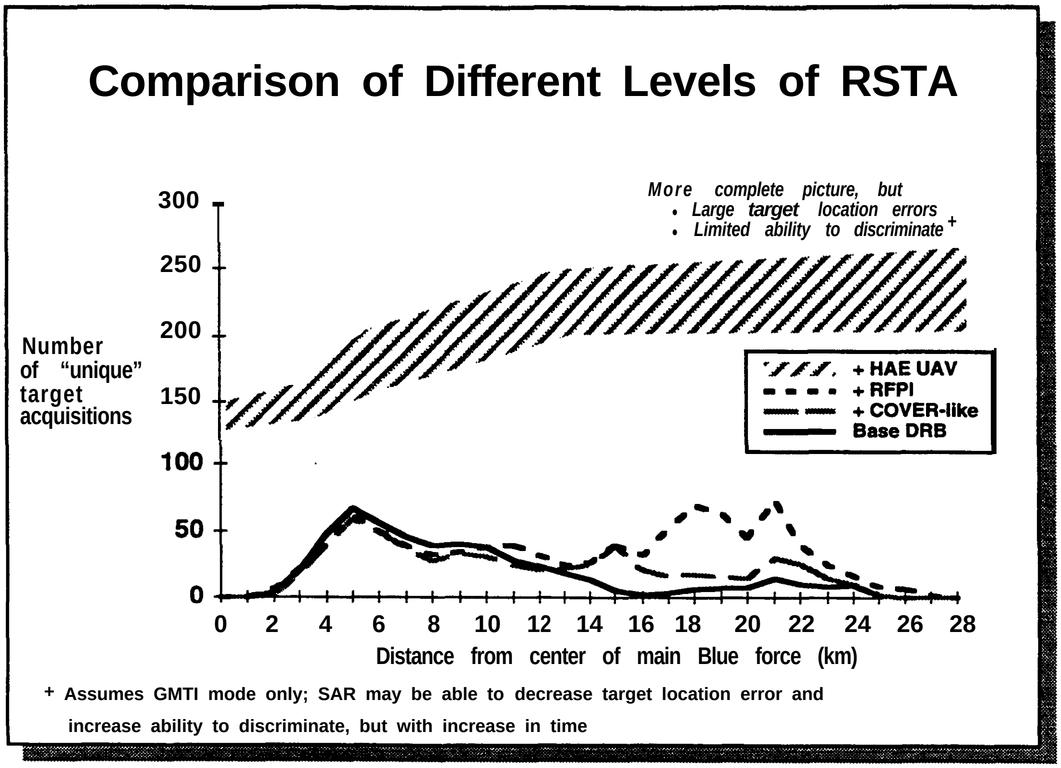
Addition of COVER-Like System Provided Utility Only When in Hide Positions



The chart summarizes the four COVER-like conditions (good and basic FLIR, moving and stationary HMMWV) just described. For comparison, the dotted lines show the detections by UAVs and FOs. In all cases, unique detections are shown over time, starting with initiation of the scenario on the left and stoppage at 58 minutes on the right.

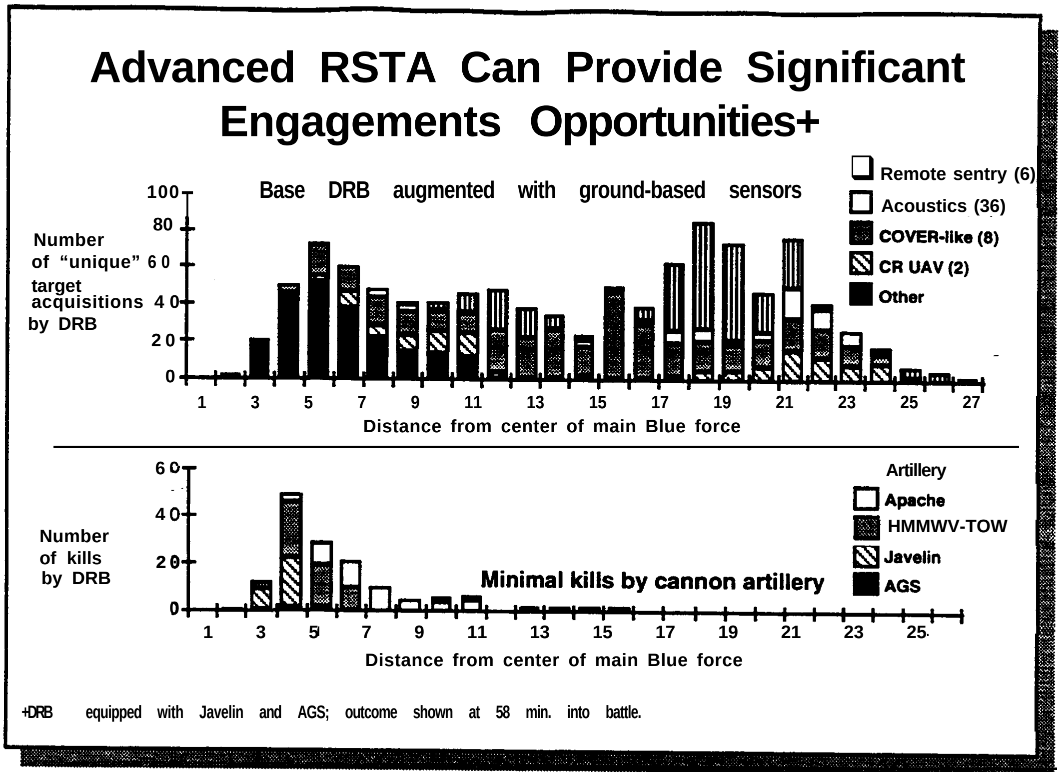
Detections by moving COVER-like systems are minimal, as shown by the lines near the x-axis. Only when the few survivors rejoin the force are there a few detections.

Detections by stationary COVER-like systems in hide are a major contribution to Blue situation awareness, and occur over a wide spectrum of times in the scenario.



This chart shows by range a comparison of RSTA detection completeness as we add each system. The base DRB systems (FO, UAV, direct fire platforms) by the solid line, with many detections at 14 km or closer. Addition of the COVER-like systems (in hide positions) provide more detections at depth, and the RFPI unattended sensors further fill out-the long-range detections. High-altitude UAV gives a picture of virtually all enemy systems.

The quality of detection also varies with system. Basic DRB systems are typically eyes on the target and tend to be high-accuracy, high-confidence detections. The other systems tend to have less accuracy and discrimination of target type, with HAE UAV in its MTI mode just providing indications of unit size, speed, and general area. SAR mode imaging of the targets can be done by the UAV with high resolution and good location accuracy, but this takes significantly more time than MTI and covers much smaller areas (returns have to be integrated over a several degree rotation angle around the target).



Advanced RSTA, as exemplified here by a force with COVER-like systems and RFPI unattended sensors, provides detection over much of the battlefield, but the organic indirect fire weapons associated with the base DRB are unable to capitalize on the information. The number of kills is essentially the same as with the base RSTA. We also noted few opportunities to effectively reposition the Blue force with the added RSTA contacts.

Findings

- What kinds of opportunities do different RSTA concepts provide?
- How do different levels of target acquisition affect long-range weapon performance?
- Given best RSTA, can external long-range weapons defeat armor attack, or will units need organic capability?
- How does dispersion affect indirect and direct fire engagement dynamics?

- Ground-based RSTA gives accurate but limited coverage, overhead systems complete the picture
- More RSTA resulted in better long-range weapon effectiveness, but only up to a point

We next introduced an exemplary weapon to the force (a long-range missile, with large-footprint submunitions) to determine the effects of different levels of RSTA combined with "external" fire support. Up to a point, additional RSTA had a strong impact on performance with this remotely-located, long-range weapon.

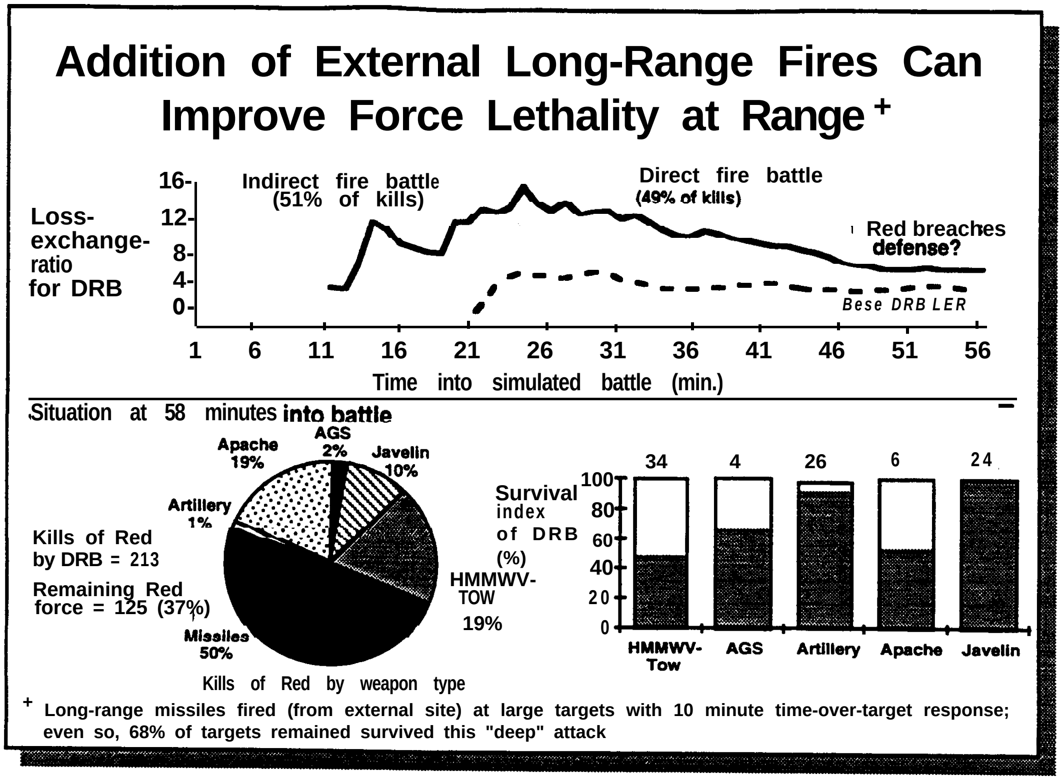
Up to a Point, More RSTA Resulted in Higher Force Effectiveness

DRB force	Number of missiles fired	Number of missile kills	Number of direct fire kills	Loss-exchange-ratio
Base DRB RSTA	N/A	N/A	136	4.2
COVER-like system	18	58	126	5.0
Plus RFPI ground sensors	34	106	107	6.8
Plus HAE UAV	36	119	108	6.8

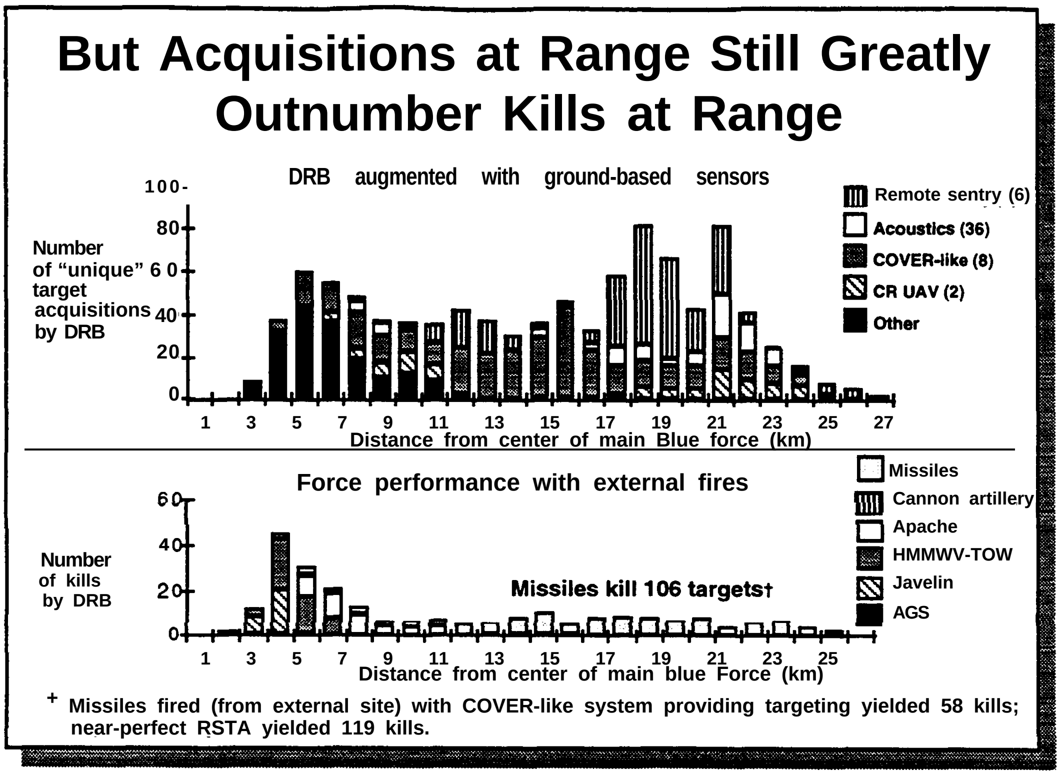
+ Missiles with largefootprint submunition fired at large targets with 10 minute the-over-target response

We assumed that the time-on-target (time from detection of the target to munitions arriving at the predicted point) was 10 minutes for the long-range weapon. Standard TTPs for this weapon required company or battalion sized targets to be present, because the weapon dispensed many individually targeted smart submunitions. In our simulation runs, an active duty artillery officer calculated lead distances and targeted the munitions as targets presented themselves on the Janus simulation screen.

The chart shows that with base DRB RSTA (FOs and UAVs), no appropriate target opportunities were seen for the long-range weapon. When the COVER-like system was added, nine aimpoints were selected (fired at with two missiles each). This resulted in 58 kills by the long-range missiles and a reduction of direct fire kills. Further addition of two RFPI RSTA systems (acoustic sensors and remote sentry) roughly doubled the number of aimpoints and kills, as did the full set of RSTA including HAE UAV. The minimal increase with HAE UAV over the RFPI sensor network seemed to be due to decreasing usefulness of further data. Most large targets were seen, and the large-footprint submunition made up for targeting errors induced from partial information. Nonetheless, the more complete information from the HAE UAV was seen to greatly increase the commander’s confidence in conducting a fire mission. Interestingly, in all cases, there was still a substantial direct fire battle, with more than 100 kills by Apache, TOW, AGS, and Javelin.



Looking in more detail at the RFPI RSTA case with remote fires, we find that target kills took place much earlier and more completely than with base DRB. The long-range weapon accounted for half the total Blue kills. Nevertheless 68% of the Red attacking force survived to engage in the direct fire battle. This may have been largely a function of the limited depth allowed for long-range attack in this scenario. Interestingly, Blue survivability was only slightly higher than with the base DRB. This suggests that added organic weapon systems or more effective long-range fires appear to be needed to reduce the direct fire intensity.



This chart highlights the problem. Even with substantial target acquisition in the RFPI RSTA case, only a small percentage of Red systems were engaged and destroyed by the long-range missile system. We next answer why this occurred.

Five Reasons Why Target Kills Did Not Match Target Acquisitions

(Using standard tactics, techniques, and procedures)

- **Acquisitions include small groupings (possibly ones and twos) of targets--inappropriate for weapon**
- **Requirement for battle damage assessment (BDA)-re-acquired targets were not serviced immediately**
- **Engagements occur well after target acquisitions--many weapons missed intended targets**
- **Targets not individually serviced--within a volley submunition logic resulted in "high-signature" targets and hulks being re-attacked**
- **Targets become more sparse and spread out over time--much harder to engage successfully**

We determined five reasons why long-range target kills were so much lower than the number of long-range acquisitions. First, many of the targets were spotted in groups of one to three-smaller groupings than required for calls for fire, even when the same targets were seen repeatedly. Second, there was a refractory period during missile flyout, in which the commander would have to wait for BDA on the targets before firing more missiles. Third, most targets were moving and would often turn at road junctions or transition into spread battle formations. This resulted in some misses with the 10 minute TOT. Fourth, the submunitions followed a group logic, in which they would distribute themselves among the targets. This logic was imperfect and often concentrated the submunitions toward high-signature targets, resulting in overkills. Finally, as the engagement ensued, targets became attrited and spread out, resulting in more difficult targeting and submunition encounter. In general, we noted the third and fourth reasons to be moderately important in this scenario, and the others to have somewhat lesser impacts.

Findings

- What kinds of opportunities do different RSTA concepts provide?
- How do different levels of target acquisition affect long-range weapon performance?
- Given best RSTA, can external long-range weapons defeat armor attack, or will units need organic capability?
- How does dispersion affect indirect and direct fire engagement dynamics?

- Ground-based RSTA gives accurate but limited coverage, overhead systems complete the picture
- More RSTA resulted in better long-range weapon effectiveness, but only up to a point
- Aggressive use of external long-range weapons resulted in diminishing marginal returns; organic capability appears essential

An important question was whether external, long-range fires alone could stop the enemy attack. Accordingly, we assumed near-perfect RSTA (all systems including HAE UAV) and examined the effectiveness of two different long-range weapon systems: large footprint-missile-delivered submunitions and air-delivered small-footprint submunitions. In order to look at many factors, a subset of the LANTCOM scenario was examined, and all runs were made with our smart munition model (MADAM) running in stand-alone mode. Interesting cases from this stand-alone parametric analysis were then examined in the larger force-on-force context in the Janus simulation.

We selected a portion of the Red attack--the south attack in column formation along the roads--for our first look at the two indirect fire weapons. Here two columns of armored vehicles (tanks, APCs, AD vehicles, and artillery) are moving along the roads. They cross several chokepoints at the river crossings and fan out into battle formations at the end of the time window examined. An active duty U.S. Army artillery officer conducted the fire missions against the vehicles as they were acquired by the RSTA network along the roads.

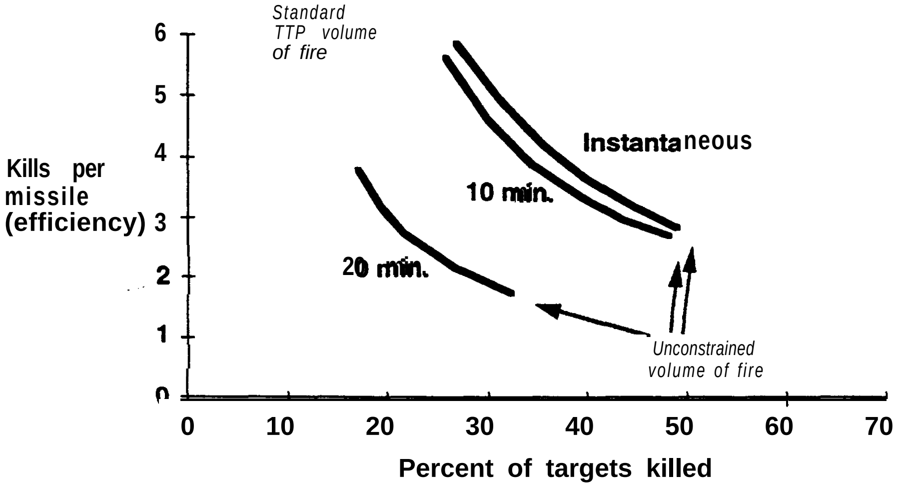
Sensitivity of Three Key Parameters Were Explored

- **Total time over target (intel processing, C3, and flyout)**
  - Instantaneous
  - 10 minute
  - 20 minute
- **Volume of fires (number of munitions employed)**
  - Conservative criteria for engagement based on TTPs
  - Aggressive engagement, increased volume of fires
  - Attack unconstrained with very high volume of fires
- **Density, shape, and predictability of target set**
  - Dense on-road column formations
  - Sparse off-road battle formations (not yet completed)

Assuming the best RSTA case, we varied three parameters in our excursions with the two long-range weapon systems. First, we set the timelines to be instantaneous (this can be thought of as immediate C2 and a very fast flyout, or as updating right over the target; it results in zero delay in the stand-alone analysis and a one-minute delay in the force-on-force simulation, for munition drop), and 10- and 20-minute TOTs. The second factor was the volume of fires applied. A conservative criterion was one missile or one munition dispenser (canister) per aimpoint, while unconstrained fires typically had four times as many missiles or canisters launched (with additional aimpoints). The last factor was the type of target set. As yet we have only targeted the dense on-road target set and plan to later move to analysis involving the more difficult and sparse off-road target set.

Single Volley Attack with Large-Footprint Weapon Did Not Result in Total Destruction of Target Set

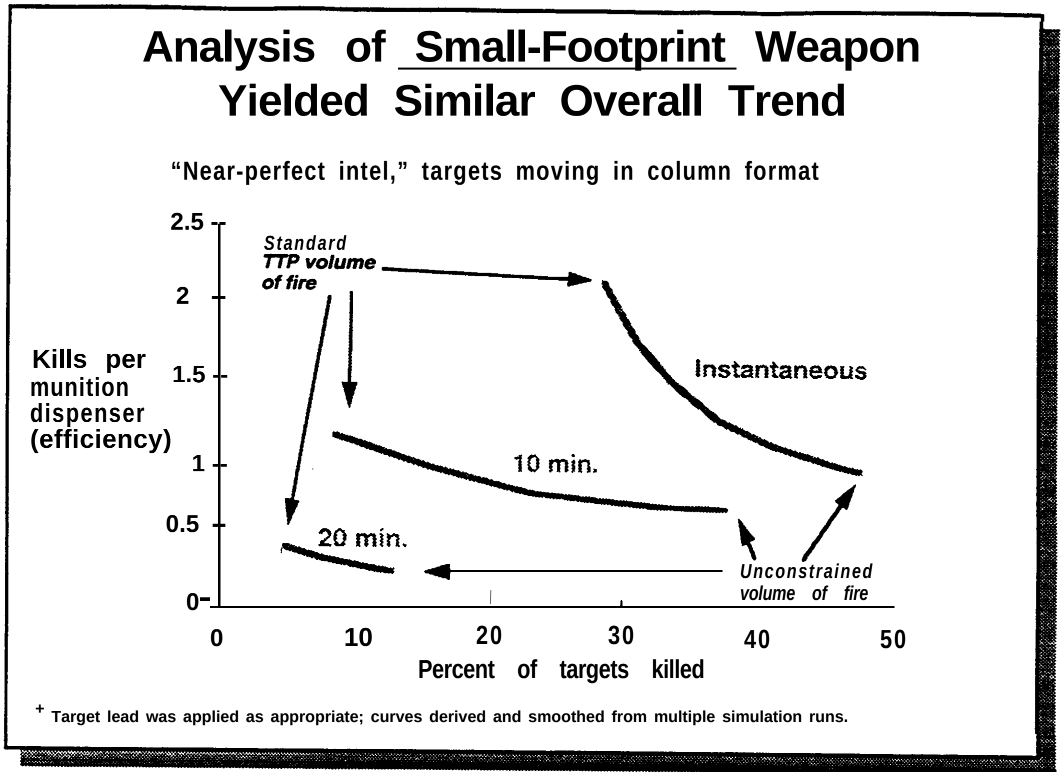
"Near-perfect intel," targets moving in column formation +



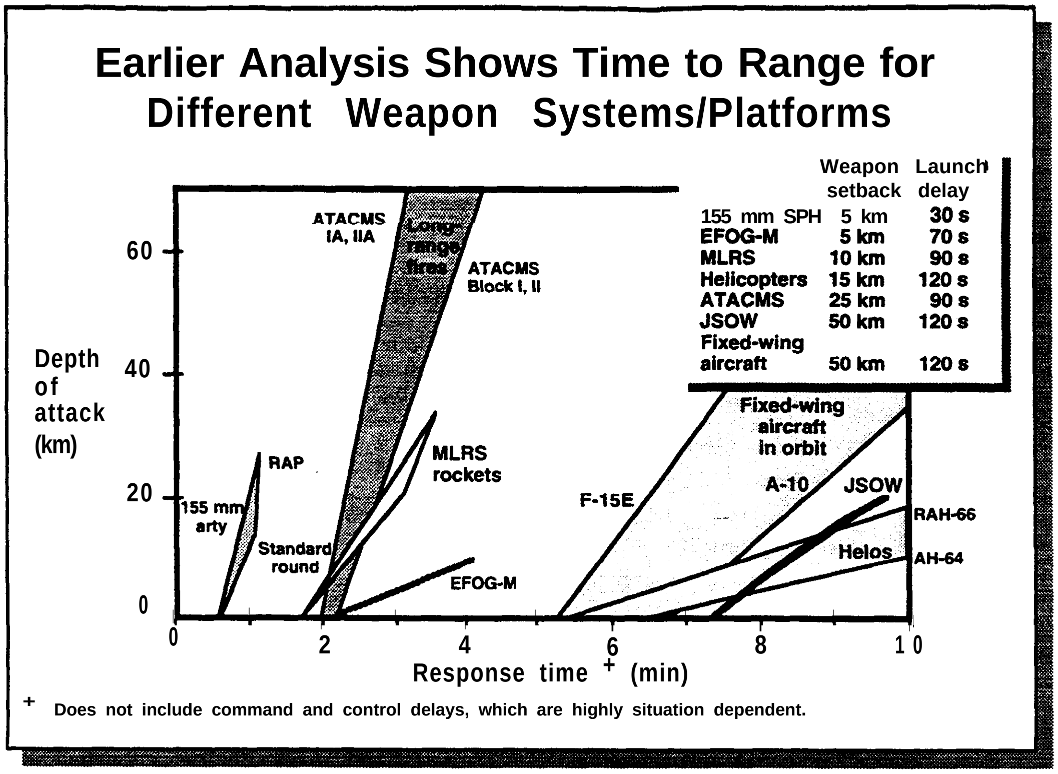
+ Target lead was applied as appropriate; curves derived and smoothed from multiple simulation runs.

This chart shows results for the large-footprint submunitions delivered by missile. The Y-axis is kills per missile, while the X-axis is scaled in percent of total targets killed. For example, on the X-axis a 50% score means that 44 of the 88 targets are killed. The lines for each TOT assumption (instantaneous, 10 minute, and 20 minute) show that diminishing numbers of targets are killed as the volume of fires goes up. In all cases, an increase in the number of missiles launched results in an increase in the total number of kills but substantially reduces the number of kills per missile. The lines also show that 10 minute TOT has almost the same efficiency as instantaneous, because the large-footprint submunition is able to make up for targeting errors induced during such short times.

It should be noted that the results shown above are for a single volley attack, without use of BDA and reattack of the targets later. Our Janus excursions showed somewhat greater effectiveness with multiple volley attacks using BDA.



The smaller-footprint weapon showed markedly higher sensitivity to TOT, as one would expect. A 20 minute TOT yielded fractional kills per munition dispenser, because the target moved out of the footprint, even with lead applied to the targeting on a road. At 10 minute TOT, the weapon was more effective but still limited. Also, higher volumes of fire did not show the same level of saturation found with the large-footprint weapon. Nonetheless, a diminishing marginal returns effect was seen. Instantaneous delivery was highly effective with this system, yet still yielded no more than 50% kill of the total target-set, even with very high volumes of fire.



To give some context for the TOT times discussed earlier, this chart illustrates expected times to range for a number of different systems. Missile systems (except for cruise missiles and EFOG-M) are much faster than aircraft and may arrive at the target after only a few minutes. Fixed-wing aircraft are typically orbiting some distance from the target and, depending on whether they overfly the target or release dispensers from standoff range, result in times on the order of 10 minutes or more. The chart above shows some representative TOTS based on approximated weapons setbacks and times to launch. The TOTs above do not include delays associated with command and control.

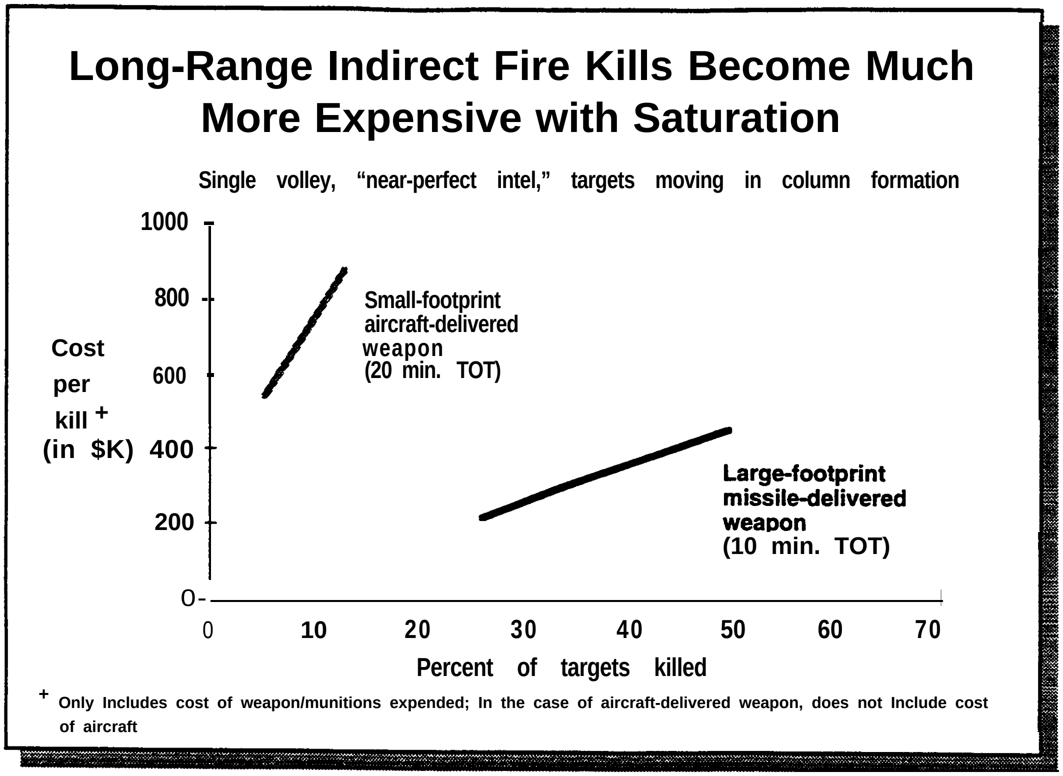
The meaningfulness of these timelines can change dramatically if there is update in flight. Then, sensitivity to target movement can be reduced; however, the long cycle time itself can present a "management of weapons flow" problem, especially if BDA is required before launching the next mission. To solve this problem, one may have to commit follow-on missiles or aircraft to attack before knowing whether the initial attack succeeds.

Weapon Cost Assumptions

(Back of the Envelope)

- **Large-footprint, missile-delivered weapon**
  - **Missile platform cost = $700K**
  - **Submunitions cost = $520K**
  - **Total assumed cost = $1,220K**
- **Small-footprint, aircraft-delivered weapon**
  - **Munition dispenser cost = $100K**
  - **Submunitions cost = $120K**
  - **Total assumed cost = $220K**

We felt it would be enlightening to perform a very rough, exemplary cost analysis for the two weapons used in these excursions. The costs shown are estimates for the two sets of delivery platforms and the submunitions they contain. The costs do not reflect development, support, or deployment costs nor do they cover losses to the ground, sea, or air platforms that launch them. They are simply rough incremental cost numbers for the missiles, munitions dispensers, and submunitions themselves.



Extrapolating data from the previous charts (using nominal C2 and flyout times), it is possible to then estimate the cost per kill for different weapon alternatives. Assuming the small-footprint, aircraft-delivered weapon will take 20 minutes to achieve TOT, it is apparent that the corresponding number of misses of the target set translates to a relatively high-cost per kill. As more munitions are fired at the target set, more targets are killed but with even less efficiency. However, very large payoffs were seen when instantaneous TOT was used in conjunction with this weapon.

On the other hand, the large-footprint, missile-delivered weapon resulted in relatively lower costs per kill because the combined TOT and size of footprint was a good "match" for the target set being attacked. Similar to the small-footprint weapon, though, as more of these munitions were fired at the target set, more targets were killed but with an increase in cost per kill.

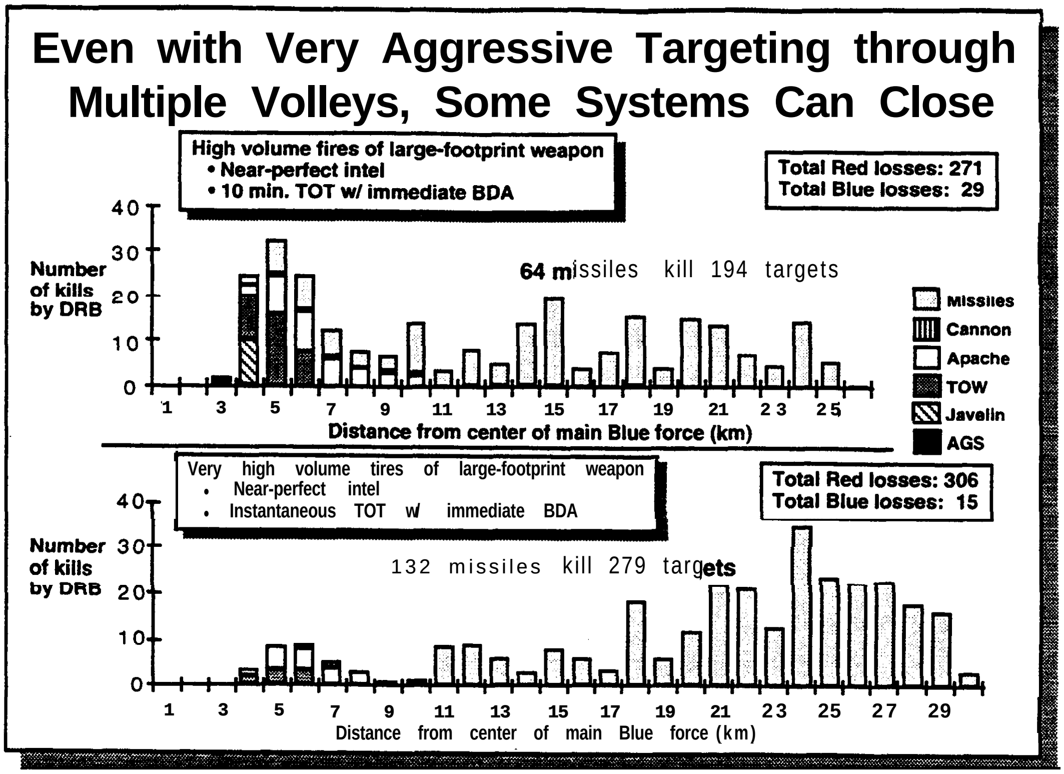
Both Increased Volume of Fires and Reduced Timelines Were Assessed in Simulation

- **Higher volume of fires**
  - **Resulted in more kills, but with less overall efficiency (kills per round) for both large- and small-footprint weapons**
  - **Resulted in many more rounds over friendly units for both large- and small-footprint weapons**
- **Improved time over target**
  - **Resulted in relatively minor effect on large-footprint weapon performance; about 10% increase in kills**
  - **Resulted in considerable performance improvement for small-footprint weapon; about 100% increase in kills**

We then extended the results obtained in MADAM by making excursions with the larger-scale Janus simulation. Here, we examined the impact of volume of fires and reduced timelines on the effectiveness of the large- and small-footprint weapons. The runs differed from those in MADAM in several ways: the entire threat force was engaged, multiple volleys were fired, and BDA was present. In all cases, near-perfect RSTA (ground sensors and HAE UAV) was assumed.

Volume of fires was varied by increasing the number of missiles or munition dispensers per aimpoint, and in some cases by adding more aimpoints. Just as with the MADAM runs, we found that higher volumes of fires led to decreasing marginal returns. We also noted that higher volumes of fires resulted in more rounds landing near friendly forces. No kills were seen, however, because the Blue vehicles were typically stationary, with limited signatures.

Improved TOT had very different effects with the two weapons, as seen in the stand-alone simulation. The large-footprint, missile-delivered weapon was able to compensate well for target movement during flyout, while the small-footprint, air-delivered weapon would often miss the moving targets when a time delay was present.



This chart illustrates the combined effect of volume of fires and TOT for the large-footprint weapon. The upper graph shows a volume of fires roughly twice that shown in the previous section, when standard TTPs were followed (see p. 23). We find that by roughly doubling the number of missiles, only 50% more kills could be achieved.

A major change is shown in the lower graph. Here we roughly quadruple the number of missiles and change the TOT to instantaneous. Long-range missile kills now occur farther out, attrit about 80% of the target set, and result in a very limited direct fire battle. This very favorable outcome comes only with exceptional conditions--near-perfect RSTA, instantaneous TOT, and very high volume of fires.

How Do External Long-Range Fires Integrate with Advanced Organic Indirect Fires

- **External fires (both large- and small-footprint) were more effective against targets at longer range**
  - **Target density was high-good match with multiple submunition weapon concepts**
  - **Target movement was highly predictable--more forgiving to longer timeline weapons**
- **Advanced organic indirect fires were seen to be effective against targets at closer range**
  - **Targets were sparse--tended to be individually and efficiently serviced**
  - **Targets moved tactically--short weapon timelines provided sufficient ability to react**

In ongoing studies for the Rapid Force Projection Initiative we have examined a wide variety of advanced organic indirect fire weapon systems, among them EFOG-M, HIMARS/Damocles, 155-SADARM, Smart-105, and PGMM.[2] This work highlights some of the apparent differences (and the complementary nature) of these organic systems with the external long-range fire systems being considered by the DSB.

Both of the external long-range fire systems we have considered are multiple submunition concepts designed to attack massed armor targets. They work well when the targets move in predictable patterns across roads and open areas, and are especially good at chokepoints.

The shorter-range organic systems, on the other hand, range from multiple submunition concepts to individually targeted missiles and artillery rounds. Many of these are able to attack individual targets moving from cover to cover with short opportunity windows. Some systems such as EFOG-M are also able to discriminate in flight between target types--live and dead, friendly and enemy, and high value and low value. Other weapons, such as HIMARS/Damocles, are effective at-longer ranges in counterbattery fire.

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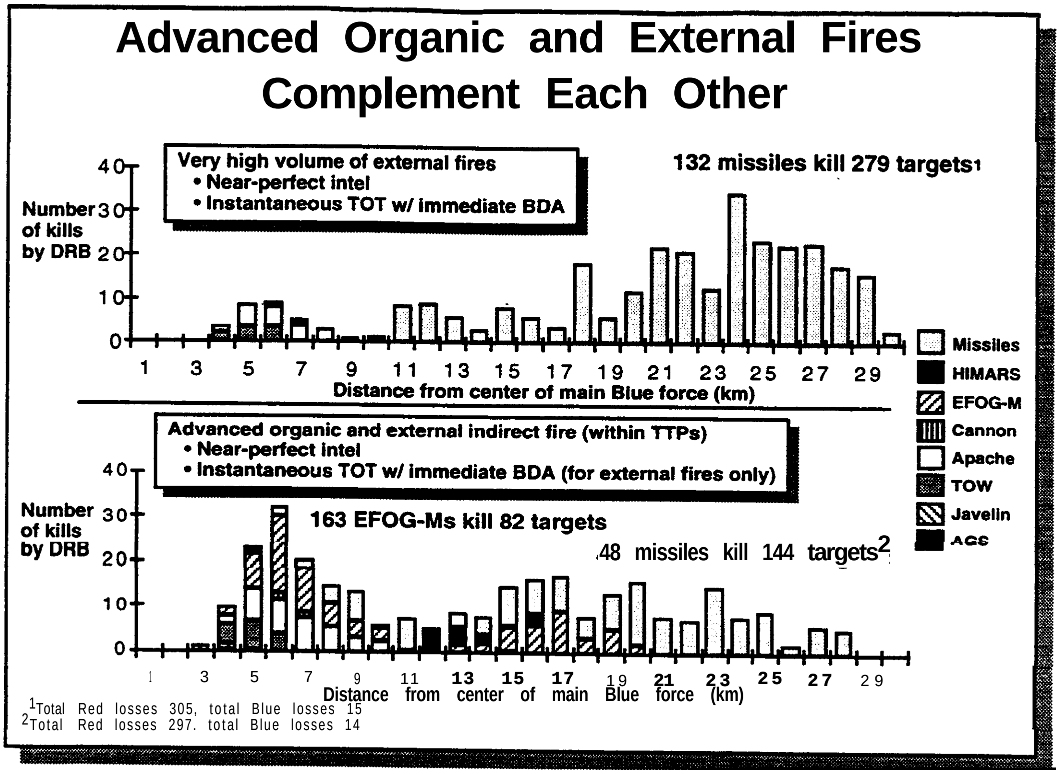
[2] For a detailed description and performance analysis of these systems, see *Rapid Force Projection Technologies: A Quick Look Analysis of Advanced Light Indirect Fire Systems*, RAND, DB-169-A/OSD, 1996.



The above charts illustrate the differences between a very high volume external missile attack and a more balanced attack (using standard TTPs) employing both external and organic indirect fire. The very high volume missile attack results in large numbers of kills at deep ranges, but the ability to attrit (and level of efficiency) drops off at closer ranges--resulting in a small residual direct fire battle. In contrast, the more balanced attack, which uses standard TTPs, results in relatively moderate attrition at deep ranges, and many of the closer-in engagements are handled by more efficient organic indirect fires. High-value enemy artillery targets are targeted primarily by HIMARS/ Damocles, while armor is primarily targeted by EFOG-M. The “shape” of the attrition is significantly different between the long-range external and combined external/organic cases, but the outcomes, in terms of direct fire battle intensity and overall LER, are quite similar.

In an additional excursion (not shown here), two less active systems, HMMWV-TOWS and AGS, were removed from the scenario. This resulted in the same overall lethality (number of Red systems killed), but reduced the Blue losses by 30%.

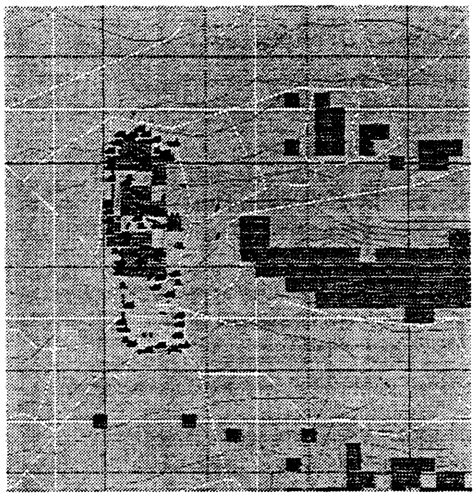
Findings

• What kinds of opportunities do different RSTA concepts provide?	• Ground-based RSTA gives accurate but limited coverage, overhead systems complete the picture
• How do different levels of target acquisition affect long-range weapon performance?	• More RSTA resulted in better long-range weapon effectiveness, but only up to a point
• Given best RSTA, can external long-range weapons defeat armor attack? or will units need organic capability?	• Aggressive use of external long-range weapons resulted in diminishing marginal returns; organic capability appears essential
• How does dispersion affect indirect and direct fire engagement dynamics?	• Dispersion reduces base DRB losses to artillery but direct fire battle is compromised

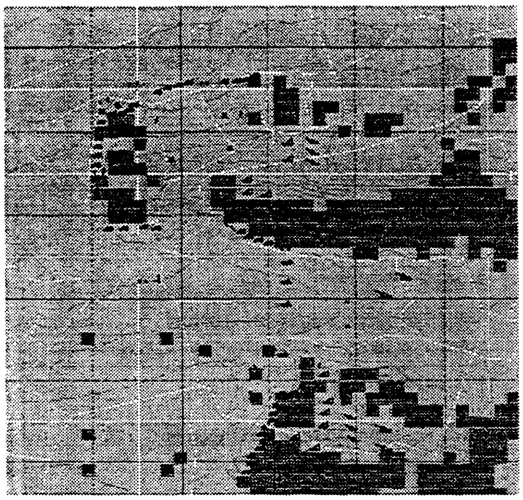
The last question involves dispersion of the force. With the base DRB, we found that a rough, first level of dispersion resulted in decreased losses to enemy artillery, as one would expect. At the same time, the larger defended perimeter resulted in a more heated direct fire battle and easier Red penetration.

In a similar vein, we looked at a first level of dispersion of the Red force. This resulted in a moderate reduction of effectiveness of Blue long-range fires.

