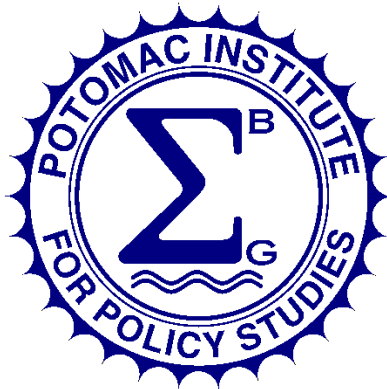

ANTIPERSONNEL LANDMINE ALTERNATIVES: ORGANIC REALTIME BATTLEFIELD SHAPING

PIPS-99-3

RESEARCH COMPENDIUM



30 SEPTEMBER 1999

POTOMAC INSTITUTE FOR POLICY STUDIES
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RESEARCH COMPENDIUM

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ANTIPERSONNEL LANDMINE ALTERNATIVES ORGANIC REALTIME BATTLEFIELD SHAPING RESEARCH COMPENDIUM

1.0 Introduction

This report covers nearly a year's worth of research on battlefield shaping as an alternative to the use of antipersonnel landmines (APL), including a summary of the background leading to this effort. It is intended to document the concept, approach, investigative work, meetings, and emerging findings for the Organic Realtime Battlefield Shaping (ORBS) effort. The report is provided by the Potomac Institute for Policy Studies to Dr. Thomas Altshuler, DARPA Program Manager for Antipersonnel Landmine Alternatives.

2.0 Background

There has been significant international and domestic pressure on the U.S. government to agree to the banning of antipersonnel landmines, whose indiscriminate use by Third World armies or insurgencies has caused heavy civilian casualties. The U.S. historically has used APLs for close-in force protection, to block expected invasion routes, and to protect antitank (AT) minefields. In contrast to the indiscriminate employment modes that drove the antipersonnel landmine ban, U.S. forces ensure that their minefields are well charted, closely monitored and carefully maintained (including removal at the conclusion of military need). In the special case of U.S. Special Operations Forces, APLs are used to delay hostile pursuit by larger enemy forces.

The Oslo Treaty, presented at the Oslo Diplomatic Conference in September 1997, addresses general obligations, definitions, destruction of stockpiled mines, clearance of emplaced mines, compliance, implementation measures, and amendments. The Treaty prohibits in all circumstances any use of antipersonnel landmines. The Clinton Administration supports this ultimate elimination of APLs, but insists on retaining them until a tactical equivalent is available.

The Department of Defense was therefore tasked to find other ways of accomplishing the APL mission without using APLs. That is, to find a way to accomplish the following on the battlefield at the unit level without using APLs: (1) deny maneuver, (2) introduce doubt, (3) cause confusion, delay, or diversion, (4) cause the enemy to make a rational, but wrong decision, (5) create the opportunity to prevent engagement, and (6) prevent a direct fire fight.

The Defense Advanced Research Projects Agency (DARPA) was directed in October 1997 to investigate approaches to developing alternatives to the use of antipersonnel landmines. During the first phase of this investigation, both near term (under the auspices of the Secretary of the Army) and far term (under the auspices of DARPA) options were examined. DARPA undertook the far term assignment by forming a Task Force that worked under the following terms of reference:

- Develop innovative concepts to provide a framework for technology recommendations to eliminate the attractiveness of landmines.
- Identify enabling technologies.
- Coordinate efforts with near term findings to avoid duplication and ensure continuity.

The results of the first phase were briefed to the Deputy Secretary of Defense (DEPSECDEF), recommending that an Antipersonnel Landmine - Alternatives (APL-A) Program be initiated. Four concepts were presented: (1) in-situ sensors/remote response, (2) remote sensors/remote response, (3) obstacles and diversions, and (4) mobile robots. Each concept was briefed to DEPSECDEF, along with their concomitant enabling technologies. The DEPSECDEF then asked DARPA to develop more details regarding known approaches, pursue and apply enabling technologies, and continue to search for new ideas. "DARPA will investigate maneuver denial approaches that may be more innovative and/or take advantage of advanced technologies." [Ref. 38]

Following the completion of the first phase, DARPA initiated the second phase of the study, focusing on the identified recommendations. DARPA approached this task through a combination of Task Force meetings and brainstorming sessions with organizations willing to engage in some original thinking about this issue for moving beyond the traditional approach to identifying technology alternatives. The suite of technology ideas resulting from these sessions was categorized into three areas: (1) in-situ sensors/remote response, (2) mobile robots and (2) obstacles and diversions. The enabling technologies within these categories included the following:

In-situ Sensors/Remote Response

- Tags/Minimally Guided Munitions (prevent or delay massive attack from dismounted forces)

Mobile Robots

- Self-healing Minefield (dynamic antitank minefield; mixed munitions)

Obstacles and Diversions

- Air Bag APL (extreme force to break ankle or foot; to protect and delay; counterbattery)
- Rapid Vehicle Halt (combustion inhibitors; to protect and delay; counterbattery)
- Advanced Spoofing (continually blur the boundaries between real and imaginary: realtime insertion of false images, holodecks, force multiplier).

DARPA's effort culminated in a report addressing the suite of technologies; the outcome of this report was for DARPA to establish a program to pursue both proposed mobile robots technologies, i.e., Self-healing Minefields and Tags/Minimally Guided Munitions, and Advanced Spoofing, i.e., Organic Realtime Battlefield Shaping.

The Potomac Institute for Policy Studies has provided continuity among these efforts as a whole, and was instrumental in building a case for probing into the entertainment

community's technologies and approaches for ORBS, to include advanced spoofing/special effects. The Institute was funded to continue the investigation of ORBS, and assist the Program Manager for Antipersonnel Landmine - Alternatives (Dr. Altshuler) in identifying possible concepts for ORBS to prove or disprove its viability. An approach, featured in this paper, is to employ a principle that has been exploited by military forces throughout history – deception.

3.0 Study Approach

The goal of this study was to identify technologies that could be applied at the unit level to develop tactical deception capabilities for organic realtime battlefield shaping that will achieve area denial, introduce doubt, cause confusion, delay, and diversion, as well as serve as a force multiplier.

We asserted that there is a universe of opportunities in the entertainment industry associated with special effects and perception management. By investigating filmmaking, stagecraft, technical theater, theme parks, and gaming we can learn more about technology efforts in areas such as projection, simulation, computer-generated imagery, and practical effects. These technologies could then be applied to ORBS to develop the appropriate tactical deception capability.

To support this assertion, the Potomac Institute proposed the approach displayed in Figure 1. A brief overview of each step is provided in the paragraphs below.