Some Level of DRB Dispersion Was Examined in this Research



Current DRB has tight formation

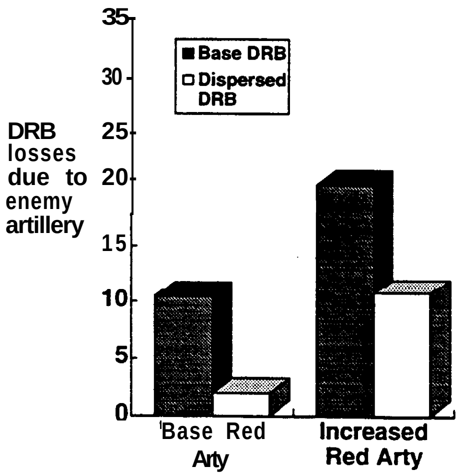


Dispersed DRB is broken into Bns

The actual level of dispersion is shown graphically above. The original Blue DRB laydown involved a laydown on a dominant hill mass approximately 4 km long and 2 km across. Dispersion of the force kept one battalion on the hill mass, and the second battalion on high ground to the south. Interlocking, supporting fires were still possible between the battalions, but the area covered by the force expanded by 5-6 times compared to the original formation. Red also modified its attack against the dispersed force, shifting its thrusts and massing its fires against new areas.

The dispersion illustrated represents a simplistic first level of spreading the force. We plan to examine more sophisticated laydowns in future work.

Dispersing DRB Can Reduce Losses from Enemy Artillery Fire...



- With baseline Red artillery levels, about one-third of DRB losses can be attributed to artillery
- With increased enemy artillery levels, over half of DRB losses are due to enemy artillery

=> Fight can be lost before it even starts

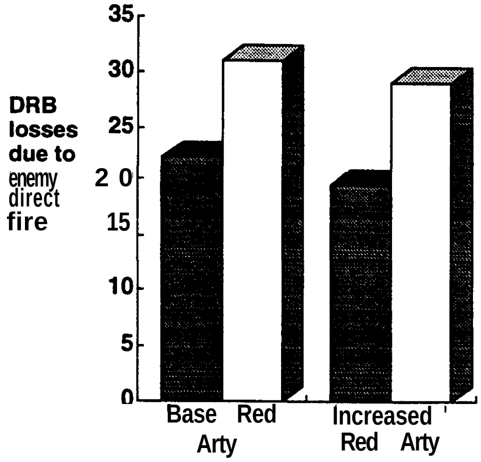
- Dispersion can provide a means to minimize the effectiveness of Red artillery fire

We found that dispersion of the Blue force did in fact reduce losses to enemy artillery. The dispersion effect was greater with the moderate level of artillery found in the basic scenario than when artillery was increased to higher levels (36 SP-152mms instead of 12 in the basic complement; 90 total Red artillery systems instead of 18 originally).

However, Dispersion Can Compromise the Direct Fire Battle

- Larger defensive perimeter increases exposure of DRB force
- Red can attack with greater simultaneity (fewer echelons)
- As a result, local Red direct fire weapon ratios are higher and more DRB losses occur

=> Early advantage from dispersion can be negated by the close fight



The picture changed dramatically in the direct fire battle. Regardless of Red artillery level, the dispersed force suffered more direct fire losses and achieved a lower overall LER than the nondispersed forces. This appeared to be because the larger perimeter resulted in less efficient overlapping fields of acquisition and fire for Blue and permitted more efficient simultaneous application of Red firepower. Red was able to more effectively mass fires and penetrate the thinner Blue perimeter.

What Happens If Red Disperses?

As a first step, Red battalion-column advance was broken up into company-sized targets

(Assuming near-perfect intel and very high volume of fire)

- **Fewer total missiles were fired by Blue (25%)**
- **Attrition started somewhat closer (3 km)**
- **Total long-range fire kills went down (15%)**
- **Nonetheless, efficiency per missile increased (10%)**
  - **Lower ratio of missiles to target; less competition for targets**
  - **Advanced submunition logic distributed submunitions with less overlap, resulting in fewer overkills**

Red has many options to counter the effects of long-range fires. One of the most fundamental of these is to disperse. We examined a first step in this direction, by breaking up the battalion units along the roads into company sized ones, with commensurate spacing down the echelons. The force was then more spread out and targeting was more difficult--missiles were fired later, fewer launches were made, and total kills were reduced. The effect would have been even greater, but the dispersed target spacing was in many places a better match with the large-footprint weapon's spread logic than the nondispersed target set, resulting in fewer overkills and misses. Further spacing may not exhibit this behavior.

Our Simulation Environment

- Basic scale constraints: size of region, terrain resolution, time step, and number of entities
- Fog of war: pace does not reflect friction, miscues, and human error
- Combat operations: still difficult to assess operational maneuver, MOUT environment, SOF/ dismount movements, large air operations
- Threat behavior: as Blue force changes shape, threat will likely change shape as well

A series of caveats must be stated with respect to our simulation environment, as with most others. The Janus-based system is intended for system-on-system warfare at the brigade/division level, and it provides only limited applicability outside that region. The system assumes prepared, motivated forces on both sides, and does not account for the "fog of war." We are in the process of extending the environment to include other missions, such as MOUT and SOF, but these are not yet in place. Finally, we assume the threat will remain as a maneuvering armor force, regardless of the Blue composition. If Blue was composed of small dismounted and dispersed teams calling in long-range fires, Red would probably instead counter with infantry operations and dispersion of its own.

5. Conclusions

Outline

- Background
- Research plan
- Findings
- **Conclusions**

This section summarizes our observations from this research.

Conclusions
(LANTCOM Scenario)

- **Enhancing DRB with external RSTA and fire support has tremendous potential for improving outcome of battle; however:**
  - **Even with multi-tiered RSTA, some portion of attacking target set was not acquired**
  - **Given best RSTA case, advanced weapon systems examined did not provide comprehensive lethality at range**
  - **Impact of long-range attack can be reduced by deliberate threat actions**
- **Given the above, DRB should be prepared to fight close battle--to achieve objective**

In general, the DSB concept for enhancing small dispersed forces with external RSTA and weapons offers tremendous potential for improving the outcome of battle. However, we note the concept relys on many steps to operate effectively--acquiring targets, passing information, assigning weapons, dispensing munitions, performing BDA, and many others. Each of these steps must function well for the concept to succeed.

Up to a point, we found that adding layers of ground-based and overhead RSTA could significantly improve situational awareness and enhance the application of external fires. The situation estimate can seldom be both complete and accurate, though, and different types of sensors contribute different inputs to the overall picture. In those cases where overlap of coverage was present, additional value was still observed in the form of commander confidence in committing rounds.

The notion of "if you can see it, you can kill it" was not demonstrated here. External fire support may exhibit long flyout and cycle times, and may not be able to engage targets as decisively as organic weapons. This can be especially true if the enemy uses deliberate countermeasures.

In view of such uncertainties, a force equipped with organic firepower appears to be essential, especially so when either an objective must be protected or an area denied to the enemy. Although our research does suggest that the amount of organic capability can be reduced given a significant presence of effective external RSTA and fire support, the most attractive and robust solution for enhancing the capability of small forces was a mix between advanced organic systems *and* external systems.

What Technologies Can Help Maximize Viability of Concept?

What can go wrong with concept and what do we need to make it work?

- **Environment might not cooperate (e.g., jungle, urban, etc.)--need all-weather, multi-mode sensors and weapons**
- **Connectivity is not guaranteed (e.g., terrain, portable jammers, etc.)--need robust, reconfigurable architectures**
- **Countermeasures can proliferate (e.g., corner reflectors, towed decoys, obscurants, etc.)--need discriminating, intelligent systems with ability to fuse multi-mode information**

The DSB concept is an ambitious one--equipping a small force to be able to carry out a wide range of missions normally performed by much larger forces. In order to ensure the viability of the concept, it must be made robust to many different influences and conditions of the environment, responses by the enemy, and even pressures of our own organizational structures. As a start, multi-mode sensors and long-range weapons with seekers may have to be modified heavily to operate in different environments. They may be stymied completely by urban environments, triple canopy jungle, monsoons, or sandstorms. Some mix of all-weather multi-spectral sensor sets, data fusion centers, and long- and short-range weapons will undoubtedly be necessary to cover a reasonable range of conditions.

One of the more vulnerable assumptions in the concept is connectivity between the many components--RSTA, communication nodes, fire direction centers, and weapon platforms. Blockages, noise, occupancy levels, node losses, reconfiguration times and other phenomena have been modeled only to a cursory level in most simulations, and few field tests have explored the types of systems being considered. Highly redundant, yet low probability of intercept architectures must be designed and demonstrated.

Enemy countermeasures, finally, cover a wide range of possible tactics and technologies. These may include attacking RSTA systems, camouflaging vehicles, spoofing sensors, disabling C2 networks, or defeating incoming munitions. As countermeasures become more sophisticated, sensors, seekers and other components will have to become more intelligent and timelines will have to be minimized.

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Section VII
‘Technology Concepts Panel Report”

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Volume 2, **Part 1,**
Technology Concepts

Defense Science Board

Tactics and Technology for 21st Century Military Superiority

Technology Concepts Panel Report

1996

Table of Contents

Technology Concepts Panel Objective

The Technology Concepts Panel was organized as part of the 1996 Defense Science Board Summer Study, "Tactics and Technology for 21st Century Military Superiority," for the purpose of identifying technologies and concepts that will provide our postulated future dispersed expeditionary force with the following attributes: (i) expanded zones of influence; (ii) increased numbers of missions; (iii) enhanced mobility, stealth, situational understanding, and connectivity, and (iv) improved remotely and locally delivered firepower.

This report begins with a discussion of enabling technologies that will be critical to a vision of highly agile, mobile forces in the 21st century supported by precision weapons and an exquisite information base made available by a robust information infrastructure.

Tactics and Technology for 21st Century Military Superiority

Technology Concepts Panel

Objective

Identify technologies and concepts that will provide smaller military forces with:

- **Expanded zones of influence**
- **Increased numbers of missions**
- **Enhanced mobility, stealth, situation awareness, and connectivity**
- **Improved firepower (long range and local)**

Technology for 21^{st} Century Military Superiority: Necessary Attributes

The panel's first task was to identify the technologies that would support 21^{st} century concepts of operations. Future forces will be able to operate in highly dispersed postures, will employ smart sensors, will utilize multipurpose weapons, will have to be supported by critical force enhancements, and will be integrated by a distributed Information Infrastructure.

The technologies required for the 21^{st} century expeditionary forces envisioned by the DSB Task Force must allow the reduction of infrastructure to move from heavy, forward-deployed forces with lots of weight and armor to forces that are small, light, mobile, and flexible. We must trade logistics dependence for a reliance on secure, reliable information connectivity for the future force's leverage and its situational understanding. And if the force is to be survivable, the information infrastructure and the situational understanding systems must be robust and secure.

Technology for 21st Century Military Superiority

Necessary attributes:

- **Distributed force structure**
  - Flexible, scalable, mobile
  - Unit size and composition matched to mission
  - Individual combatant enhancements
- **Smart sensors**
  - Distributed, multistatic, multispectral
  - UAV-based with space/ground augmentation
- **Multipurpose weapons**
  - Affordable, precise, indirect fire
  - Nonlethal
- **Force enhancements**
  - Littoral operations
  - Mobility, INFIL/EXFIL
  - Logistics

Integrated via a distributed information infrastructure

Enabling Technologies

The Technology Panel reviewed a broad range of potentially enabling technologies for this vision of the 21st century force. Future military forces will be more mobile, require less logistics resupply, possess excellent geolocation capability, operate in stealthy modes, possess exquisite situation understanding of the local and total theater battlespace, and be interconnected locally and globally via an intelligent information infrastructure. In addition, the smallest warfighting units of the ground force — combat cells — will be supported by highly precise, smart weapons that will both protect and extend the lethality of the future 21st century force. The technologies identified here are critical to enabling these capabilities.

Enabling Technologies

- High strength / lightweight materials
- High performance power sources
- High energy density materials
- Precision clocks / IMUs
- Solid state electronic / optical materials
- Advanced microfabrication, microdevices
- Stealth techniques
- Cognitive algorithms
- Intelligent software agents
- Complex networks / system design tools
- Human factors
- Other (e.g., Directed Energy, biological systems)

Technology for 21st Century Military Superiority: Vision *circa* 2020

In developing a vision for 21st century military superiority, we have established four principle themes: (i) an integrated information infrastructure to provide connectivity and battlespace situational understanding, (ii) brilliant targeting systems that enable military combat cells to be light, yet lethal when utilizing precision indirect fires, (iii) loiter weapons that move with the individual combat cell as it maneuvers within its sphere of influence (e.g., sensors/weapons mounted on autonomous vehicles) and (iv) force enhancements that either support operational units or assist in infiltration/exfiltration of troops and/or materiel.

In the discussions to follow, we will discuss technologies that support these four themes. The material is organized somewhat differently than the presentation in Volume I, Section V. In this Technology Panel Report we cover seven technology areas: Reconnaissance and Surveillance, remotely delivered Precision Weapons, Force Enhancements (which include insertion/extraction/sustainment), Local Area Surveillance and Weapons, Urban Operations, and Systems for the individual combatant. These are all integrated by the seventh foundational area: a distributed Information Infrastructure.

Technology for 21st Century Military Superiority

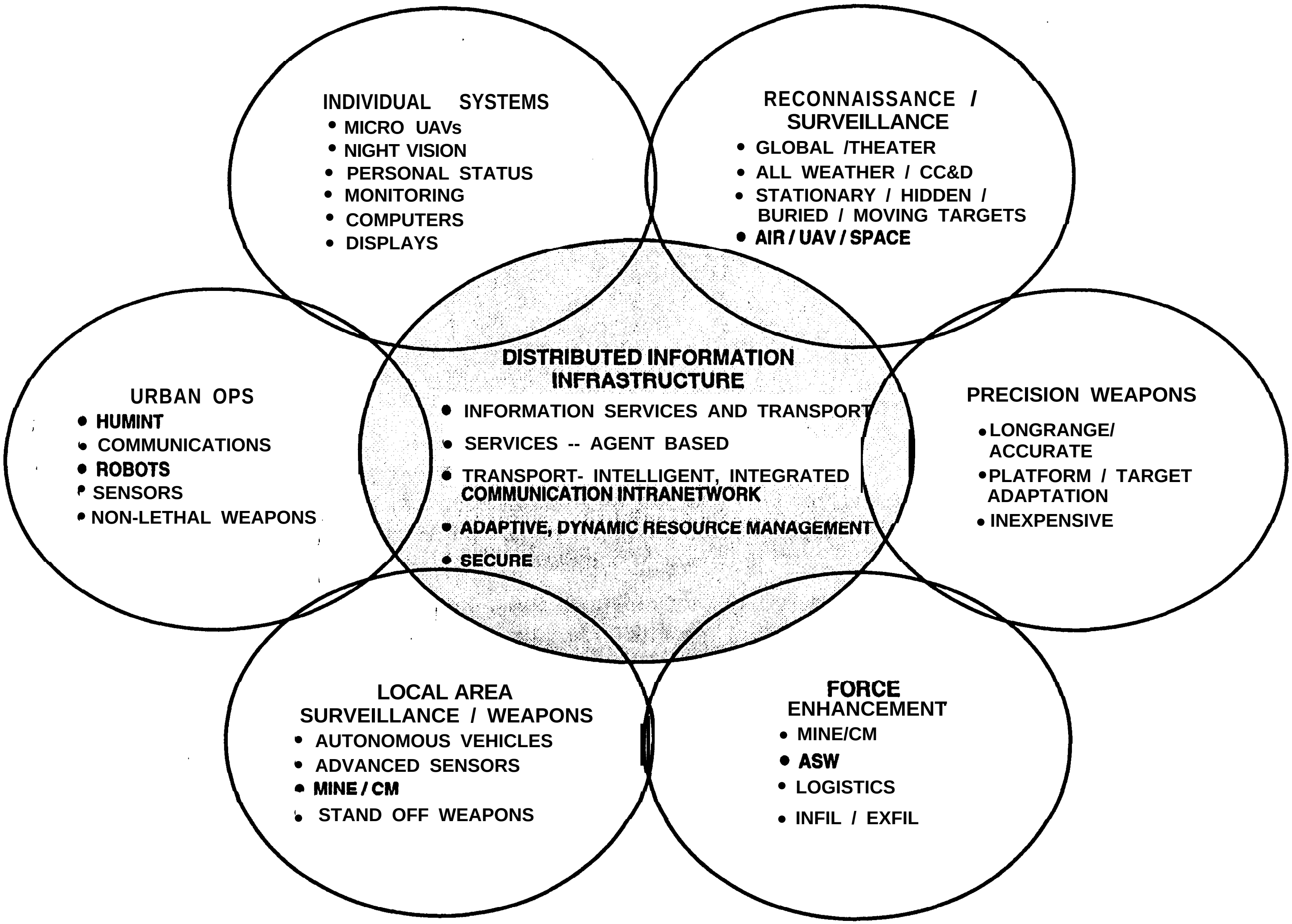
Vision *circa* 2020

- Integrated information infrastructure
  - Global, multimedia networks
  - Robust, survivable communications
  - Distributed software agents
  - Distributed computational resources
  - Secure networks
  - Formalized methods for system design
- Brilliant targeting systems
  - Advanced multispectral sensors
  - Autonomous vehicles
  - Cognitive algorithms
  - Precision weapons
  - Highly integrated
- Loiter weapons
  - Autonomous ground / air vehicles
  - Target-specific weapons
  - Self-learning
  - Distributed and networked
- Force enhancements
  - Active sonar, ASW
  - Remote sensing for countermine
  - Stealth mobility, INFIL / EXFIL vehicles
  - Precision logistics
  - Automated, advanced systems for individual combatants

Information: The Key to Successful Operations

There is no question that information is critical to modern warfare. It is the *sine qua non* in operations involving small forces. Information, information processing and communication networks — collectively, the distributed Information Infrastructure — are the core of virtually every aspect of military activity, including communications, navigation and geo-positioning, surveillance, weapons support, force enhancement, information control, and logistics support. Improvements in the distributed Information Infrastructure enhance each of the aforementioned areas of military activity, and improve our ability to use these areas together in coherent, synergistic fashion to enhance lethality, precision and force-effectiveness as well. This chart depicts the relationship between the distributed Information Infrastructure and the six primary areas of military activity mentioned above.

Information: The Key to Successful Operations



Information Infrastructure: Warfighter Needs

The Tactical Information Infrastructure (TII) must meet several key requirements if it is to realize its potential to enable the Defense Science Board's vision of small "Distributed Combat-Cell" operations.

As stated in Joint Staff Vision 2010, a military force must be able to receive or transmit all of the information it needs for the successful and efficient prosecution of its mission, from any point on the globe in a flexible, adaptive, reconfigurable structure capable of rapidly adapting to changing tactical environments. The information infrastructure must support these needs, while allowing force structures of arbitrary composition to be rapidly formed and fielded. Furthermore, the infrastructure must adapt to unanticipated demands during crises and to stress imposed by adversaries.

The infrastructure must allow information to be distributed to and from anyone at any time. Its architecture must not be constrained to support a force-structure hierarchy conceived *a-priori.* Most importantly, *the information and services provided to an end user through the infrastructure must be tailored to the user's needs, and must be relevant to the user's mission without requiring the user to sort through volumes of data or images.*

Information Infrastructure: Warfighter Needs

- Provides facilities to move information from any source to any destination
  - Sources = sensors => eyes and ears of teams
  - Users = warfighters and weapons => muscle
  - Information infrastructure = processors and communications = neural system
- Provides tailored information when and where required
  - Automatic data storage, retrieval and management
  - Automatic data fusion
  - Intelligent information dissemination
  - Supports multimodal information
- Facilitates force-structure tailoring
  - Assure interoperability of all service C4ISR systems
  - Close existing seams between military communication systems
  - Close existing seams between C4ISR systems intra/inter service
- Provides robust, reliable information services
  - Survivability through replication and self adaptation
  - Quality of Service to meet dynamic requirements
- Exploits commercial information technologies
  - Adopts open-system standards and protocols
  - Minimize use of service/system unique C4ISR hardware and software
- Does not place warfighters at risk of being detected and targeted

Information Infrastructure: An Overview

To meet these key requirements of the future force, the information infrastructure must provide tailored information services to diverse users from a single person, a collection of people, sensors, and/or weapons. It will accomplish this by means of "intelligent agents" – software entities under the general control of the user that are goal-directed, migratory, able to create other software entities, and can provide services or functions on behalf of the user.

The information infrastructure must include multimedia data transport including land-line, radio, and space-based elements. All of these media must be integrated into a ubiquitous, store-and-forward data internetwork that dynamically routes information from source(s) to destination(s), transparent to the user. This data transport segment of the infrastructure must: (I) be self-managed; (ii) be adaptive to node or link failure, and (iii) provide services to its users based on quality-of-service (QoS) requests. These services include, for example, bandwidths, latency, reliability, precedence, and services (point-to-point, point-to-multi-point).

The infrastructure interface will link the user to a distributed processing environment that includes all types of computers situated at locations commensurate with their needs for power, environment, and space. This distributed computing environment will be integrated via the data-transport element of the infrastructure, thus enabling these processors to exchange data dynamically, share computation loads, and cooperatively process information on behalf of (and transparent) to the user. These attributes are summarized in this chart.

Information Infrastructure: An Overview

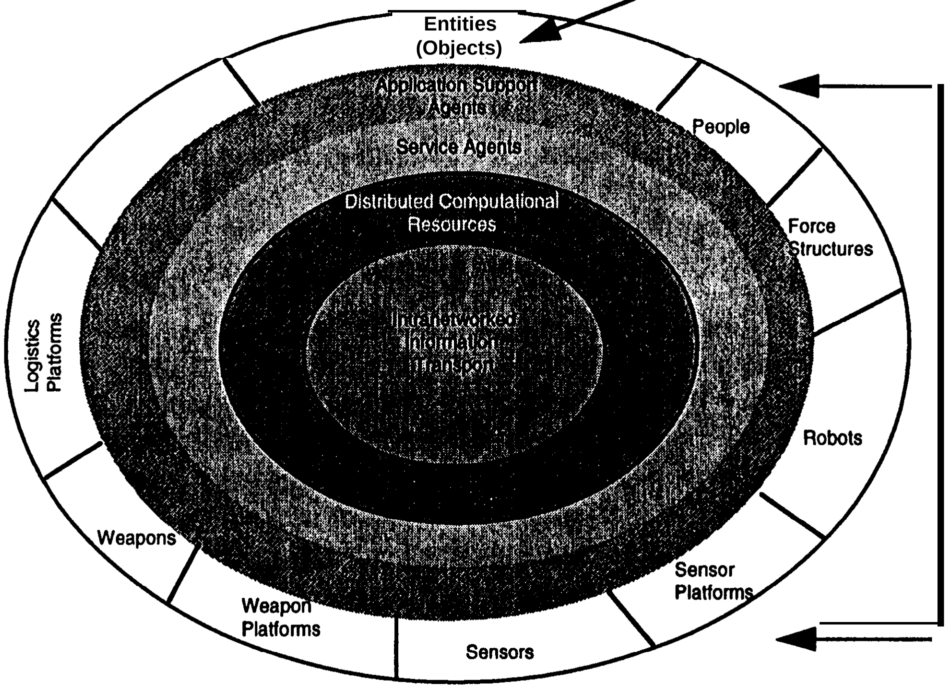
- "An integrated, scaleable, fully distributed processing and transport environment" that
  - is dynamic, adaptive, self reconfiguring, robust and secure
  - provides tailored information automatically as required when required
- The information services
  - are hosted on distributed computers, of many types, fully interconnected via the transport environment
  - are provided via intelligent software agents
- The transport services
  - are based on a network of networks = internetwork
  - provides intelligent, adaptive routing at network/internetwork levels

Information Infrastructure: A Conceptual View

Because computing resources are distributed throughout the infrastructure, the infrastructure can adjust the amount of processing resources serving a force entity. The force entities' processor need only: (I) provide access to the infrastructure; (ii) provide an adequate interface to the user entity, and (iii) enable the acquisition of, and present information to, the user. Thus, for example, a dismounted infantry troop's information ensemble would be dedicated to supporting a rich human-computer interface (with voice recognition, heads-up display, speech synthesis, and communications). General computing resources would reside within the infrastructure itself.

To the maximum extent feasible, the infrastructure transport components take advantage of commercial technology and networks by utilizing open-systems standards and protocols. It minimizes the use of service- or function-unique hardware and software. For applications where military-unique functions are required (e.g., anti-jam, low probability of intercept, and spectrum utilization), military products will be developed or adapted to interface with the overall architecture. This chart provides an overall conceptual summary of the distributed Information Infrastructure.

Information Infrastructure: A Conceptual View



- Entities
  - Sources and users of information
  - Diversity of information needs
    - ~ Type, quantity, timeliness
    - ~ Change as a function of mission & situation
- Information infrastructure (II) functional decomposition
  - Layered concept. Each layer:
    - ≈ Provides services to layer above
    - ≈ Receives services from layers below
    - ≈ Dynamically adapts to meet information needs of entities
    - ≈ Tightly coupled to each other to permit adaptation as an integrated system

- Agents = a software entity that is autonomous, is goal directed, is migratory, is able to create other entities and provides a service or function on behalf of its owner

Information Infrastructure: Tiered Transport

The information transport infrastructure consists of the four tiers depicted in this chart. These tiers are conceptual, because the interfaces between tiers are seamless and transparent to the user. “Tiering” only serves to relate the information infrastructure to organizational/doctrinal concepts. In fact, any user in the information infrastructure may be directly connected to, and interact with, any other entity. While we expect that such ubiquitous connectivity will be a very powerful force multiplier, we also expect traditional organizational and doctrinal constructs to change more slowly than the technology that makes such connectivity possible.

The first tier is the cell/tactical layer. This infrastructure component comprises local-area networks that provides voice and data services to entities operating together in tactical or support missions. These transport networks are store-and-forward, packet-switched data systems that are self-managed and adaptive, and provide peer-to-peer data relay and processing. These networks adapt to changes in the locations (i.e., the mobility) of the end-users. They have no centralized nodes or base stations that would enforce the use of a vulnerable “star” topology, and they automatically route information among participating nodes based on real-time assessments of the network connectivity. These local-area transport networks can support a single person or a force structure of any size (through appropriate subnetting).

At the second tier, the information transport infrastructure incorporates air-borne networks and processors for data transport and information services among force entities that require connectivity beyond the local area network – the inter-cell level. A swarm of autonomous air vehicles (AAVs) under local control provide medium-area networking services. These platforms are cross-linked between themselves and the space-borne network, as required, and are linked to the local-area networks.

At the third tier, the information transport infrastructure provides connectivity over widely dispersed areas through incorporation of LEO satellite and aircraft relays.

The fourth tier includes HEO/GEO coverage for global connectivity.

The routers[1], depicted as “R” in the figure, understand the entire system’s topology and connectivity in real-time. In conjunction with the intelligent software agents, the routers make dynamic decisions, based on this understanding, to ensure that information is transported from all sources to all destinations, as required. The dynamic routing is accomplished through advanced protocols and distributed algorithms that extend those presently used in the commercial sector today.

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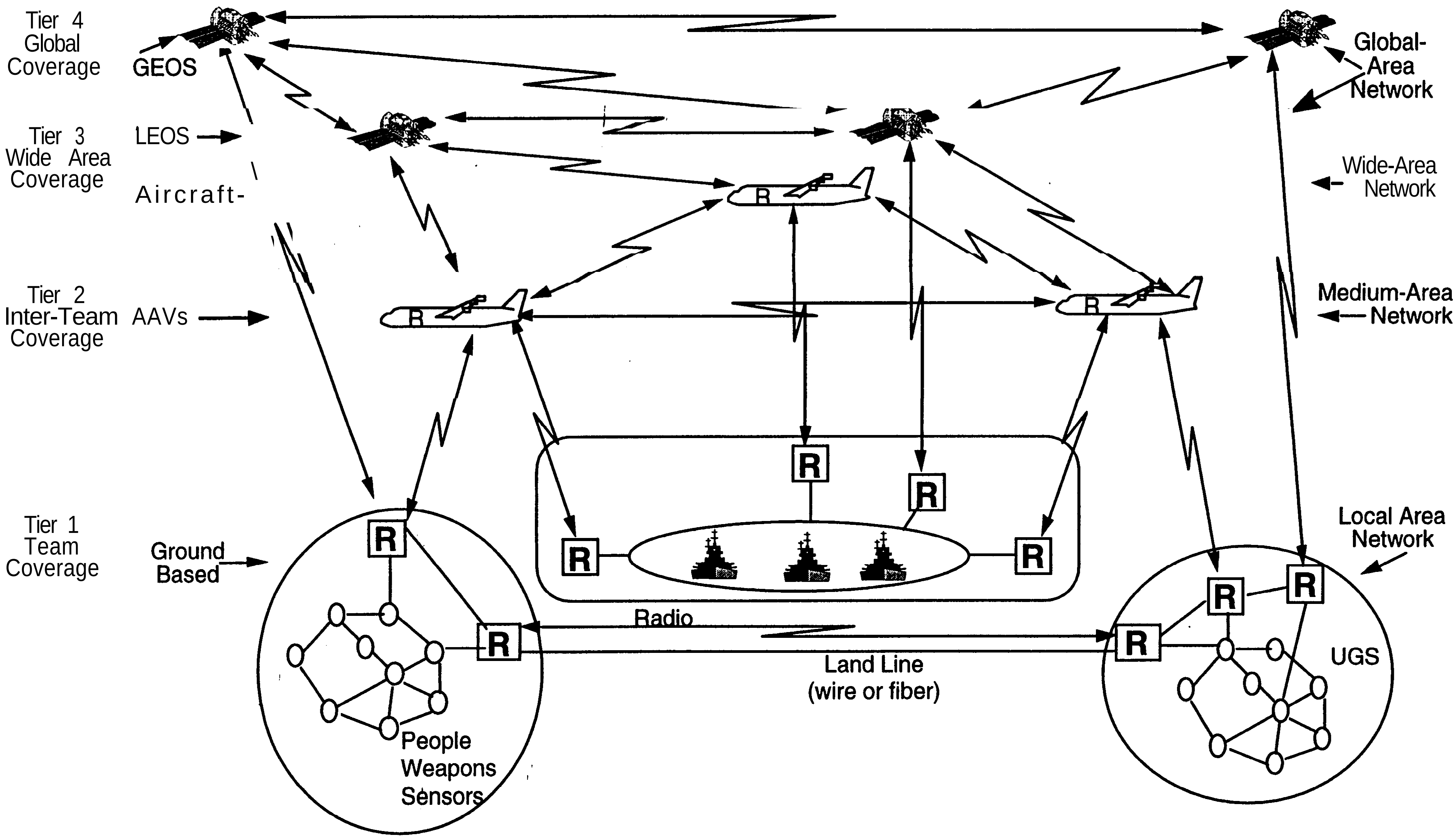
1 Routers are currently used in the commercial internetwork.

Information Infrastructure: Tiered Transport



Information Infrastructure: Transport (I)

Several attributes of the information transport infrastructure can be identified:

- The Information Infrastructure must provide fully-integrated connectivity to the combat cells. Local communication resources must be internetted to area and global resources to ensure that the warfighter can, at all times, communicate to entities intra- and inter-cell. These entities will include people, sensors and weapons, among others. There must be no seams between transport (communication) resources. All systems are fully cross-linked and are integrated into a network of networks — an “internetwork.”

- All communication nodes (radios, switches, routers) must be intelligent. They must understand, in real-time, their connectivity and, based on this knowledge, provide dynamic, adaptive routing of information from sources to destinations. This adaptivity must be used to meet the quality-of-service, reliability, and survivability demanded by the warfighter.

- The transport infrastructure must be flexible and scaleable. Flexibility implies that any network can be automatically integrated, via appropriate routers, with any other network(s). This flexibility is imperative if we are to mix-and-match force elements (combined arms, joint and coalition) to meet operational needs. Scaleability of the transport segment of the infrastructure is required so that we can support any number of distributed combat cells, weapons, and sensors to meet an operational requirement. Adding networks and/or communication nodes should be as easy as adding another network to the Worldwide Web today (where one is added every 30 minutes!).

Information Infrastructure: Transport (I)

- **Attributes**
  - **Based on open system protocols and standards**
    - » ***Fully internetworked*** **— no boundaries between segments**
    - » ***Automated management*** **— self aware**
    - » ***Adaptive*** **— to user needs and adversary action**
    - » ***Flexible*** **— allows for mix and match of force structure entities**
    - » ***Scaleable*** **— common protocols/standards allow segments to be added or deleted as required by mission**
    - » ***Fully integrated*** **— tightly coupled to distributed computing resources and agents**
    - » **Utilizes existing military and commercial technologies**
    - » **Facilitates introduction of new communication systems**

Information Infrastructure: Transport (II)

To meet these requirements for an integrated, scaleable transport infrastructure (that could include many hundreds of thousands of communication nodes), the following technology challenges must be met:

- Distributed algorithms and protocols that dynamically manage: Communication hardware to provide dynamic, real-time control of radio waveforms, link capacity and network topology, routing of data intra- and internetwork, distribution of network state information for adaptive, real-time self-management, distribution of state information exchange between transport and information processing layers.
- Distributed internetwork management and control algorithms/protocols that permit the configuring of the topology and balancing the loads across the network.
- Distributed algorithms and protocols that will adapt to meet dynamic quality-of-service requests made by the war-fighter.

Information Infrastructure: Transport (II)

- **Example technology challenges**
  - ***Distributed algorithms* and *protocols* that *dynamically manage***
    - » **Communication hardware to provide dynamic, real-time control of radio waveforms, link capacity and network topology**
    - » **Routing of data intra- and internetwork**
    - » ***Distribution of* state information distribution for adaptive, real-time self management**
    - » ***Distribution of* state information exchange between transport and information processing layers**

Information Infrastructure: Warfighter's Personal Information Ensemble

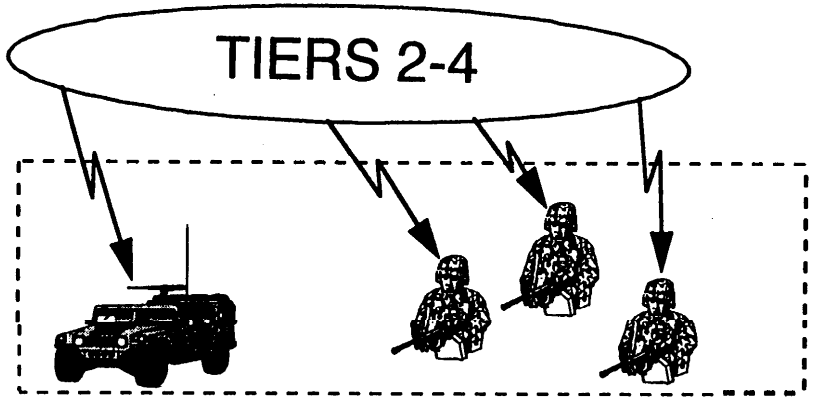
The war-fighter connects to the broader information infrastructure through a personal information ensemble that is based on commercial cellular and digital assistant technologies. This ensemble provides: (i) integrated mulitmode and multiband services; (ii) position and navigation; (iii) precise timing, and (iv) pertinent, tailored situational understanding through commands to, and reports from, intelligent software agents. Warfighter interaction with the personal communications ensemble is interactive, voice- and video-based, hands-free and does not require computer or database expertise. This chart summarizes these attributes.

The personal communication ensemble is fully integrated with protective personal gear and other standard military equipment, and offers anti-jam and security features.

The protocols and algorithms developed for the warfighter's personal communication ensemble will provide numerous services to the user. Examples of these services are multicast and broadcast information reception and distribution, conferencing facilities, network time (absolute and relative to a combat cell), and real-time reporting of a combat cell's geolocation and logistics status.

Information Infrastructure: Warfighter's Personal Information Ensemble

- To support unit cohesion within small, distributed cells: a need to be satisfied



TIER 1
Combat Cell
Local Area Network

- Integrated processing and communication resources
- Based on commercial cellular and digital assistant technologies
- A "networked" device; supports integrated multimode services - Paging, Conferencing, Imaging
- Integrated POS/NAV Function; precise time; terrain, enemy & teammate positions
- Supports quality of service requests (e.g., bandwidth on demand)
- Supports multimodal interfaces (e.g., voice recognition, heads-up display)
- Integrated into the Tactical Information Infrastructure

WARFIGHTERS' PORTAL INTO TII

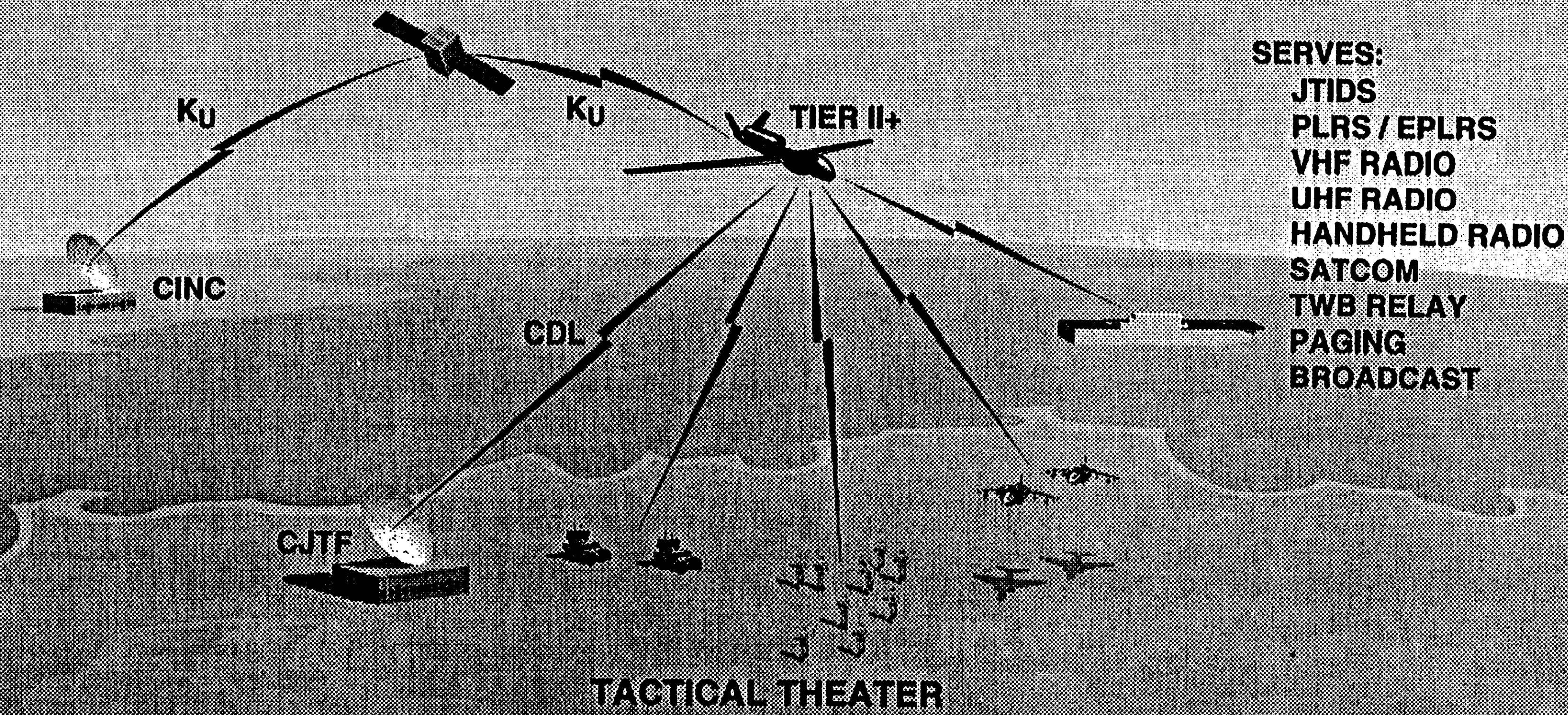
UAV Communications Node

With the advent of High-Altitude, Long-Endurance Unmanned Air Vehicles (HALE UAV), such as the Tier II+ (Global Hawk), the opportunity for a truly long-range radio relay platform is at hand. From a cruise altitude of 65,000 feet, the UAV is within line-of-sight (LOS) of ground radios at ranges out to 150 miles (or more, depending on terrain). The UAV's line-of-sight to other airborne platforms can be considerably greater. From this vantage point, forces that would otherwise be out of touch due to terrain blockage or rapid maneuvering can be connect by relay through the UAV. Since communications between many types of disparate equipment could be relayed through the UAV, it would also be desirable to provide on-board gateways and routers that would extend the connectivity and utility of current tactical communications equipment. And since the Tier II+ is being procured with a K_u-band SATCOM terminal on-board, this could be used to provide out-of-theater connectivity.

The concept for a network of Airborne Communications Nodes (ACNs) is based on utilization of the Tier II+ UAV, modified from its SAR/EO surveillance sensor payload configuration. The ACN concept provides theater-wide communications and reach-back connectivity to out-of-theater sites in CONUS or elsewhere through direct satellite communications links. The payload would operate with equipment currently fielded by the Services, as well as provide new classes of service that are not yet deployed (e.g., theater-wide broadcast of intelligence and other data, hand-held radios modeled after commercial cellular systems, and paging services).

The essential communications services provided by the ACN are (i) range extension, and (ii relay between users that are not within line-of-sight of each other (but who are all within line-of-sight of the ACN). The need for an ACN relay could arise because of intervening terrain or, simply, because the combat cells have moved beyond line-of-sight of one another due to rapid maneuvers. The ACN can also provide connectivity, to complement the limited amount of communications gear that might be carried in by early entry combat cells due to inadequate air- and/or sea-lift capacity. The ability of forces to have the freedom to maneuver — yet still maintain connectivity — allows new operations concepts to develop. This beyond line-of-sight communications is essential to new amphibious assault techniques being planned by the Navy and Marines.

UAV COMMUNICATIONS NODE



- DARPA STUDY EXAMINED COMMUNICATIONS PAYLOAD FOR TIER II+
- 65,000-ft ALTITUDE PROVIDES LINE-OF-SIGHT EXTENSION UP TO 150-mi RADIUS FOR CURRENT AND NEW COMMUNICATIONS SYSTEMS
  - — CONNECTS ISOLATED AND RAPIDLY MANEUVERING FORCES
  - — PROVIDES REACH-BACK CONNECTIVITY FROM FORWARD ELEMENTS
  - — OPPORTUNITY FOR ON-BOARD GATEWAYS AND NETWORKING
- INSTANT COMMUNICATIONS INFRASTRUCTURE FOR DEVELOPING THEATERS EASES INITIAL AIR- AND SEA-LIFT REQUIREMENTS

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Information Infrastructure Issues: Robust Communication Systems

The Tactical Information Infrastructure (TII) includes wireless (satellite and radio) communications resources. These resources are used to connect various segments of the TII's "fixed" backbone network, as well as to provide a deployable theater extension network that serves dispersed users. An important issue concerns providing seamless connectivity between the wireless and wired resources, as well as among the different wireless resources.

Satellite resources currently available to military users include the DSCS, FLTSAT and MILSTAR satellite communications (SATCOM) systems and the increasing number of commercial systems. These systems have vastly different capabilities because they were typically designed to meet very specific, different user needs. As a result, providing connectivity between these diverse systems can be a difficult task.

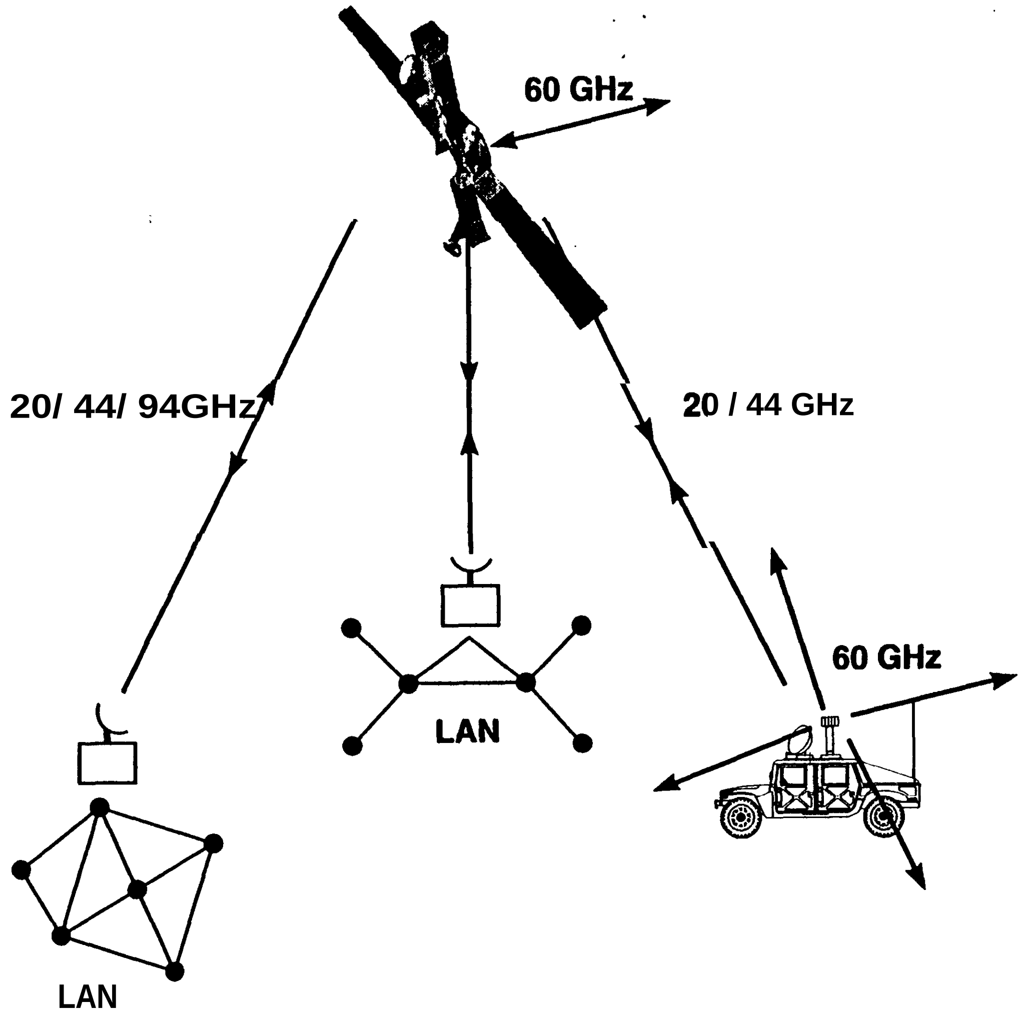
The DSCS system consists of transponder satellites that are primarily used to carry high data-rate transmissions from fixed sites and deployed, transportable tactical trunking terminals. Most DSCS terminals do not provide anti-jam protection, although some low-rate anti-jam terminals do exist.

The FLTSAT satellite uses UHF transponders to serve small mobile users at low data rates. FLTSAT circuits are typically used to provide military radio "push to talk" and specialized tactical data networks. A Demand Assignment Multiple Access (DAMA) system is being established that will use Time Division Multiple Access (TDMA) to increase the user capacity of the FLTSAT system.

The MILSTAR system is a processing satellite system that will operate at EHF and provide jamming protection for all of its users (including small terminals). MILSTAR is a circuit switched system that can provide data rates ranging from 75 bps to 1.5 Mbps per user. The MILSTAR system will, at least initially, be used in a similar way to FLTSAT and DSCS to provide dedicated circuits in support of specific functions or ground networks.

A major issue for future systems that will support small highly mobile forces operating in hostile environments is the development of a robust high frequency satellite communication system that provides anti-jam and low-probability-of-intercept (LPI) communications. The current MILSTAR system must be replaced by a future system that provides higher data-rate circuit and packet switched communications to a broad variety of mobile users. The chart displays the high level characteristics of such a future system.

Information Infrastructure Issues: Robust Communication Systems



- AJ via Bandspreading and Nulling
- Small Mobile SATCOM Terminals
- 20 / 40 GHz for Theater Coverage
- 94 GHz for High Speed Trunking
- 60 GHz For Cross-Links
- 60 GHz for Ground Relay to Hand-Held User Sets
- UAV as Surrogate for Satellite
- Phased Array Antenna for Agile Multiple Narrow Beams
- Serves Both Switched Circuits and Packet Data

Information Infrastructure Issues: Communication System Threat

The arguments for communication system operations at high frequencies (K_a band), and the utilization of anti-jam and low-probability-of-intercept techniques within those systems, are based on assessments of the difficulty for an enemy to build credible jammers using commercially available hardware.

The figure illustrates the cost of a potential mobile jammer that could be constructed at UHF and SHF uplink frequencies by integrating available COTS equipment. An EHF jammer in a similar mobile configuration could be built from nondevelopmental items (NDIs), although not all parts, particularly the traveling wave tube amplifier (TWTA), would be as readily available as the COTS equipment for SHF or UHF.

The UHF jammer is easy to build, inexpensive, and would be very effective against all UHF SATCOM systems. The SHF jammers are more costly and would be effective against today's military and commercial SATCOM systems. The EHF jammer is harder to build, more costly and would not be effective against military systems that employ anti-jam techniques. For these reasons, military operations in hostile territory must have a robust anti-jam core capability to provide connectivity to critical mobile users. That capability will probably be implemented at operating frequencies above K_a band.

Information Infrastructure Issues: Communication System Threat

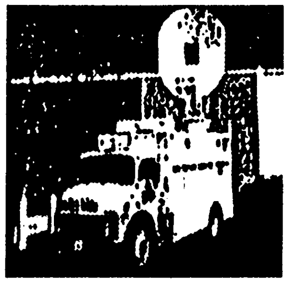
Difficulty: Lowest → Highest

Band

Effectiveness: Highest → Lowest

UHF
- Mobile Jammer Trivial to Assemble from COTS Equipment at Very Low Cost (~$40K)
  - Jeep-Mounted: 39-45 dBW EIRP

SHF
- Mobile Jammer (C, X, or Ku-Band) Easy to Build from COTS Equipment at Low Cost (~$400K)
  - TV Uplink Vans Can be Used
- X-Band EIRP From Mobile COTS Jammer: 77-83 dBW for Bandwidths up to 500 MHz
- Equivalent Effectiveness from COTS at C and Ku-Bands



EHF
- Mobile Jammer (84-90 dBW) More Difficult to Build at Moderate Cost (~$1M)
  - Limited Supply of HPAs (Power Above 250 W Requires a Development Effort)
  - Jammer Does Not Know if it is Being Effective Against Processed Satellites

Information Infrastructure: Examples of What Is Happening Now

We live in a period of history characterized by a remarkable rate of change in information technology. Within the past six years, commercial investment has propagated a Worldwide Web of information services. Commercial activity is moving aggressively to set standards fostering open, interoperable architectures. The commercial information technology industry investment in R&D is huge and growing, as companies compete to rapidly transition information technology to the market place.

Within DoD, numerous studies on C^4ISR have been completed or are in progress. These studies recommend various strategies, visions, jnteroperability schema, requirements and architectures. However, there is no overall, integrating, organizing principle against which these competing ideas may be measured. Further, DoD is sponsoring numerous and diverse technology development efforts, including multiple radio programs, C^4ISR platform and product initiatives, and programs to explore new technology in the areas of information collection, fusion, and management. These, too, are poorly coordinated, duplicative and not organized along a central set of protocols and standards. To its credit, DoD is reorganizing to focus on C^4ISR. Among the steps DoD has taken in this direction is the appointment of a Corporate Information Officer. The success of this effort remains to be seen: it is like many such steps taken in the past, which ultimately had little real effect on the way DoD C^4ISR-related systems are planned and procured.

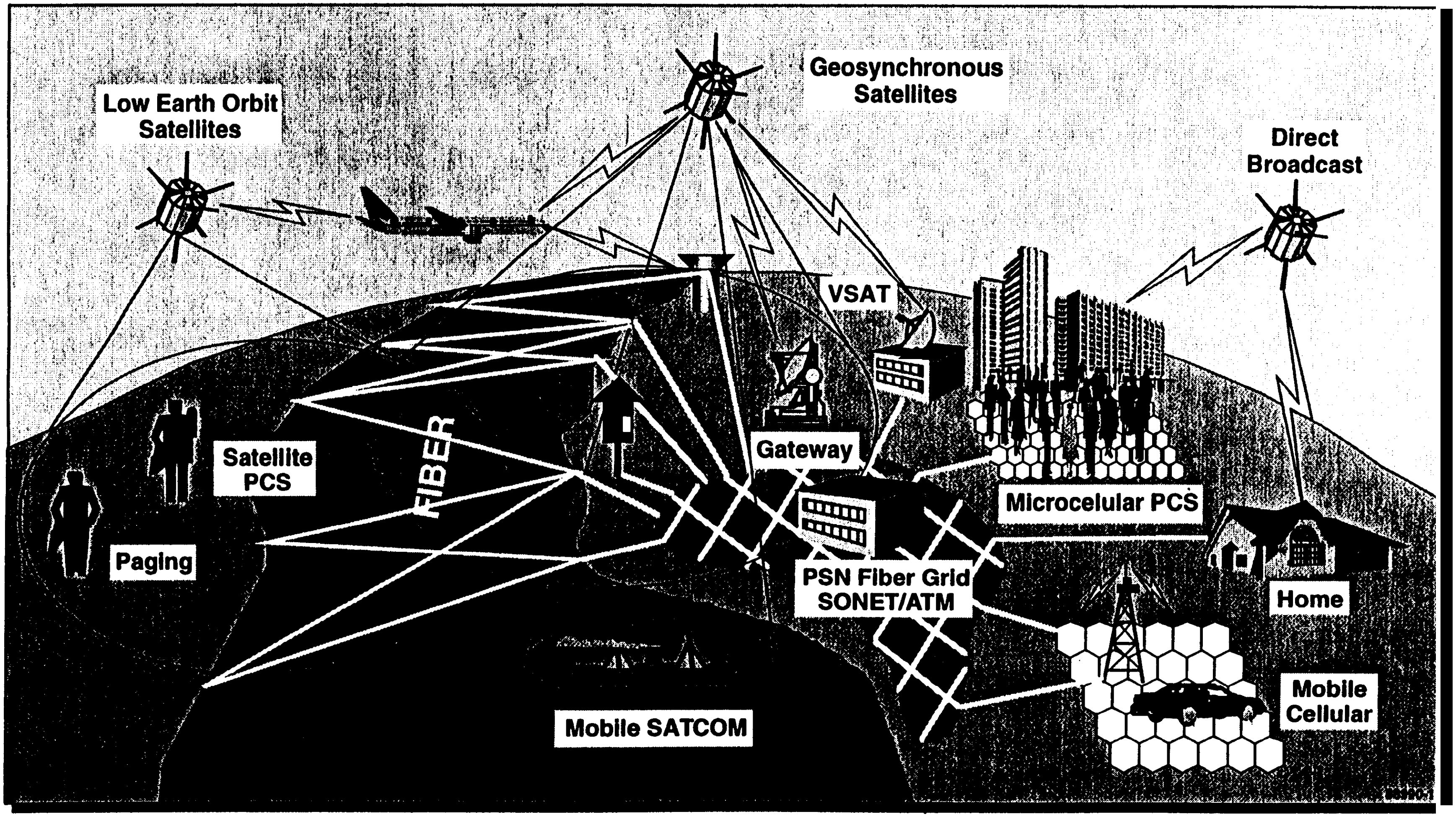
Similarly, DARPA and the Service Labs are developing elements of the Tactical Information Infrastructure. Examples include: the Global Mobile program (investigating technologies to support mobile computing); the Battlefield Awareness and Data Distribution Program (investigating broadband, broadcast information distribution); Intelligent Information Integration (investigating accessing and aggregating information for many heterogeneous databases), and network management technology development.

However, in all of these initiatives, the goals of each program are being pursued nearly independently of each other. Furthermore, the visions of the environment in which the various technologies are to be applied are modest compared to that envisioned for the Tll. In TII, we foresee many hundreds of thousands of communication and processing nodes distributed globally, all cooperating to provide robust, reliable information transport and intelligent information services to the combat cells and other users. The number of nodes involved, and the fact that they are self-managed (on a peer-to-peer basis in order to provide rapid adaptation to a continually changing environment), requires an S&T program focused on intelligent information infrastructure as envisioned in this report.

The global information infrastructure today serves as an example of the necessary ubiquitous connectivity required of the future Tactical Information Infrastructure. The limitations of today's Worldwide Web, especially at the "point of conflict" under stressed conditions, highlights the need for technology development to put a Tactical Information Infrastructure in place.

For example, America On Line experienced a 16 hour outage of its computer network on August 7, 1996. A similar outage in the Tactical Information Infrastructure during a period of military operations (when that network is likely to be under the greatest stress) would be catastrophic. If we are to enjoy the military operations benefits of leveraging information technology, we must at the same time ensure that the continued, uninterrupted functioning of that technology is accorded protection commensurate with its use.

In ormation Infrastructure: Examples of What is Happening Now

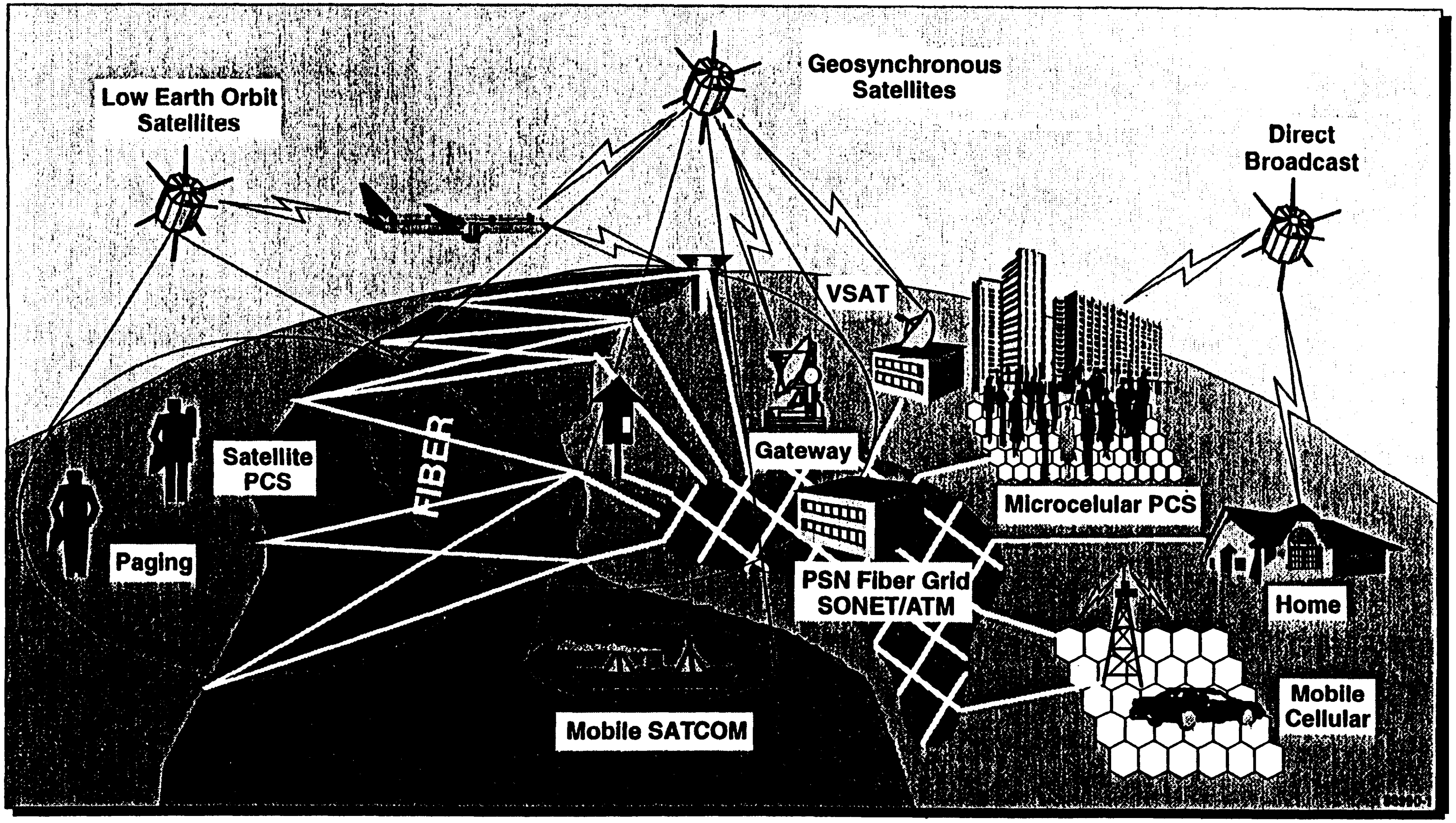


The World Wide Web Today

Necessary But Not Sufficient

This chart, representative of the transport infrastructure that exists as part of the Worldwide Web, is an example of what we envision for the TII. Similarly, the information services (data storage and retrieval software) emerging on the Web are very early examples of what we envision for the "intelligent software agents" (discussed below). We do not suggest that the Worldwide Web be the TII. However, we do suggest that the technologies (protocols, standards, algorithms and information applications concepts) provide a starting point for establishing a baseline TII in support of military operations. This baseline, owned by DoD, would then be augmented through a DoD S&T program to meet the vision presented herein. Similarly, as commercial IT technologies mature, they would also be leveraged into the TII.

Information Infrastructure: Examples of What is Happening Now



The World Wide Web Today

Necessary But Not Sufficient

Information Infrastructure: Distributed Computing Resources

The Information Infrastructure must seamlessly integrate distributed computing resources for user and software agent functions, i.e., in a way that is transparent to the user. Distributed processing provides the computational resources necessary at all times and under all conditions, regardless of adversary-induced damage to the network. This is accomplished through dynamic resource management, wherein the network and network software agents intelligently respond to changing needs and network conditions. The attributes of these distributed resources include a wide variety of computers, integrated processing resources, a "meta" computer that enables unlimited computational power, ultimate availability, and resource management that dynamically adapts to meet user's needs in the presence of adversity.

The technology challenges that must be addressed in providing these distributed computing resources include:

- Operating systems that provide coarse-grain, distributed parallel processing between dispersed processing systems.
- Distributed algorithms that permit dynamic load'leveling, adaptive computation, and self management to assure graceful degradation at the point of service
- Algorithms and protocols that tightly integrate distributed computational resources with transport infrastructure

Information Infrastructure: Distributed Computing Resources

- **Attributes**
  - ***Many types of computers*** **— personal digital assistants to massively parallel**
  - ***Processing resources integrated --*** **a distributed collection of cooperative computers**
  - ***Meta computer --*** **integrated resources provide unlimited computational power**
  - ***Available*** **— to all users of the infrastructure at all times under all conditions**
  - ***Dynamic resource management*** **— to meet user's requirements and to cope with adversary**
- **Example technology challenges**
  - **Operating systems to provide coarse-grain (distributed) parallel processing**
  - **Distributed algorithms to permit dynamic load leveling, adaptive computation and self management**
  - **Distributed algorithms to support dynamic allocation/deallocation of computational resources**
  - **Algorithms and protocols that tightly integrate computational resources with transport infrastructure**

Information Infrastructure: Intelligent Software Agents

The infrastructure is an intelligent network. Each component exchanges state information with each other, in order to enable the entire infrastructure to adapt to user requirements and any stresses imposed on the network by an adversary. This adaptability also enables the infrastructure to change its scale as necessary to support force structure(s) of arbitrary size, or to incorporate new processing, network, and communication technologies as they are developed. Thus, this infrastructure is a scaleable computing environment.

Within the infrastructure, each user is served by "intelligent software agents" that are proactive in providing and disseminating appropriately packaged information (e.g., such functions as fusing and filtering information, and delivering the right information to the right user at the right time. "Proactive" in this sense means that the software agents are aware of the user's situation and needs, and can provide information relevant to those needs without a specific user request. This chart provides a conceptual rendering of these agents.

These agents multiply the personnel resources available to the combat cells by gathering and transforming data into actionable information to support cell operations — just as cell members would have to if the software agents were not available. Cell members are, therefore, freed from routine chores in favor of actual operations.

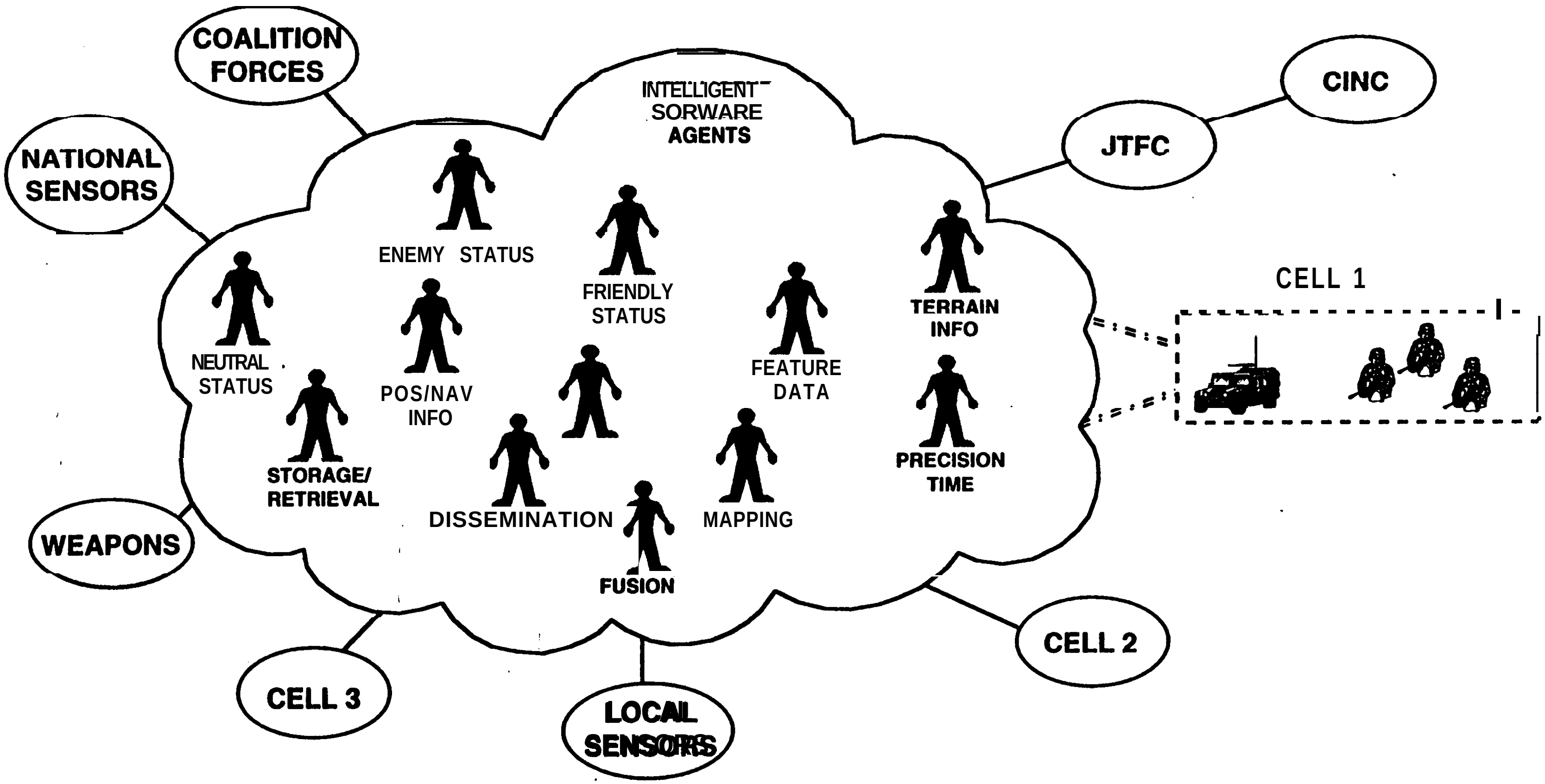
The key attributes of these software agents include:

- Intelligent service application software agents must provide tailored, human-centric data acquisition, processing, data fusion, information generation and dissemination to users. These agents act to deliver processed, synoptic information to users instead of volumes of data and images. The service application software agents collaborate with other agents to achieve general goals set by users. Based on user profiling, they proactively generate pertinent situation changes that may be of interest to the user. The agents support automatic, dynamic, adaptive allocation of transport and processing resources, and replicate, as necessary, for efficiency and to ensure continuity of services provided to the user.

- Intelligent application software agents must provide an array of functions appropriate to the user's mission and situation. They must also exchange information and status with other application software agents to provide integrated, yet distributed, execution of requested user services. These agents automatically select and perform their functions depending on specific user requirements and profiled user interest areas. The agents provide discovery and integration of data from multiple, heterogeneous databases, broker between other agents for sharing of information, and negotiate with service agents to establish appropriate network and resource allocations to achieve their goals. These agents are adaptive, i.e., they profile user needs against direct user nput, past user requirements, and an understanding of user mission, status, and intentions.

Incorporation of such software agents poses several technical challenges, examples of which are:

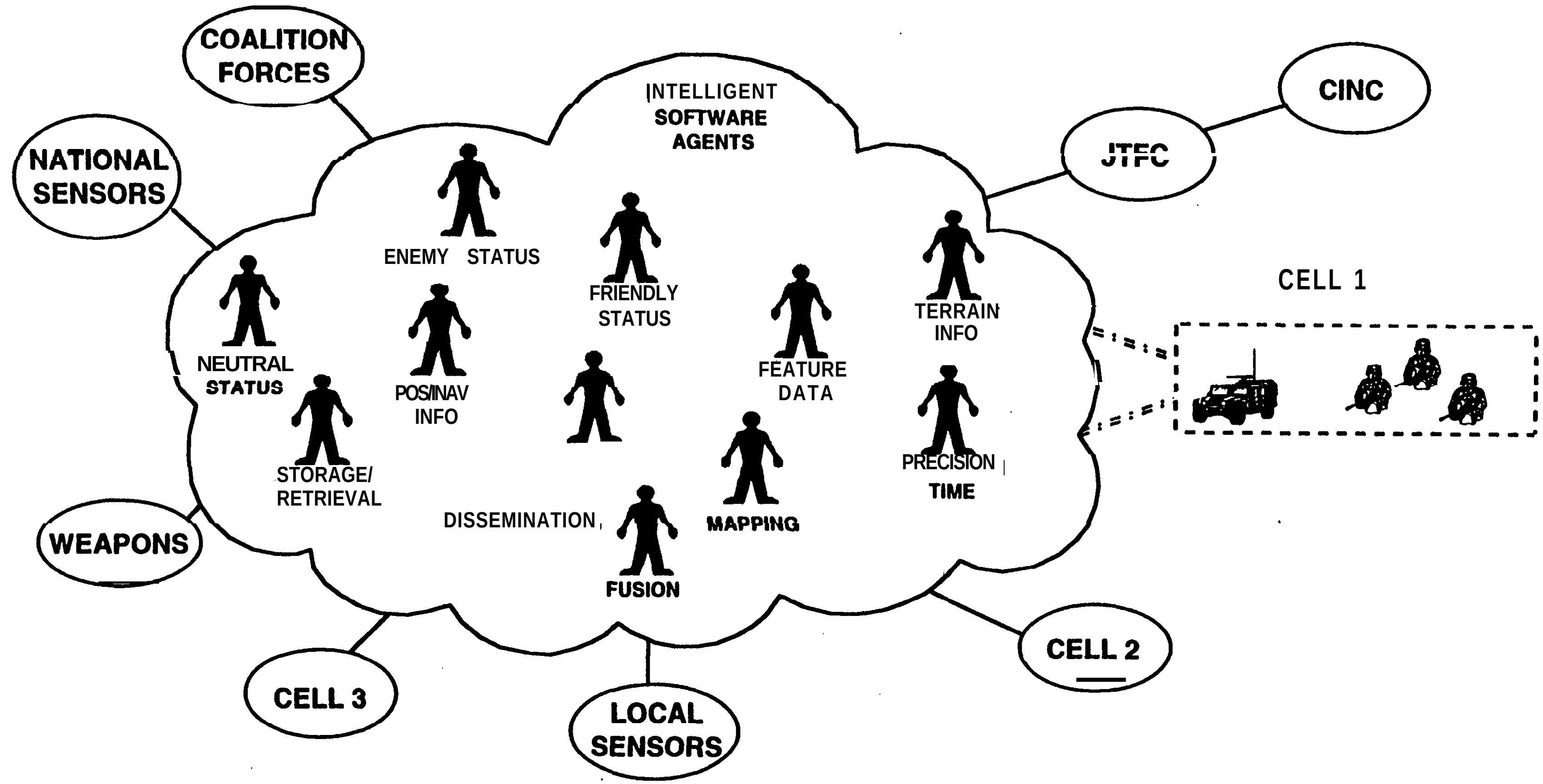
Information Infrastructure: Intelligent Software Agents



- Intelligent Software Agents:
  - Relieve Cell Members of Information Management Functions
  - Provide Data Fusion, Information Storage, Retrieval and Dissemination
  - Tailor information at the right time, to the combat cells needing it
  - Allow users to request information in mission specific terms
  - Provide geospatial and time information services

- Protocols, standards and operating environments to support object-based system design and implementation are necessary to enable the creation of intelligent software agents.
- Representation technology for knowledge in object-based systems, by which software agents may describe their attributes to and understand the attributes of other software agents and resources.
- Representation technology for system resources, plans and other entities in the infrastructure.
- Distributed algorithms, and appropriate protocols and languages for agent definitions, communication and adaptation.
- Universal representation of domain knowledge for exchange between software agents and resources.
- Comprehensive, universal language and computational models for declaring agents.
- Distributed algorithms and appropriate protocols for real-time distributed agent management, interagent negotiations and information exchange.
- Automated learning and user profiling techniques.

Information Infrastructure: Intelligent Software Agents



- Intelligent Software Agents:
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  - Allow users to request information in mission specific terms
  - Provide geospatial and time information services.

Information Infrastructure: Security

Security in the distributed Information Infrastructure merits special discussion. The exploitation of commercial protocols and standards provides the technology base necessary for the 21st Century integrated information infrastructure. Because portions of the infrastructure will incorporate commercial networks and structures, and because much of the infrastructure will be based on commercial equipment, security must be an integral design consideration throughout the infrastructure's development. Further, because the infrastructure will also necessarily incorporate commercial systems, these systems must be carefully evaluated to balance the benefit of such incorporation versus the risk each such incorporation presents to the network. For example, commercial systems provide only those security features consistent with competition in the commercial market place, a very different standard than those which would be consistent with military necessity. In general, commercial equipment offers little anti-jam or low-probability-of-intercept functionality, operates in generally fixed topologies offering limited adaptability, and requires a fixed, pre-deployed infrastructure — leading to surge capacity limitations and potential denial-of-service problems.

Appropriate security for the distributed Information Infrastructure can be accomplished through development of a comprehensive security architecture, which provides flexible, dynamic, adaptive, and rapidly reconfigurable security configurations in collaboration with the software agents at work in the infrastructure.

To enable incorporation of the requisite infrastructural security, technology challenges to be addressed include:

- Distributed algorithms and appropriate protocols and representation technology to support dynamic security policy dissemination, arbitration, and enforcement within the distributed Information Infrastructure. These resources must include dynamic transport routing, data distribution and processing/resource allocation.
- Representation technology that permits software agents to exchange security access credentials.

Information Infrastructure: Security

- Issues (Defensive Information Warfare):
  - A new framework and architecture are necessary
    - » To allow system adaptability described earlier
    - » To permit flexibility envisioned for intelligent software agents
    - » To support dynamic user groups
  - Security architecture:
    - » Integrated from communication links (TRANSEC) through distributed computers to software agents
    - » Developed concurrently and in collaboration with realization of information infrastructure technologies and vision
  - Technology challenges
    - » Software agents need security clearances!
    - » Distributed algorithms and protocols to support dynamic security policy dissemination and enforcement
      - Data transport routing
      - Dynamic data distribution
      - Dynamic processing — resource allocation

Information Infrastructure: Cell Communications and Commercial Technologies Issues

The wireless communications links that tie together the elements of the information infrastructure must be reliable, secure, adaptable, and capable of much greater performance than today's systems. This is particularly true, at the combat cell level, where terrain problems, enemy action, increasing demand for service, and the vulnerability of troops to radio location are greatest. Equipment now in inventory falls well short of 21st Century tactical needs. New approaches to combat cell communications must be developed to assure that the small units can operated effectively in the field.

Point-to-point communications technology now used in most battlefield systems is unreliable, heavy, and subjects troops to enemy targeting. Packet-based, multinode communication systems based on self-organizing cellular radio concepts can be robust, overcome terrain and jamming, and provide bandwidth sufficient for the full range of small unit communications needs. If implemented at EHF frequencies, such systems can be immune to radio location. Soldiers' equipment could be rugged, low power, secure, and lightweight, i.e., designed along the lines of commercial cellular telephones.

The development of the wireless physical communications system of the 21st Century will require investigation of technology developed to solve commercial cellular, PCS and wireless LANs. This chart list several of the commercial technologies issues that need to be addressed.

In addition, reexamination of battlefield system operation principles, including packet communications, low cost, disposable nodes, and network self-organization algorithms are required.

Information Infrastructure: Commercial Technologies — Issues

- **Possible surge capability limitation, if not leased a priori (assured access?)**
- **An array of regulatory restrictions (e.g., host nation frequency approvals)**
- **Denial of service (through gateway or spacecraft TT&C)**
- **Minimal AJ and LPI capabilities**
- **Limited commercial terminal battery life**
- **Potential blockage of space signals in urban environment**
- **Restoration priority and dynamic resource allocation**
- **Survivability of commercial hardware (e.g., ruggedization)**
- **Integration into tactical environment**

Information Infrastructure: Summary Needs

Through an appropriate management structure, investment strategy, and with focused resolve and energy, DoD can realize the vision presented here. Several technology challenges must be solved. Key challenges are listed in this chart.

The private sector has developed the necessary baseline technology, as evidenced in the World Wide Web (WWW). This information infrastructure is today's embodiment of our vision that addresses the emerging information needs of private-sector users. The WWW is an existence roof for DoD – a necessary, if inadequate, development of technology (standards, protocols, and algorithms) that will facilitate the development of the required integrated information infrastructure. The WWW is not adequate for direct exploitation as a Tactical Information Infrastructure because it is not sufficiently robust against intelligent adversaries, and it cannot support warfighters within difficult environments. The WWW, as captured in the Joint Technical Architecture (JTA), does, however, provide a starting point.

By implementing the JTA, by focusing a segment of the DoD Science and Technology Program on the technology challenges identified here, and by addressing the security issues noted in the preceding chart, we can realize the Tactical Information Infrastructure necessary to achieve military superiority in the 21st century.

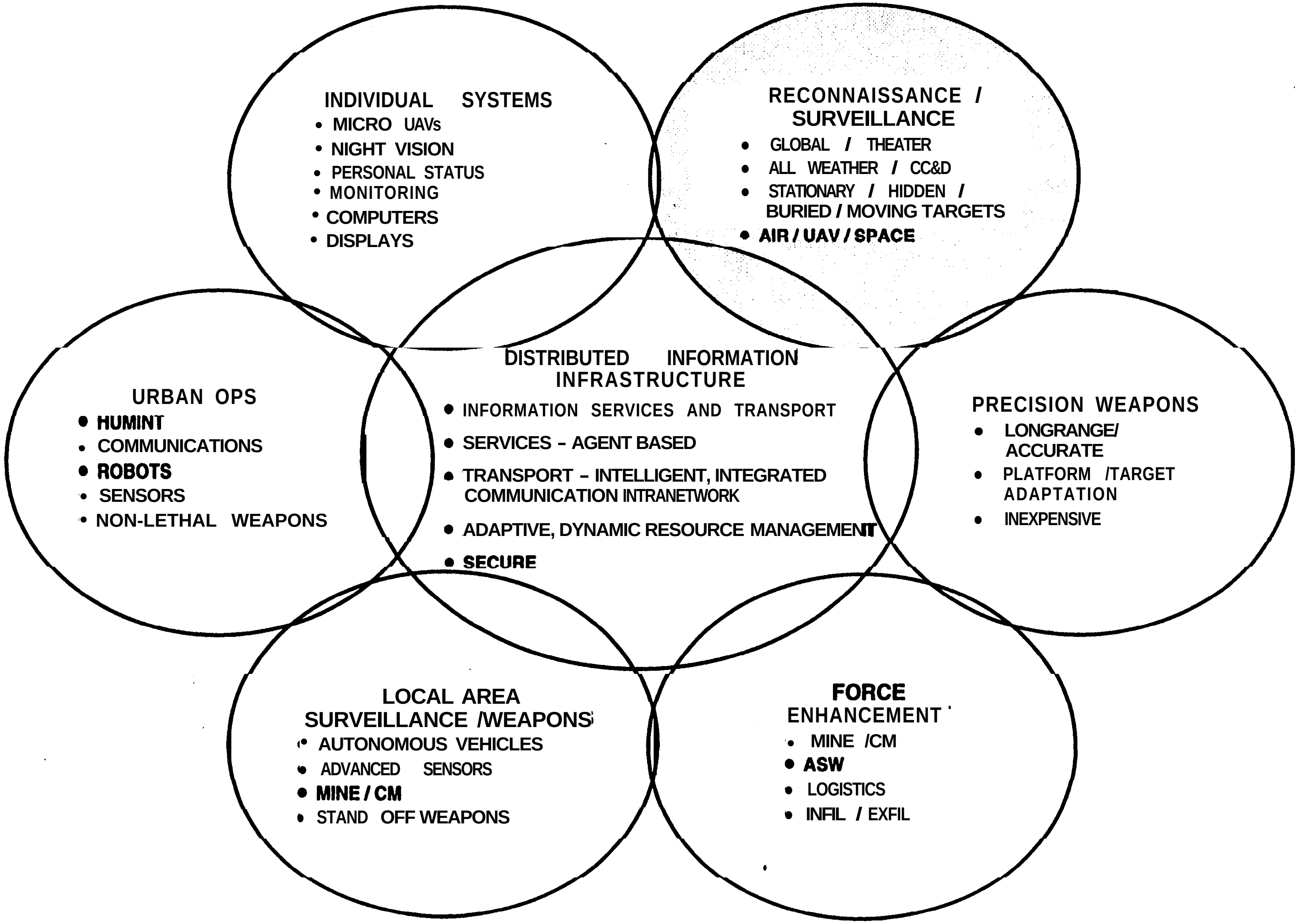
Information Infrastructure: Summary

- Means to appropriately leverage commercial information technology, while not assuming poorly understood risks
- Architectural integration of heterogeneous networks, including adaptive, flexible interfaces and appropriate, network-of-networks protocols
- Adaptive transport protocols, including incorporation of commercial internetwork protocols, where appropriate, and new network management protocols and algorithms
- Means to develop software agents, including knowledge representation and "intelligent" action

Reconnaissance / Surveillance

TACTICS AND TECHNOLOGY FOR 21st CENTURY MILITARY SUPERIORITY

TECHNOLOGY CONCEPTS PANEL



Reconnaissance / Surveillance — Goals

Reconnaissance/surveillance of the surface is an essential part of successful battlefield operations. National and emerging commercial space systems offer the prospect of responsive global intelligence, situational understanding, map generation and fixed target identification on timescales appropriate to peacetime or to the buildup of hostile conditions. For military operations, sensor systems must be developed to continuously collect data on an entire theater of war and derive actionable intelligence against fixed- and moving-targets under all levels of camouflage, concealment, and deception (CC&D) in near-real-time. In recent years, the United States has set itself on a path to realize this vision with the procurement of very capable wide-area airborne sensors.

Reconnaissance / Surveillance — Goals

- Timely global imagery from national and emerging commercial space systems for intelligence, situation awareness, map generation, and fixed target identification

- Continuous theater-wide situation awareness for future military operations — smaller units, urban ops
  - Robust, survivable, continuous wide-area surveillance
  - Fixed- and moving-target identification under all levels of CC&D

Reconnaissance /Surveillance — Status/Needs

Effective surveillance of significant areas requires not only excellent sensors, but also robust automatic target recognition (ATR) technology to enable modest numbers of human analysts to keep up with a flood of sensor data. Currently (or soon-to-be) deployed surveillance sensors are capable, in principle, of supporting general target recognition via visible, infrared or high-frequency (X-band and higher) synthetic aperture radar (SAR) imagery. These sensors are all restricted to targets in-the-open. For one of these sensor types - high frequency SAR -ATR is now mature enough to support wide-area, real-time human analysis of unobscured, stationary vehicular military targets.

Detection of obscured or buried targets will be assisted by multimode (e.g., multiple-viewing-angle) or multispectral sensing or multisensor fusion, because hiding an object from, for example, imaging in many different bands or from many different viewing directions simultaneously can be difficult. ATR technology for recognizing moving targets with radar is emerging now. ATR for recognizing obscured targets (particularly targets hidden under foliage) is making progress but remains a research area. Multi-sensor fusion represents an obvious challenge to sensor coordination, tasking, and data relay, as well as to basic algorithmic technique. The challenge is greater still for targets that move, stressing system-of-system timelines.

Reconnaissance / Surveillance — Status / Needs

- Good reconnaissance, surveillance, and ATR in near-term for fixed targets in clear
- Improved multimode, multispectral sensors needed for obscured and buried targets
- ATR development needed for moving- and obscured targets
- Improvements required in sensor coordination, tasking, data relay, and data fusion

Wide-Area Sensor Systems

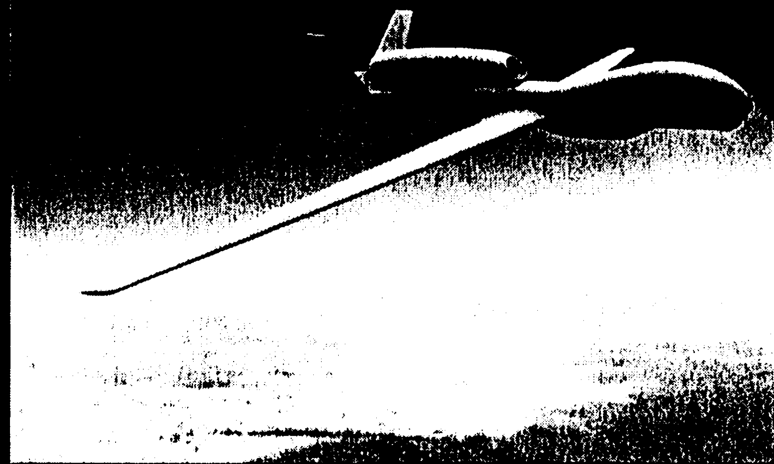
Present-day thinking about military wide-area imaging is dominated by three airborne platforms: the High-Altitude Endurance (HAE) Unmanned Air Vehicles (UAVs) Dark Star (designated Tier III- with sensors included) and Global Hawk (designated Tier II+ with sensors included), and the manned U-2R. All are 60,000-ft-class air vehicles; Dark Star is low-observable.

Tier II+ and Tier III-, which are not yet operational, will be revolutionary in carrying SARs (X-band for Tier II+, K_u-band for Tier III-) capable of producing 40,000 sq. nm of SAR stripmap imagery at an unprecedented 1 m resolution, with $10M per unit flyaway cost.

The ASARS II radar (X-band) on the decades-old U-2R platform collects SAR stripmap imagery at an even greater area rate, although at significantly coarser resolution. Planned ASARS upgrades will significantly refine its stripmap resolution.

WIDE-AREA SENSOR SYSTEMS

TIER III–
(DARK STAR)



TIER II+
(GLOBAL HAWK)

U-2R

279744-1P

Semi-Automated IMINT Processing

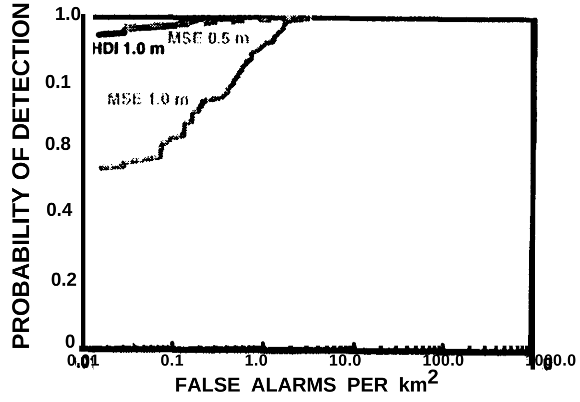
The Tier II+ and Tier III- SARs represent both a challenge and an opportunity for military image analysis — for essentially the same reason. The challenge comes from combining large-area-rate with relatively fine resolution, which means that a huge number of image pixels must be exploited. The opportunity arises because the relatively high resolution brings effective ATR-based screening into the realm of the practical. ATR for SAR imagery reckoned (by conventional standards) at 1 m resolution is especially workable because SAR imagery (when available in complex form) can be super-resolved using modern signal processing techniques such as High Definition Imaging (HDI). HDI has been shown to consistently refine the effective resolution of SAR imagery by roughly a factor of two.