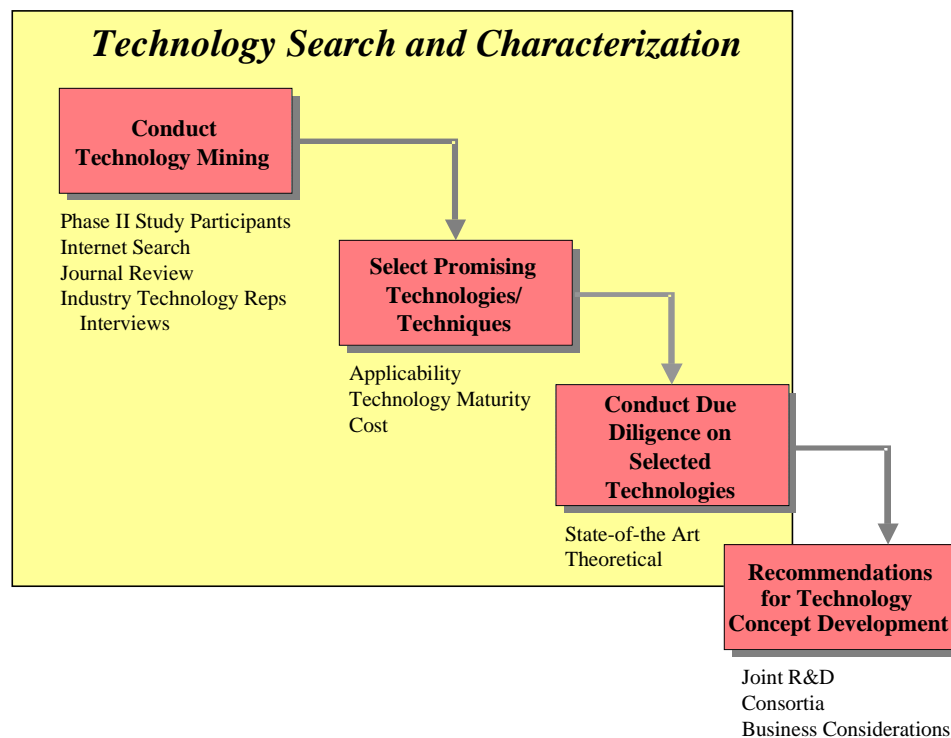


Figure 1. ORBS Technology Alternatives Approach

The first step in our approach was to conduct technology mining. To accomplish this, participants from the second phase of the APL-A Study were interviewed to provide insights into their recommendations. Multiple Internet searches coupled with journal reviews were performed to identify those technologies with potential relevance to ORBS. Interviews with the attendant industry technology representatives were conducted to gain additional information on the technologies.

In the second step, a qualitative assessment of the potential technologies was conducted to select promising technologies or techniques. In the assessment, three criteria were employed: applicability to the ORBS concept, maturity of the proposed technology, and the relative cost. This assessment was not intended to be comprehensive in terms of unambiguously determining the performance measures, fielded or lifecycle costs, or technical risks, but was intended to provide a general reference to the potential for near term development. Following this assessment, a subset of promising technologies was selected for further research, i.e., due diligence. Throughout this third step, broad reviews of the technologies, both state-of-the-art and theoretical, were performed to identify likely operational strengths and weaknesses, as well as any potential issues.

In the final step of our approach, recommendations for technology and concept development were provided for consideration by DARPA decision-makers.

4.0 Framework

“Organic Realtime Battlefield Shaping” uses tactical deception by means of visual, acoustic, and other sensory signals (tactile, smell) to disrupt an opponent’s situation assessment process, and to modify his behavior to the U.S. defender’s advantage. “Organic” means that ORBS technology/equipment is part of the tool set assigned to a typical squad, platoon, or company. “Realtime” refers to on-demand use of ORBS by a defending (friendly) unit. “Battlefield shaping” refers to the use of tactical deception in conjunction with terrain features, minefields, and other complex obstacles to influence the positioning and deployment mode of hostile forces on the battlefield. Historically, minefields composed of antipersonnel or antipersonnel and antitank mines have been an important element of battlefield shaping by (a) canalizing (channeling) an enemy’s approach; (b) deterring him from entering an area that is either mined or is perceived to be mined; and (c) delaying enemy pursuit of a retreating friendly unit.

ORBS proposes to employ tactical deception, a discipline well developed outside the U.S. in countries such as Britain and China, although with little application of advanced technology. The U.S. Army and Marines used deception systematically in World War II, albeit mostly positional (decoys such as rubber tanks and dummy aircraft), although elaborate acoustic, visual, and electronic ruses were used on D-Day to “pin” German armor units to Calais so that they were unable to support the beaches of Normandy. Recent examples of military deception include Serbia's use of dummy tanks in Kosovo and submarine acoustic decoys. Today, the most systematic use of deception is done by U.S. tactical aircraft and ships. Tactical deception by U.S. ground units relies principally on the use of decoys and sophisticated obscurants, and electronic deception.

The Department of Defense (DoD) defines military deception as actions executed to deliberately mislead adversary military decision-makers as to friendly military capabilities, intentions, and operations, thereby causing the adversary to take specific actions (or inactions) that will contribute to the accomplishment of the friendly mission [Ref. 6]. The five categories of military deception are strategic, operational, tactical, Service, and Operations Security (OPSEC). This study focuses on tactical military deception, i.e., military deception planned and executed by and in support of tactical commanders to cause adversary actions that are favorable to the originator's objectives and operations [Ref. 6]. Deception is also critical to the entertainment industry, where deceiving a person's observations and discernment processes using external devices is key to the industry's success. Our technology mining effort focused on those practices of the entertainment industry which could be used as a military deception tool, i.e., organic realtime battlefield shaping.

4.1 Elements of Behavior

Deception concentrates on five elements of behavior: (1) importance of the norm - people see what they expect to see; (2) simulation - objects are made to look like something familiar; (3) interpretation - ambiguity is resolved in favor of the familiar; (4) attention control - focus is drawn away from the critical element; and (5) suggestion and inducement - preconceptions and biases are used to control behavior. These five elements were mapped to the minefield functionality derived in Phase I of the APL Study and five candidate functions were chosen as compliant with military deception objectives.

4.2 Functions of Military Deception

The potential functions of deception in a military context can be described in terms of the effect that the deception has on the behavior or capability of the opponent. In this section we describe those candidate functions along with the technologies that may enable a U.S. military unit to eliminate the need for APLs.

The first of these functions, *instigation of avoidance/aversion behavior*, is a direct analogue of a primary function of minefields. By causing the enemy to detour around an area perceived as dangerous or impassable, friendly forces can protect vulnerabilities in their own positions, cause enemy delay, or can channel the enemy forces into routes that are advantageous to the friendly forces.

The second function, *attention diversion or attraction*, is also intended to create a delay or detour by enemy forces. It can also be used to hide the positions or movements of friendly forces by presenting the enemy with an alternative area, feature, or perceived movement which commands greater attention.

The *disorientation/confusion* function may be accomplished by presenting the opponent with observations which either conflict with each other or with previously established 'facts'. The purpose of the disorientation may be to cause the enemy to doubt current observations (either from instruments or subordinates) or to create uncertainty regarding

other information sources (e.g., maps or intelligence). In either case, the enemy commander is compelled to make decisions with less information or greater uncertainty, resulting in delay and poor decisions.

The *hiding* function is similar to that of camouflage, but is intended to be more robust. Simulation of objects that the enemy expects in the area to shift the enemy's focus away from the objects to be hidden, are potential mechanisms for this function.

Group coherence disruption is directed towards reducing the unit cohesion and effectiveness of enemy forces. This function is meant to cause delay in command decision-making and uncertainty or delay in the execution of orders.

These five functions can affect the enemy in some specific ways, as shown in Figures 2 and 3. The first four categories, listed in Figure 2, describe effects on individual combatants; the remaining category, shown in Figure 3, cites effects on small combatant groups. It should be noted that all of these effects have an impact on the decision cycle of enemy forces, i.e., the ability to receive and process information, and to make decisions and take actions based on that information. Any U.S. capability that extends an opponent's decision cycle time provides an advantage to U.S. forces, even if the ultimate enemy decision is the correct one (from the enemy point of view). Close-in, high-tempo operations can benefit from even short duration delays/disruptions to the opponent's decision cycle, while larger scale operation with inherently longer decision cycles would be significantly delayed only be deceptions that remain effective for long periods.

- **Instigation of avoidance/aversion behavior**
 - Perceived Obstacle
 - Perceived Threat - natural
 - Perceived Threat - force generated
 - Physical Discomfort
- **Attention Diversion or Attraction**
 - Friendly/Benign Environment
 - Threat/Opportunity Attraction
 - Non-specific Attraction
- **Disorientation**
 - Fact Conflict
 - Uncertainty Generation
 - Physical Disorientation
- **Hiding**
 - Masking/Camouflage
 - Dazzling



Figure 2. Deception Effects on Individual Combatant

- **Group Coherence Disruption**
 - Disagreement/Confusion over Commander's Intent
 - Disagreement/Confusion over Specific Orders

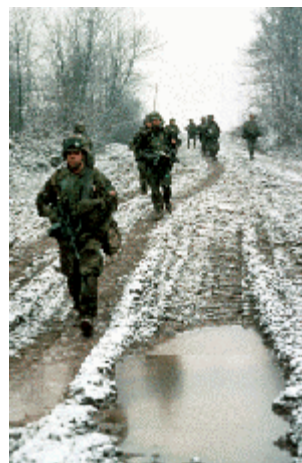


Figure 3. Deception Effects on Combatant Groups

5.0 Example Missions Using ORBS

In order to expand the use of deception and its enabling technologies, it is important to consider how deception might benefit combat operations. New doctrinal concepts, and the supporting tactics, will need to be developed to maximize the benefits of battlefield deception techniques. To illustrate these benefits, several example missions are proposed: disrupting enemy maneuvers, guarding allied movements, decoying enemy attention, and protecting non-combatants. In performing these deceptions, four means are used: projecting sound, smell, and images (the last will sometimes be holographic); employing infrared (IR) image generators and radar reflector patterns;¹ the use of non-lethal weapons, and disrupting communications. The last two mechanisms can be incorporated into the deception in order to cause confusion and to reinforce the projected image or sound. In each case, ORBS attempts to raise the perceptual “clutter-to-noise” ratio by generating the illusion of many false targets, or it can degrade the “signal-to-noise” ratio, much as chaff generates confusing clutter around a real target return. Tables 1 through 5 (see Results of Technology Search and Characterization Efforts Section) discuss how these projections could be accomplished and their specific benefits. Clearly, circumstances dictate to a considerable extent how effectively available technologies will create these deceptions. For example, projected images or sounds will be more effective at night when it is difficult to verify the projections. It is also important to note that the fidelity of the deception (which affects the time required to discover the deception) will depend on the nature of the surrounding military operations. Thus, high-tempo operations may benefit from short duration deceptions or disruptions, while operations at

¹ These IR and radar decoys can be combined, so that both radar and IR signatures are correlated. They can be delivered by artillery or rocket, or emplaced by hand. Once in position, they could transmit location so that the projected visual and sound images will overlay the IR and radar decoys. Such combination may not be necessary at the tactical level, however. If conflicting information is received from two sensors (one decoyed and one not decoyed) the resultant enemy decision cycle pause for data deconfliction may produce a militarily useful delay.

a more deliberated pace may need deceptions with longer effective time. The following paragraphs discuss each of the missions and a proposed concept of operations.

5.1 *Disrupting Enemy Maneuvers*

The goal of denying the enemy maneuver space and slowing the tempo of battle can be furthered by deception techniques if they offer a more attractive route, or make certain areas appear to be difficult or dangerous to enter. In the next two figures, projections are used to channel movement to desired avenues. Both images and audio may be projected in either case. In addition, IR image generators and radar reflector patterns may be employed to add validation to the tank sounds and visual projections.