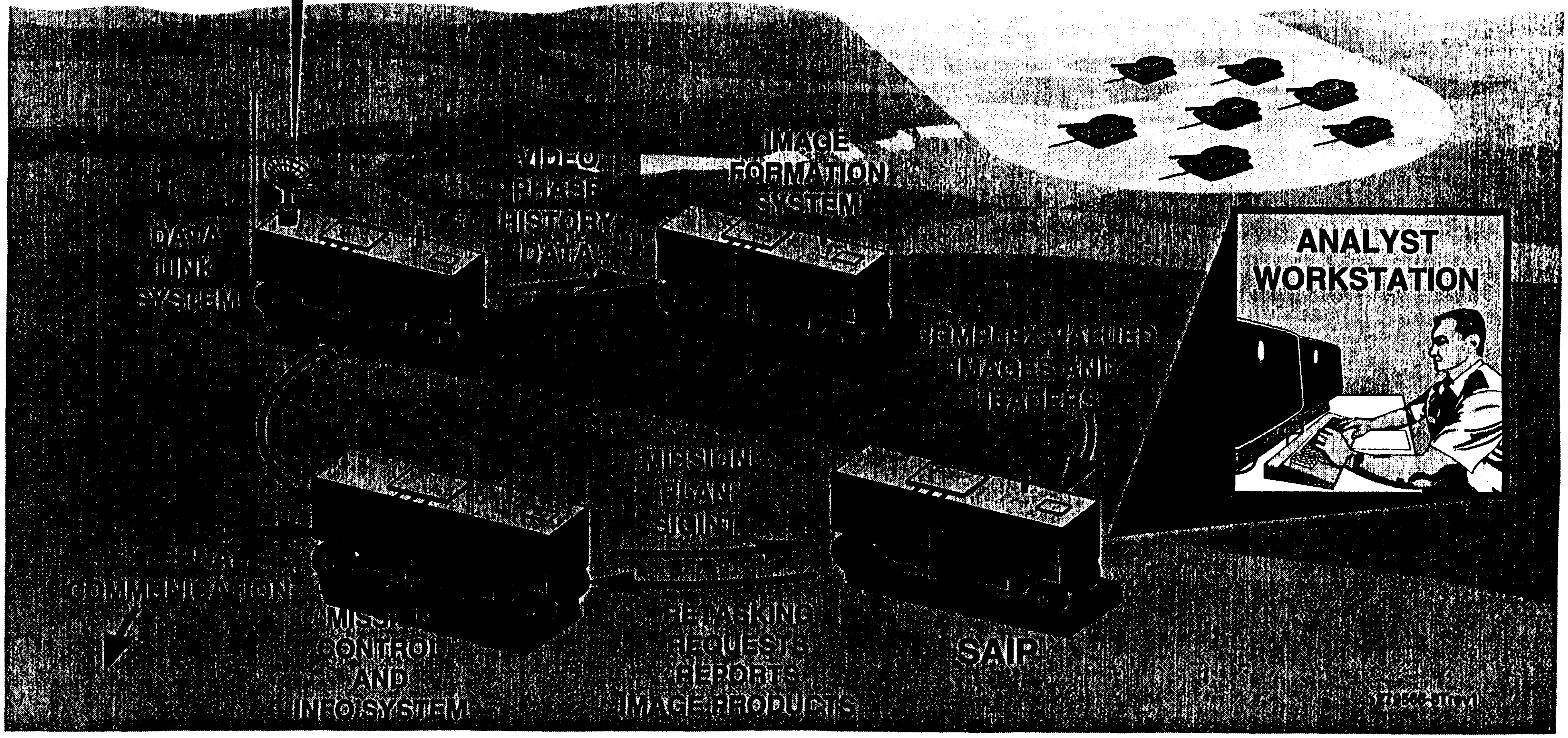
The potent combination of ATR (in its most mature form, i.e., mean-square-error (MSE) template-matching) and HDI, together with a robust suite of additional false-alarm-mitigation techniques, is to be demonstrated in the DARPA/DARO/OSD-sponsored Semi-Automated IMINT Processing (SAIP) Advanced Concept Technology Demonstration (ACTD). The ultimate goal of SAIP is to enable two or three image analysts to exploit the entire Tier II+ stripmap in real-time. Numerically, this amounts to requiring, on human factors grounds, that the algorithmic system produce no more than one false alarm per 100 sq. km., at high probability of target detection — a level of performance that has already been demonstrated in controlled testing with instrumentation-quality sensor data.

SAIP is scheduled to begin shakedown in the field in early CY1997, with an engineering demonstration at Operation Desert Capture 97 (ODC97) in March 1997.

SEMI-AUTOMATED IMINT PROCESSING

- TEMPLATE MATCHING ATR
- HIGH DEFINITION IMAGING
- CHANGE DETECTION
- FORCE STRUCTURE ASSESSMENT
- ADVANCED HUMAN COMPUTER INTERFACE
- PERFORMANCE GOALS (Unobscured Deployments):
  - $P_d = 0.9$
  - FAR $= 0.01/km^2$





Surveillance Capability, Parsed by Target

A tree-like taxonomy provides a convenient graphical "language" for thinking about various target dispositions and the capability of current surveillance sensors and recognition techniques to deal with them.

Moving targets in the open are readily detected today with moving-target-indicator (MTI) radar as implemented, most familiarly, on Joint STARS. Classification of moving targets in the open is expected to be a reality in the mid-term (i.e., in roughly five years) as technology for imaging moving ground vehicles matures. MTI also readily detects partially obscured moving targets because detection requires only that enough of a target be exposed to generate a nontrivial radar reflection.

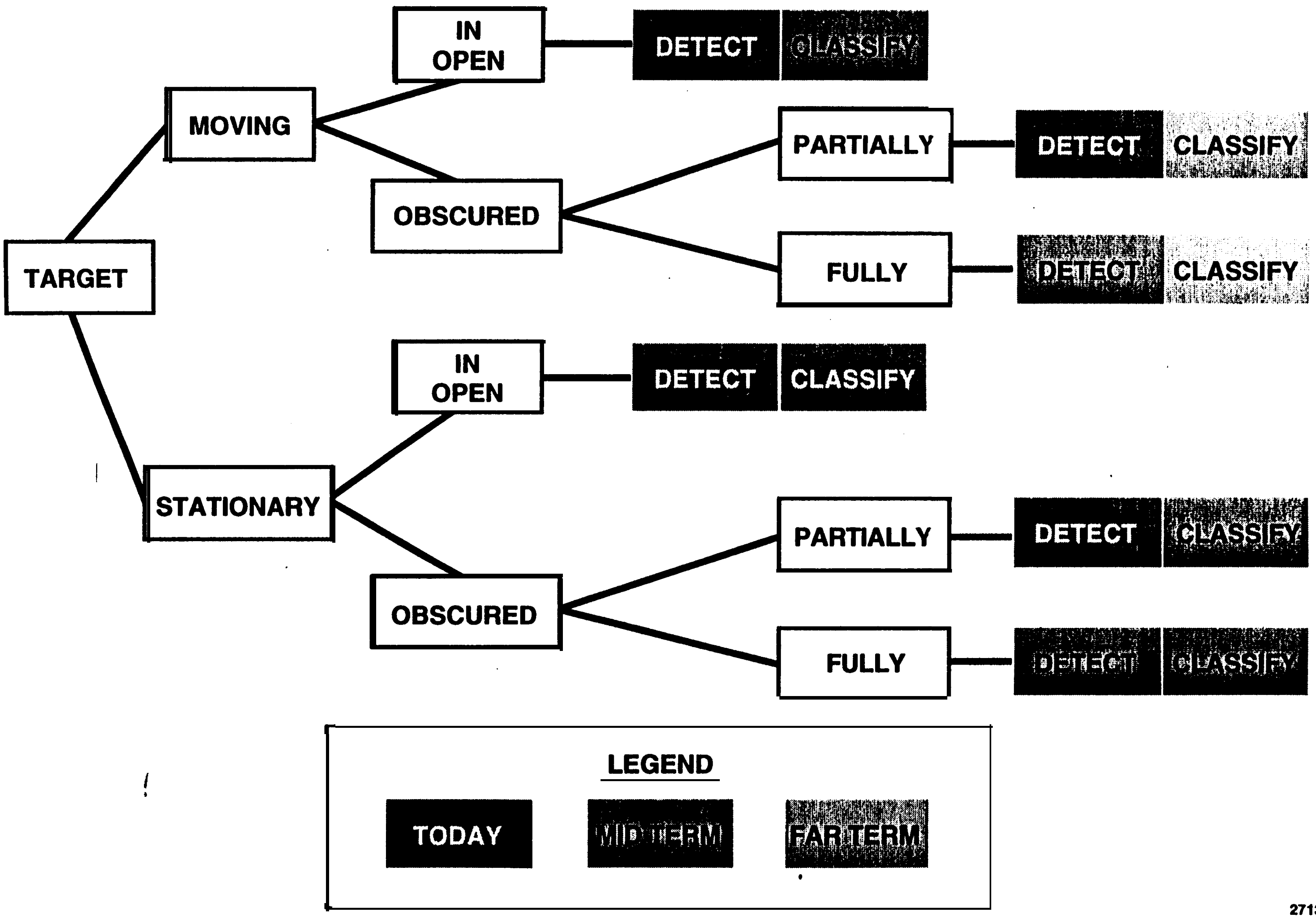
Classification of partially obscured movers is a different matter. Either the target is partially obscured in space (i.e. some features aren't visible to the radar), in which case one has a situation with incomplete information, or the target is partially obscured in time (i.e. it passes in and out of view), in which case the dwell time for adequate image quality may be in short supply. In either event, definitive solution is a longer-term development.

Detection of fully obscured moving targets is technologically possible in one important instance: when the obscurant is foliage. In that case, MTI at foliage-penetrating (FOPEN) frequencies (UHF and below) is technologically feasible today (subject to significant limitations on grazing angle and therefore standoff range). Although not quite "off the shelf," FOPEN is a latent capability of the UHF radar on the E2-C. Classification of moving targets fully obscured by foliage is subject to all the uncertainty of classifying stationary targets fully obscured by foliage (see below).

Detection of stationary targets in the open or partially obscured is a relatively mature art (albeit with more false alarms than for moving targets, which benefit from cancellation of stationary clutter) for SAR imagery, where metallic objects stand out brightly against natural backgrounds. SAR-based classification technology for unobscured stationary targets is now moving out of the laboratory into serious user evaluation, spearheaded, for example, by SAIP. Classification of partially obscured targets – coping with various degrees of incomplete information – remains an area of active research.

Detection of stationary targets fully obscured by foliage with FOPEN SAR is more difficult than detection of target in the open. Even though radiation at UHF and lower frequency can penetrate foliage, the penetration is not without loss, which compromises image contrast. For the same reason, among others, target classification under the trees using FOPEN SAR is presently a research area.

SURVEILLANCE CAPABILITY
PARSED BY TARGET



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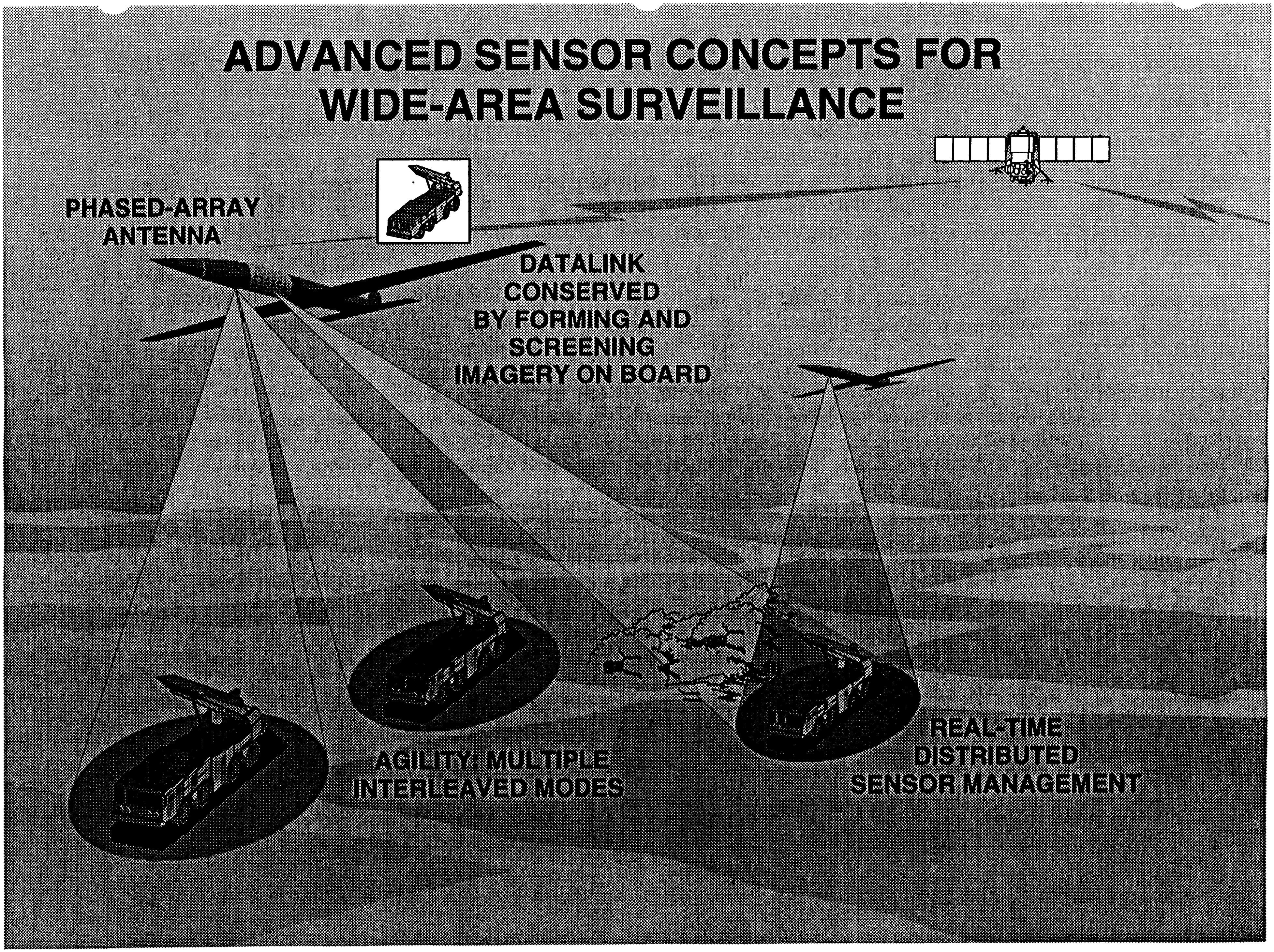
Advanced Sensor Concepts for Wide-Area Surveillance

We see a number of advanced, but generic, capabilities as being essential for realizing the full potential of modern sensing technology. Phased-array antennas (i.e., electronically scanned in two dimensions) will enable radars to point anywhere at a moment's notice with virtually no mechanical slewing delay. The capacity to interleave modes (e.g., SAR and MTI, or multiple SAR exposures of different areas on the ground) will enable radars to respond quickly to new tasking without interference from time-consuming imaging already underway. Real-time sensor management is essential for bringing multiple sensors to bear quickly when the information available to a single sensor is insufficient to support definitive target ID. In any event, the data to be collected by the wide-area sensors of the very near future will, if not radically compressed, require very expensive wideband datalinks. We foresee eventually mitigating this requirement by relying on ATR onboard the airborne surveillance platforms to intelligently screen imagery before data is transmitted to the ground.


ADVANCED SENSOR CONCEPTS FOR WIDE-AREA SURVEILLANCE
PHASED-ARRAY ANTENNA
DATALINK CONSERVED BY FORMING AND SCREENING IMAGERY ON BOARD
AGILITY: MULTIPLE INTERLEAVED MODES
REAL-TIME DISTRIBUTED SENSOR MANAGEMENT

UAV-Based Microwave Sensing

In addition to their function as surveillance assets, UAV-based sensors will also be crucial in providing the targeting information that will allow small forces to bring to bear remote weapons on enemy targets. In this case, the ability to locate targets with high precision and to communicate this information in a timely manner to the shooter is of paramount importance.

Because of their extended time on station, long endurance UAVs can provide essentially continuous coverage of a region of interest. Operating at high altitude and close to, or within, enemy territory, they are also less vulnerable to terrain masking — and SAMs — than manned platforms.

A key limitation on the SAR stripmap search rate achievable with Global Hawk UAV (Tier II+) is the processing throughput that can be realized on-board the UAV within the weight, power, and above all, cost constraints. The planned processor for Tier II+ will have a throughput of ~10 GFLOPS to support a SAR stripmap image swath width of 10 km. Growth in processing technology, combined with highly parallel processor architectures and improvements in software tools that increase processor efficiency, can be expected to support a tenfold increase in the SAR area coverage rate achievable with a UAV radar system. Furthermore, progress in the area of automatic target cueing and recognition will be able to support on-board image data pre-processing to reduce the load on the data link to the user ("intelligent data compression").

A notional UAV radar system incorporating advanced concepts and technologies is shown in the figure. The primary SAR imaging and MTI radar operates at X-band. A separate UHF radar for foliage penetrating (FOPEN) SAR imaging and MTI is also shown.

The X-band radar system consists of a 1-D active array radar aperture and separate, fixed beam receive antenna for the SAR stripmap as shown. The receive antenna supports continuous SAR stripmap imaging and avoids the more costly alternative of additional receive beams in the active array. By partitioning the transmit pulse into subpulses with waveforms appropriate to the various radar modes, and transmitting these subpulses at the proper beam positions, the radar can obtain simultaneous tripmap SAR, MTI, and SAR spot mode coverage.

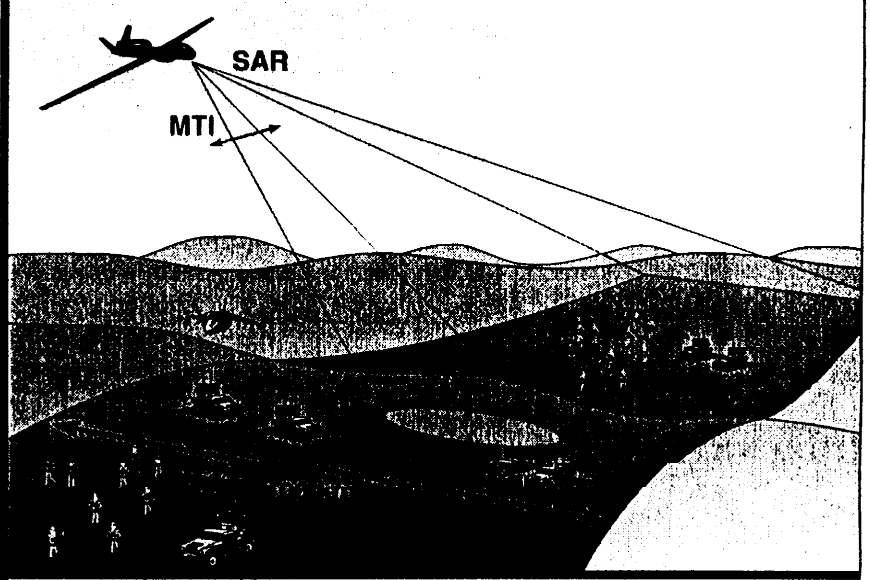
In addition to providing surveillance information for situational understanding, a UAV radar system will need to provide accurate targeting data to support the use of remotely launched weapons. With the aid of GPS and advanced navigation

UAV-BASED MICROWAVE SENSING

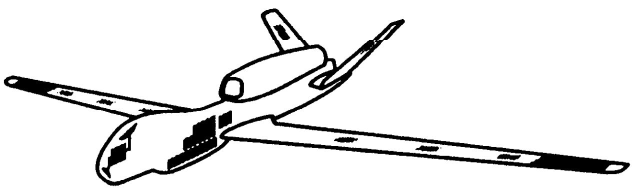
CAPABILITIES

- ALL WEATHER OPERATION
- DETECT, IDENTIFY, AND TRACK STATIONARY AND MOVING TARGETS AND FORCE UNITS
- LARGE AREA COVERAGE AND HIGH REVISIT RATE
- PRECISION LOCATION OF TARGETS
- FOLIAGE PENETRATION / MINE FIELD DETECTION
- HOSTILE EMITTER LOCATION AND IDENTIFICATION
- ON-BOARD SENSOR DATA INTEGRATION AND WIDE AREA DATA DISSEMINATION

OPERATIONAL CONCEPT



SYSTEM CONCEPT



- SHARED / MULTIPLE APERTURE, MULTI-BAND, MULTIBEAM ACTIVE ARRAY RADARS
  X-BAND (MTI, SAR, IFSAR)
  ULTRA-WIDEBAND LOW FREQ. (FOPEN SAR / MTI, Mine Fields)
- ESM ANTENNA ARRAY / MULTIBEAM RECEIVERS
- WIDE-BANDWIDTH DIGITAL SIGNAL PROCESSING
- ON-BOARD IMAGE, ATR / ATC, SIGINT AND INTEGRATED SENSOR DATA PROCESSING
- WIDE-BAND DATA LINKS
- RESPONSIVE AND FLEXIBLE SENSOR RESOURCE MANAGEMENT

ENABLING TECHNOLOGIES

- HIGH POWER T / R MODULES
- LOW LOSS PHASE SHIFTERS
- HIGH SPEED A / D CONVERTER AND DIGITAL SIGNAL PROCESSORS
- WIDEBAND DIGITAL WAVEFORM SYNTHESIZERS
- HIGH THROUGHPUT AIRBORNE DATA PROCESSORS
- HIGH PERFORMANCE ATR / ATC FOR STATIONARY AND MOVING TARGETS

AT LOW WEIGHT, POWER, VOLUME, AND LOW COST systems, the location of the UAV can be accurately determined. Calibration of the radar system will also allow accurate location of targets in range and angle relative to the UAV. Precise designation of target position for inertial guided weapons also requires accurate data on terrain height (within a few meters).

UAWBASED MICROWAVE SENSING

CAPABILITIES

- ALL WEATHER OPERATION
- DETECT, IDENTIFY, AND TRACK STATIONARY AND MOVING TARGETS AND FORCE UNITS
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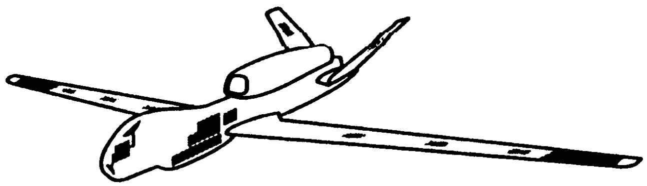

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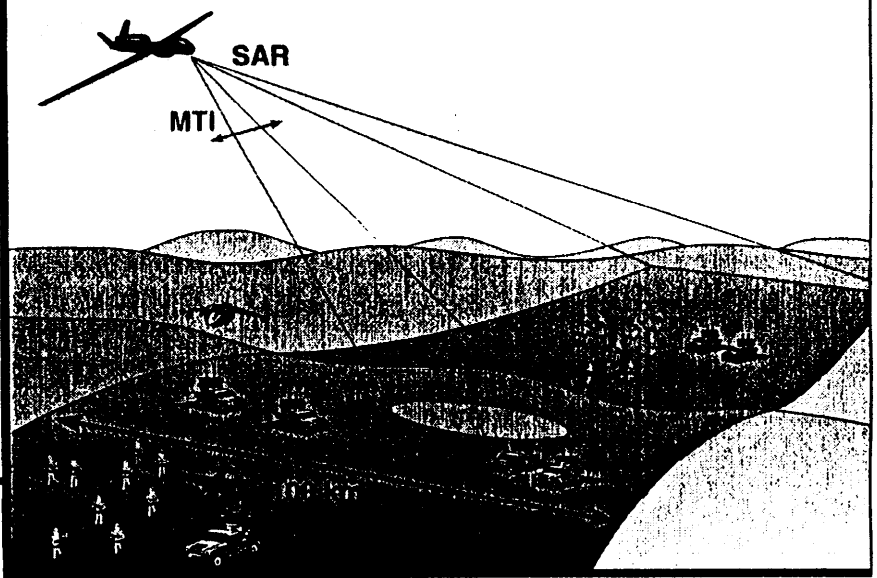

ENABLING TECHNOLOGIES

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AT LOW WEIGHT, POWER, VOLUME, AND LOW COST

UAV-Based Hyperspectral Surveillance and Targeting

We also considered the concept of equipping a UAV with a compact, large-aperture, multi-spectral telescope with scanning/staring, high-sensitivity focal plane arrays (in multiple wavebands) to enable hyperspectral (visible, MWIR, and LWIR) surveillance and targeting. While feasibility studies are preliminary at this time, the new capabilities enable by such a configuration (see chart) are compelling, and this approach deserves further examination.

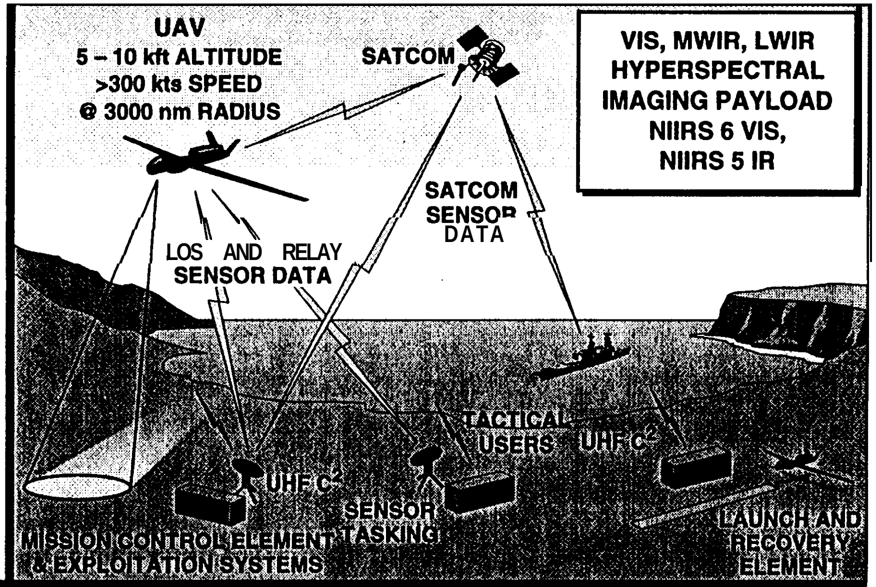
Advanced EO systems that provide surveillance support from the air will be multi-spectral. Experimental multi-band IR imagers are already flying. Such multi-spectral imagers can support color night vision for enhanced situational understanding, clutter suppression for enhanced targeting, and can penetrate obscurants. They can also be used to localize chemical plumes passively, and work in coordination with active illumination probes (e.g., tunable lasers) to better localize chemical and biological agents. All such capabilities require both multi-spectral sensing and processing algorithms. As we move to hyperspectral imagers (essentially imaging spectrometers), environmental sensing for chemical and biological agents will be feasible on a large scale in real-time. However, they will require the development of adaptive band selection algorithms and integrated spectral pattern recognition capabilities directly into the imaging cameras. The sensors will not only produce images in select bands, but also chemical composition maps of the viewed scene in real-time.

Developing the technology for compact, accurate hyperspectral imagers will be important both for small, real-time (e.g., vision) imagers, and also for large, slower surveillance imagers. There are two different and possible separate application areas: first, low-light level, where photons may not be discarded, and second, applications in which the number of photons is not the limiting factor, but the number of spectral channels is very stressing.

UAV-BASED HYPERSPECTRAL SURVEILLANCE AND TARGETING

NEW CAPABILITIES

- PROVIDES LONG-RANGE, NEARLY ALL-WEATHER, DAY AND NIGHT HYPER-SPECTRAL IMAGING FOR:
  - TARGET DETECTION AND ID
  - CHEMICAL DETECTION
  - BATTLE DAMAGE ASSESSMENT
  - COUNTER CAMOUFLAGE
  - SMOKE / OBSCURANT PENETRATION



IMPLEMENTATION

- IMPROVED SENSITIVITY FOR DAY AND NIGHT OPS
- ON-BOARD HYPERSPECTRAL IMAGE PROCESSING
- PAYLOAD ON SMALL, SURVIVABLE LOW ALTITUDE UAV

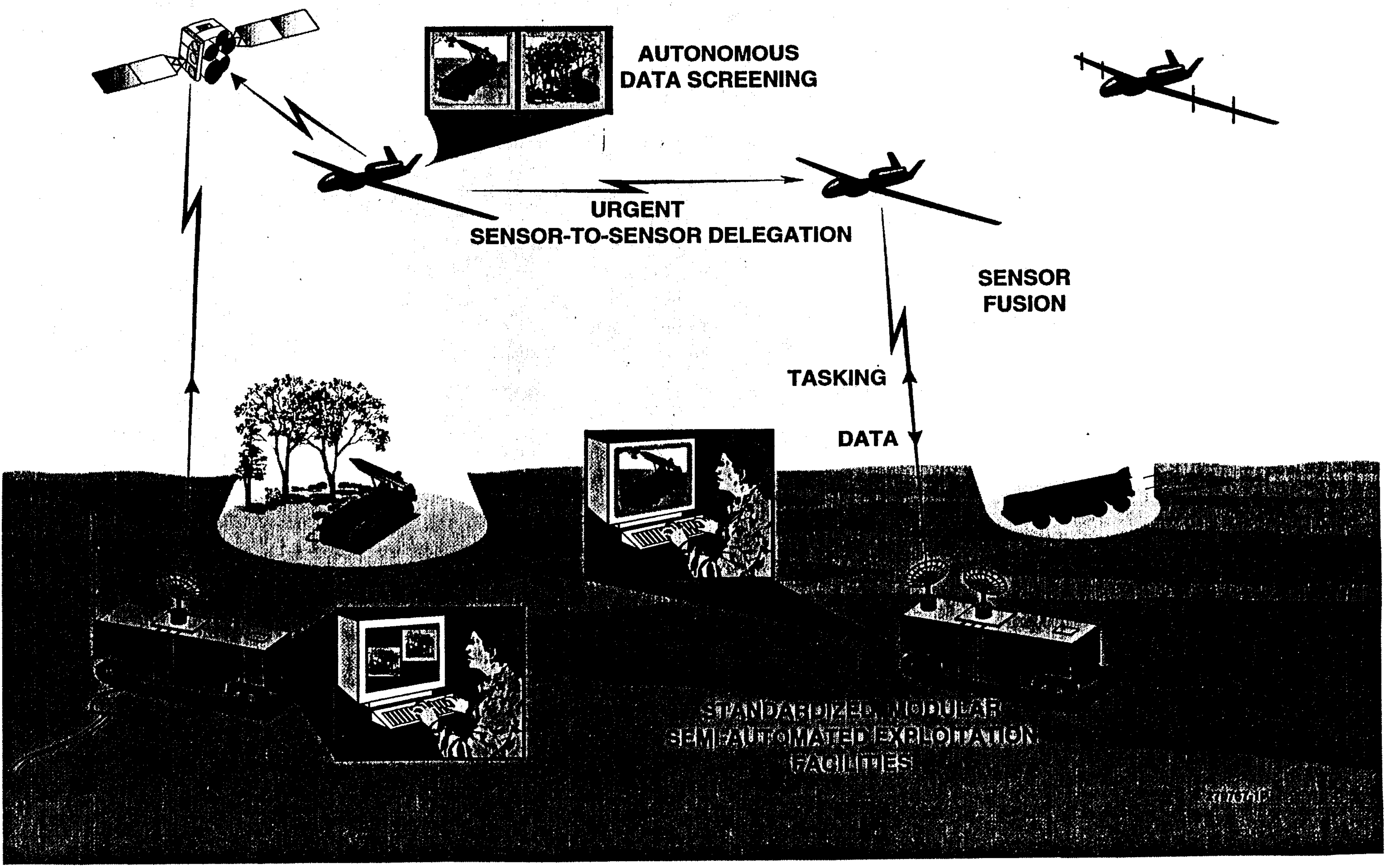
ENABLING TECHNOLOGY

- COMPACT, LARGE-APERTURE MULTI-SPECTRAL TELESCOPE
- SCANNING / STARING HIGH-SENSITIVITY FPAs (Multiple, Wavebands)
- EFFICIENT PROCESSING ALGORITHMS

Distributed Surveillance and Control

What will it take to create the most flexible surveillance "system of systems" for the 21st century battlefield? First, the processing, exploitation, and tasking apparatus must be highly modular to support dispersal over wide theaters, to scale gracefully with an increasing number of low-cost but highly capable sensor platforms, and to "bound the pain" of inevitable upgrades in processing technology. Modularity notwithstanding, human data exploitation will be done hand-in-hand, with computer-driven cueing, because of copious data streams and limited analyst populations, and copious data streams will require some degree of automated image intelligence on board sensor platforms to keep communication links affordable. As we learn more about the strengths and limitations of single-sensor ATR technology in the current period of serious user evaluation, we expect the benefits of multi-sensor fusion for optimizing sensor payoff to become apparent. The need to fuse data streams from multiple sensors on multiple platforms will undoubtedly change forever the way sensors are tasked and scheduled. The change will be especially radical when moving targets are involved, i.e., where operational timelines can be too short for the familiar cycle of user-request-bureaucratic-approved sensor redirection. In such cases, sensors may have to evaluate the need for additional information, identify high-payoff candidates for supplementary sensing, and re-arrange sensor schedules to support urgent re-tasking — all without direct operator intervention.

DISTRIBUTED SURVEILLANCE AND CONTROL
DRIVEN BY WIDE AREAS, SHORT TIMELINES, LOGISTICAL FLEXIBILITY



Wide Area Reconnaissance / Surveillance Summary

To summarize: National and commercial satellite systems, together with present and planned airborne sensors, represent a sensing infrastructure that will span the spectrum from peacetime intelligence, indications, and warning, to continuous all-weather, wide-area sensing of the battlefield. ATR is required to enable small numbers of human analysts to derive actionable intelligence from the resulting very-high-rate data stream. Serious demonstrations of the necessary ATR-based exploitation capability, for unobstructed vehicular military targets, are beginning now. Improvements in ATR techniques — much of them making encouraging progress right now — will be needed to enable effective automatic recognition of moving and/or obscured ground targets. Improvements in sensing technology will be needed to make military "commodities" of agile, microwave (SAR/MTI) and foliage penetration (SAR/MTI), as well as multi/hyperspectral sensing. Beyond this, the 21st century vision of responsive, wide-area battlefield surveillance will require focused development of a variety of "system-of-systems" technologies.

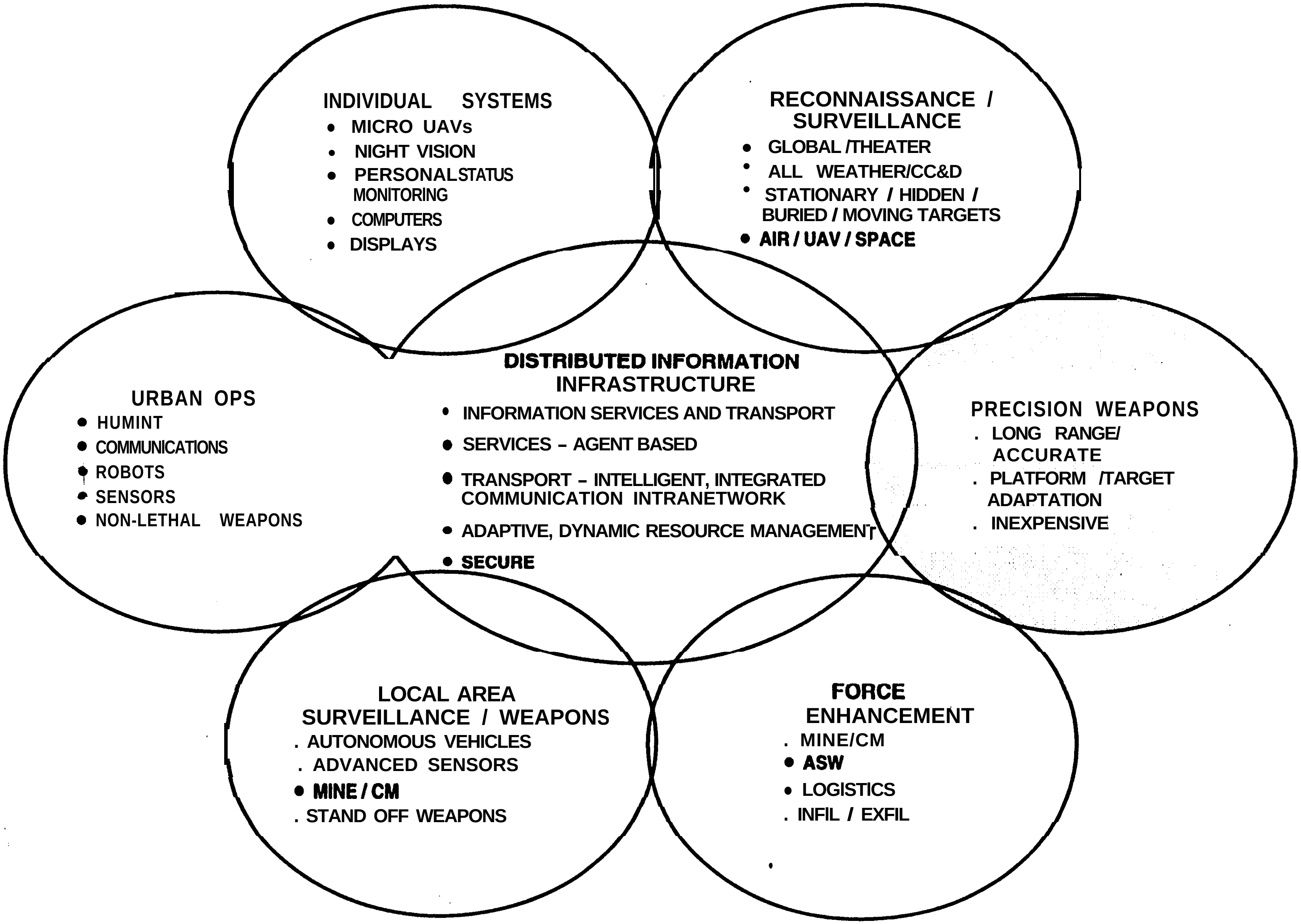
Wide Area Reconnaissance / Surveillance Summary

- National systems' capability augmented by emerging HAE UAVs and upgraded U2 will provided enhanced capability
- Planned ATR demonstrations for stationary non-obstructed military targets
- Improved techniques required for moving, obscured, and buried targets
- Improved sensors required
  - Microwave radar (MTI/SAR) phased arrays
  - Low frequency radars (FOPEN, mines, SIGINT)
  - EO / IR (multi-hyper spectral)
- Development required
  - Sensor / mode control
  - Wideband data relay
  - Sensor data fusion
  - Multi-sensor ATR techniques

Precision Weapons

TACTICS AND TECHNOLOGY FOR 21 st CENTURY MILITARY SUPERIORITY

TECHNOLOGY CONCEPTS PANEL



Precision Weapons Scope

The broad area of "Precision Weapons" can be subdivided into three categories: Individual, Force Organic, and Long-Standoff Fire Support. While legitimate needs exist for development of precise direct and indirect weapons at the Individual and Force Organic levels, the third category, Long Standoff Weapons, strongly and directly influences the overarching force amplification vision of this study. (Weapons for Combat Cell and Urban Operations are discussed below in the "Local Area Surveillance/Weapons" and "Urban Operations" sections respectively.) Moreover, we felt that specific recommendations could be made to address current limitations in those weapons. Therefore, we chose to limit our assessment of Precision Weapons to Long Standoff weapons, and the current deficiencies in those systems.

Precision Weapons Scope

Individual – man-carried (direct or indirect)

Force organic – squad-controlled, company-operated, brigade-based and supported (direct or indirect from organic ground or air vehicles)

Long Standoff

Sea-Based	–	500 nm	land-, sea-, and air-platforms based at the stated radii (indirect fire only)
Theater	–	1,000 nm	
Regional	–	3,000 nm	
Global	–	6,500 nm	

The Geography and Timing of Long Standoff Fire Support

Let us first consider the geographic framework of the application and launch sources for Long Standoff Fire Support weapons.

Ship-based weapon platforms (e.g., the F-18) may operate out to a nominal radius from the ship of ~500 nautical miles. Theater-based weapon platforms in the future may be required to operate at radii up to 1,000 nautical miles from fairly secure airfields. Regional-based weapon platforms must "reach" nominally out to 3,000 nautical miles to take full advantage of various political sanctuaries around the world (e.g., Guam and Diego Garcia). Global weapon platforms are primarily CONUS-based and, hence, must operate at a radius up to 6,500 nautical miles.

Actual weapon launch standoff from the platform to the target varies, depending on the time-urgency of the kill-cycle response and the type and location of the launch platform. Time-urgent targets should be attacked within 2 minutes (total response "lag"), which suggests a hypersonic (2 km/sec) weapon, a 200-km standoff from an intrusive air platform or from a forward-based ground launcher. This time scale also demands a command lag from target designation to weapon launch of less than one-half minute. The weapon launch standoff is less restrictive for non-time-urgent targets because the required time-of-flight can be several (i.e., ~5-10) minutes – yet still assure good coordination of impact times from multiple launch sources while minimizing target alertment.

The Geography and Timing of Long Standoff Fire Support

Weapon Launch Source	Weapon Launch Vehicle Type	Nominal Operating Radius (nm)	Mode of Employment	Weapon Launch Standoff (km)	Weapon Response Time (min)
Air	Ship-based Air	500	Intrusive	200	<2 } Time-urgent (SEAD, CAS, fleeting)
	Tactical Air	1000	Intrusive	200	<2 }
	Regional Air	3000	Standoff	1000	~9
	Global Air	6500	Standoff	1000	~9
Ground	Armored Vehicle	Local	Forward	200	<2 } Time-urgent (close-support, fleeting)
	Truck	In-theater	Sanctuarized	500 (INF-limited)	~7
Sea	Combatant Ships	Regional	Littoral	500	~7
	Arsenal Ships	Regional	Sanctuarized	2000	~17

Force Amplification Vision and Long Standoff Precision Attack Missions

In the following discussion, we're going to focus primarily on weapons launched from sea, theater, regional and global platforms (cf. the previous chart). The theme of this year's study – amplify the effectiveness of small engaged forces – means that we must, to a greater degree than ever before, separate the Observation (targeting) function from the Nullification (weapon) functions. This separation, which defines our force amplification vision, will be accomplished using third party surveillance (i.e., space-, air-, and ground-based[2] surveillance assets). As discussed above, we will use remote standoff weapons (i.e., air, sea and ground launched).

Separating the Targeting and Nullification functions enables responsively supporting the directly engaged forces and limiting the enemy's ability to control, move, and support his own forces. The long standoff precision attack missions include deep strike, interdiction, offensive counter-air (treated here as Suppression of Enemy Air Defenses, SEAD), pre-assault neutralization (in the case of forced entries), anti-armor, and close ground combat support. We also recognize that the weapons that we use for this purpose may be appropriate for ocean surface warfare.

2 Ground-based systems may include both human and unattended ground sensors.

Force Amplification Vision

<u>Separate the Targeting and Nullification Functions</u> - Use third party surveillance (space, air, and ground based) and remotely sourced standoff weapons (air, sea, and ground launched) to precede and then responsively support directly engaged forces.

Long Standoff Precision Attack Missions

- Deep strike
- Interdiction
- Offensive counterair
- Preassault neutralization
- Anti-armor
- Close ground-combat support
- Ocean surface warfare

Objective of Long Range Precision Attack

The objective of long range precision attack is to affordably, assuredly, and quickly neutralize (with little collateral damage) a wide spectrum of fixed, relocatable, and slowly moving military targets from sanctuaried, economical, easily replenished launch sources. Some targets may, structurally, be very "hard," e.g., deep underground facilities, bridges, runways and aircraft shelters, and ammunition storage. Stationary armored targets are hardened point targets that generally operate on the surface. Moving armor targets further complicate the problem and place new requirements on weapon guidance approaches. Stationary soft targets include SAM sites, parked trucks, and exposed troops. "Moderately protected forces" are targets that may be entrenched or may comprise urban resistance, i.e., positioned in buildings or are otherwise somewhat obscured and, possibly, mixed among civilians. As mentioned earlier, the target set may certainly include other slowly moving vehicles such as ships.

Objective of Long Range Precision Attack

To affordably, assuredly, and quickly neutralize (with little collateral damage) a wide spectrum of fixed, relocatable, and slowly moving military targets from sanctuaried, economical, easily replenished launch sources.

Tactical Targets

Structurally Hard
- Deep underground leadership
- C^2/weapon bunkers
- Ammunition storage
- Aircraft shelters
- Runways
- Shallow POL
- Rail lines
- Trestles
- Bridges

Stationary Armor
- Isolated tanks (parked)
- Tank column (choked)
- Isolated APC (parked)
- APC column (choked)

Moving Armor
- Massed tanks
- Massed APC

Stationary Soft
- Parked aircraft
- Hangars
- Surface POL
- SAM sites
- Portable C^3
- Surveillance radar sites
- Isolated parked trucks
- Truck columns (choked)
- Parked train
- Ships/subs in port
- Port facilities
- Camped personnel & supplies

Moderately Protected Forces
- Entrenched troops
- Urban resistance

Moving Ocean Vehicles
- Ships

Current Deficiencies in Long Standoff Precision Attack

Currently, the greatest deficiency in long standoff precision attack weapons is the high cost-per-target-nullified. Today's long standoff weapons are clearly quite expensive, e.g., very long standoff weapons such as Tomahawk will cost, even in the most optimistic projections, ~$400K - $600K (a considerable decrease from past costs, but still decidedly unaffordable for tactical purposes).

Our second concern is vulnerability. In many cases, "cheap" standoff weapons do not "stand-off" very far, e.g., only 30-75 nm Use of such weapons makes the launch platform – the truly expensive component of the system – vulnerable.

Our current standoff weapons have a slow response for two reasons: (I) the launch platform must first transit to the launch point at subsonic speeds, and (ii) the platform must then maneuver to orient the weapon prior to launch. From a C^2 perspective, the command chain to the launch vehicle must also be shortened: current C^2 lag typically delays response by several minutes.

Historically, some standoff weapon strikes have been embarrassingly or tragically non-surgical: the next-generation of precision-guided weapons will improve on this dramatically, with the design objective of limiting collateral damage while radically increasing single-shot kill probability.

In many cases, visible launch platforms that "trundle" toward the target alert the enemy to the weapon's approach. The Tomahawk takes a major fraction of an hour to arrive at its target. However, if a launch warning is issued, the enemy may take damage-limiting actions during the weapon's time-of-flight, blunting its ultimate effectiveness.

Our objective was to overcome these deficiencies affordably in making our recommendations for precision attack weapons.

Current Deficiencies in Long Standoff Precision Attack

- High in cost per target nullified,
- Vulnerable to defensive weapons or counterstrike,
- Slow in response,
- Non-surgical in collateral damage, and
- Tactically alerting in application.

Desirable Traits for Long Range Precision Attack Weapons

What are the desirable traits for long range precision attack weapons?

The single most important trait is cost. We need to bring these weapons down to the $30K - $100K flyaway cost range so that we can afford to shoot at individual targets (e.g., trucks), whose asset value is of the same order as the weapon. Our goal is achieving acceptable cost exchanges.

These weapons must offer rapid response (i.e. under 2 minutes) to deal with time-urgent targets, i.e., targets which are either immediately threatening engaged forces, which are moving, or which may disappear shortly after being discovered. Poorer response times will forfeit opportunities. This capability must come from launch platforms that: (I) don't have to be immediately overhead; (ii) can be at ranges of ~200 km, and (iii) do not have to reorient completely in order to launch. To engage the classes of targets that may not be quite as time-perishable, but which comprise targets against which we'd like to mount a coordinated surprise attack, a response time of <10 minutes would be desirable from theater level ranges (in this case 1,000 km standoff for air-launch and 500 km for INF treaty-limited ground launch).

These weapons must be resistant to countermeasures (e.g., decoys), which are presenting increasing difficulty for precision weapons. The issue is not whether the target can be hit, rather, whether a real target is actually being engaged. Once alerted, a target can immediately deploy decoys to confuse the intercept end-game.

We require launcher compatibility, i.e. modular sizing to fit all the existing strategic and tactical platforms (ground and ship as well as air).

The warheads must be capable of coping with the wide variety of targets discussed above., Therefore, the precision attack weapon requires a "tailorable warhead," i.e., one whose size and destructive capability can be selected to match the defeat requirements of a specific target.

In addition, some means must be designed into the precision weapon of coping with a target that may be moving slowly, e.g., armor and trucks.

We require high survivability for both the weapon and the base or platform from which it was launched. That means that its transit speed must be very high in order to gain immunity from enemy attack. Desirable qualities are stealth and evasive and maneuverable terminal-phase flight for penetration of close-in defenses. As discussed above, the weapon must be launchable from a sanctuary base or platform, which means the standoff distances may have to be quite

Desirable Traits for Long Range Precision Attack Weapons

- Affordable Cost - $30K-$100K flyaway cost even in short 5,000 unit production runs for an economic ratio against low cost tactical targets (e.g., trucks).
- Rapid Response - <2 minute response for close ground combat support from 200 km standoff; <10 minute response for coordinated tactically surprising strike from 1,000 km standoff.
- Countermeasure Resistance - geodetic targeting with jam resistant, high-grade GPS/inertial guidance instead of deception-sensitive target feature homing.
- Launcher Compatibility - modularly sized to fit all tactical and strategic aircraft, ground MLRS, and VLS-equipped ships.
- Assured Lethality - tailorable ordnance loads with hypersonic (i.e., high kinetic energy), selectable terminal approach path to cope with the full spectrum of soft to hard, point and area, stationary and moving targets.
- Moving Target Accommodation - terminal phase update by third party surveillance or smart submunition ordnance load to cope with moving targets.
- Hiqh Survivability - long standoff (200-3,000 km) for sanctuary, high fast transit for enroute immunity, and stealthy, evasively maneuverable terminal phase for final defense penetration.
- Minimal Collateral Damage - <20 m CEP in GPS jammed environment to allow effective use of small <250 lb ordnance loads and to permit close approach to juxtapositioned friendly forces or politically sensitive enemy assets.
- Surprising Arrival - Distant launch and stealthy, hypersonic transit to reduce or eliminate target-reactive passive damage-limitation measures.
- Treatv Compliance - <500 km INF treaty-limited ground launch and unambiguous shape differentiation for long standoff launch from “non-strategic” aircraft.

substantial. Conceivably, the standoff could be as little as 200 km for close air support against time-sensitive targets (and out to 2,000 km for ship-launched, long-standoff regional assets).

Minimum collateral damage is essential, which can really only be achieved by tight CEPs, i.e., CEP < 20 meters in GPS-jammed environments. Surprise arrival suggests that an optimal weapon system will have remote-launch and hypersonic transit, as well as stealthiness, to eliminate the target-reactive passive damage-limitation measures that the enemy may invoke.

The ground-launch weapon system must be INF-treaty-compliant. The air-launch treaties are not so restrictive, provided certain steps are taken to clearly differentiate our tactical weapon from strategic weapons.

Desirable Traits for Long Range Precision Attack Weapons

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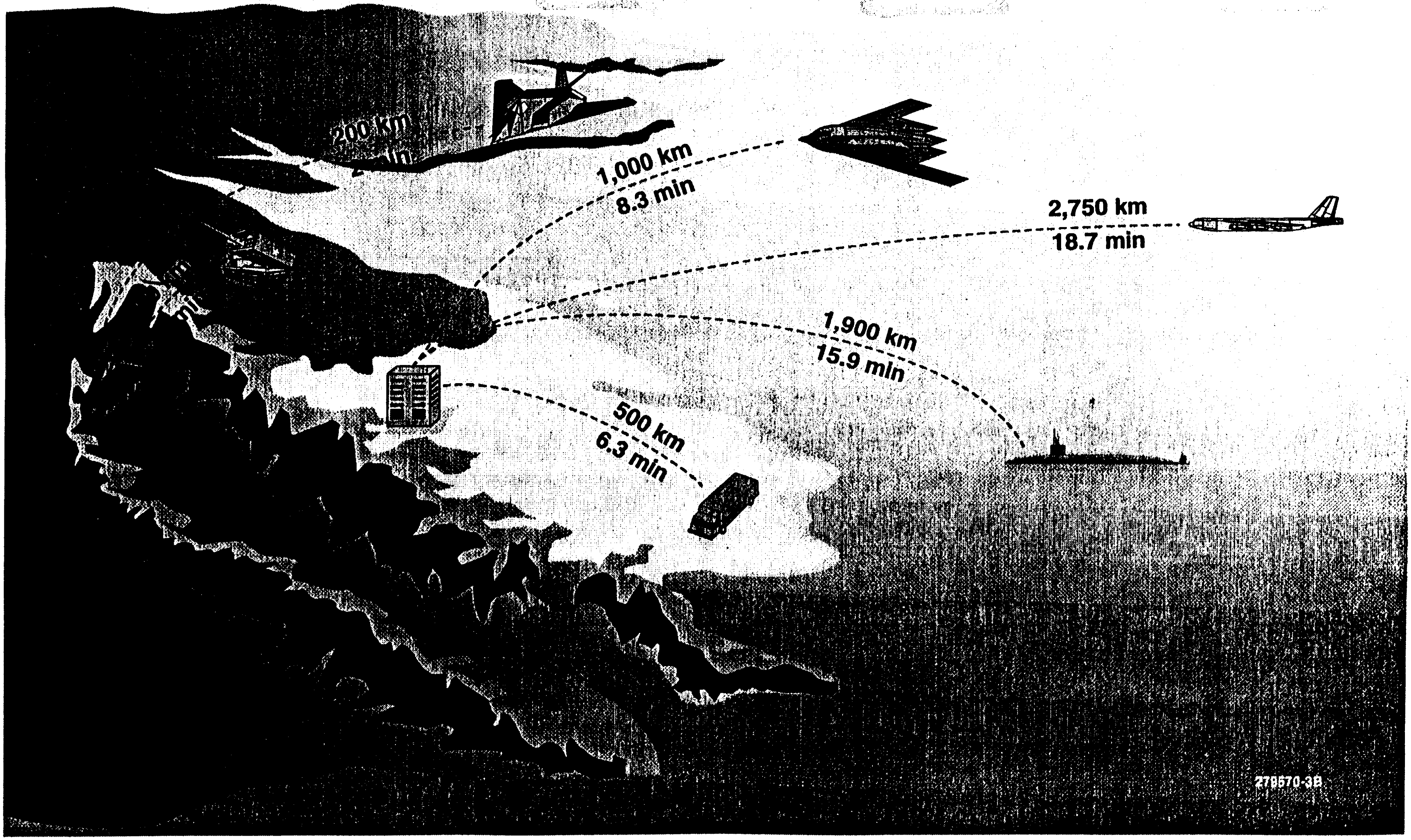
Long Range Precision Weapons: Compatibility with Full Spectrum of Launch Sources and Standoff Ranges

This chart illustrates the broad set of platforms that might be employed for precision weapon launch. The concept of "long standoff" aims ultimately at reducing the cost of the launch vehicle as well as the weapon. The objective is both to limit the logistics of carrying weapons forward into the theater and to shift to a different class of launch vehicles (e.g., conventional trucks instead of armored vehicles, arsenal aircraft that are really cargo aircraft, and arsenal ships). Combat aircraft should not be required except for those classes of weapon applications that are short-standoff ("short" meaning 200 km). The 2-minute time response described above for some applications may require the launch platform to be positioned over enemy territory at the time of launch to enable close proximity to the target area. But, for as much of our magazine capacity as possible, we want to stand away from enemy territory so that we can afford to use less-costly launch platforms.

Having identified the desirable characteristics of these weapons, we now turn to identifying the high-leverage technology development opportunities for improving these weapons in the future, i.e., for dramatically reducing their size and, hence, their cost. We found that this set of highly effective opportunities is limited: our technology development recommendations in this arena are quite specific. We first quantify this in terms of the improved CEPs that may be realized in future weapons via improved guidance technologies. In conclusion, we will offer an example of the dramatic reduction in weapon mass and physical size that might be achieved in a next-generation weapon benefiting from these recommendations. We stress that this example is held out strictly as a strawman paper-study concept against which to benchmark other, more complete system design analyses,

LONG RANGE PRECISION WEAPONS

COMPATIBILITY WITH FULL SPECTRUM OF LAUNCH SOURCES AND STANDOFF RANGES



Long Range Precision Weapons: Alternative 250 lb Ordnance Laydown Patterns

We considered two aspects of the future long range precision weapon, much of it having to do with the "front end of the weapon": the warhead and the weapon guidance. In this chart, we first compare a variety of 250-lb ordnance laydown patterns utilizing bombs, penetrators, flechettes, and Mk77 grenades.

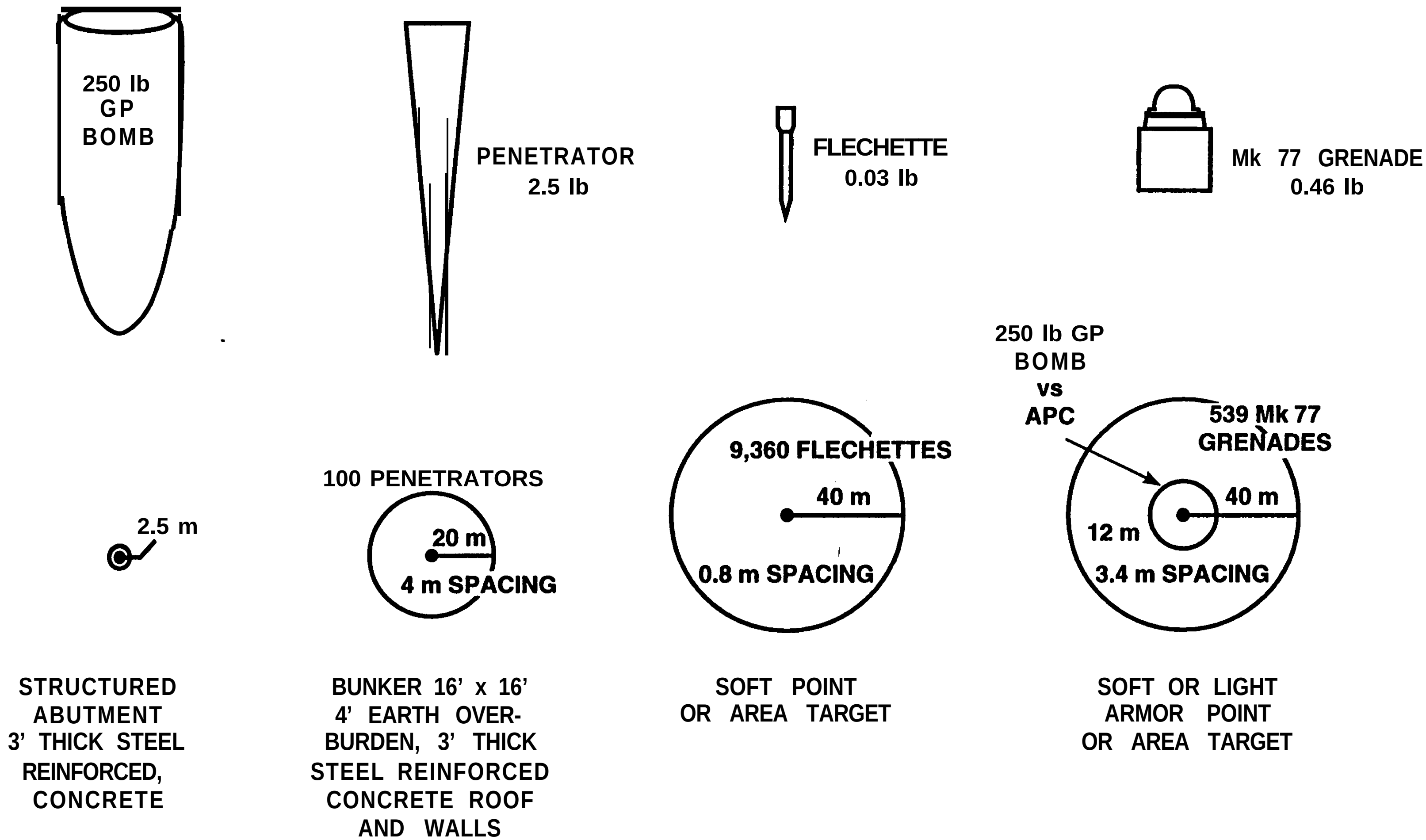
As described above, the future long range precision weapon must have a tailorable warhead. This means that different classes of lethal agents can be installed, depending on the target, e.g., monolithic general purpose warheads used against concrete abutments, 2-1/2 lb penetrators that can top-penetrate typical shallow-buried bunkers, and 12-g flechettes for use against exposed personnel. The more typical "dumb" grenade submunition is used in huge numbers (e.g., in current 155-mm artillery weapons). The future long range precision weapon must be able to accommodate all of these different types of lethal agents as well as smart submunitions (which may be more appropriate for use against moving targets such as armor).

It is extremely important to recognize that the lethal areas provided by these different classes of warhead payloads are quite different. Note first that 539-Mk77 shaped charge grenades (100 mm armor piercing shaped charge and lateral anti-personnel shrapnel) with 3.4 m spacing or 9,360 flechettes (hypersonic anti-personnel) with 0.8 m spacing can be laid down in 80 m diameter patterns (i.e., football field-size) to assure 0.95 probability (2 x CEP) coverage of a severely jam-degraded 20 m CEP impact distribution. Alternatively, 100 hypersonic 2.5 lb bunker penetrators could cover with 0.95 probability a 10 m CEP unjammed impact distribution.

Only the very hard structural targets (e.g., bridges and underground facility entrances) would present a problem for current 10 m CEP unjammed impact distributions. A 250 lb GP bomb (for instance) needs <2.5 m CEP and, preferably, an orthogonal, direct hit to take down even a 3' thick steel reinforced concrete abutment. That is, we require vastly superior CEPs (e.g., down in the 2-1/2 meter range, almost a direct hit) in order to defeat the targets. Therefore, while it is possible to focus on the large class of targets for which 20 meter CEPs provide adequate accuracy and lethality with 250 lb of ordinance, *the net* ***result*** **is** a requirement for a very large weapon to transport a payload of this size over the considerable distances **of interest here.** As we'll demonstrate, realizing dramatic cost payoffs lies in reducing the warhead – and, as a result, the **overall weapon** – size, by improving the impact accuracy.

Long Range Precision Weapons

Alternative 250 lb ordnance laydown patterns



- **COMPATIBLE WITH SMART SUBMUNITIONS PACKAGE FOR MOVING GROUND TARGETS**

Weapon Payload vs. Guidance Performance

Moving targets can be defeated by one of two means: (i) utilize smart submunitions to remove targeting uncertainties, or (ii) update the weapon in late mid-course or in terminal phase from third-party sensors to reduce impact error due to the target's motion. For fixed targets, impact accuracies can be improved beyond what has historically been recognized as "doable" via geodetically-targeted weapons (i.e., utilizing GPS).

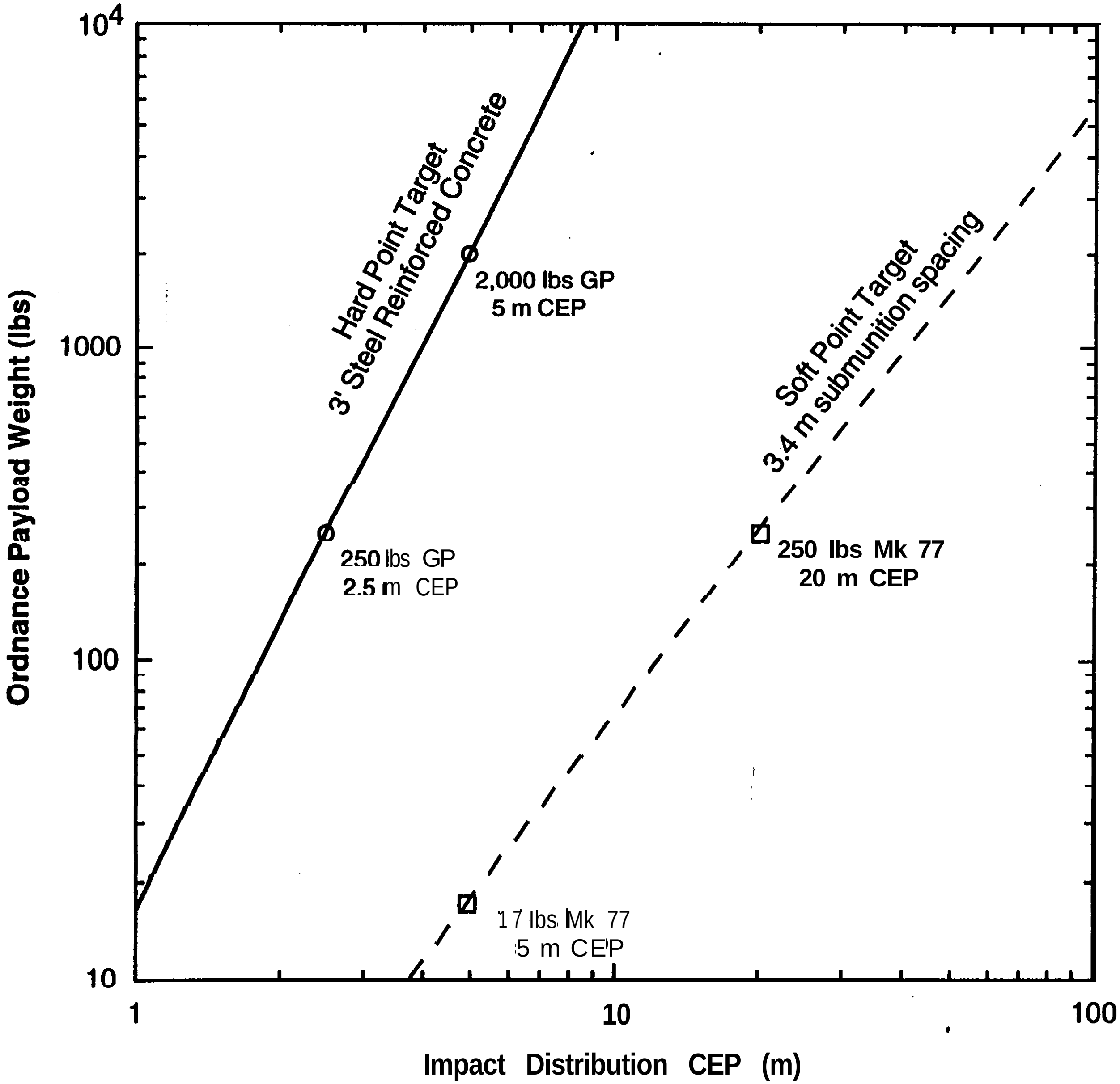
An example illustrates the problem: in a jammed environment, loss of signal to GPS for, perhaps, 40 seconds before impact, results in an 80 km distance-to-go before impact (for a 2 km-sec^{-1} weapon). In the chart, we have plotted ordnance payload weight as a function of impact distribution. In such a case, the figure shows that an inertial drift of ~1 nm-hr^{-1} would give a terminally maneuvering missile a 20 meter CEP (which is within our stated need, if we are content to carry 250 b. of ordnance). Our objective is to reduce this dramatically.

As we see in the plot, if we can reduce the CEP from 20 meters down to 5 meters, we could reduce, in theory, the 250 lb of ordinance down to 17 lb of ordinance to cover the same 2xCEP-radius with the same aerial density. For weapons that require blast such as GP bombs (where the lethal radius goes as the cube root of the yield), the graph shows that the advantages offered by improved accuracy are even more extreme. We must work in the 2-3 meter impact accuracy CEP to achieve an acceptably high probability of damaging tough structural targets, or targets that may be underground and highly compartmented.

So, there is a high payoff associated with reducing our current 20 meter CEP in a jammed environment to ~3 meters. This can be done in one of two ways. One is to put a terminal homer on the weapon, which will remove any remaining positional uncertainty in targeting. This poses an additional cost to the weapon, and it is subject to classes of countermeasures that might defeat a terminal homer. This countermeasure, however, would not defeat the third party sensors which provided the targeting information in the first place. Which leads us to the second option: improve the GPS guidance system by advanced inertial enhancement to provide this impact accuracy. This enables low CEPs in spite of enemy jamming that might be attempted.

We feel the latter approach is the proper path for several reasons. First, if imaging is provided by standoff resources or ground-base personnel use laser positioning, the observer is typically able to register a target to within about a one meter CEP of keystones within the target vicinity. So, we have every reason to believe that target positional uncertainty in the future may be reducible into the 1-2 meter range. Secondly, the improvement in GPS is steady, as the CEP data from

Weapon Payload vs Guidance Performance



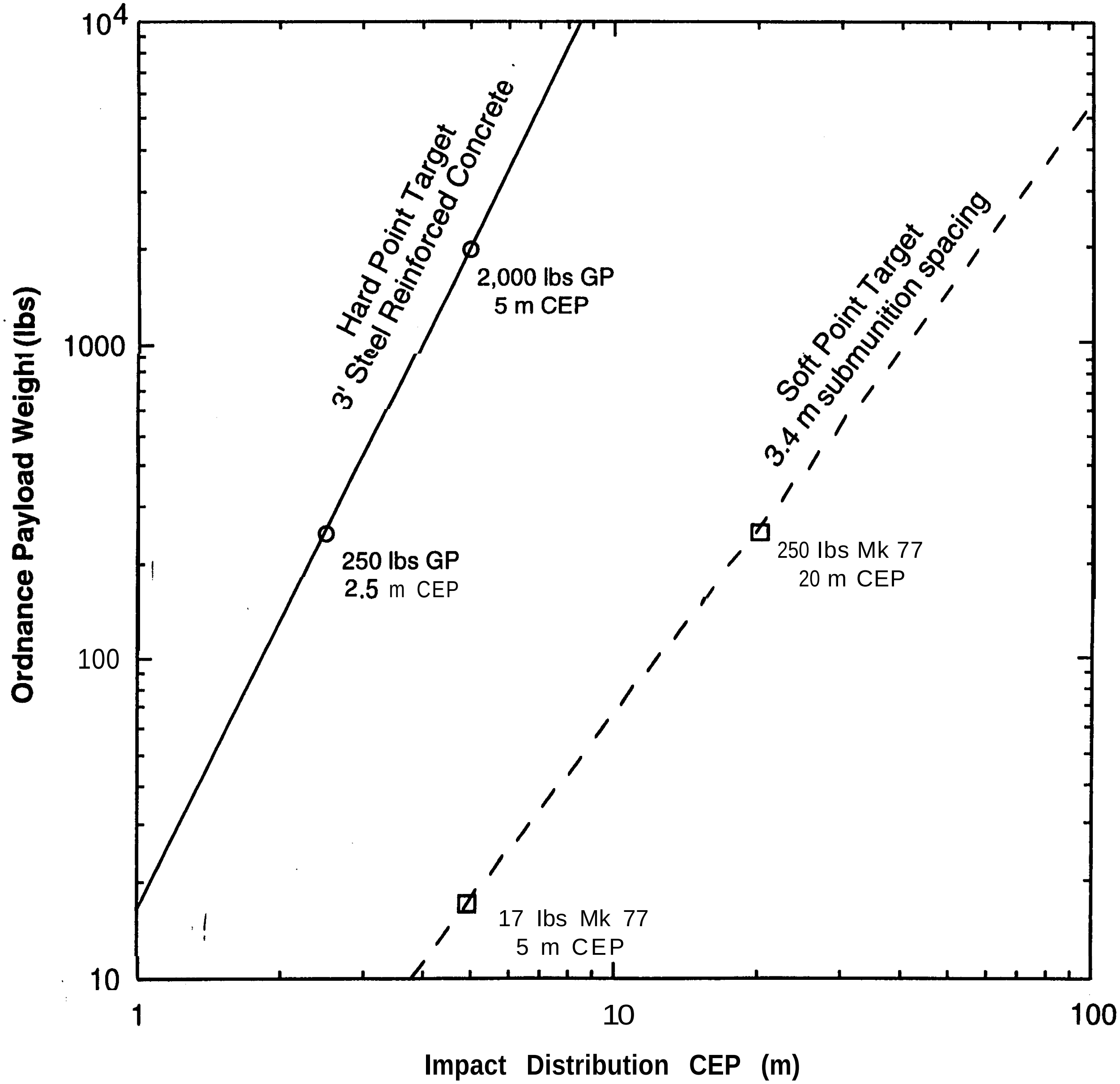
	Non-Differential GPS Unjammed	
	CEP (m)	SPE (m)
Advertised	10	16
Achieved	4.0	6.8
WAGE 1	3.2	5.6
WAGE 2	2.7	4.8
WAGE 3	2.4	4.3
Next Gen.	1.4	2.4

Impact Point Deterioration in Jammed Environment

Loss of GPS Signal		Inertial Drift	
Time to go (secs)	Distance to go (km)	1 nm/hr (m)	0.3 nm/hr (m)
20	40	10	3
40	80	20	6
60	120	30	9

the Wage 1, 2, and 3 programs show in the upper right-hand corner of the chart. A CEP of 2.4 m is not an unreasonable design objective within the next 3 years. Furthermore, when we consider the next generation of GPS receiver equipment, we find the equipment contribution to CEP to be ~1-1/2 m in an unjammed environment.

Weapon Payload vs Guidance Performance



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60	120	30	9

Common Avionics

The question now becomes, “If we can have an accurately positioned target, and if we have very good knowledge of our trajectory as long as we have GPS availabie, do we have reason to believe that we can hold that accuracy within limits after loss of GPS signal in jammed environment?” Through improvements in anti-jamming antennas and emplacement of better clocks on board the weapon, it does appear that we may be able to hold signal into 40 kilometer standoff, which means 20 seconds time-to-go. Assuming inertial compensation of ~0.3 nautical mile per hour, we should be able to keep a highly maneuvering missile to within a 3 m CEP at impact.

The evolution of advanced fiberoptic gyros shown in this chart is making possible 0.003 deg-hr^{-1} bearing drifts, enabling fractional-foot impact CEPs for non-maneuvering terminal phase. So, one should recognize that 3 meter CEP would be the worst case in a highly maneuvering terminal phase with the application of GGP (GPS guidance package). And the costs, as shown, are dropping dramatically.

Therefore, we strongly believe that there is technology on the horizon in the form of improved anti-jam antennas, better clocks, improved GPS receivers, plus better ephemeris data. When coupled with the vastly improved low-cost fiberoptic gyros, these could provide very low-cost, geodetically-oriented guidance that eliminates the need for seekers (and the associated cost of seekers) for standoff weapons that can address a large variety of targets. All of this enables one to move toward the lower left hand region of the graph in the previous chart, leading to dramatically smaller, lighter, less expensive systems, as illustrated in the next chart.

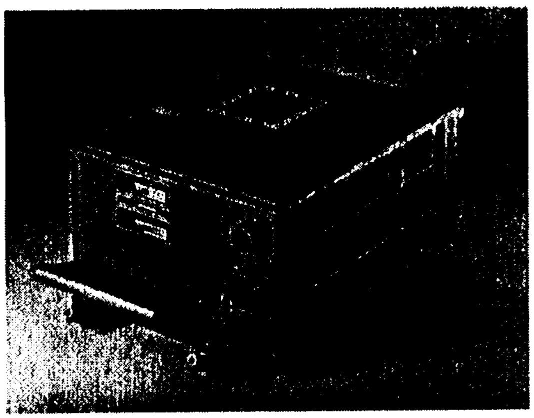
Reduction in Weapon Mass and Dimensions with Decreased Ordnance Payload

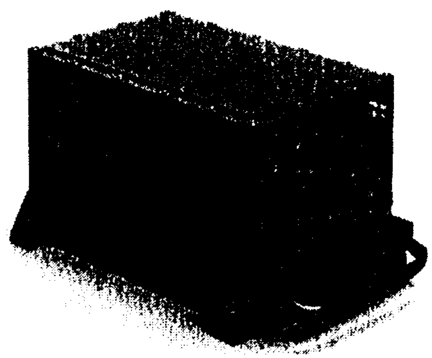
We offer an example of the dramatic reduction in weapon mass and physical size that might be achieved in a next-generation weapon benefiting from these recommendations. Shown are two variants on a weapon design that has equivalent effectiveness against a target located at a ground-launched range of 500 km. The full-scale 250 lb payload weapon (with a CEP ~20 m) is shown at the top of the chart, with a total launch weight of ~1840 Ibs. Assuming the guidance and other advancements just discussed are accomplished, a CEP of slightly over 3 m will enable a weapon payload of ~25 lb (see graph on earlier chart), resulting in a weapon design only 60% as long, weighing only ~1/6 as much (~314 lb, versus ~1840 lb), and costing about 1/3 as much as the 250 lb payload weapon.

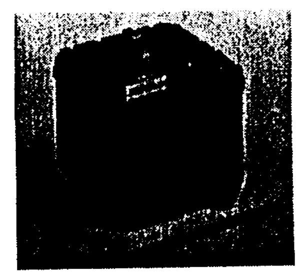
We stress that this example is held out strictly as a strawman paper-study concept against which to benchmark other, more complete system design analyses.

Common Avionics

Inertial Navigation System Technology Evolution







CAINS II   AN/ASN-139

WEIGHT:	47.3	lbs
VOLUME:	1418	cu in
POWER:	141	Watts
MTBF:	3500	hrs
COST:	$100	K

EMBEDDED GPS/INS (EGI)

WEIGHT:	18	lbs
VOLUME:	480	cu in
POWER:	40	Watts
MTBF:	6000	hrs
COST:	$70	K

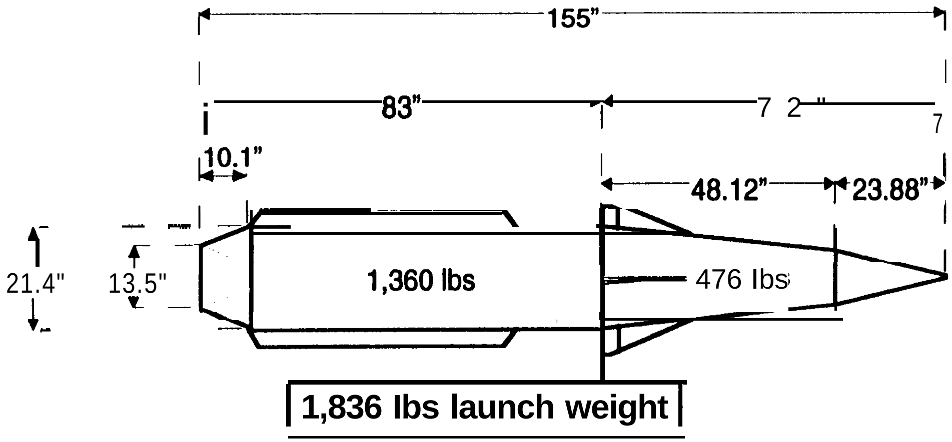
GPS GUIDANCE PACKAGE (GGP)

WEIGHT:	7	lbs
VOLUME:	100	cu in
POWER:	25	Watts
MTBF:	8000	hrs
COST:	$15	K

Originated by: NAWC, Indianapolis

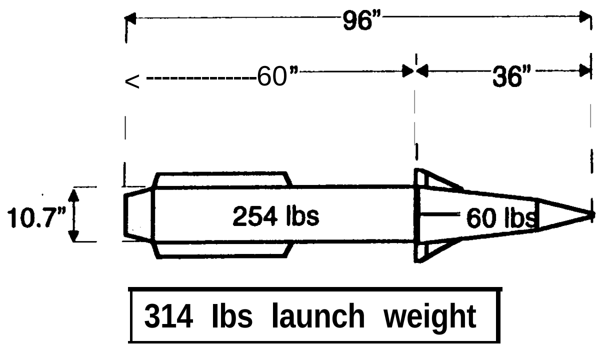
Reduction in Weapon Mass and Dimensions with Decreased Ordnance Payload

Equal surface-launched weapon range of 500 km



Full-Scale LCPAW

Propellant Isp of 254 seconds
Ordnance payload of 248 lbs
stage propellant mass fraction 0.90
Av = 8,975 ft/sec = 2.735 km/sec



Small-Scale LCPAW

Propellant Isp of 240 seconds
Ordnance payload of 25 lbs
stage propellant mass fraction 0.85
Av = 8,976 ft/sec = 2.735 km/sec

Summary

In summary, the big lever for the future long range precision attack weapon is improved impact precision. This cascades throughout the design of the rest of the weapon. It reduces the warhead size. It reduces the missile size. It then means that more missiles can be carried per launch platform, and it means that the individual weapons are far more affordable. Further, it reduces logistic cost of transport and replenishment in direct proportion to weight.

Other leveraging technologies, such as increased warhead lethality and better I_{SP}'s for missile propellants, were examined during our analysis. These, however, offered far less promising cost reduction opportunity than guidance improvements.

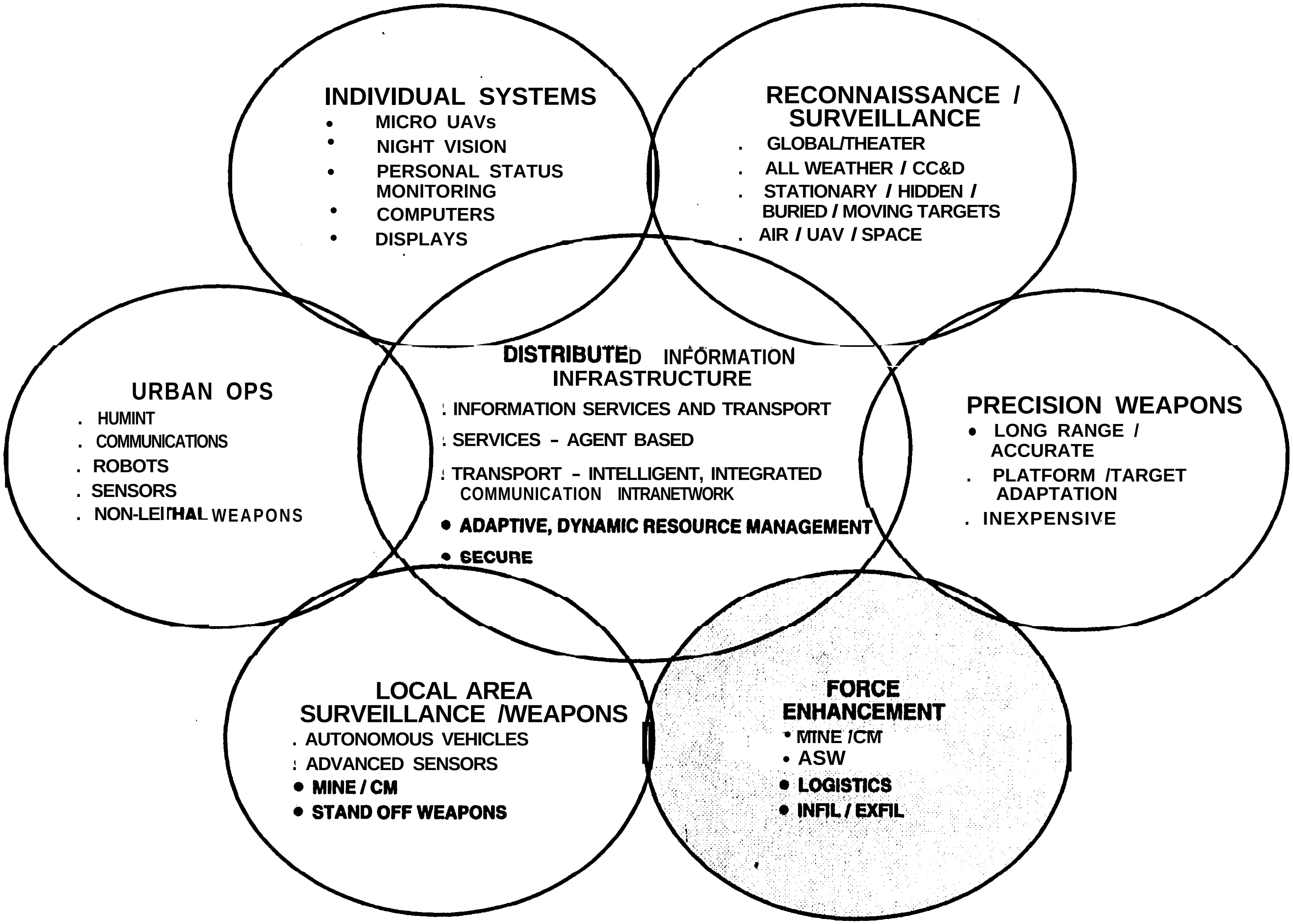
Long Range Precision Attack Weapons — Summary

- Characteristics
  - Long range
  - Precision robust GPS / INS
  - Maneuverable, hypersonic
  - Target-specific warheads
  - Multi-launcher compatible
- Critical technology
  - Guidance system accuracy
  - Fuel and propellant energetics
  - Ground penetration warheads
  - Moving target warheads
- Development goals
  - Affordable costs in moderate unit size production
  - Reduced gross weight
  - Improved lethality for buried hard targets

Force Enhancements

TACTICS AND TECHNOLOGY FOR 21st CENTURY MILITARY SUPERIORITY

TECHNOLOGY CONCEPTS PANEL



Force Enhancements — Goals

We list here the goals for force enhancements, which deal with the security and efficiency of covert, possibly rapid, force insertion mobility during operations, resupply, and extraction. In this discussion we focus our attention on improving littoral operations and on precision resupply logistics capability, where we felt some of the more compelling development issues lie.

Force Enhancements — Goals

- Improved littoral operations
  - Advanced sensor fpr Countermine
  - Improved active and passive ASW
- Low observable vehicles for infiltration / exfiltration
- High speed mobility vehicles for small unit transport
- Precision resupply logistics capability

Advanced Sensors for Remote Minehunting

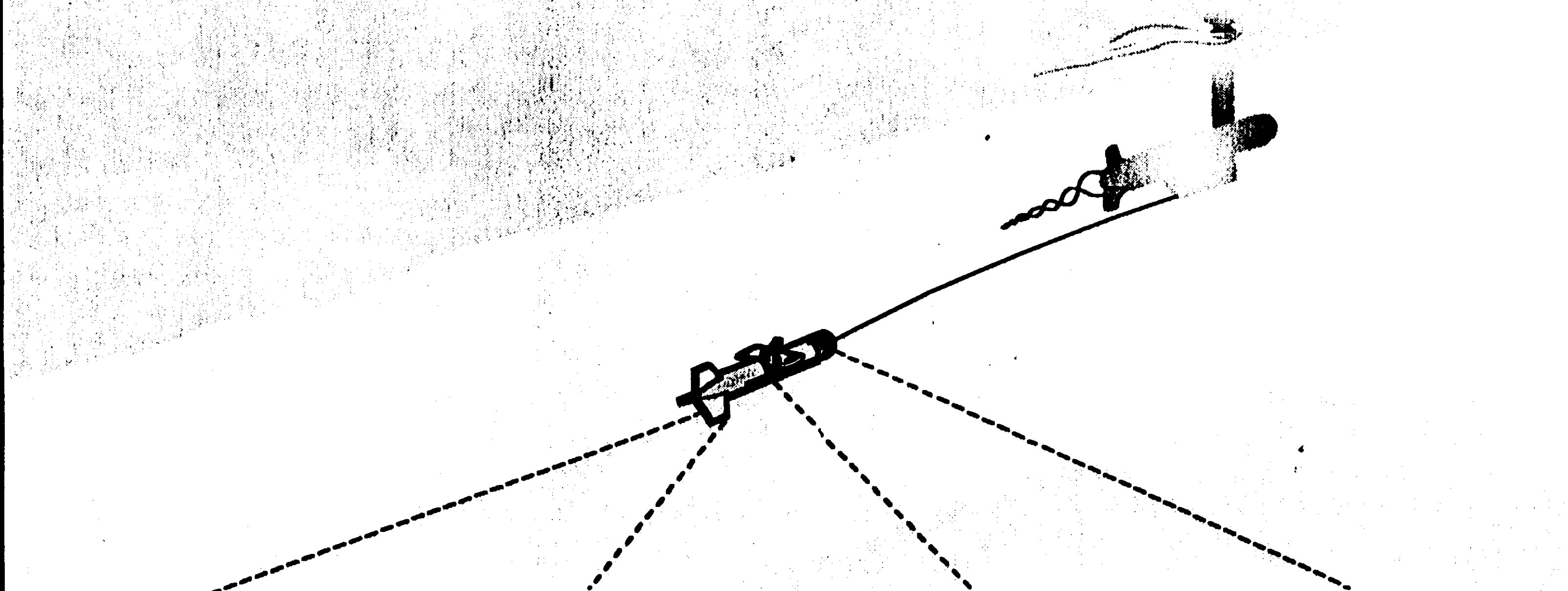
Mine warfare is a critical problem both politically and militarily, and is very complex and difficult technologically. With the end of the Cold War, Navy operations have focused increasingly on shallow-water regions (10 - 40 foot depths) and support of littoral warfare. Operations in the Persian Gulf are characteristic of this new emphasis. More than half of the casualties to naval vessels in terms of damage and sinking of the past several decades have been due to encounters with mines. The emphasis of current mitigation techniques is on the removal and detonation via mine-sweeping. Currently there are no broad area mine surveillance techniques readily available. The accessibility and low cost of potentially stealthy mines can provide any adversary with the means to inflict significant damage. Current mine sweeping techniques are either slow (removal) or incomplete (detonation).