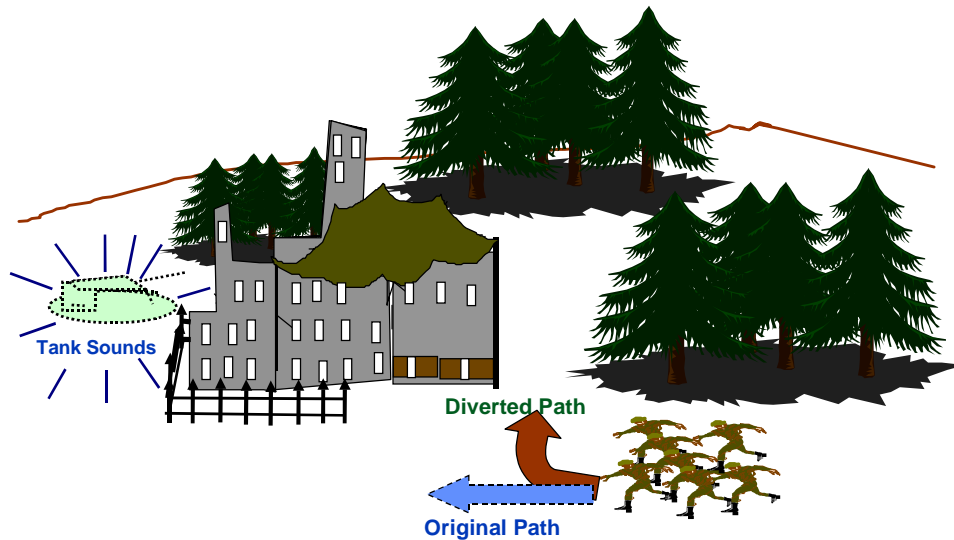


Figure 4. Disrupting Enemy Maneuvers by Channeling their Movement

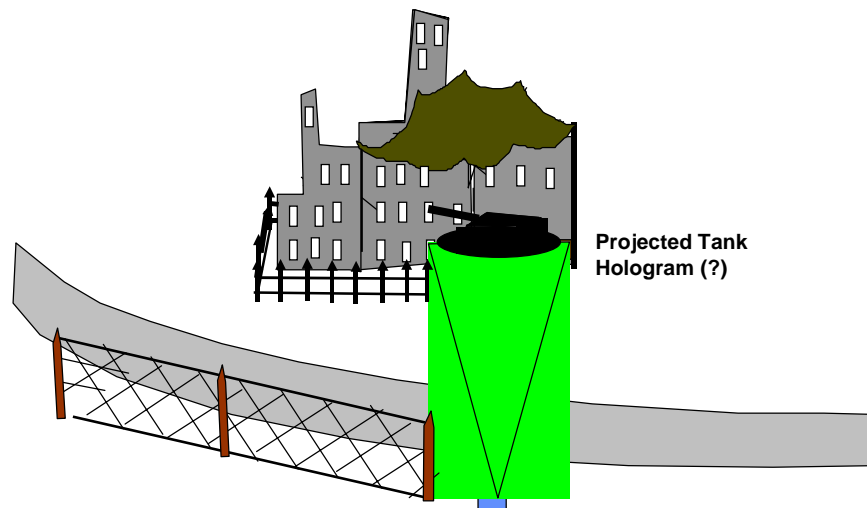


Figure 5. Disrupting Enemy Maneuvers in Urban Areas with Projected Images

5.2 Guarding Allied Movements

Creating the illusion that allied troop movements are more secure than is the case may allow maneuvers that would otherwise be blocked by enemy counter-moves.

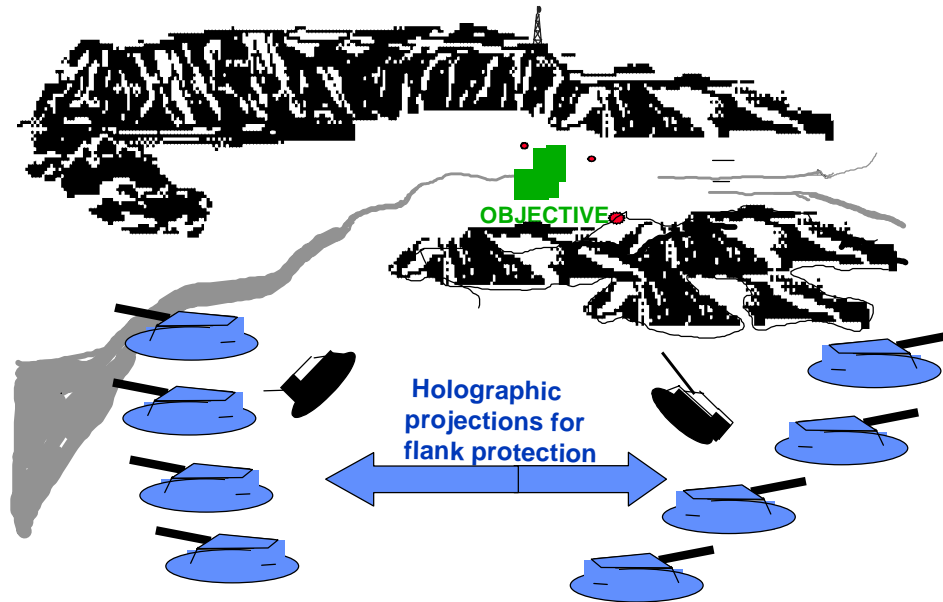


Figure 6. Flank Protection

Small unit flank protection may be possible through the projection of threatening images. Although this may not stop a sophisticated enemy, it may slow them down until they have confirmed the illusion. Audio and olfactory projections and flash lamps, as well as IR image generators and radar reflector patterns can reinforce the images.

5.3 Decoying Enemy Attention

Projections may also be used to divert the enemy's attention and movements. Images, troop movement sounds, and odors (e.g., diesel exhaust) may be used, singly or in combination, to deceive the opponent as to the actual area of friendly force concentration. This may be used to divert substantial enemy force maneuvers and also to add confusion in fire-fight scenarios. Close combat deception which causes an enemy commander to either delay decisions to advance or to redeploy troops against a non-existent U.S. force, may offer friendly forces significant self-protection or offensive tactical advantage. IR signature generators (solar or battery-powered) and radar reflector arrays could be inserted into the area by artillery or aircraft to further the illusion if the opponent has tactical use of remote sensing information. This is illustrated in Figure 7, below.