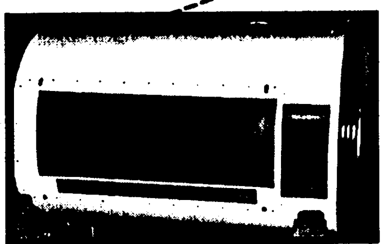
The Navy is currently pursuing programs utilizing towed underwater sensors for remote minehunting. In the concept shown here, a remote-controlled vehicle tows a subsurface platform for several different types of mine sensors: a dual-frequency SAR sonar (shallow water application), superconducting magnetic gradiometer (detects buried mines while rejecting clutter), and underwater electro-optic sensors for mine identification. The data fusion from these sensors will provide a very high probability of detection and classification, with significant reductions in false alarms. Deeper waters will be searched by the toroidal volume search sonar (for detecting and classifying moored mines with a high area search rate) and an advanced side-looking sonar (not shown) for bottom mines.

Mine detection and identification tend to be slow, and mine destruction is dangerous and labor-intensive. Ultimately the detection and identification of minefields must be augmented by the use of overhead assets (UAVs or space) to monitor mine-laying on a continuous basis.

NSWC
Naval Surface Warfare Center
DAHLGREN DIVISION

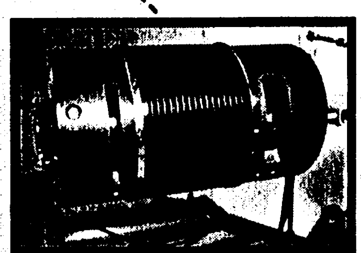
Advanced Sensors for Remote Minehunting





SYNTHETIC APERTURE SONARS FOR VERY SHALLOW WATER
- High resolution imaging
- Buried mine detection

SUPERCONDUCTING MAGNETIC GRADIOMETER
- Buried mine detection
- Rejection of mine-like clutter



UNDERWATER ELECTRO-OPTIC SENSOR
- Mine identification

TOROIDAL VOLUME SEARCH SONAR
- Moored mine detection & classification
- High area search rate

Undersea Surveillance Active Sonar

The quieted nuclear submarine poses a difficult problem in both wide-area surveillance and tactical settings. In either case, it is fundamentally SNR-limited and, thus, its detection is range-limited. Detection improvements, for both surveillance and tactical systems, will rely on the capacity to narrow sensing beamwidths or employ innovative background filtering. The traditional approach to narrowing beamwidths is via long hydrophone arrays. However, tactical systems have had difficulty using towed arrays during maneuvering periods. This potential deficiency will become increasingly more important as detection ranges decrease due to signature reduction. Also, as the detection ranges decrease, more signal features will play a role in detection and classification and, thus, the operator loading will quickly become unmanageable.

Active acoustic techniques are extremely difficult from monostatic measurements due to the low target scattering cross-section and the lack of discernible features between the targets and background clutter, including sea mounts, biologics, and reverberation. Multi-static measurements provide additional features for exploitation. Two potential characteristics to distinguish small (diesel-electric and limited crew) submarines form the background are symmetry and spatial scales. An active acoustic system that exploits these scattering characteristics directly may be a viable approach for this mission.

Two source technology efforts could be exploited to provide both stealth for active acoustics surveillance assets and high source power: the development of a low-probability-of-intercept sonar and the development of leave-behind sources. The LPI sonar using spread spectrum and chaotic waveforms maintains the stealthy characteristics of both the attack submarines and the stealth ships under development. Both rely on stealth for survival and would not employ active acoustics unless assured of maintaining stealth. The leave-behind source provides a means for multi-static measurements as well as desirable source-target-receiver geometry. Any source that would be used would be programmable to allow skip frequency waveforms to allow the signal processing algorithms to exploit the spatial scale variations between submarines and the underwater topology.

Undersea Surveillance Active Sonar

- Active sonar systems
  - Source development
    - >> Develop higher power, broadband sources that are lighter-weight and smaller than current systems
    - >> Example: lead magnesium niobate (PMN) material development
  - Develop new active system concepts
    - >> Leave-behind active source for multistatic ASW
    - >> Interoperable ASW using helicopter and surface ship sonars
- Active sonar signal processing
  - Develop advanced signal processing algorithms for reduced false alarm rates and accurate target classification
    - >> Leverage university and industry signal processing research
    - >> Emphasis on COTS / open-architecture systems
  - Transition algorithms to fleet systems via roadmap agreements with SYSCOM managers

Logistics: Precision Resupply

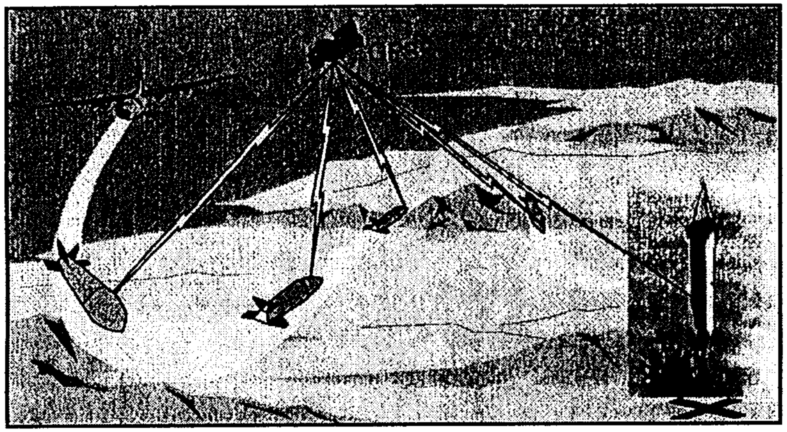
Precision logistics is critical to the sustainment of smaller mobile ground forces. Two variations are shown: (i) a clandestine delivery system (JPODS) with limited payload capability, but which is capable of precise delivery to ranges up to 50 nm, and (ii) a parafoil system capable of greater payloads, but only to ranges of ~14 nm (and with less accuracy than JPODS). Comparative design characteristics are summarized in the lower center of the chart. These two options, as well as many others that can be developed, depend critically on the use of precision guidance and GPS to achieve the geolocation accuracy needed to guarantee timely delivery of the critical supplies and munitions necessary to sustain operations.

Operationally, the JPODS is launched from a "mother aircraft" and navigates to the designated objective delivery point about 250 feet above the 'ground. It then deploys a parachute and falls to earth, as depicted in the figure. The cargo/supplies are removed, and the vehicle is either destroyed or recovered for further use. Powered versions of JPODS are available with extended ranges as required for specific mission applications.

For smaller mobile combat cells to be effective it will be critical to develop an accurate, clandestine, all-weather, inexpensive, long-range precision resupply system with large payload capacity.

Logistics: Precision Resupply

Joint Precision Offset Delivery System (JPODS)



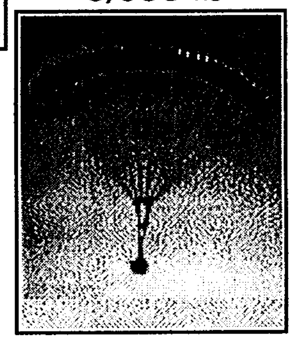
- Clandestine Resupply
- Scaleable Vehicle
- Accurate in Adverse Weather
- Uses Existing Technology
- Propulsion Could Be Added to Increase Range

Parafoil Systems

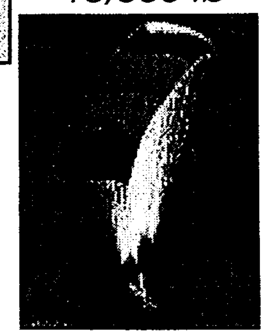
1,000 lb

- Mass Resupply
- Large Payloads
- GPS Guided

6,000 lb



10,000 lb



Characteristics Summary

JPODS		Parafoil
300 - 2000	Payload Wt - lb	1000 - 40,000
15 - 90	Payload Vol - ft^3	as Req'd
Up to 50	Range - NM	14 From 30K ft
100	Accuracy - m	Wind Dependent
Low	Signature	High
1 - 4	Time of flt - min	10 - 20
Various - A-10, B-2, C-130, C-2, C-17, F-15, F-16, F/A-18	Delivery Systems	Transports - C-130, C-17

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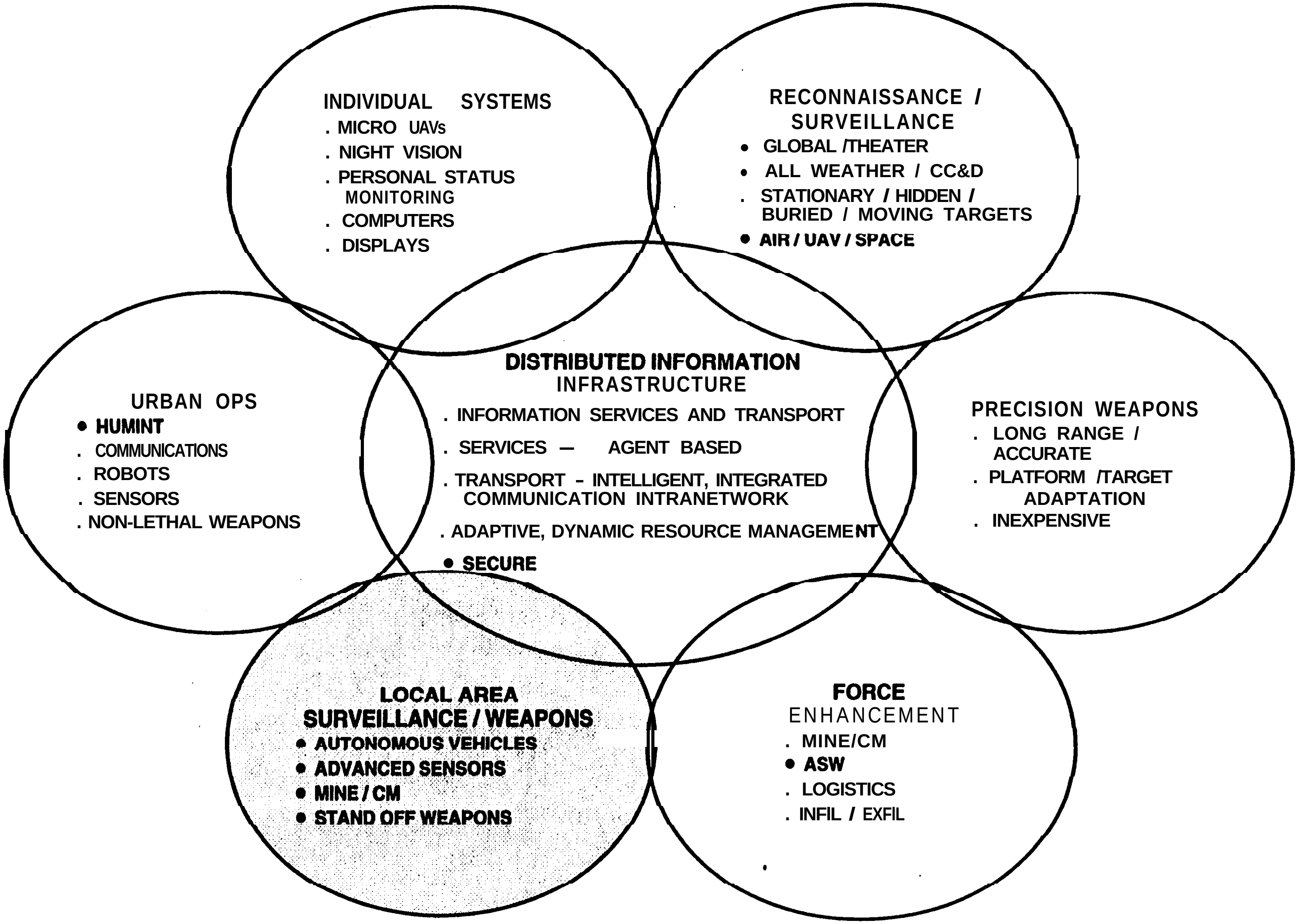
Local Area Surveillance / Weapons

TACTICS AND TECHNOLOGY FOR 21st CENTURY MILITARY SUPERIORITY

TECHNOLOGY CONCEPTS PANEL



The Vision for Combat Cell Operations

Having established the more global supporting assets for the collection of individual units, the combat cells, that are dispersed throughout the battlefield, we now consider the combat cell itself. The vision for the combat cell's effectiveness is the extension of its area of influence — currently ~3 km radius — by at least an order-of-magnitude. The principal enablers for doing so can be classed into three groups:

1. Improved mobility through the use of agile, mobile platforms — many autonomous — for transporting and/or emplacing people, sensors, weapons, and supplies;
2. Advanced sensors capitalizing on trends in miniaturization and multiple phenomenology on single platforms coupled to greatly improved sensor system processing capabilities to provide the individual combat cell with a "virtual presence anywhere on the battlefield" in near real-time;
3. Improved measures for self-defense, including locally controlled devices with adequate standoff to protect the location of the combat cell and/or allow it to control areas of its choosing.

The Vision for Combat Cell Operations

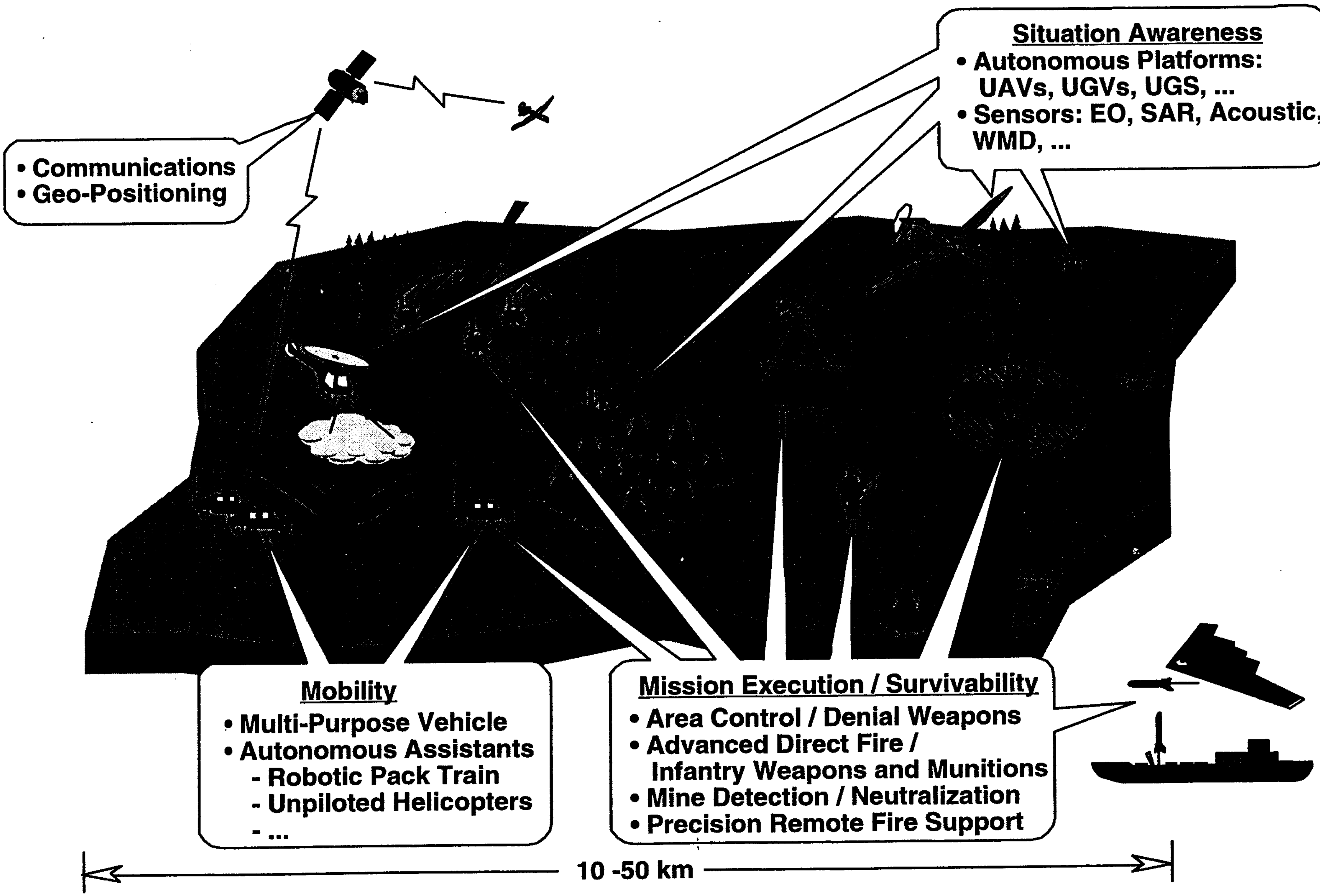
Extend the combat cell's area of influence by at least an order of magnitude with:

- Agile, mobile platforms — many autonomous — for people, sensors, weapons
- Miniaturized, multi-spectral sensors and sensor architectures with extensive real time fusion for targeting and environmental characterization
- Organic weapon capabilities for area control and self-defense

Future Operational Capabilities for the Combat Cell

This schematic takes the vision to the next level, with notional capabilities for each of three enablers as well as highlighting the ties to theater assets for communications, location, and remote fires.

Future Operational Capabilities for the Combat Cell



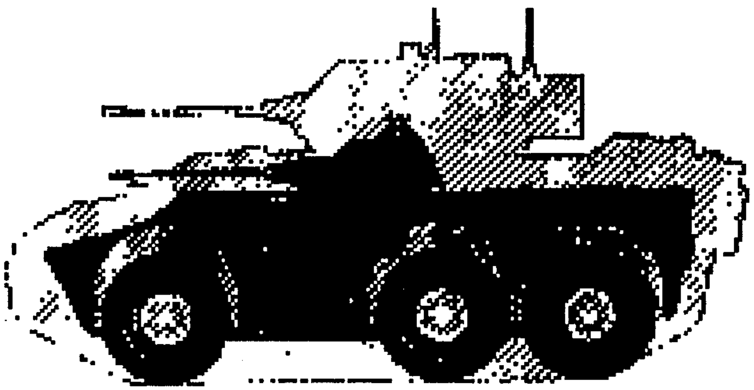
Mobility Platforms

Two venues for improved ground mobility are worthy of development for the combat cell. The first is an augmented version of DARPA's fuel-efficient, hybrid-engine-based Advanced Electric Combat Vehicle (AECV) that would carry a limited-kill-capability weapons suite and could also serve as a base power source (e.g., a battery recharging station or fuel cell refueling source). The "power station" feature is especially important for increasing the war-fighter's "foot" mobility by relieving him of the growing cache of throw-away batteries he typically carries in his pack.

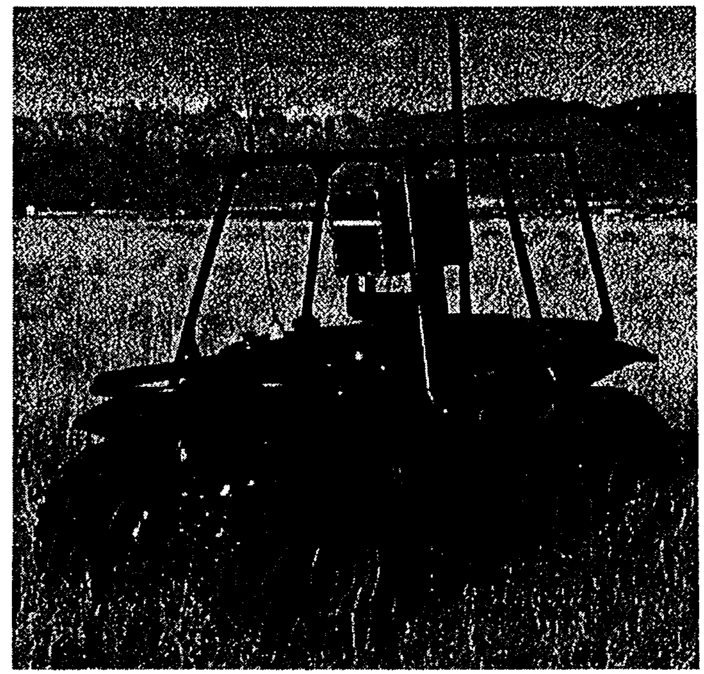
A second concept for improved mobility is an autonomous assistant shown on the right — i.e., a rugged, all-terrain robot executing simple, but necessary functions for packing equipment and supplies, performing straightforward maintenance tasks, and, when required, providing a casualty transport capability.

Both platforms would greatly improve combat cell mobility, with the multipurpose vehicle probably more appropriate for larger unit sizes (20-50 combatants) and the autonomous assistants being suited for units/combat cells of any size.

Mobility Platforms



Multipurpose Vehicle
- All terrain, high speed
- Tactical air lift compatible
- Light weight, fuel efficient
- With options for
  * Advanced gun system
  * Limited transport
  * Power/recharging source



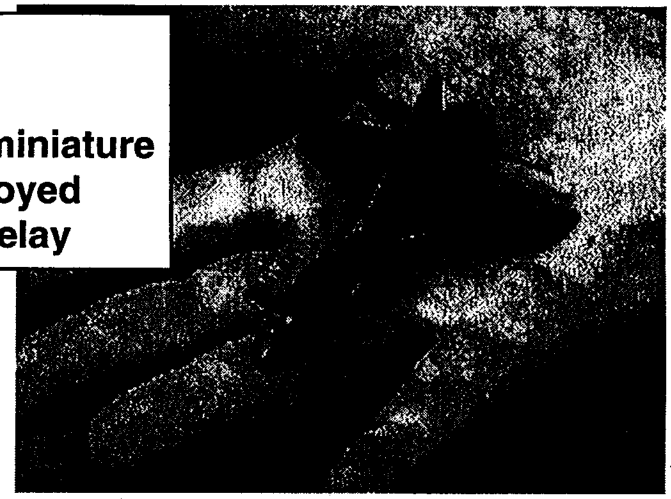
Autonomous Assistants
- Autonomous pack-train
- Cross-country "mules"
- Simple maintenance tasking
- Casualty transporter

Autonomous Airborne Sensor Platforms

The focus on large-platform, high altitude UAV development to-date should be expanded to bring along simpler, smaller, lightweight – and low-cost – autonomous options for providing future ground forces with a locally-controlled capability. A key part of increasing the combat cell's area of influence is its ability to "see" much more of the local environment than the enemy can – and on demand. This requires an indigenous platform (with the appropriate sensing capabilities), such as a small, man-transportable VTOL for "pop-up" quick looks. An alternative, or additional, option is a small UAV for loitering or sentry functions.

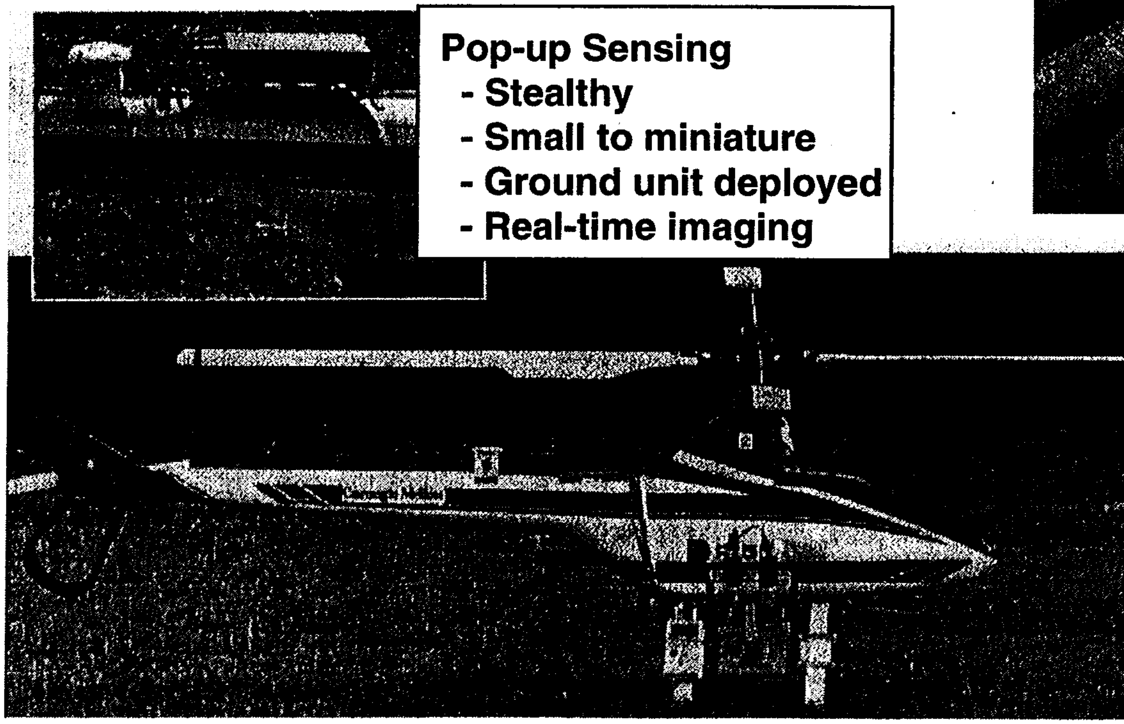
The chart highlights an existing autonomous helicopter with demonstrated simple imaging and flight control capabilities. Advancing technology will reduce the size of such a platform while increasing its functional capabilities. Also shown is a mock micro-UAV, which could provide a throw-away, forward-environmental sensing capability (e.g., for CW or BW) and/or perform a limited surveillance function.

Autonomous Airborne Sensor Platforms



Loitering
- Stealthy
- Small to miniature
- UAV deployed
- Sensing/relay

Pop-up Sensing
- Stealthy
- Small to miniature
- Ground unit deployed
- Real-time imaging



← ~8 Feet →

Remote Autonomous Ground Sensor Platforms

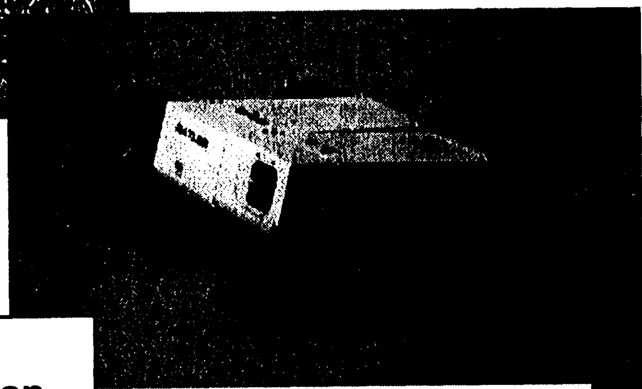
The airborne platforms for combat cell situational understanding will be comparably augmented by autonomous ground sensor platforms possessing complementary sensing capabilities (e.g., seismic, acoustic, and limited-FOV, but close-in, imaging). These ground platforms will be able to identify targets more completely and anticipate enemy approach in environments obscured from overhead surveillance. In addition, these sensor platforms may provide a “trigger” to a nearby weapon when a time-critical target is unambiguously identified. They may also be able to “tag” — physically or electronically — targets that are less time-urgent, i.e., they may be dealt with later.

The chart highlights the potential evolution of these platforms. In the upper left is shown a recently demonstrated unattended ground sensor (upper left) able to acquire combined imaging and acoustic signatures of passing traffic, sort out target vehicles, and transmit the “hit” in near real-time to a remote command center. The size is ~18” square. The center frame captures the next step in improved functionality, a prototype MUGS (mobile unattended ground sensor) that can be air-dropped and then moved in some limited fashion to optimize its location (e.g., hidden along a transit route or repositioned away from objects obscuring its initial field of view). Further evolution takes the MUGS to the mini/micro scale allowing proliferated and leave-behind deployment. A tracked microbot version is shown, but close-terrain environments will likely require more versatile locomotion modes, such as hopping or crawling. At the microbot stage, one can imagine that the mini-MUGS can become a target tag directly by “catching a ride” with a passing suspect vehicle.

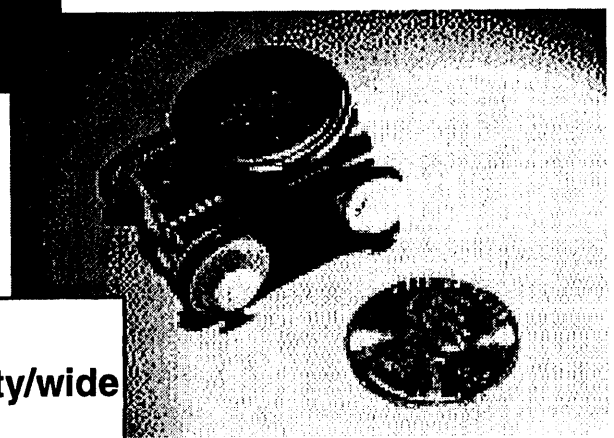
In parallel with shrinking of both airborne and ground sensor platforms, the miniaturization of the sensors and processing payloads must also take place.

Remote Autonomqus Ground Sensor Platforms

Unattended Ground Sensors
- Vehicle, convoy tracking
- Structure, facility monitoring
- Target tagging
- Target ID



Mobile UGS
- Optimal location
- Survivability
- Adaptability/reuse



Miniature MUGS
- Greater survivability/wide area coverage .
- Tagging

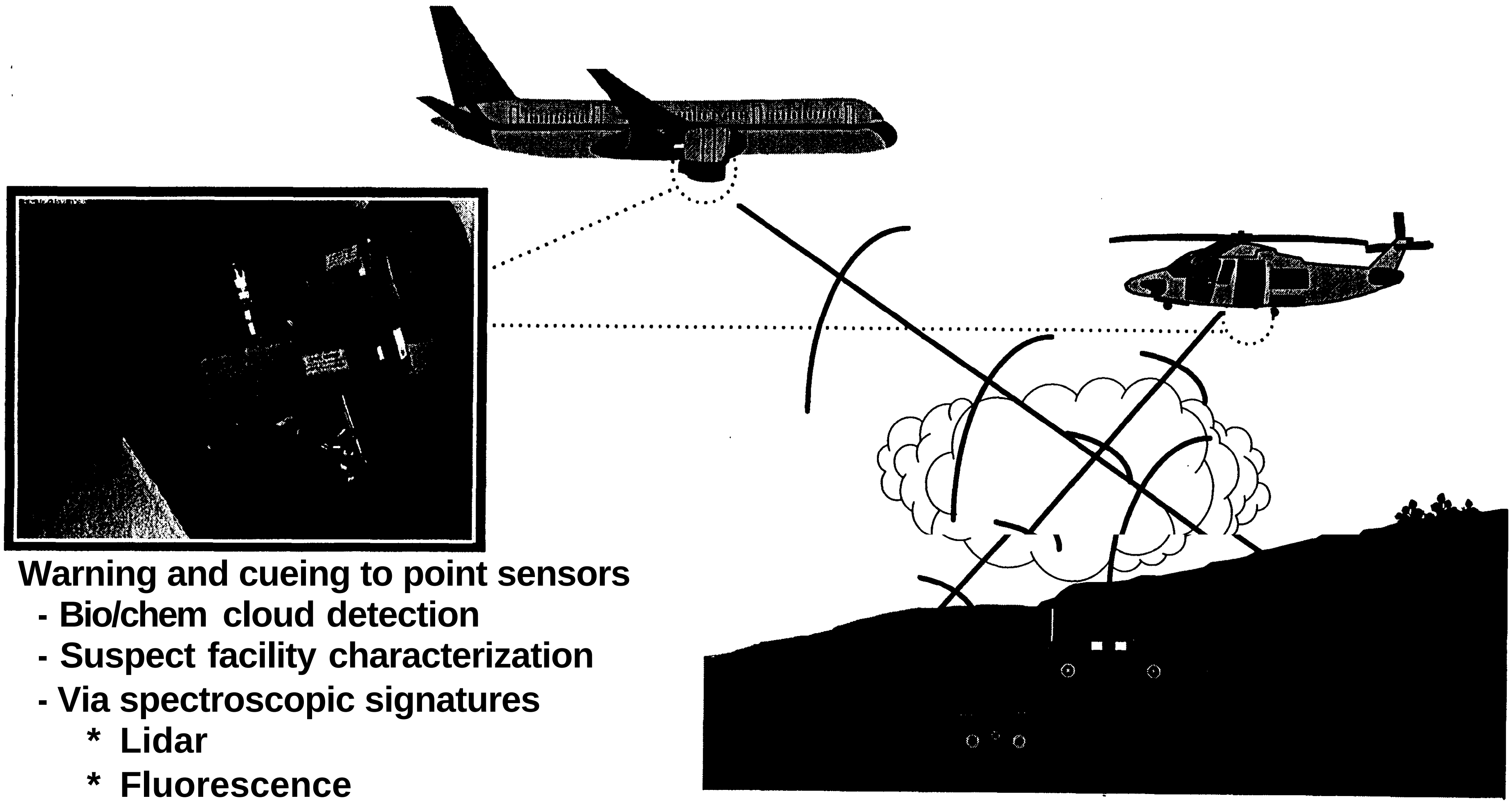
Remote Sensing for WMD Environments

Less mature in both technology development and architectural concepts is the area of CW and BW detection and characterization. No single system currently under development (or imagined) appears to offer a solution to both detection and agent identification at ranges that provide adequate warning for defensive measures to be taken – especially for the BW threat. Instead, the emerging concept is similar to target detection, ID, and tracking architectures. In this case, a remote sensor with wide area coverage detects a suspect agent cloud and cues a localized point detector capable of agent characterization and, ideally, identification.

Laser-based systems on airborne platforms are currently being developed for the remote capability. Chemical and limited biological aerosol cloud detection is being demonstrated. While UV fluorescent based systems offer the most promise for bio-agent characterization, the limited range of such systems make the less discriminating, but longer range, IR systems the current leading deployment candidate.

Note: Remote detection of nuclear detonations is a well-developed capability and will not be discussed further. However, the potential for operations in radiological environments generated by material dispersal devices, or by very small yield weapons, dictates the need for a localized ionizing radiation detection capability, which is addressed on the next chart..

Remote Sensing for WMD Environments



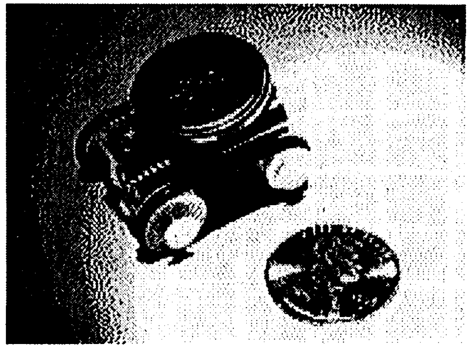
Warning and cueing to point sensors
- Bio/chem cloud detection
- Suspect facility characterization
- Via spectroscopic signatures
  * Lidar
  * Fluorescence

Miniature Point Sensors for WMD Environments

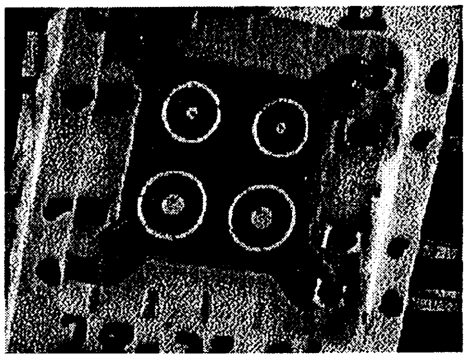
The other element of the notional WMD architecture is the local sensor suite that can identify the agent and yet be small enough to be forward deployed on small autonomous platforms to allow the appropriate defensive measures to be taken in a timely manner. The goal is to move from the cumbersome and highly. vulnerable forward deployed, man driven HMMWV-based chemical and biological detection systems currently headed for deployment (BIDS is highlighted in the chart) to widely dispersed microsensors on micro, autonomous platforms. Small room temperature semiconductor based radiation detector systems exist today. Micro spectrometers and chem/bio detectors have been demonstrated in many laboratories, but multi-agent, micro-detection, field deployable **systems** are still several years away.

Miniature Point Sensors for WMD Environments

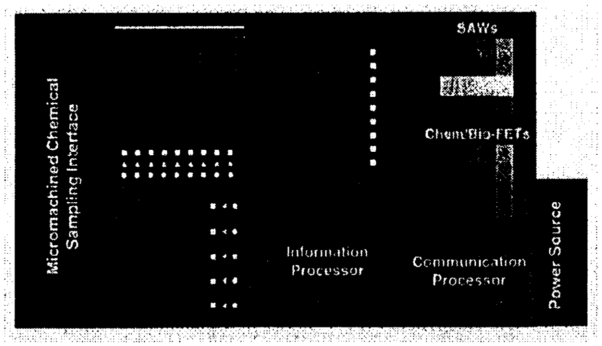
From | **To**



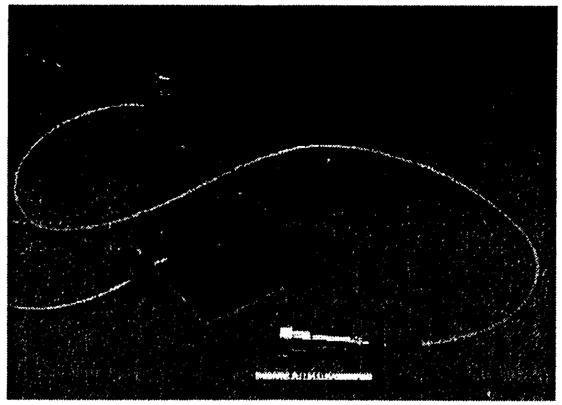
Through Miniaturized Sensors & Processors



- Ambient temperature, neutron/ gamma detection



- Molecular recognition of bio/chem agents

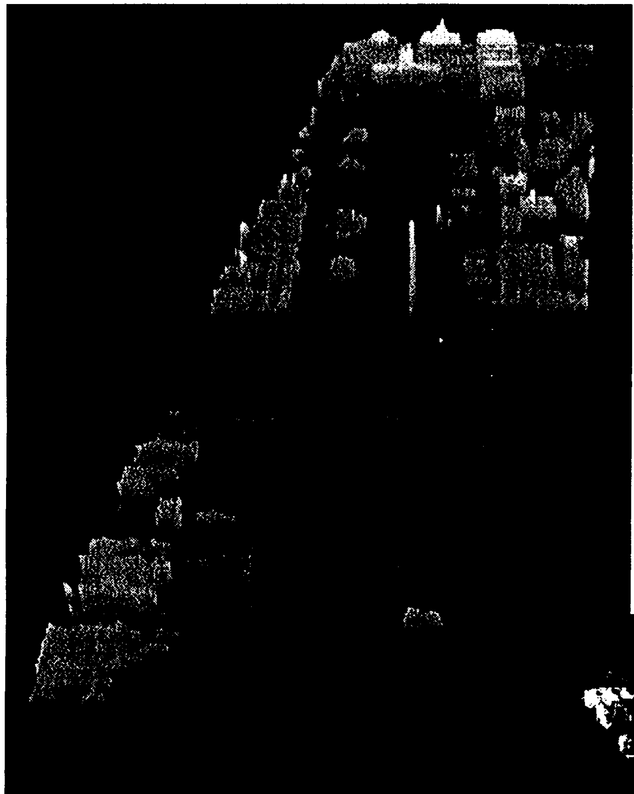


- Spectroscopic signatures

Sensor Fusion — Today

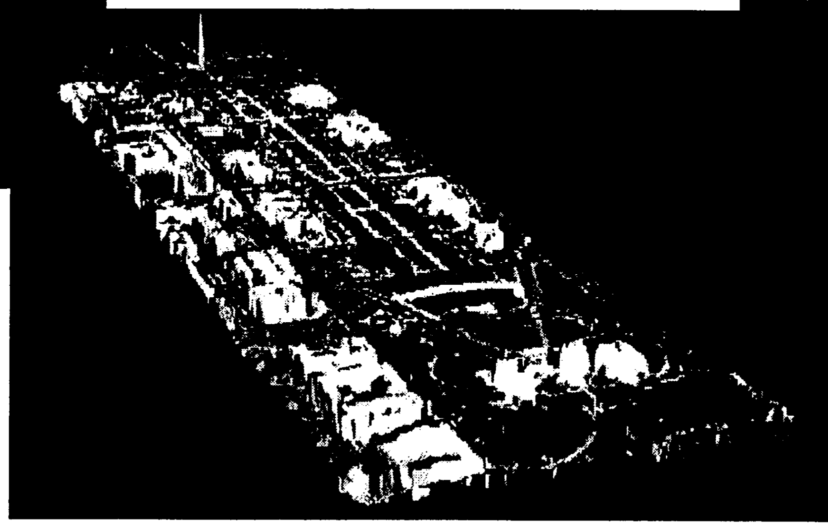
The next, and most critical, step in technology development to support the combat cell is the fusion of sensor data to provide a succinct and intuitive picture of the combat cell's operational environment. And that picture must greatly surpass, in both coverage and accuracy, the competing view available to the enemy in order for the combat cell to maintain the upper hand. Efforts must move from continuous improvement of individual sensor and platform capabilities to the fusion of data from multiple platforms carrying the same basic sensor suites, as well as disparate platforms measuring different phenomenologies. The chart illustrates today's capabilities, in which SAR and multi-spectral data can be combined to produce a three-dimensional, true-color visualization of the area of interest. This is a long way, however, from the vision painted in the next chart.

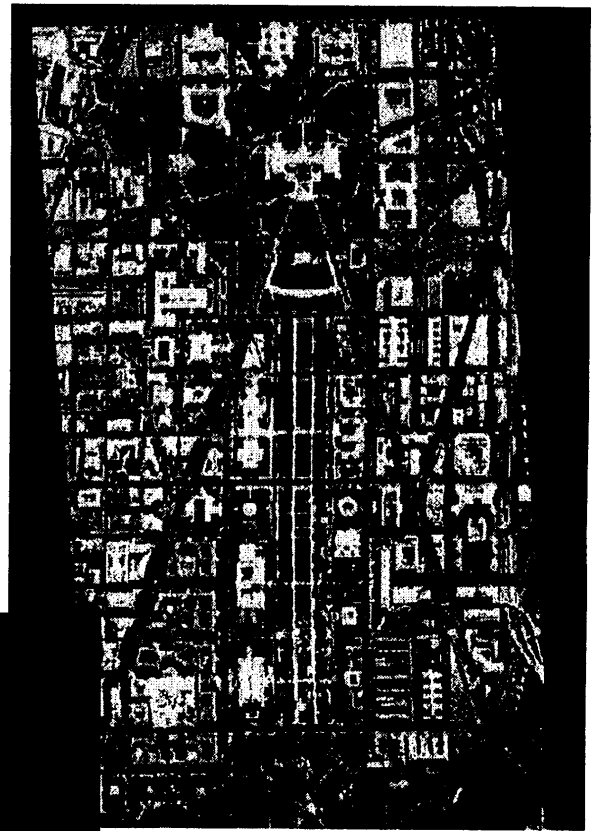
Sensor Fusion —Today



SAR Elevation

Fused 3-D True Color





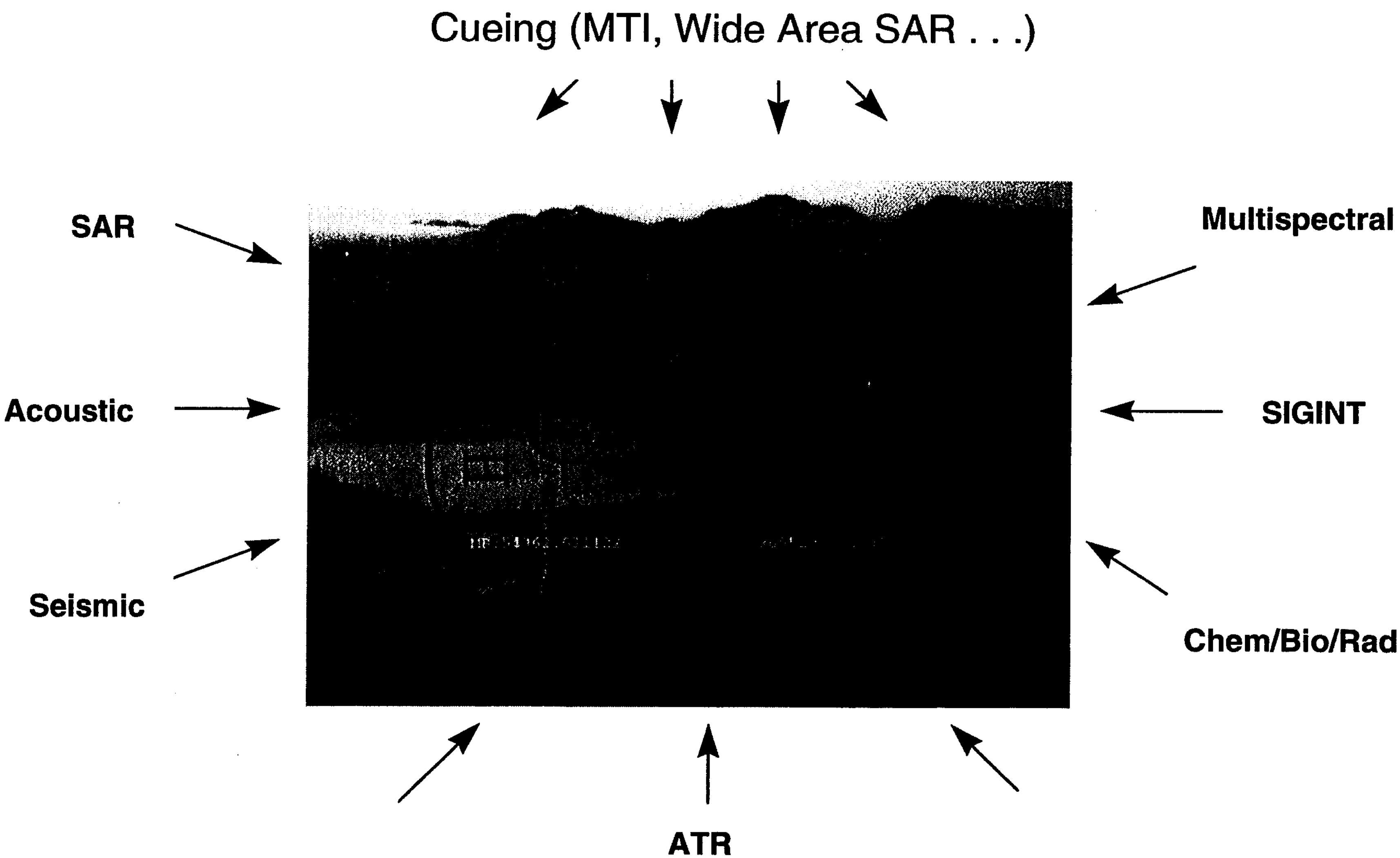
Multispectral

Sensor Fusion — The Vision

The 20-year vision for the combat cell in the field is the individual soldier's ability to view through a simple helmet- or wrist-mounted display an augmented vision of the environment in his domain of interest. In this augmented vision, obscuring factors (e.g., clouds, fog, trees, hills) are "penetrated" to show enemy and friendly force locations and type. In addition to the visual depiction shown in the chart, the soldier could also *hear* what is transpiring in an area of interest, giving him a "virtual presence on the battlefield".

But the simplicity of this vision belies the complexity of sensors, sensor management, and data processing that must take place within the supporting infrastructure in order to present such information to the individual soldier on demand. The contrast between today's capabilities and this vision may make this area the most challenging technical advance of any discussed in this report.

Sensor Fusion — The Vision



Area Control/Denial Weapons

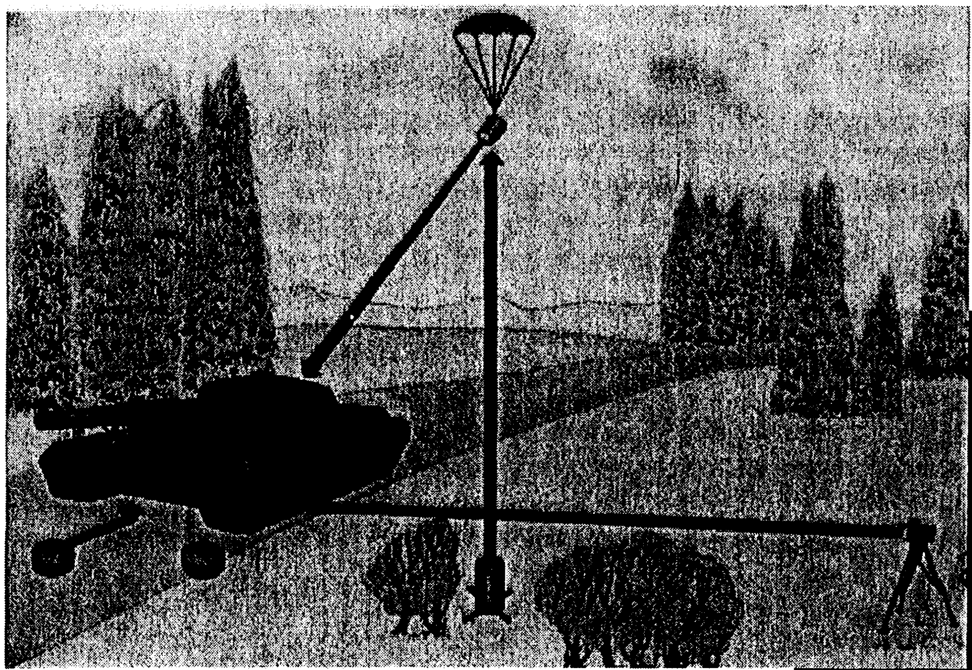
The ideal operational scenario for the combat cell is that it is able to identify enemy targets unambiguously, aided by the cueing and characterization of the supporting sensor and information architectures. Precise and timely indirect fire may then be called in to neutralize those targets. The combat cell itself would never be detected and never have to fire a shot itself. The achievement of such an operating environment in 20 years, however, is probably not realistic, although many of the improvements discussed above, if realized, would move capabilities far along that path. Therefore, we must consider what forms or options of organic fire power the combat cell should have at its disposal.

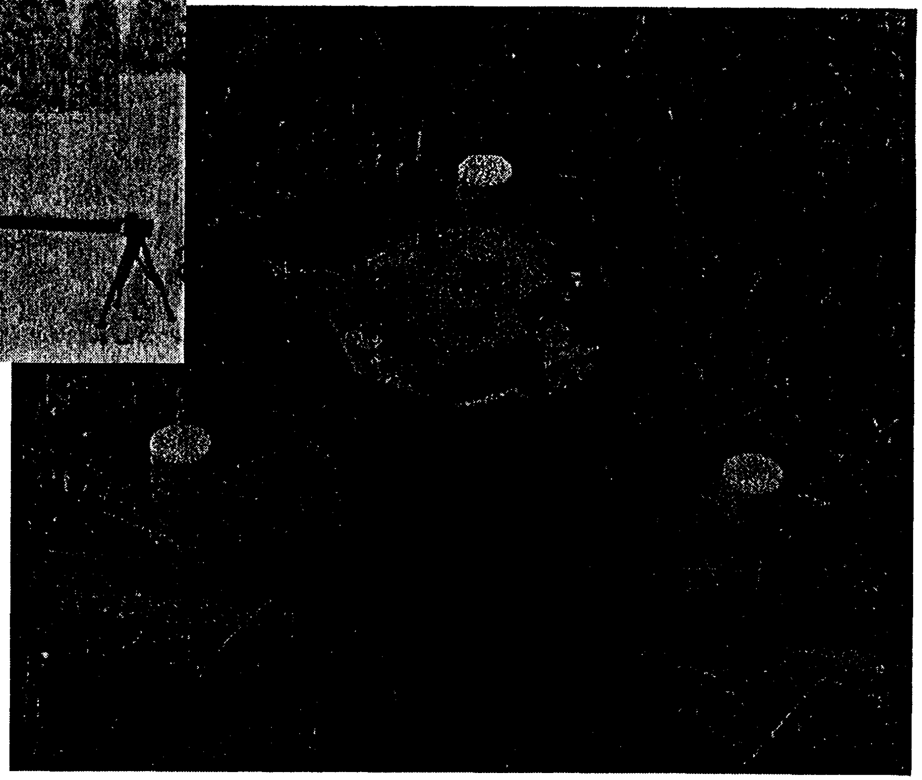
The first of these is an area control or denial weapon. The panel recommends a significantly improved version of the Army's Wide Area Munition (WAM), which is shown in this figure in its current configuration. Capabilities twenty years from now would include:

- Combat cell or other command level control for activation/deactivation and disablement/self destruct, to avoid the legacy issues of conventional mines today;
- Connectivity to nearby or indigenous UGS and local UAVs for target cueing;
- Indigenous target identification "smarts" to avoid anti-personnel triggering;
- Mobility to optimize its location relative to the target, as illustrated in the cartoon, and/or to offer limited area control redefinition as dictated by the combat cell;
- Lethality sufficient to allow it to stand-off from targets to avoid detection, as well as to separate it from the combat cell; and
- A cooperative capability with other nearby weapons to allow disruption of enemy unit movement by attacking critical parts of, for example, a convoy, to force the entire column to stop.

Such a capability provides a timely response to many time critical targets while still not giving away combat cell location.

Area Control / Denial Weapons



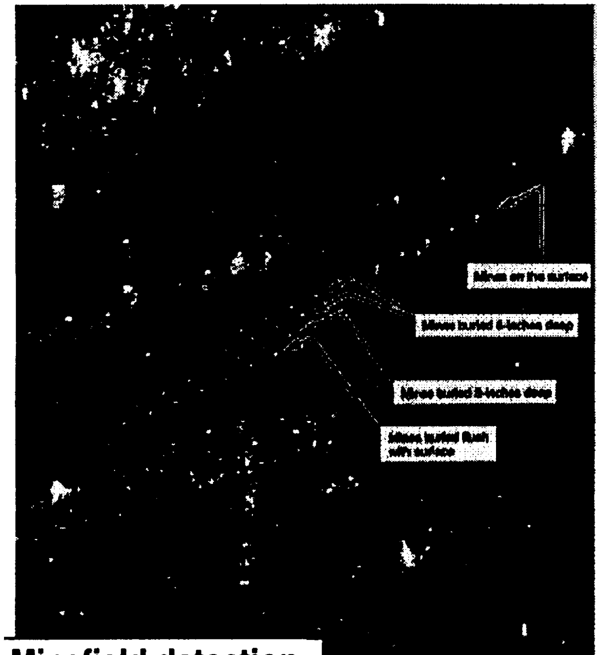


- Remote on/off
- Command disable
- Target cueing from indigenous assets
- Discrimination (target ID)
- Mobile
- Standoff lethality
- Cooperating with other mines

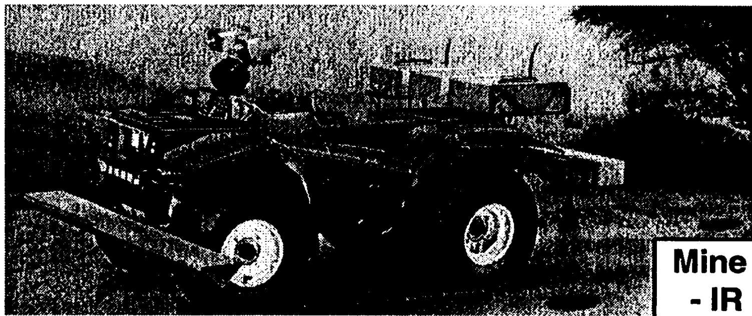
"In-Stride" Countermine Capability

The defensive counterpart to the area control weapon is some sort of countermine capability. This is a difficult enough problem that the ideal operating environment would entail minefield detection by overhead assets, so that the mined area could be avoided altogether. Some promising developments in SAR and LIDAR, coupled with change detection algorithms, could greatly enhance our capabilities in this area. In the event that overhead detection does not work and/or the mined area must be traversed anyway, then the combat cell will require some in-stride localization capability, preferably robotically-assisted. A number of technologies, some of which are listed on the chart, are under development, but the wide variety of explosives, casings, and shapes (over 600 known worldwide at last count) preclude the selection of any single sensing technique. In some cases, it may also be necessary to destroy the mines when found. Several options, as noted in the chart, exist or are near-term for addressing this phase of the demining operation.

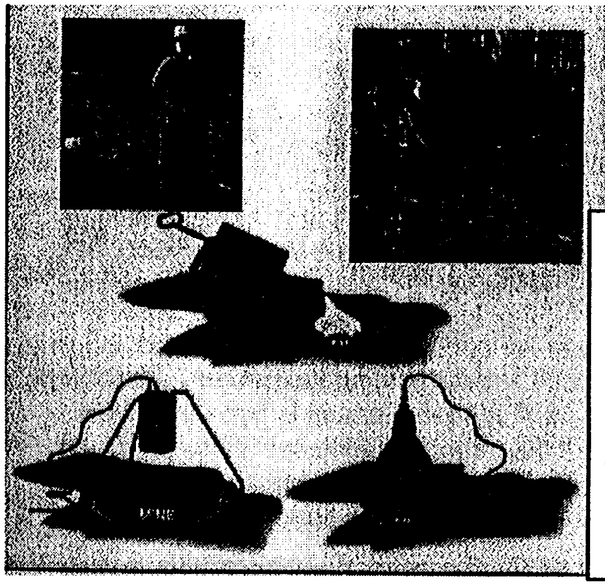
"In-Stride" Countermine Capability



Minefield detection
- SAR
- Lidar
- Change detection



Mine localization
- IR
- GPR
- Hyperspectral
- Laser reflectance
- MIR tomography
- Acoustic tomography
- Infinite "dogs"
- Expendable robotics (ATVs)



Destruction
- Explosives with foam mitigation
- EM disablement
- Sacrificial robots w/ explosive charges

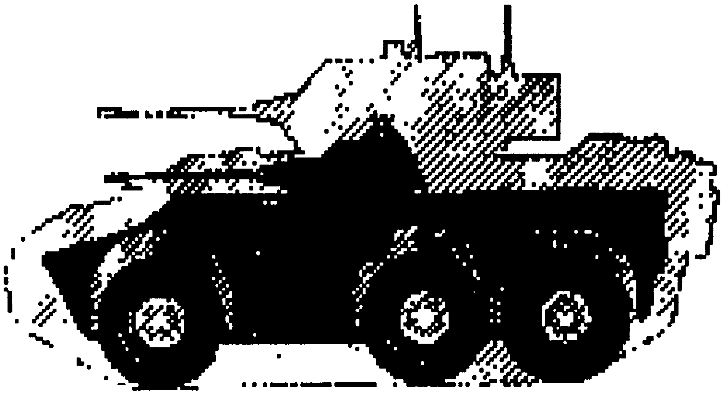
"Smart" mine avoidance
- Decoys and spoofing
- Simple jammers

Advanced Direct Fire / Infantry Weapons

The choice of last resort for the combat cell operating in a widely distributed deployment is direct fire. At that point the combat cell's location is pinpointed, and it is relegated to a "kill or be killed" situation. Nonetheless, the combat cell must have some self-defense capability, and some significant improvements can or could be made on several fronts.

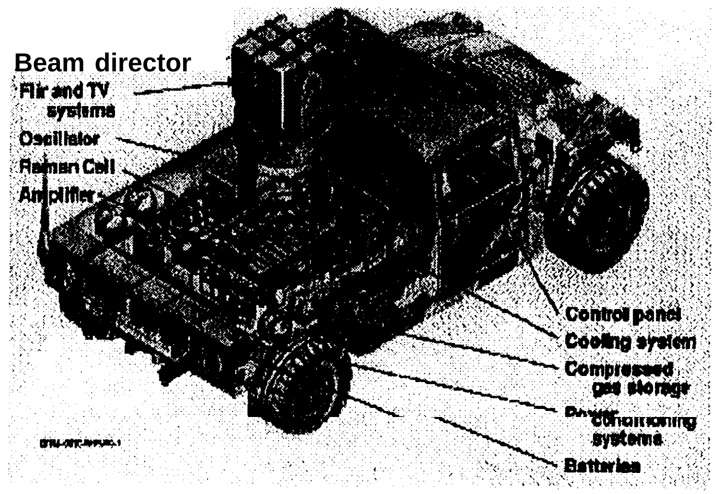
A new generation of the warfighter's rifle is already under development under the Objective Individual Combat Weapon Program. It will include both a smart bullet and short-range mortar double-barrel capability. The needed improvements for that weapon are lighter weight, lower cost munitions, and higher energy density munitions to allow heavy-armor kill. If the combat cell is large enough to warrant wheeled capability, then the Multi-Purpose Vehicle discussed above should include an advanced gun able to fire munitions tailored to the target and light-weighted and/or higher in lethality (based on new gun designs able to achieve higher kinetic energies). The option for directed energy weapons should also be developed as the most attractive for disruption or kill of enemy communications and electronics.

Advanced Direct Fire / Infantry Weapons



Advanced gun
- Higher KE through electro-thermal, RAM, RAP, etc.
- Mission specific munitions
  * Seeker assisted
  * HEDM
  * Penetrators

Individual combat weapon
- Multi-mode
- Lightweight, low cost munitions
- HEDM munitions for heavy armor kill
- Seeker



Directed energy weapons
- ECM negating C^3I and SEAD facilities
- Dazzling, blinding EO systems
- Ground or UAV based

Combat Cell Operations — Summary

The summary recaps our vision for the operational capabilities of the combat cell. The order-of-magnitude increase in area effectiveness is achievable through the combination of:

1. Mobile platforms with the flexibility to be adaptable to people, sensors, and weapons, and in many situations, to operate autonomously;

2. Miniaturized sensors employed in a distributed fashion and sensing a wide array of phenomenologies coupled to an information processing system that provides highly accurate and intuitive pictures of the warfighter's area of interest in near real-time; and

3. Combat cell-controlled weaponry for both local standoff and direct fire engagements.

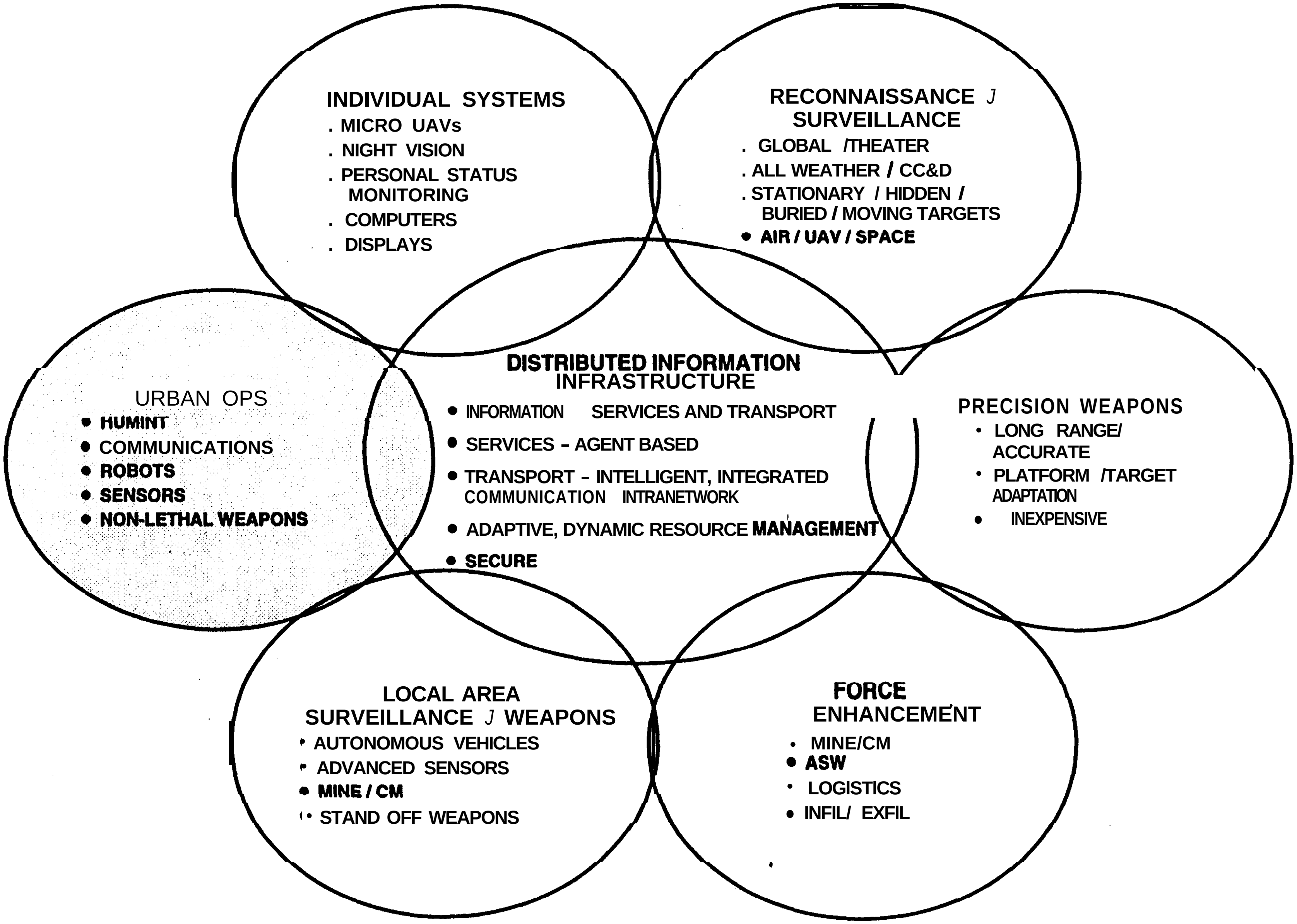
Combat Cell Operations — Summary

- Agile, mobile platforms for people, sensors, weapons
  - Un-piloted helicopters for pop-up sensing
  - Small tactical UAVs for local situation awareness
  - Unattended ground platforms with sensing, localization, ID
  - Cross-country robotic assistants for field maintenance, casualty, and supply movement
- Miniature sensors and distributed sensor architectures for targeting and environmental characterization
  - Radar, seismic, acoustic, imaging, HUMINT for all targets
  - Unique signatures for special targets
- Organic area control weapons and self-defense
  - Remote controlled, distributed, standoff smart “mines”
  - Advanced kinetic and directed energy concepts

Urban Operations

TACTICS AND TECHNOLOGY FOR 21st CENTURY MILITARY SUPERIORITY

TECHNOLOGY CONCEPTS PANEL



The Vision for Urban Operations

The urban environment presents some unique challenges to the combat cell for several reasons. First, line-of-sight is highly constrained — by buildings and other structures outside and by walls, doors, and corners inside. Next, the enemy engagement space is often complicated by the presence of innocents and/or neutral noncombatants. Finally, neutralization of the enemy often means destruction of significant infrastructure, if conventional explosives are the only means of engagement. These complications lead quite naturally to the vision for effective operations by the combat cell in the urban environment:

- "Virtual line-of-sight"; i.e., seeing around corners, through buildings and walls;
- The ability to precisely locate friends and distinguish neutrals from the enemy;
- Options to minimize or prevent collateral damage to the infrastructure and killing of innocents.

While characteristics of urban operations may be generalized, the needs for engaging the enemy are often dictated by the mission. As such, our vision is complete when the combat cell is able to access the right technologies for the mission at hand.

The Vision for Urban Operations

Technologies matched to the mission and constraints:

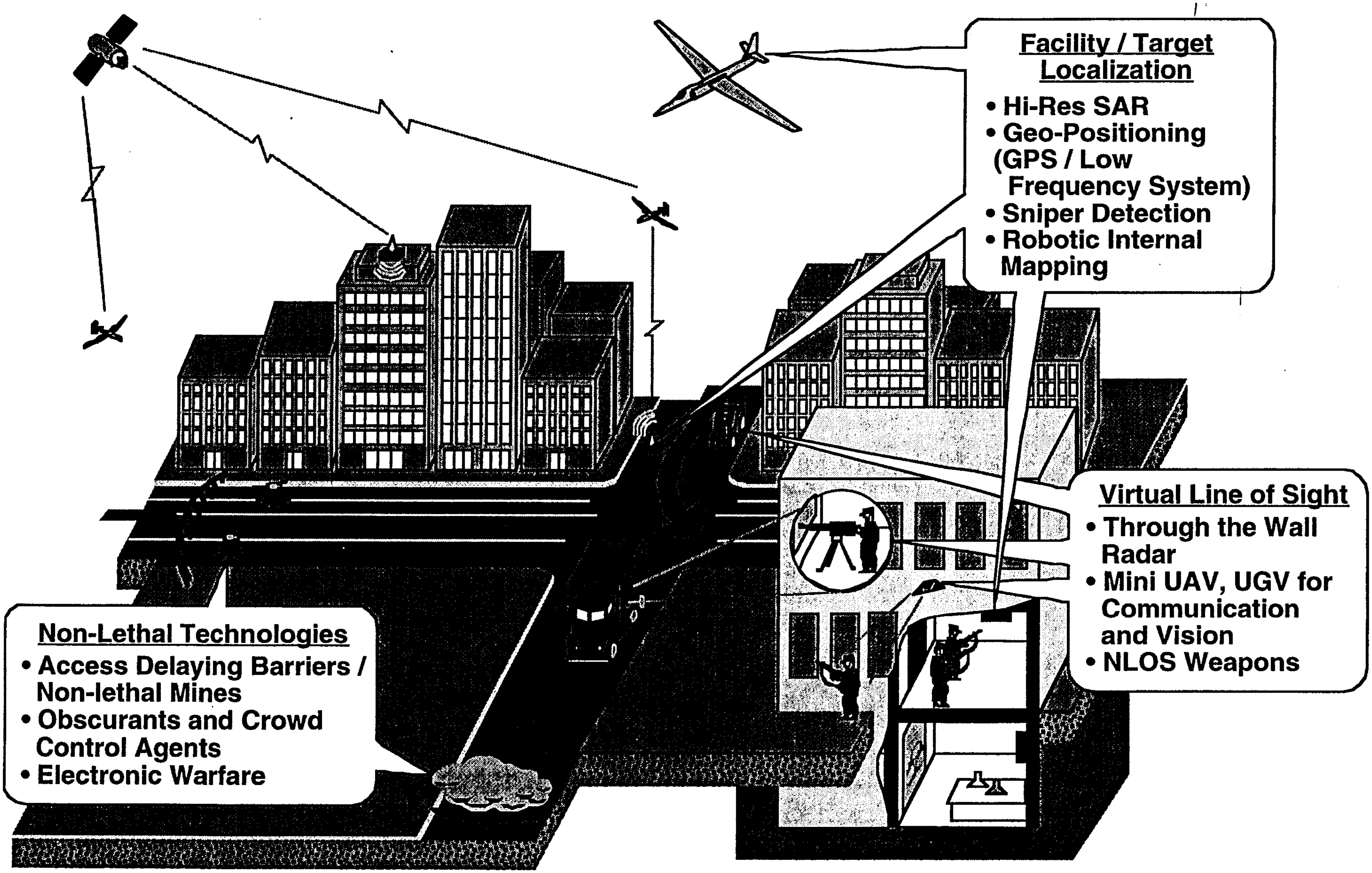
- Virtual line of sight
- Precise location of friends, innocents, foes
- Minimum to no collateral damage

Operations in the Urban Environment

The graphic illustrates the principal technologies that could enable more effective urban operations in the future. The virtual line-of-sight could be aided by such advances as through-the-wall radars, non-line-of-sight weapons, and small robotic and airborne assists for seeing and communicating around corners or obstructions. In sorting noncombatants from combatants, locally controlled airborne and ground assets with high resolution sensors to detect, for example, sniper fire and to provide accurate layouts and position (especially inside buildings) would allow much more effective pinpointing of the enemy. To address mission objectives for minimizing collateral damage and neutralizing adversaries in the midst of non-combatants, non-lethal weapons will be critical parts of the combat cell's tool kit.

On the next several charts, we highlight a few of these technologies in more detail.

Operations in the Urban Environment



Micro UAVs

True Micro-UAVs (8-20 cm wingspan) could enable a revolution in airborne surveillance in urban operations. The modest ranges required in urban operations (1-10 km) makes possible considerable miniaturization of on-board components.

Recent studies have shown that micro vehicles are feasible. One challenge is providing adequate performance in the low Reynolds number aerodynamic regime, for which there is limited experimental data. Lift, drag, and propeller performance can be degraded in this regime. On the other hand, micro vehicles derive a benefit in that their volume-related mass decreases more rapidly than wing area as size decreases. For electric propulsion, advances in battery technology are required to provide adequate power and energy densities – but these improvements can be expected during the next decade. Internal combustion engines are more efficient and miniature versions are currently under development and will be available over the next several years. Microturbines will also become available, which could provide thrust or electric power.

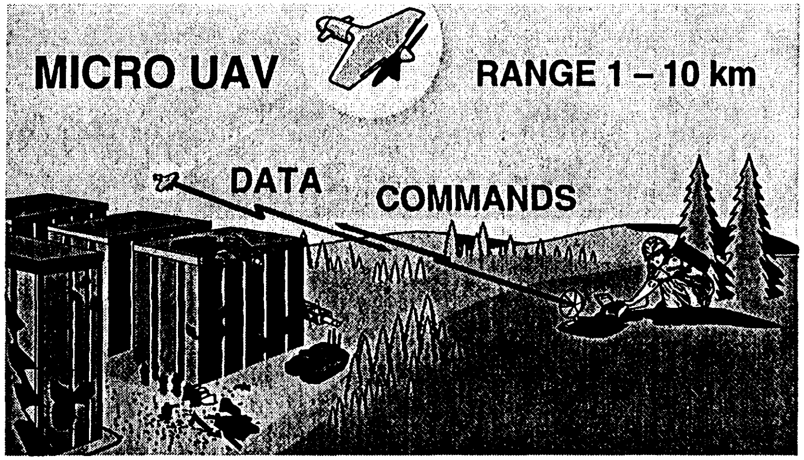
Fixed-wing configurations may not be the best for applications which require close-in surveillance or data gathering. Rotary-wing vehicles that hover have been built (e.g., the Lear Puma) and are being considered for tactical applications. Hover capability is particularly intriguing for small- and micro-vehicles, where the ability to fly vertically as well as fly forward faster than wind speeds (the hummingbird analogy) would be particularly useful for urban warfare. Hovering could be achieved through various means, such as rotating wings, ducted fans, or even ornithoptry. The ability to hop or perch could also be useful. Hovering vehicles are less efficient than fixed-wing flyers, and they will always have smaller payload-to-total-weight ratios. However, with expected improvements in propulsion technology for micro-vehicles; they may become practical over the next decade.

The detection of nuclear, biological and chemical (NBC) contaminants in the atmosphere is particularly suited to UAVs, which permit wide-range sampling without risk to personnel. This application requires flying at mid- to low-altitudes, where such contaminants will be found. It is desirable to use small vehicles to reduce vulnerability to detection and attack, as well as to reduce cost. The simplest approach, which is applicable to the smallest vehicles, is simple to gather samples in evacuated collection bottles and return them to a ground site for analysis. However, on-board detectors are desirable to provide timely alerts and to avoid the need to handle contaminants. NBC detectors are currently under development, and their weight will decrease as the technology advances.

MICRO UAVs

NEW CAPABILITY

- MAN PORTABLE, LOCAL USER CONTROL
- COVERT
- FLYING / HOVERING
- MISSIONS:
  - URBAN WARFARE, LOCAL SURVEILLANCE
  - CHEM / BIO SAMPLING
  - SPECIAL WEAPONS / SENSOR DELIVERY
  - OTHER



IMPLEMENTATION

- 8 – 20 cm SPAN MICRO VEHICLES
- SENSORS:
  - HIGH DEFINITION VISIBLE / IR IMAGING
  - ACOUSTIC, SEISMIC, etc.
  - CHEM / BIO
- HIGH FREQ, JAM-RESISTANT COMM LINK
- LOW COST USING MICRO FABRICATION TECHNIQUES

TECHNOLOGY CHALLENGES

- IMPROVED POWER SOURCES, BATTERIES
- MEMS SENSORS, ACTUATORS
- MINIATURE GPS / IMU
- MINIATURE COMMUNICATIONS / CONTROLS
- ADVANCED INTEGRATION / PACKAGING TECHNIQUES
- LOW REYNOLDS NUMBER AERODYNAMICS

Other types of sensors, such as acoustic, seismic and magnetic, are applicable to small vehicles, particularly those which can deposit payloads on the surface where detection of personnel and ground vehicles is important. Such sensors are already available in small packages and could be attached to small UAVs that are designed to parachute or crash onto the surface. Small UAVs could also deliver “stick-on” RF or laser sources, providing homing (“tag”) targets for smart weapons.

MICRO UAVs

NEW CAPABILITY

- MAN PORTABLE, LOCAL USER CONTROL
- COVERT
- FLYING / HOVERING
- MISSIONS:
  - URBAN WARFARE, LOCAL SURVEILLANCE
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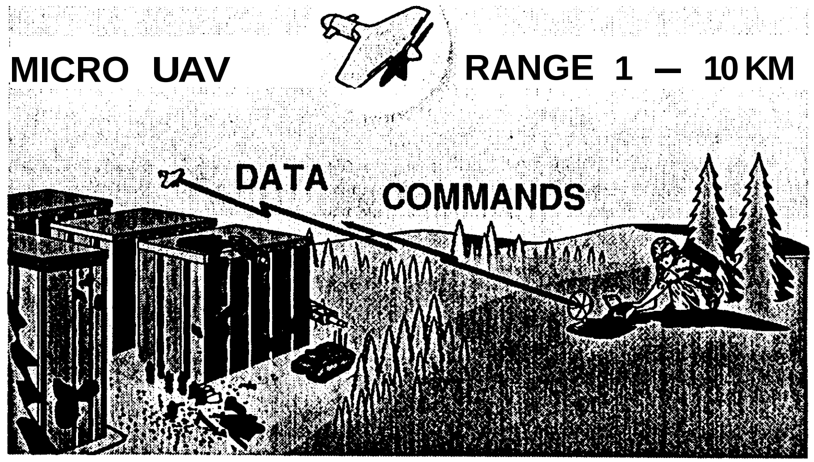

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- LOW REYNOLDS NUMBER AERODYNAMICS

Miniature Disguised Robotic Platforms for Urban Operations Support

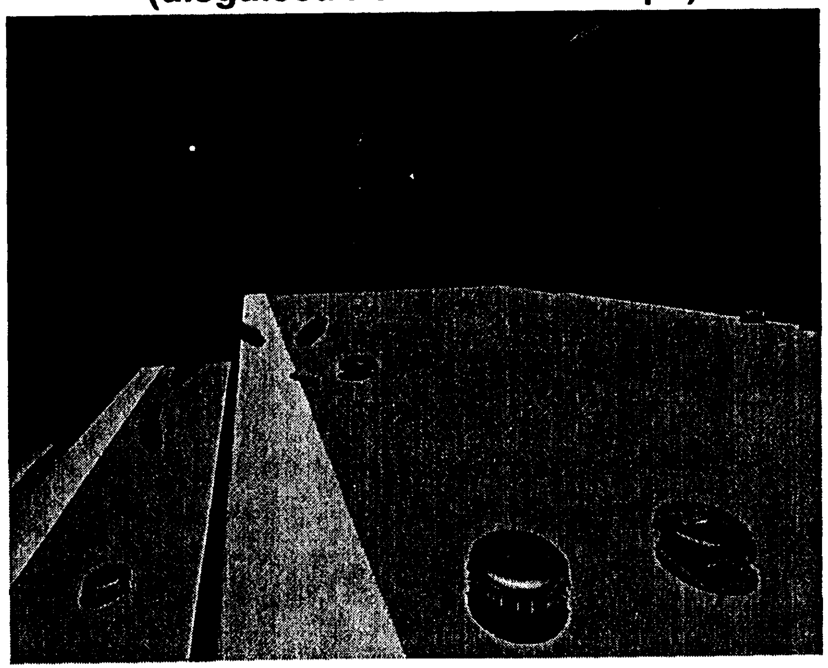
Complementing the micro-airborne platform are small ground robotic platforms, disguised in our vision as commonplace articles (e.g., litter, construction materials). These small platforms (and possibly some larger) allow covert entry into buildings for mapping, specialized detection, communication links, sentry duty, seeing around corners – in short, all those functions that represent significant risk to the individual warfighter as he enters an unknown, constrained environment or needs someone/something to cover his backside.

The concept illustrated in the chart shows a transport device disguised as a brick in the upper left. Such devices, in varying disguises, could be dispersed throughoutthe urban setting and, on command, (preset or in real-time), deploy their smaller devices to perform mission-specific tasks. The cartoon shows a bottle cap being airlifted by a balloon. The bottle caps, capable of jumping up stairs and sliding under doors, then enter and move through the building to perform simple distributed tasks, as suggested in the lower right corner of the chart.

Miniature Disguised Robotic Platforms for Urban Operations Support

Small Vehicles to Distribute Microbots
(disguised here as bricks)

Intel/Surveillance Sensors
(disguised here as bottle caps)



Miniature Imaging Systems

The kind of miniature optics of possible application to a Micro-UAV is shown here. The multi-spectral IR imaging system offering a 40º x 40º FOV in a size comparable to the dimension of the common housefly generates remarkably clear imagery, as shown in the simulation in the upper right.

An imager of a microsensor must be highly integrated into its overall system to be practical. Current-production, high-performance imagers are usually very large or have few integrated functions on the imager's silicon. Very high-quality visible imagers are being made by several vendors (mostly Japanese) with small physical size (~0.25 inch diagonal), but these all require support chips much larger than the imager itself, and also require ~1 Watt for TV-like operation. There are few integrated imagers available commercially; all are relatively large and have poor performance compared with the best non-integrated imagers.

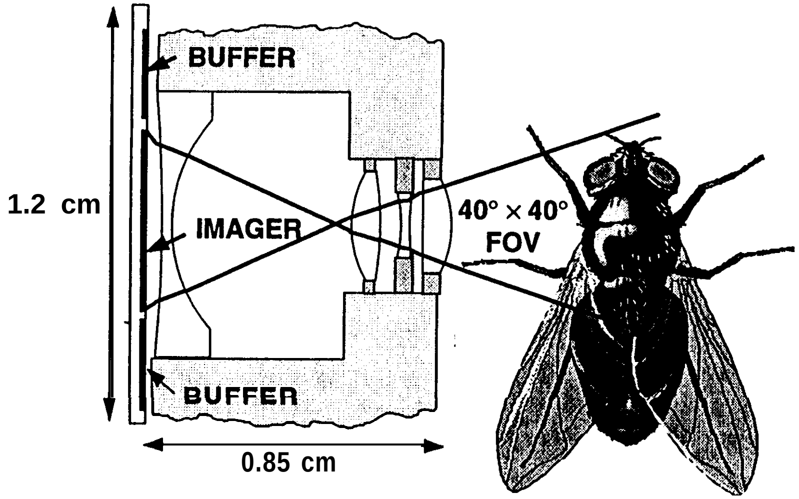
High performance integrated microminiature imagers have been proposed using two different technologies – conventional CCD/CMOS imagers and active pixel sensors.

CCDs have the current major advantage in that high-performance, low-noise imagers with frame rates up to several kHz are available. The next technology addition is to incorporate timing, analog processing, and digital conversion to an imager without compromising its noise and image quality. Work is currently in process to add a digital converter; to an imager, eliminating the need for external analog processing and its associated system complexity.

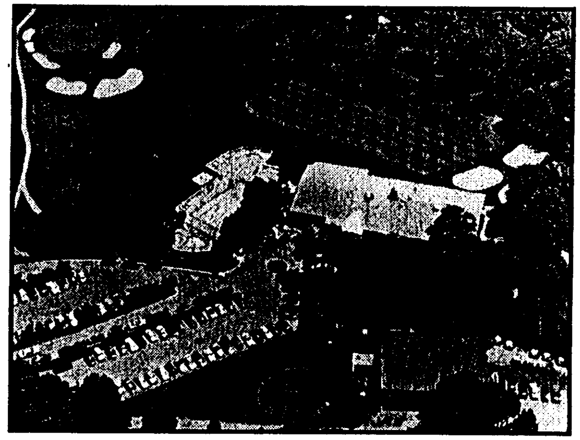
Active pixel sensors (APSs) have the advantage that they can have adaptive resolution and processing at the photosite prior to readout. Current performance lags that of CCDs, but progress is being made to resolve some of the performance shortfalls. The lower fill factor of an APS photosite is being addressed two ways – with microlenses concentrating the light onto the photosensitive area, and with higher resolution lithography, reducing the overhead area required by the active electronics in the photosite. Some combination of the two is likely to yield the best systems solution.

MINIATURE IMAGING SYSTEMS

VISIBLE CAMERA LAYOUT



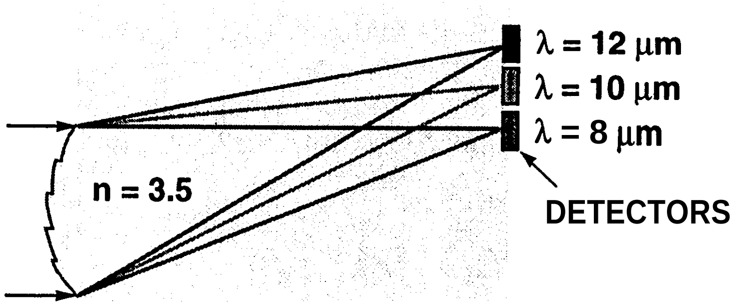
SAMPLE VISIBLE IMAGE



100 m ALTITUDE, 45º ASPECT
40ºx 40º TOTAL FOV
1000 x 1000 pix; 4-BIT GRAYSCALE

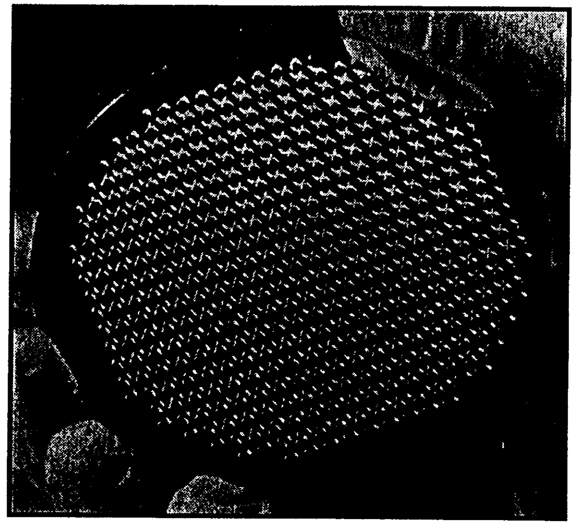
BINARY MICROOPTICS

- CONSTRUCTION BY MICROLITHOGRAPHY
- EASE OF MANUFACTURE (Replication)
- LOW WEIGHT AND COST
- IMPROVED EFFICIENCY
- UNIQUE ELEMENTS (Design and Materials)



MULTI-SPECTRAL IMAGING 8-12 μm

F/1 MICROOPTICS



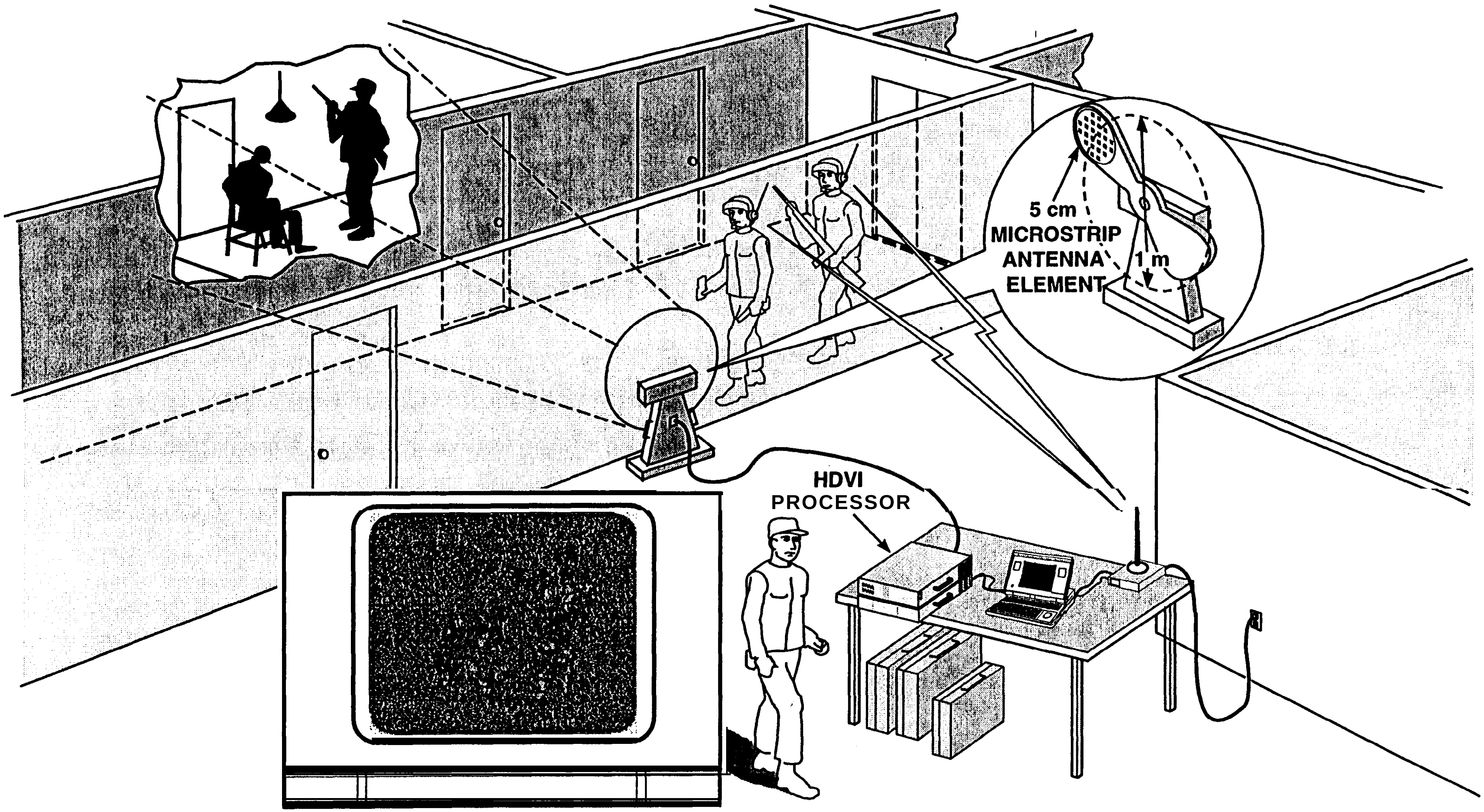
Man-Portable Through-The-Wall Radar

The effectiveness of many small unit (combat cell) operations would be enhanced by a synthetic aperture radar (SAR) image of the scene on the other side of an obstructing wall. Propagation phenomenology does permit radar energy to penetrate walls constructed of many common building materials if. the operating frequency is sufficiently low (below 400 MHz). But with such a long wavelength, target resolution is usually inadequate. Recent development of High Definition Vector Imaging technology has shown that operationally useful resolution can be obtained with a radar operating at these low frequencies.