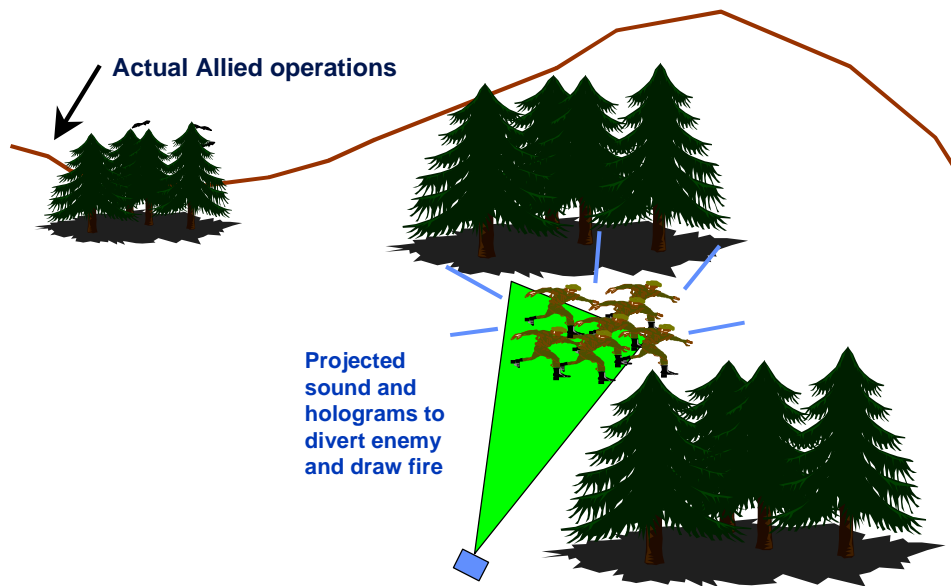


Figure 7. Decoy Concept

5.4 *Protecting Non-Combatants*

Significantly, today's battlefield often involves a large number of non-combatants. During the past few years, combat operations have affected cities, villages, and rural areas where the threat of civilian casualties inhibited deployment and engagement of U.S. troops. If deception could be used to keep the civilian population from dangerous areas or encourage them to move to and remain in safe zones, combat operations could proceed against the opposing forces without a concern for civilian lives. These same deception technologies could also be used to facilitate communication with non-combatants, as well. In Figure 8, the image of a soldier is projected into a position from which to negotiate with a group of civilians, to warn them of an impending attack, or to give them instructions concerning a planned allied bombing mission. Audio is projected as well, perhaps through translator software. This removes U.S. troops from exposure to sniper fire. If hostility is evident among the non-combatants, allied troops projecting the images can resort to the less-than-lethal weapons cited in Table 1. The projected image will also reveal the presence of snipers by drawing his fire. This concept could also serve civilian law-enforcement as well.

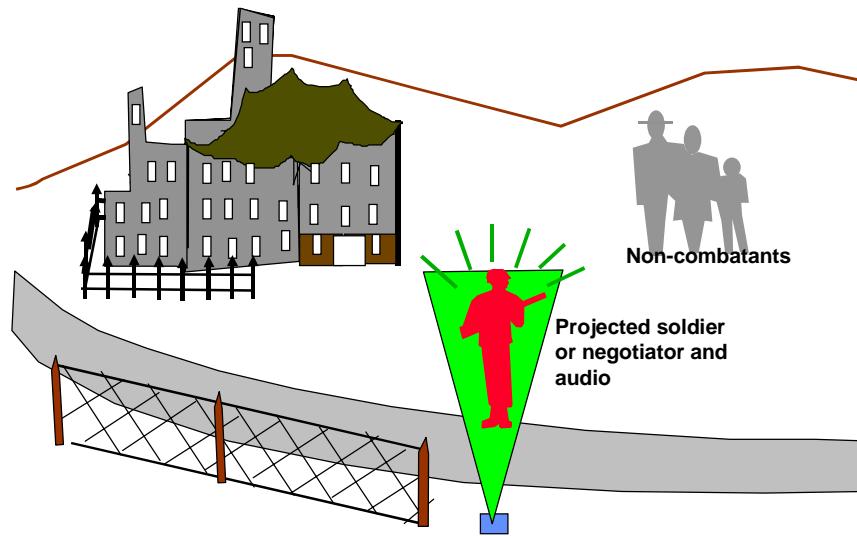


Figure 8. Instructions through a Projected Soldier

These are examples of deceptions with three purposes: (1) saving U.S. lives by delaying or avoiding the use of lethal force; (2) enforcing standoff, thereby avoiding the high casualty close battle; and (3) disrupting enemy decision cycles and situation assessments.

6.0 Results of Technology Search and Characterization Efforts

Our research focused on those technologies which might have applicability to the concept of battlefield shaping and was conducted through web searching, phone interviews, journal reviews, meetings, and source documentation examinations. The following series of tables and their concomitant descriptions address the intended deception effect, proposed operational effect, supporting technologies, operation and technical issues, and potential sources of the technologies. Additional detail on a technology's functional description, use, and maturity is provided in the sections following the tables.

Table 1. Instigation of Avoidance/Aversion Behavior

ORBS EFFECT	OPERATIONAL EFFECT	SUPPORTING TECHNOLOGIES	OPERATIONAL ISSUE(S)	TECHNICAL DEVELOPMENT ISSUE(S)	SOURCE(S)
Perceived Obstacle Project Images of Barriers or Obstacles (Projected on Image Planes of Opportunity or on Created Image Planes)	Causes Delay for Situational Assessment May Cause Additional Delay for Breaching Preparations May Cause Detour to Another Route	Audio and Video Projectors Materials for Projection	Clear Projection Field, e.g., LOS Increased Own Force Detection (Overt System) Logistics Equipment Positioning, e.g., Time, Range	Image Size and Fidelity Duration of Projection Integration/Matching with Ambient Optical Environment Glinting Color and Texture Mapping Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal. Santa Barbara U-N. Carolina
Perceived Threat, Natural Project Images of Natural Operational Threat, e.g., Fire, Hazardous Terrain, Inimical Animal Life (Projected on Image Planes of Opportunity or on Created Image Planes)	Causes Delay for Situational Assessment May Cause Additional Delay for Breaching Preparations May Cause Detour to Another Route	Audio and Video Projectors Materials for Projection	Clear Projection Field, e.g., LOS Increased Own Force Detection (Overt System) Logistics Equipment Positioning, e.g., Time, Range Culturally Influenced Perceptions	Image Size and Fidelity Duration of Projection Integration/Matching with Ambient Optical Environment Glinting Color and Texture Mapping Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal.- Santa Barbara U-N. Carolina
Perceived Threat, Force Generated Project Images of Force-Generated Operational Threat, e.g., Fire Zone, Tanks, Artillery or Bomb Detonations (Projected on Image Planes of Opportunity or on Created Image Planes)	Causes Force Redeployment to Defensive Posture Additional Delay may Arise from Preparation and Execution of Assault May Cause Detour to Another Route Incorrect Intelligence may be Relayed to Commanders and Additional Forces may be Committed to Area	Audio and Video Projectors Materials for Projection Aerosol/Olfactory Sources	Clear Projection Field, e.g., LOS Increased Own Force Detection (Overt System) Logistics Equipment Positioning, e.g., Time, Range Culturally Influenced Perception	Image Size and Fidelity Duration of Projection Integration/Matching with Ambient Optical Environment Color and Texture Mapping Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal.-Santa Barbara U-N. Carolina

Table 1. Instigation of Avoidance/Aversion Behavior (cont.)

<i>ORBS EFFECT</i>	<i>OPERATIONAL EFFECT</i>	<i>SUPPORTING TECHNOLOGIES</i>	<i>OPERATIONAL ISSUE(S)</i>	<i>TECHNICAL DEVELOPMENT ISSUE(S)</i>	<i>SOURCE(S)</i>
Physical Discomfort Provides Visual/Acoustic/Tactile Shock that is Non- Lethal	Causes Temporary Degradation in Warfighting Capability May Cause Retreat or More Rapid Advance	Tesla Lightning Sources Vortex Projectors Projector-Entrained Materials (Smokes, Irritants, Optical- Dazzler Particles/Chaff) Olfactory Sources	Effect Selectability Single/Multiple Effects Choice and Timing/Sequencing Effects Targeting (Single vs. Group) Logistics Own Force Vulnerability	Range Power Effect Assessment	American Technology Corp. Honeywell/Randi Foundation SARA/kVa Effects

Table 2. Attention Diversion or Attraction

ORBS EFFECT	OPERATIONAL EFFECT	SUPPORTING TECHNOLOGIES	OPERATIONAL ISSUE(S)	TECHNICAL DEVELOPMENT ISSUE(S)	SOURCE(S)
Friendly/Benign Environment Project Images of Advantageous Environment Clear of U.S. Forces, e.g., Clear Road, Good Concealment, Shelter (Projected on Image Planes of Opportunity or on Created Image Planes)	Isolate/Distract Individuals (Squad Leaders, Point Scouts) Detour to Selected Area Cause False Sense of Security; Reduction on Force Wariness	Audio and Video Projectors Materials for Projection Olfactory Sources	Effect Duration Source Delivery, Timing, Phasing Clear Projection Field, e.g., LOS Increased Own Force Detection (Overt System) Logistics Equipment Positioning, e.g., Time, Range Culturally Influenced Perception	Single-Combatant Behavior Image Size and Fidelity Duration of Projection Integration/Matching with Ambient Optical Environment Color and Texture Mapping Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal.-Santa Barbara U-N. Carolina
Threat/Opportunity Attractment Project Images of Advantageous Environment for Engagement with U.S. Forces, e.g., High Ground, Good Concealment, U.S. Forces in Apparent Exposed Position (Projected on Image Planes of Opportunity or on Created Image Planes)	Channeling (Create "Fire Sack" or Avoidance) Distract/Decoy (Escape and Evasion)	Audio and Video Projectors Materials for Projection Olfactory Sources	Effect Duration Source Delivery, Timing, Phasing Clear Projection Field, e.g., LOS Increased Own Force Detection (Overt System) Logistics Equipment Positioning, e.g., Time, Range Culturally Influenced Perception	Single-Combatant Behavior Image Size and Fidelity Duration of Projection Integration/Matching with Ambient Optical Environment Color and Texture Mapping Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal.-Santa Barbara U-N. Carolina
Non-specific Attraction "White Noise"(Acoustic, Olfactory, Aerosol)	Isolate/Distract Individuals (Squad Leaders, Point Scouts) Detour to Selected Area Cause False Sense of Security; Reduction in Force Wariness	Audio Projectors Olfactory Sources	Single/Multiple Effects Choice and Timing/Sequencing Effects Targeting (Single vs. Group) Logistics Own Force Vulnerability	Single-Combatant Behavior Duration of Projection Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Honeywell/Randi Foundation SARA/kVa Effects

Table 3. Disorientation

ORBS EFFECT	OPERATIONAL EFFECT	SUPPORTING TECHNOLOGIES	OPERATIONAL ISSUE(S)	TECHNICAL DEVELOPMENT ISSUE(S)	SOURCE(S)
Fact Conflict False vs. Real Object	Induce Incorrect Actions Reduce Confidence in Information Sources Causes Delay for Situational Assessment Increase Hesitancy to Act Disorient Leader	Audio and Video Projectors Materials for Projection Olfactory Sources or Projection	Single vs. Multiple (Hybrid) Effects Timing, Sequencing Duration Range Targeting (Individual vs. Group) Logistics	Image Size and Fidelity Duration of Projection Integration/Matching with Ambient Optical Environment Color and Texture Mapping Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal.-Santa Barbara U-N. Carolina
Uncertainty Generation Presentation of Ambiguous Information	Induce Incorrect Actions Reduce Confidence in Information Sources Causes Delay for Situational Assessment Increase Hesitancy to Act	Acoustic Projectors Materials for Projection Olfactory Sources	Single vs. Multiple (Hybrid) Effects Timing, Sequencing Duration Range Targeting (Individual vs. Group) Logistics	Physiology of Smell, Visual, Aural, Acoustic Duration of Projection Image-Only vs. Multimedia Effects Timing/Sequencing of Multimedia Effects	American Technology Corp. Boeing LEOS Division Honeywell/Randi Foundation Hughes/JVC and Laser Magic MIT Media Lab SARA U-Cal.-Santa Barbara U-N. Carolina
Physical Disorientation Acoustic Isolation (Hear Sounds Others Don't) Skin "Crawling" Effects Inside-Head Noise Nausea, Disorientation Visual Chaff/Dazzlers Smells	Reduce Operational Effectiveness May Cause Retreat or More Rapid Advance	Acoustic Projectors Olfactory Sources Optical Grenades Stun Grenades Strobes, Pulsers "Guided Lightning"	Countermeasures Passive Protection Soldier Conditioning (Prior Exposure) Own Force Vulnerability Logistics	Physiology of Effects (Single vs. Multiple, Sequenced vs. Concurrent) Countermeasures Passive Protection	Honeywell/Randi Foundation SARA

Table 4. Hiding

ORBS EFFECT	OPERATIONAL EFFECT	SUPPORTING TECHNOLOGIES	OPERATIONAL ISSUE(S)	TECHNICAL DEVELOPMENT ISSUE(S)	SOURCE(S)
Masking/ Camouflage Manipulate Own Force Signatures, e.g. Blend vs. Stand Out Against Ambient Noise/Visual Environment Generate False Signature "Decoy" Degrade Identification ("Chaff")	Failure to Engage Degrade Enemy Situational Awareness	Active Camouflage Multi-Sensor-Domain Fabrics and Coatings, with Controllable Realtime Optical/IR/RF Signatures Signature Control Over Multiple Domains	Blend vs. Non-Blend With Ambient Environment (All Domains) Autonomous vs. Controlled Blending Individual vs. Group Blending Human/Equipment Blending Mask vs. Unmask: Timing, Level, Sensor Domain (All vs. Single Domain) Logistics	Active Camouflage Fabrics: Durability, Other Metrics Electronics, Sensors for Blending Over Multiple Domains	Army Waterways Engineering Station DARPA DSO EIC Laboratories, Inc. FMC Corp. Honeywell/Randi Foundation Physical Sciences, Inc. U.-Ohio U.-Texas Dallas
Dazzling Disorient Stun	Failure to Engage Reduce Operational Effectiveness Immobilization	Optical Grenades Stun Grenades Pyrotechnic Aerosols "Guided Lightning"	Hostile Force Situational Awareness Own Force Situational Awareness Own Force Vulnerability Logistics	Countermeasures Conditioning Duration of Effect	American Technology Corp. Honeywell/Randi Foundation SARA/kVa Effects