A radar able to "see" inside a building can be installed in a delivery van; another man-portable design can "see" inside the next room. Although this technology is in its early development stages, the following capabilities should be available in a ten-year time frame:

1. Image resolution sufficient to detect and track concealed weapons;
2. Image capture rates sufficient to limit blurring to less than one pixel due to typical human motion;
3. High mobility, including man-portable units for deployment in large building complexes, and covert vehicle-mounted systems;
4. Image update rates sufficient for near real-time support strike forces;
5. Ability to penetrate typical building wall materials; and
6. Low-cost for widespread deployment among small units (combat cells) operating worldwide.

MAN-PORTABLE THROUGH-THE-WALL RADAR



SYSTEM OPTIONS

- DETECTION
- MOVING TARGET TRACKING
- STATIONARY / MOVING TARGET IDENTIFICATION

Counter-Sniper System

This chart illustrates a virtual line-of-sight counter-sniper system. The multi-site, bistatic radar system shown utilizes two systems using a single radar transmitter and a set of netted receivers. In the concept shown, the transmitter/receiver is mounted on a HMMWV; several receivers (e.g., on telephone poles, in-building, and a head-mounted receiver) are included as alternatives. If the system is to operate in a limited corridor, a restricted field-of-view antenna could be used to provide a narrow beam in both azimuth and elevation directions to enable lower transmit power requirements. Precision siting of the receivers can be easily accomplished with GPS receivers, and the geometry of the system is very flexible.

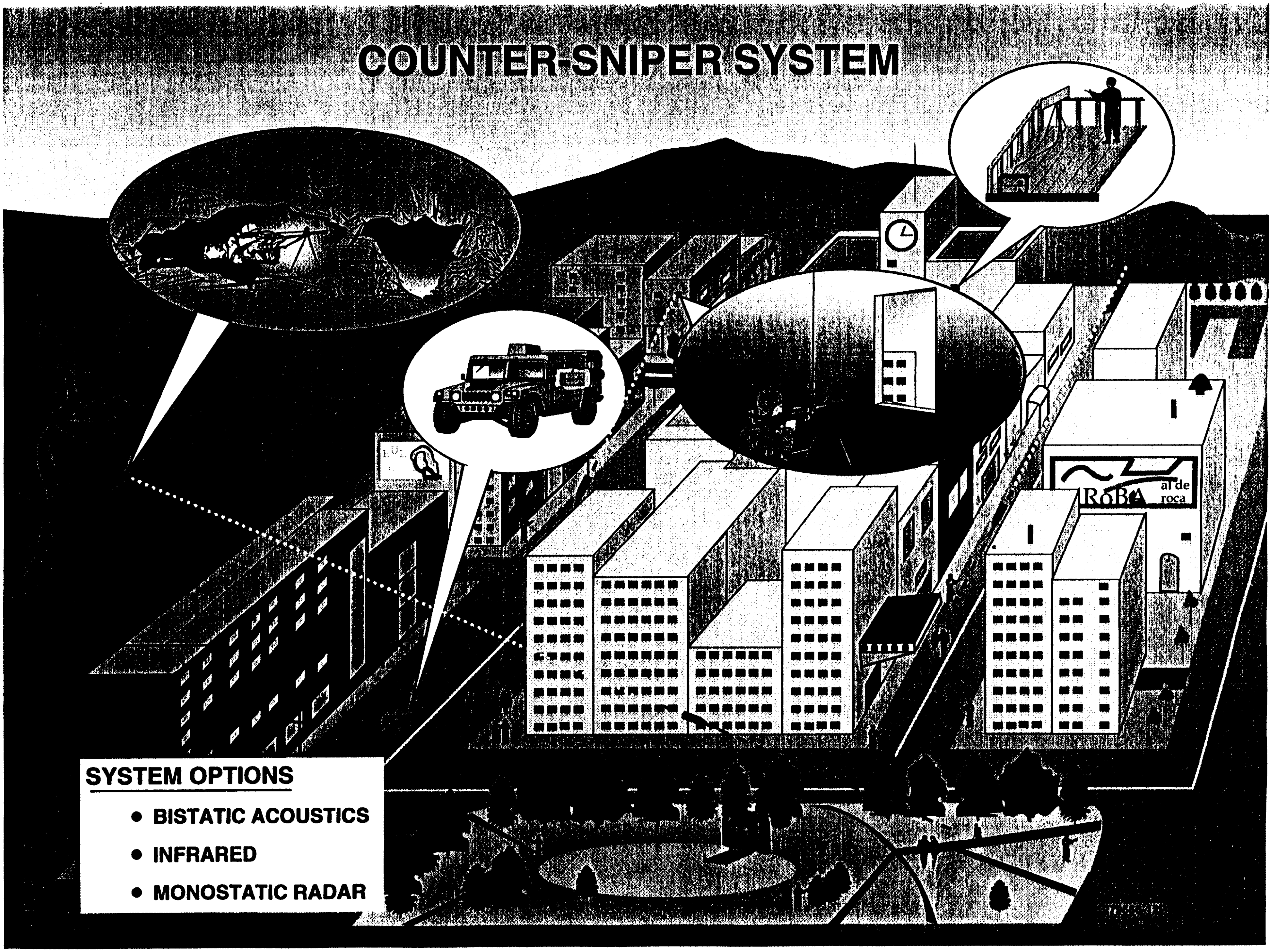
Acoustic and optical approaches suffer some critical shortcomings, primarily that they are subject to tactical countermeasures that prevent the sensor from having a line-of-sight view of the sniping weapon muzzle. In addition, acoustic sensors have poorer accuracy than IR or radar sensors. The radar tracks the sniper bullet along a portion of its trajectory and extrapolates back to the firing point which need not be in view of the sensor. Typical radar deployments would focus on the area to be protected rather than on the locations where snipers might be located. The radar options allow the use of lower power transmitters with small antennas, suggesting hardware cost can be low.

The figure illustrates the sniper shooting geometries. Hidden snipers operating from inside buildings or from bunkers avoid accurate location by acoustic sensors or sensors which depend on muzzle flash for detection/location.

System concepts to meet these goals must achieve these objectives:

1. High accuracy sniper location determination, with a 5-foot maximum horizontal error;
2. Operation with partly obscured bullet flight path, with the required accuracy being achieved with 100-300 m observation of a 1-km flight path being visible;
3. Capability to detect, backtrack, and locate the first bullet;
4. Sufficient sensitivity to handle 5.45 mm to .50 cal bullets;
5. Operationally appropriate size.

(C


COUNTER-SNIPER SYSTEM
SYSTEM OPTIONS
• BISTATIC ACOUSTICS
• INFRARED
• MONOSTATIC RADAR

A Compendium of Non-Lethal Weapons

The table offers a top-level summary of the wide variety of non-lethal weapons that have been proposed and developed – with varying levels of maturity. The relative lack of operational experience and bio-effects data for many of these technologies makes it difficult to identify clear "winners" for deployment. However, the roles for non-lethal technologies could be many, e.g.,

- Conducting operations in the presence of non-combatants and civilians
- Neutralizing equipment and vehicles
- Stopping moving targets for lethal kill
- Reducing damage to facilities and buildings
- Buying time / evasion / escape
- Maintaining concealment / covertness (when the available lethal alternatives provide a location signature)
- Engagement escalation control
- Neutralizing targets that cannot be engaged with explosives, such as a WMD facility.

A Compendium of Non-Lethal Weapons

Mechanical

Kinetic energy
(projectiles, fluids)

Binding agents
(entanglements, sticky foam, adhesives)

Conductive devices
(particles, ribbons, ...)

Obscurants
(fogs, smokes)

Sabotage devices
(fillers, caltrops, coatings)

Electromagnetic

High -energy particles

X-ray devices

UV lasers

Visible light
(lasers, beams, omni-directional sources)

Microwave
(deception, antipersonnel, HPM)

Radio wave, EMP

Direct current
(stun, cattle prod, vehicle stopper)

Chemical

Material modifiers
(viscosity, corrosive, caustic, embrittling, depolymerization, combustion, soil/cloud destabilizers)

Anti-biologicals
(calmatives, gastrointestinal, neuropharmacological, irritants, odors, livestock agents, herbicides)

Supporting Technologies

Delivery vehicles
(robot, UAV)

Sensors
(shock, location, WMD,intrusion,...)

Misc.
(Personal ID, translators)

Acoustic

Subsonic, Sonic, Ultrasonic
(acoustic projection/jamming, infrasound, flash bang)

Biological

Organic biocides

Consuming Organisms

Pathogens

Non-Lethal Technologies for Access Delay/Denial

The chart selects one role for non-lethal technologies and highlights some of the available and developing options. (Note: "Caltrops" are tetrahedral "jacks" with sharply pointed ends. When deployed with a sticky foam in the path of a vehicle, as illustrated in the photo, forward motion of the vehicle is quickly stopped.)

Non-Lethal Technologies for Access Delay / Denial

Aqueous Foams

Entanglements/Barriers

Sticky Foam

Caltrops

Low-Temp. Pyrotechnic Smokes

Urban Operations — Summary

A host of technologies could provide the combat cell much greater operational capability in the urban setting. To deal with communication and visualization constraints beyond line-of-sight, autonomous mini- to micro-platforms and sensors, both airborne and on the ground, are key. Target localization is dependent on the scenario, but the combat cell's tool kit should include robotics with capabilities to map, locate, sense, and tag, as well as more conventional systems available or currently under development for hostile fire detection and response, and appropriately packaged low-frequency geolocation systems to tie with GPS positioners for operations inside buildings. Target neutralization is complicated by the presence of neutrals and noncombatants and by the desire to preserve the infrastructure. Therefore, non-lethal options become a critical additional capability in accomplishing many missions in the urban environment.

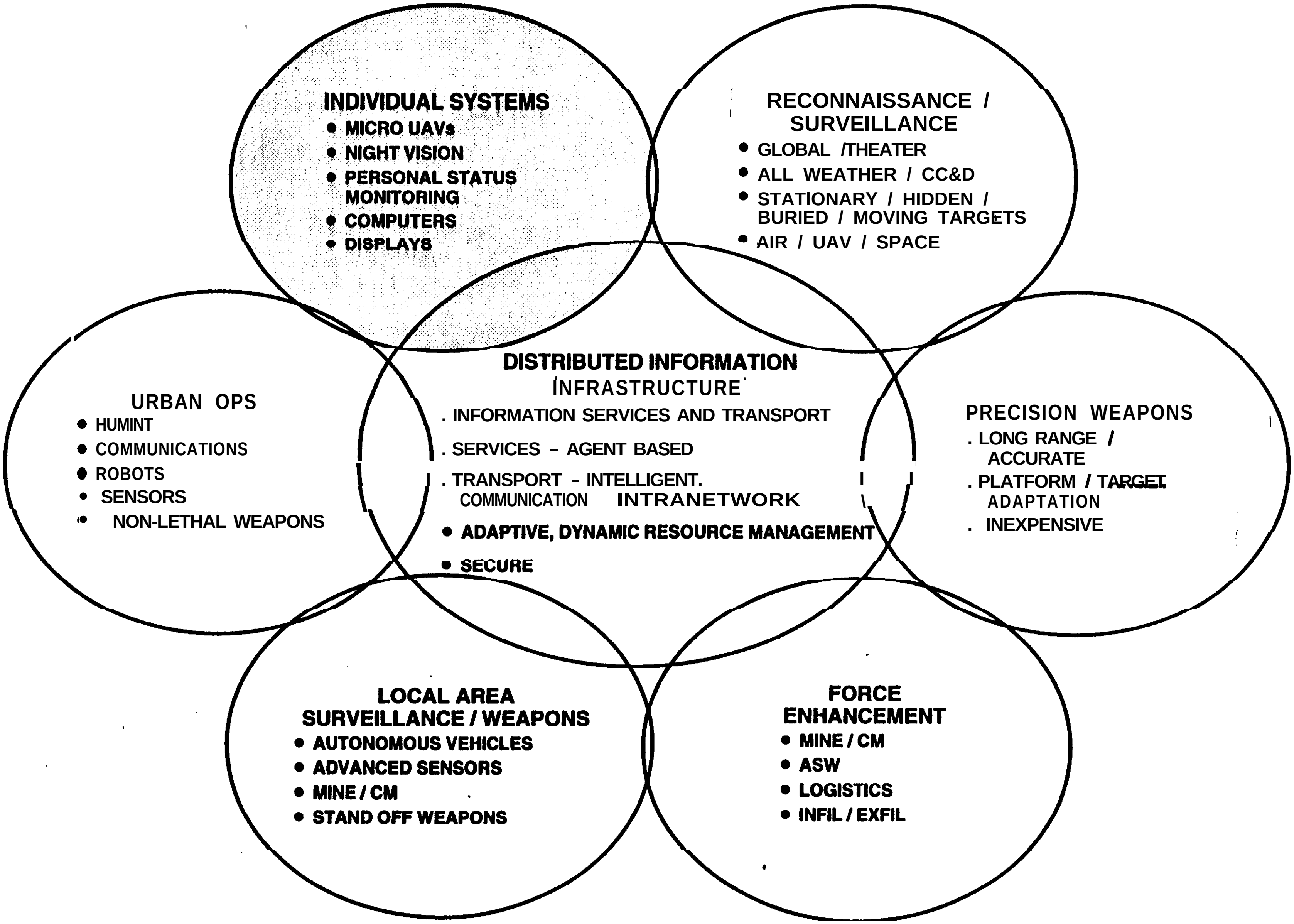
Urban Operations — Summary

- Communications and visualization beyond line-of-sight
  - Small-to-micro UAVs and robotic assistants
  - Sensors for detection and characterization of targets within buildings
- Target location and neutralization
  - Covert RF or chemical tagging systems
  - Robotic mappers, locators to infiltrate building
  - Low frequency and GPS geolocation systems
  - Sniper / hostile fire point detection and response systems
- Non-lethal weapons
  - Robotic sentries and area control barrier concepts (e.g., foams, smokes, nets, dumb- and smart bean-bags, caltrops, smoke / obscurants)
  - Temporary personnel incapacitators (e.g., acoustic, microwave, holography, spotlights)

Individual Systems

TACTICS AND TECHNOLOGY FOR 21st CENTURY MILITARY SUPERIORITY

TECHNOLOGY CONCEPTS PANEL



Individual Combatant Systems — Goals

Inherent in our vision for the future force comprised of dispersed, small combat cells is the need to "lighten the load" on individuals to provide them both greater mobility *and* enhanced warfighting capability at the same time. The Technology Panel reviewed the six areas shown in this chart. A brief discussion of a subset of these follows.

Individual Combatant Systems — Goals

Reduced individual load from current 90 lbs while providing enhanced capability:

- Precision geolocation
- Improved night vision goggles
- Personnel status monitors
- Improved displays
- High performance power sources
- Advanced miniature radios

Geolocation

Inherent in the concept of the dispersed, small combat cell is the ability for an individual troop to identify his position precisely (including within urban areas). Low-power, miniaturized technologies are being developed to assist in the geolocation of dismounted troops. This chart depicts three functions that are being integrated into a handheld situational awareness system:

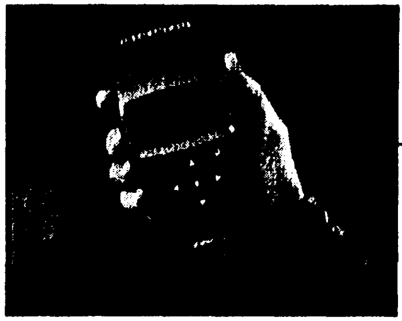
1. A miniature, multichannel Global Positioning Svstem (GPS) receiver. This receiver will have low power components and power management features to extend endurance of operations and battery life.

2. An all digital, miniaturized LORAN navigation set. LORAN frequencies are lower than those of GPS, and, therefore, are more available and reliable in the shadow of (or inside) urban structures, forest canopy, etc.

3. Microelectromechanical altimeters. The problem of geolocation inside urban structures includes the need for identifying vertical position, i.e., determining the floor on which the troops are operating. Accordingly, microelectromechanical altimeters are being investigated for vertical position measurements.

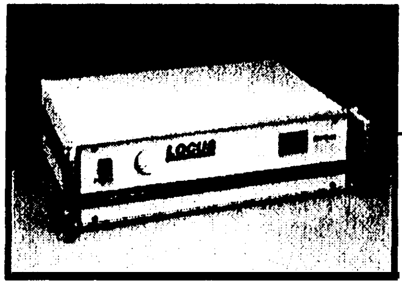
Not shown, but also being considered, are microelectromechanical inertial sensors consisting of a triad of low power, lightweight, low cost instruments that sense three dimensional displacement and rotation.

Geolocation



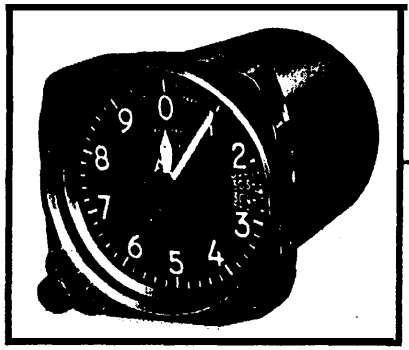
GPS Receiver

Power Manage
Miniaturize



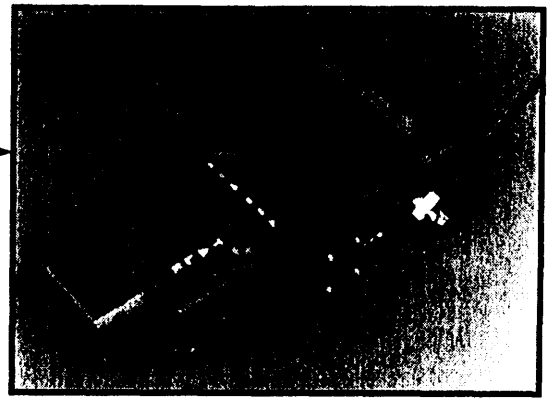
Loran Receiver

Digital
Miniaturize



Altimeter

Micro
Electromechanical



Integrated Handheld Locator

Advantages

- Robust Geolocation and Navigation
  - Integrated GPS/Loran
- Precision Operation in Urban Areas
  - Inside Buildings
- Low Power, Low Duty Cycle Operation
  - Reduced Battery Requirements

Electronic Vision Enhancement Goggles

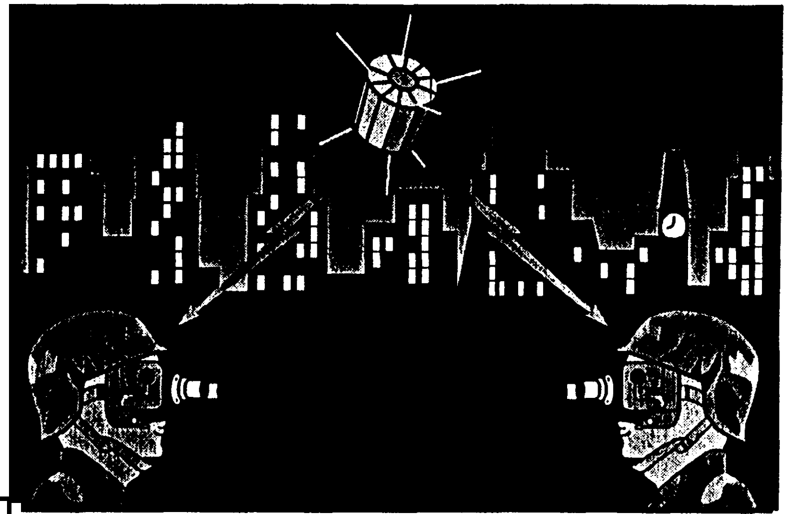
It is paramount to realize that, as we advance the soldier's vision enhancement capabilities, our adversaries are doing this as well. A good example is night vision. "Owning the night" is an important tactical advantage our forces currently enjoy. However, our adversaries can now purchase Gen II intensifier tubes, and soon there will be available Gen III tubes and uncooled thermal IR imagers in the commercial market place. Solid state imaging technologies will lead to robust and inexpensive night vision systems available to all forces.

Technologies that support enhanced visual perception and eye safety for soldiers on the battlefield (including urban battles) will be critical for small force success. Operating in a dangerous urban environment in battle will demand that each soldier have Electronic Vision Enhancement Goggles (and weapon sights) able to see through and cue in day, night, fog, rain, snow, dust, and smoke. Through the miniaturization and integration of low-light CCD and thermal imagers, computing electronics, displays, GPS, broadcast/receive electronics, low power IC technology, and all important lightweight battery technology, the soldier will be able to see through the cloak of darkness and obscuration and even see around the corner (through the sensors of a mobile ground robot or a fellow soldier). He will be able to "shoot/launch" a smart mobile micro-robot imaging sensor (and listening device) into a building and view (hear) the interior before entering. He will be able to see overhead views provided by micro/mini-UAVs. Overall situational understanding will be greatly expanded, and remote commanders will understand the situation from the perspective of the soldier as it evolves in real-time, leading to safer and more effective small force operations in urban areas.

Electronic Vision Enhancement Goggles

NEW CAPABILITIES

- WIDE FOV COLOR DAY / NIGHT VISION
- FOG / HAZE / SMOKE PENETRATION
- CHEMICAL MAP IMAGING OF SCENES
- SEE THRU EACH OTHER'S GOGGLES
- VIEW STATUS MAPS FROM HOME BASE
- EYE PROTECTION FROM LASER AND CHEMICAL ATTACK



IMPLEMENTATION

- IMAGE IN MULTIPLE SPECTRAL BANDS
- INTEGRATED IMAGE PROCESSING
  - CONTRAST ENHANCEMENT AND FUSION
  - MOTION / FLASH / CHANGE DETECTION
  - CHEMICAL SPECTRA RECOGNITION
  - IMAGE COMPRESSION / RECONSTRUCTION
- INTEGRATED GPS AND COMPASS TAGS IMAGERY WITH LOCATION AND ASPECT
- INTEGRATED IMAGE TRANSMIT / RECEIVE OVER WIRELESS MOBILE COMM NET

ENABLING TECHNOLOGIES

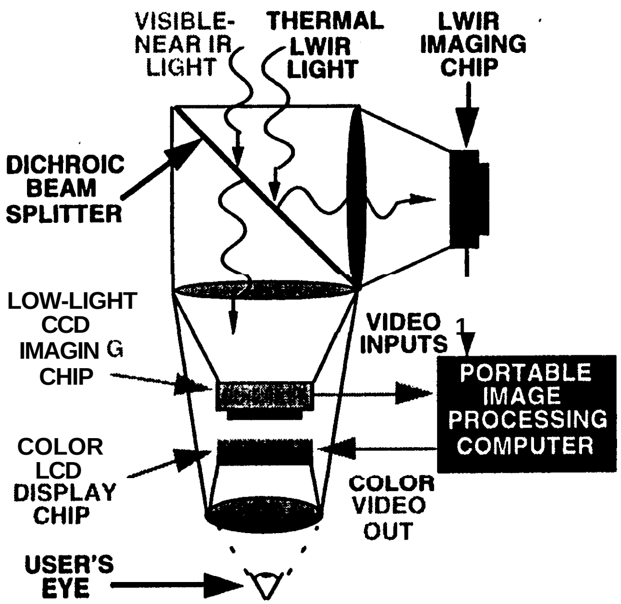
- SUPER SENSITIVE LOW-NOISE CCDs
- MINIATURE HYPERSPECTRAL IR FPAs
- NEUROMORPHIC IMAGERS AND OPTICS
- LOW-POWER HIGH RES COLOR HMDs
- ULTRA-LOW POWER ICs
- 3D STACKABLE THIN FILM ICs
- IMAGE PROCESSING ASICs
- PATTERN RECOGNITION ASICs
- HIGH DENSITY BATTERIES

Color Fusion Night Vision Device

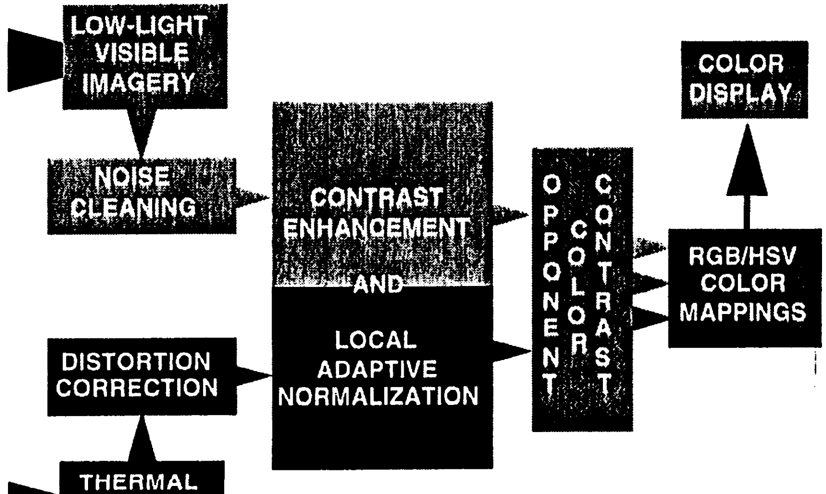
Shown is an apparatus and methodology to support real-time color imaging for night operations. Registered imagery obtained in the visible-through-near-IR band is combined with thermal IR imagery using principles of biological opponent-color vision. Visible imagery is obtained using a Gen III image intensifier tube fiber-optically coupled to a conventional CCD, and thermal IR imagery is obtained using an uncooled thermal imaging array. The two fields of view are matched and imaged through a dichroic beam splitter. Realistic color renderings of a night scene is illustrated. Both grayscale and color fusion of intensified-CCD/FLIR imager obtained have been demonstrated. Progress in the development of a low-light-sensitive CCD imager with high resolution and wide intrascene dynamic range, operating at 30 frames/sec, has also been achieved. An example of CCD imagery obtained under controlled illumination conditions, from full moon down to overcast starlight conditions and processed by our adaptive dynamic range algorithm is shown. The combination of low-light-visible CCD imager and thermal IR microbolometer array in a single dual-band imager, with portable image processing computer implementing neural net algorithms and a color LCD display, yields a compact, integrated version of a system in the form of a solid state color night vision device. These systems have application to a large variety of military operations and civilian needs.

Color Fusion Night Vision Device

SYSTEM SCHEMATIC

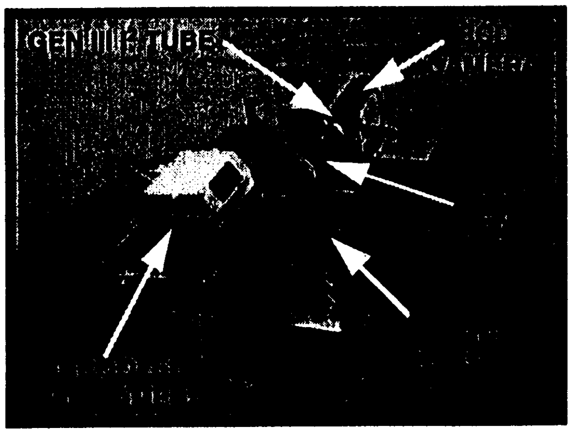


PROCESSING SCHEME

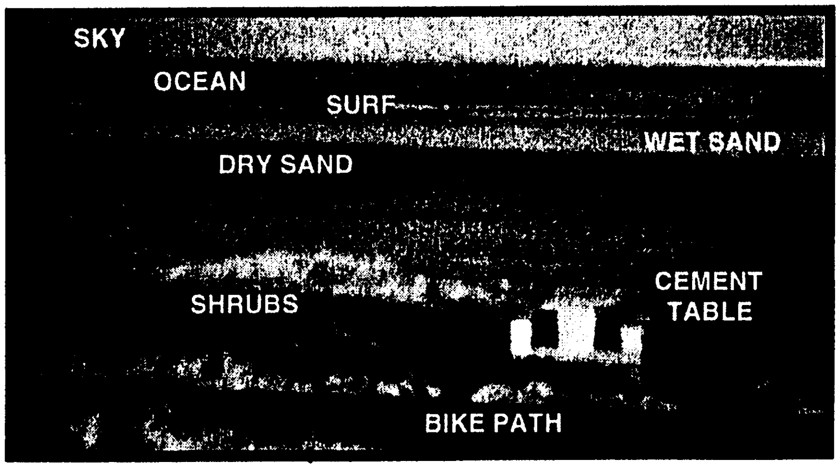


COMPUTATIONAL LOAD 75 ops/pixel
LATENCY < 33 msec (1 Frame)

EXPERIMENTAL SENSOR POD



FUSED COLOR IMAGE
NAHANT, MA ; OVERCAST MOON; JAN 14, 1995



Personnel Status Monitor

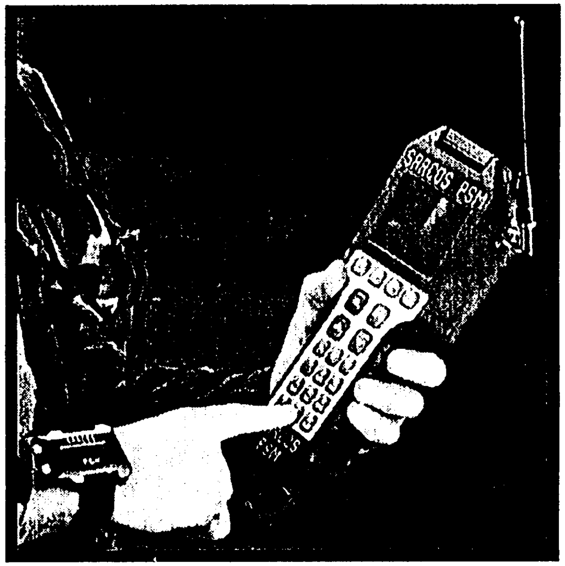
The key to successful trauma care on the far-forward battlefield is the presence of a smoothly functioning emergency medical system prior to the occurrence of injuries. For emergency medical care on the "digital battlefield" of the future, the keystone will be the Personnel Status Monitor (PSM) System. The goal of PSM is to revolutionize patient acquisition on the battlefield and substantially improve combat casualty care. PSM is a multicomponent system designed to reduce battlefield mortality and morbidity by determining life state, physiologic condition, and geolocation of each individually identified combatant.

Prior to injury, PSM Soldier Units will determine, record, and, upon request, wirelessly transmit to PSM Medic and Command Units the physiologic conditions and geolocation of combatants. This information will permit commanders to monitor the readiness of their troops and avoid injury to friendly forces. Immediately following injury, the PSM Soldier Unit of each casualty will transmit to a PSM Command Unit the geolocation, life state, and physiologic state of that individual. Expert systems logic will rank the severity of injury of multiple casualties, determine the distance and direction of those casualties and then prioritize data to Medic Units. This will permit medics to rapidly reach those casualties who may benefit most from urgent care — and avoid the risks and costs associated with attempting to aid those who will not benefit.

The PSM System promises several significant improvements in battlefield medical care. The ability to locate and identify friendly forces will reduce fratricide (friendly fire accounts for 20-25% of American combat deaths). Medical attention will be directed promptly to those casualties who will benefit most, and resources will not be risked on those who will not benefit (about 20% of casualties are sustained in the act of trying to help others). The ability to promptly identify both the occurrence and location of a casualty will avoid delay in initiating care beyond the "golden hour," during which interval treatment is most likely to prevent death or disability. The availability of physiologic data and protocols to guide initial evaluation and management will improve trauma care in the field. Ongoing monitoring and recording of physiologic data during evacuation — with expert systems to identify conditions that warrant an alert — will avoid discontinuity and reduce risk of care during transport to and through higher levels of care. Finally, the ability to simulate and present physiologic data representing a variety of combat casualty conditions will help develop and maintain combat casualty management skills during peacetime.

Personnel Status Monitor

- Sensor Unit (Non-invasive probes)
  - ♦ body shiver reflex
  - ♦ blood pressure
  - ♦ saturation oxygen
  - ♦ skin temperature
  - ♦ body position
  - ♦ respiration rate
  - ♦ heart rate
  - ♦ transdermal pH
  - ♦ cardiac output
  - ♦ motion
- Sensate Lining (future)
- Soldier Unit (with body "LAN")
  - ♦ Global Positioning System
  - ♦ Identify Friend or Foe (IFF)
- Combat Medic Unit
- Command Post Unit



Advanced Battlefield Casualty Care

Advanced technologies are being exploited to project greatly enhanced casualty care to the zone of close combat. The result will provide the first opportunity in two centuries to dramatically impact combat casualty mortality and morbidity – a projected saving of 30-50 percent of lives traditionally lost in far-forward areas of the battlefield.

Approximately ninety percent of combat deaths occur in the zone of close combat prior to medical or surgical intervention, and fratricide continues at casualty rates as high as 20%-30%. Casualty location is a continuing battlefield problem. Realistic peacetime combat medical and surgical training is minimal. Medical Theater-of-War communications have been archaic and non-functional. Here we summarize the objectives and accomplishments of the different facets of the Advanced Battlefield Casualty Care program:

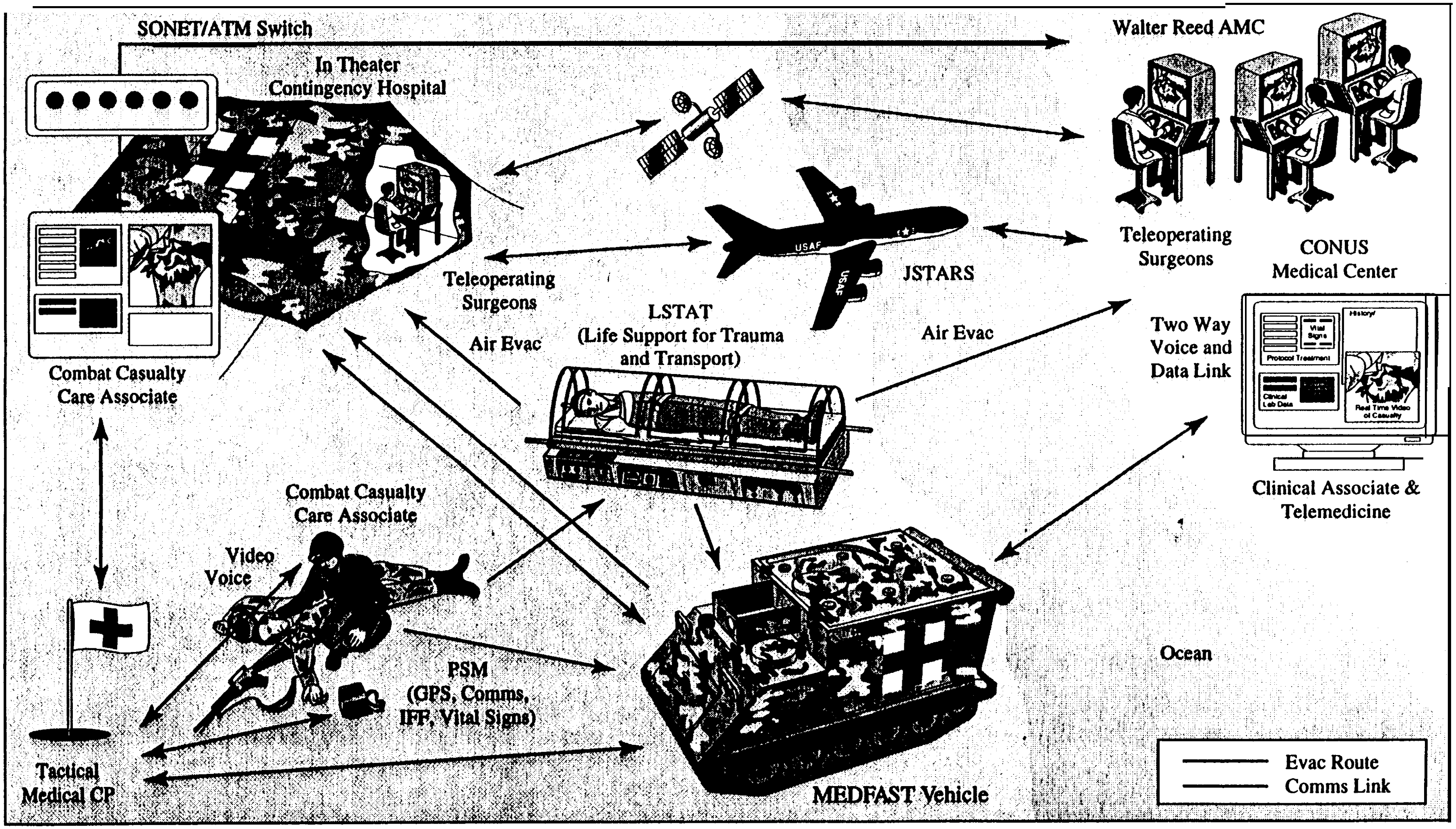
The goal of the Advanced Biomedical Technologies Program is the development of technologies for far-forward, non-invasive diagnosis, more immediate medical and surgical intervention, advanced simulation to improve the training of battlefield health care providers and to ensure skill currency, and the development of an advanced health, care information infrastructure to support the entire combat trauma care technology base.

The Health Information Infrastructure Program (HIIP) program is developing a blueprint for "Any Time, Any Where" useful health information. The technologies and tools will focus on the user and understanding their needs. They will form the basis of a new approach for managing the development and evolution of health information systems which are affordable, interoperable, extensible and evolvable. The blueprint will define a common architecture for heterogeneous components which will substantially reduce acquisition costs, time and risk to deploy health information systems for DoD and the nation.

The Ultrasonic Imaging Program is aimed at acquiring high-resolution, real-time ultrasound images using portable hand-held devices (with 2-D planar arrays) and the transmission of these images (tele-ultrasound) to rear echelons. Focus must be upon high quality image acquisition and real-time display of 3-D images in a format that reproduces the normal patient anatomy.

Into its second year of development, the Personnel Status Monitor (PSM) system is an integral part of the 21st Century Land-Warrior program (21CLW), GEN II program of SARDA. The PSM, described in the previous chart, is to be worn by the individual combatant for tactical and medical dual-use allowing the location of combat casualties and IFF for the tactical command. It consists of a triad of devices based on a suite of biosensors for vital signs, global positioning, and data communications. As discussed above, interpretation of critical life-status and its sequelae will enhance medical command and control, and allow remote triage and intervention.

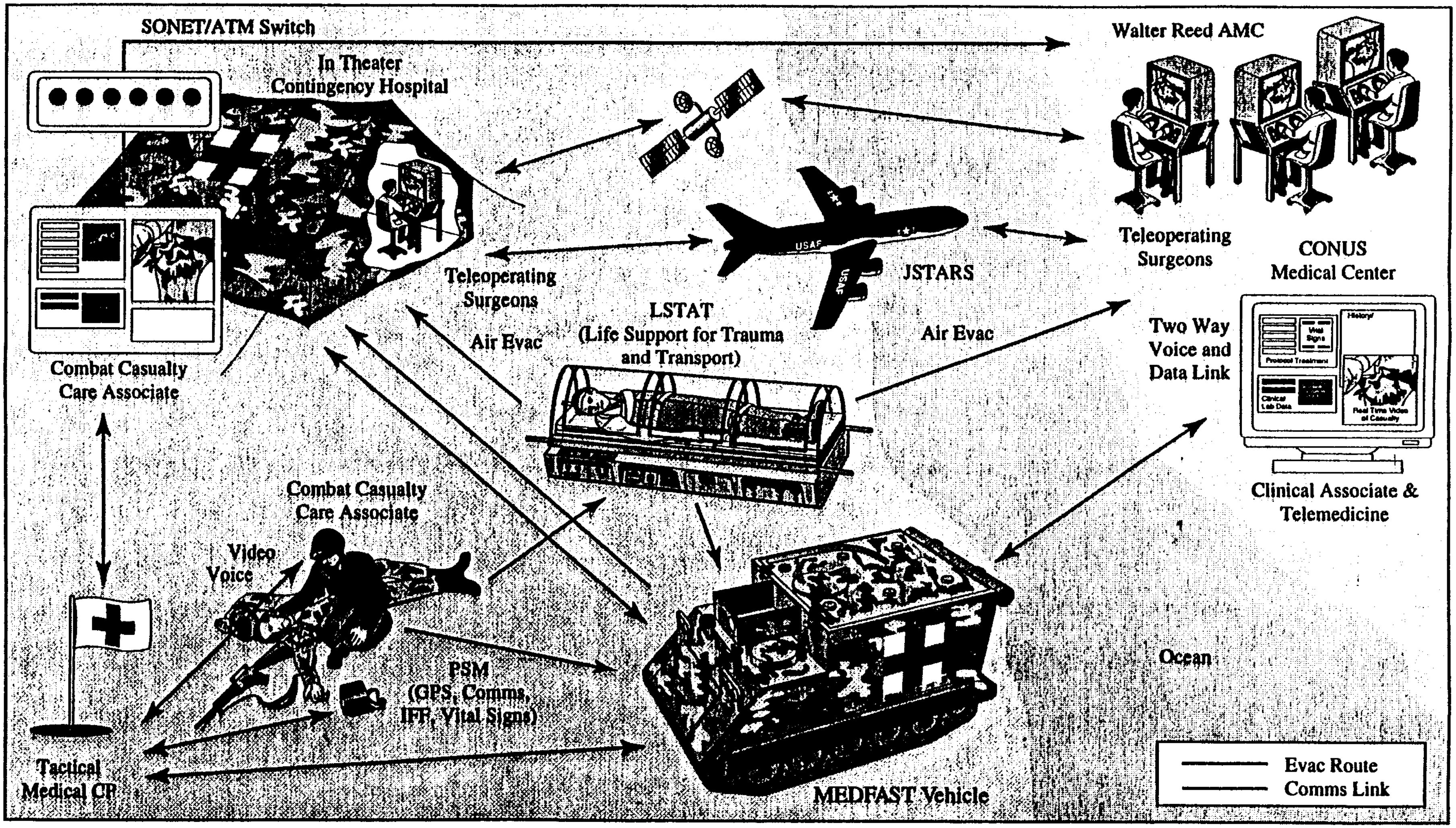
Advanced Battlefield Casualty Care



Remote telepresense surgery (RTS), in early prototype stage, demonstrates the creation of devices involving 3-D imagery, robotic surgical instrument manipulation, force feedback and haptic responses. The RTS prototype unit has demonstrated that remote surgery used in conjunction with telesurgical mentoring can be applied directly to battlefield surgical intervention bringing expertise of the surgical specialist into the battlefield, via telemedicine.

Life support measures to integrate into far-forward medical care, will enable the transport of casualties, previously too critically injured for evacuation. Development of a critical-care pod (LSTAT) is in prototype form that provides a ubiquitous evacuation platform containing biosensors, and intervention response capabilities.

Advanced Battlefield Casualty Care



AMEDD

Defense Sciences Office

Appendix: Technology Concepts Panel Members

Technology Concepts Panel Members

Vincent Vitto (Chairman)	Ira Kuhn
Delores Etter	Joshua Lederberg
Mike Frankel	Tom Meyer
George Heilmeier	John Nuckolls
Bill Howard	Dave Oliver
Dick Howe	Gene Sevin
Mim John	Rich Wagner
Herb Kotler	George Whitesides

Panel Support: Chip Smith