Table 5. Group Coherence Disruption

ORBS EFFECT	OPERATIONAL EFFECT	SUPPORTING TECHNOLOGIES	OPERATIONAL ISSUE(S)	TECHNICAL DEVELOPMENT ISSUE(S)	SOURCE(S)
Disagreement/Confusion over Commander's Intent Communications Loss or Disruption	Reduce Speed of Command Extend or Influence Red Decision Cycle Reduce Unit Effectiveness Disperse Unit Causes Delay for Situational Assessment	Acoustic Spotbeaming Detect Disruption (Directional Mikes, Optical Trackers) Lightweight Handheld Acoustic Projectors	Timing, Duration Feedback, Track Developments From Standoff Identifying Unit-Disruption Signatures Tracking and Beam-Following at Standoff Range Set-Up Time Logistics	Spotbeaming Tracking Accuracy Integrity of Spotbeam Development of Identifiers for Automated Assessment from Standoff Range Robust Optical, Lidar Sensors	American Technology Corp. Honeywell/Randi Foundation MIT Media Lab SARA UC-Santa Barbara
Disagreement/Confusion Over Specific Orders Communications Diversion/Replacement	Reduce Speed of Command Extend or Influence Red Decision Cycle Disrupt Squad Integrity Reduce Confidence in Communications and Orders Reduce Unit Coherence	Acoustic Spotbeaming with or without "White Noise" to Isolate Squad Members Rapid Audio Translation	Timing, Duration Feedback, Track Developments from Standoff Identifying Unit-Disruption Signatures Creation of Credible Intrusion (Language) Communications Dependence (Hand Signals vs. Voice Command) Access to Enemy Links (Line of Sight) Logistics	Spotbeaming Tracking Accuracy Integrity of Spotbeam Development of Identifiers for Automated Assessment From Standoff Range Voice Generation Cross-Language Set of Commands	American Technology Corp. Dragon Systems Honeywell/Randi Foundation

6.1 Acoustic Projection Technology Descriptions

Acoustic measures for ORBS require both projectors and content for projection. Content is likely to be application and scenario specific, and may consist of either prerecorded material or locally generated material. Additional issues that would need to be resolved for an operational system include acoustic content, language translation, (see Supporting Technologies), operational concepts, and culture-dependent approaches. These issues will not be discussed further here.

6.1.1 Acoustic Sources

FUNCTIONAL DESCRIPTION

In order for ORBS units to project acoustic signals to the vicinity of dismounted enemy units for deception purposes, they need highly portable, robust, energy efficient sources that demand minimal set up time or pre-positioning. These sources could operate in two modes: (a) as distributed sources (including mini-sources) that operate cooperatively to phase their wavefronts or (b) as single emitters.

USE

Two companies (American Technologies Corp. and SARA, Inc.) and two universities (University of California at Santa Barbara and MIT Media Lab) have developed or conceptualized acoustic sources useful for ORBS deception.

In acoustic projection, the most promising (and most mature) technology is American Technology Corp.'s (ATC) HyperSonic Sound™ (HSS™), an award-winning proprietary technology in sound reproduction that employs ultrasonic tones to produce sound directly in the air. The audio source (voice, engineered noise) is converted to a complex ultrasonic signal, amplified, and emitted into the air by a transducer. The highly directional ultrasonic energy forms a virtual column of sound directly in front of the emitter, while along the column the air creates new sounds that replicate the original audio input signal. The sound heard is created in the column and does not spread; measured divergence is only 3-6 degrees, allowing spotbeaming of individuals at ranges of several hundred yards. To hear HSS™ sound, a listener's ear must be in line with the column; alternatively, one can hear the sound if it is bounced off a flat surface in the vicinity. HSS™ minimizes distortion and produces highly realistic illusions of sound location when bounced off walls or surfaces. The lightweight, low volume equipment can be packaged as a hand-held projector that folds up when not in use. ATC believes it can extend this technique to acoustic lasers.

ATC has also patented and is commercializing a unique hypersonic-mixing acoustic technique for highly confined (3 deg. - 6 deg. divergence) sound projection. It has extended this to small handheld voice (and non-voice) communicators, which it has prototyped and field tested. These devices, say ATC, "fold up like a Swiss army knife" when not in use and have a range of 100-200 yards.

*Maturity Level: **High***

SARA has developed large, high power siren-type acoustic sources for DoD for non-lethal incapacitation of individuals in confined spaces or at close standoff ranges. It also has proposed using small distributed acoustic sources that can intelligently phase their output for cooperative beam forming. SARA has also proposed lightweight and ultra-lightweight single and distributed acoustic sources, but has not done any engineering toward such configurations. The company's current single source family of acoustic emitters is large, heavy, high power devices designed solely for non-lethal impairment. An another acoustic source developer (MIT Media Lab) has demonstrated spotbeaming, although little has been disclosed publicly in terms of design details or achieved performance specifications. The University of California at Santa Barbara (UCSB) is also experimenting with acoustic spotbeaming for use in stage dramas; however, nothing is known about the maturity of their technology.

*Maturity Level: **Low***

For several of these acoustic sources, power supplies will be an issue. This is particularly true for SARA's distributed sources, where power supplies may be a limiting factor because of the run times needed for ORBS engagements. For all sources, power considerations include (a) the energy losses (and other parasitic losses) involved in generating acoustic energy from prime power (small fuel cells, micro-turbines, compressed gas bottles, etc.) and (b) the weight and mass of such acoustic sources, which affects their deployability. If the power problem can be solved for the proposed distributed sources, the cooperative time phased performance of such distributed sources could be enhanced. This can be accomplished by incorporating "micro-radio" chips (e.g., "Micro Electro-Mechanical System (MEMS) RF" chips) to boost their RF interconnectivity and thus their "collective intelligence", and also by improving their intelligence with embedded microprocessors.

MATURITY

With the exception of ATC's hand-held projectors, all of these power sources need considerable work.

*Maturity Level: **High** (for ATC), **Low** (for SARA, UCSB and MIT)*

6.2 Video Imaging Technology Descriptions

Video image projection requires three elements: a projector, an image plane on which to project the image (unless holographic techniques are used), and image content (program material). Image planes may be pre-existing surfaces (e.g., sides of buildings), natural suspended materials (e.g., fog), or emplaced materials. Both projection and image plane technologies are in need of substantial improvement to be useable in an ORBS scenario. Technologies and skills exist for producing simple on scene or elaborate prerecorded content; at issue will be the cultural and situational needs for the content. Content issues will therefore need input from operational concept developers rather than the technology community and will not be discussed further here.

6.2.1 Video Projectors

FUNCTIONAL DEFINITION

Video projection for ORBS-equipped units require lightweight, power efficient equipment which is capable of projecting clear, realistic imagery to tactically significant distances (the latter would be defined by the ORBS squad's "area of regard" – so far undefined). Projected content could include stationary natural or physical artifacts, moving objects, or forces from either side.

USE

In a typical ORBS scenario, projecting video and imagery would be more demanding technically and operationally than projecting acoustic signals. The eye perceives more detail – and is more sensitive to discontinuities and false signals – than is the ear. Depending on the nature and duration of the projected imagery, the factors that play in such projection include:

- image fidelity (e.g., lack of "flicker," consistency across the image plane), which is influenced by viewing range, image size and resolution, blend with ambient terrain, time displayed, time to analyze, etc.)
- image duration and its proposed tactical use, also the perceptual "psychophysics" of combining image/video and acoustic projection (e.g., using one to cue the other or to pin ("fix") the attention of the targeted unit);
- viewing angle (particularly for laterally distributed members of a targeted unit) and image depth (i.e., viewing an image from the side causes loss of depth);
- creation of a standoff image plane that exploits ambient materials or materials projected from an undefined launcher, with sufficient density to support realistic imagery for a desired period of time;
- coordination of projection requirements for (a) image plane materials (e.g., engineered particles) with those for (b) video/image projection (e.g., siting of both classes of projectors (co-siting vs. separate siting), set up time, operational timing) and (c) acoustic projection (unless the ORBS unit desires silent imagery); and
- in scenarios where ORBS units opt for exploiting ambient image plane materials (local water particles, dust) rather than projecting synthetic materials, the determination of ambient particle densities and how to exploit.

MATURITY

In video imagery projection, a promising candidate is a laser illuminated light-valve projector being developed by a team of Hughes/JVC and Laser Magic, Inc. Laser Magic claims the projector can produce a human-scale image at a standoff range of 1 kilometer, compared to much larger images caused by higher divergence projection methods. Laser Magic also claims it can exploit image planes of opportunity (ambient terrain). The projector operates at lower temperatures and higher optical/energy efficiencies than conventional projectors employing arc lamp illuminated light valves. Laser Magic believes its projector could be packaged for portability but notes that the laser would dominate the projector's mass, weight, and complexity.

*Maturity Level: **Low***

The University of North Carolina is developing projectors which use digital micro-mirror display (DMD) technology to combine 3-D data capture with simultaneous image display. The developers of this technology have also considered the use of his technology for deception in urban warfare. Realistic artifacts have been produced using multiple (2-5 projectors) in an enclosed space. Removal of artifacts (i.e., make things disappear) may be possible with the same method. Extending this deception technique to larger outdoor scenes would be more demanding and would take considerably more projectors to replicate the hostile viewer's angle of view on a scene. Also, not every backdrop is amenable to DMD projection.

*Maturity Level: **Low***

Boeing has given thought to illusioning methods, including image projection and laser and holographic projection, including multi-hologram video projectors with relay optics. Boeing has also "second harmonic generation" of light patterns on surfaces to create illusions at select locations. These include linear illusions (e.g., the kind one sees in the air/water interface, where there is a linear displacement of the image) and non-linear illusions, which exploit the non-linearity of a turning mirror. Boeing believes these illusions could probably spoof sensors but not the human eye, since it is very hard to deceive.

*Maturity Level: **Low***

6.2.2 Particles for Projected Image Planes

FUNCTIONAL DEFINITION

In order to create image planes for projecting deceptive imagery, ORBS units may employ particle or aerosol projectors that can create tailored, localized particle concentrations in free space with enough density to allow images of the desired range, resolution/fidelity, size, and duration. Ideally this would be done without using traditional low velocity projectiles (e.g., grenades) to dispense such materials in flight and by using equipment whose power requirements, mass, and weight allow employment by dismounted soldiers.

USE

Material projection methods relevant to ORBS include (a) linear projection for uniform dispersion of engineered particles or aerosols along a predetermined axis to a tactically significant range (defined by an ORBS force's area of regard) and (b) non-linear projection for multi-axis dispersion of materials, particularly obscurants for self-masking. Linear projection of tailored optical particles and electrically conductive metal dusts appears uniquely suited to producing image planes on demand, as well as electrically conductive free space waveguides (e.g., for "guided lightning"-type electrical discharges or other optical effects). Projected materials would include multi-spectral obscurants, irritant gases, conductive metal dusts, engineered optical-MEMS particles and possibly macroscale particles or materials like filaments. The projection method and the Blue force's tactical intent strongly influences the size and nature of the projected material (gas, particle, filament, engineered MEMS object), as well as its projection range and suspension time.

Projected materials for creating image planes should be transparent or should blend with ambient backgrounds so as not to call attention to themselves. One possible technology is cooperative arrays of optical-MEMS particles that would operate as free space equivalents of deformable micro-mirrors like those employed in displays. However, whereas the latter are hard-mounted and are electrically controlled in deflection, micro-mirrors drifting in free space would require different techniques (so far undefined) to achieve the effect of a continuous “screen.”

The only non-projectile method for directed (axial/linear) projection that is known to this study is the ring-vortex projector, which can entrain desired materials in an air “slug.” Whether acoustic lasers or ultrasonic sound can be used to similarly project particles to useful tactically useful distances is unknown. On the other hand, projection methods for more conventional particles or aerosols such as multi-spectral chaff and smokes – which generally do not require straight line dispersion to standoff distances – have been well defined by the Army and Marines. The projector would be used to create free space waveguides for such applications as image planes, conductive discharge channels (“greased lightning”) and obscurant barriers. However, suspension times and drift behaviors for such particles – especially hypothetical optical-MEMS particles – must be addressed.

MATURITY LEVEL

The use of water droplets (10-micron range) to create image screens is well developed by companies like Mee Industries for use in theme parks, displays, and entertainment. The use of other materials in image planes, whether engineered or natural/ambient, is unknown. Whether more sophisticated materials like optical-MEMS particles can be used in image planes is also unknown.

*Maturity Level: **Medium to High***

Current ring-vortex projectors offer limited range (50-100 yards), which is not adequate for supporting ORBS units’ standoff distances from hostile units. Such vortex projectors have also undergone only limited field testing. Projection of image plane materials in appropriate densities represents another unknown.

*Maturity Level: **Low***

6.2.3 Ambient Image Plane Materials

FUNCTIONAL DEFINITION

An ORBS unit could also use ambient airborne particles and aerosols as image planes, but will need to be able to manipulate the material into a sufficiently dense and stable configuration to form an acceptable image plane.

USE

According to SARA, it is theoretically possible to use the company’s proposed mini-acoustic sources to acoustically manipulate ambient water droplets and dust. By using methods derived from the well-known phenomenon of “acoustic agglomeration,” it may be possible to clump such particles and aerosols into vertical bands of sufficient density to serve as image planes.

MATURITY

While acoustic agglomeration is used on a small scale in confined spaces, its use in free space at extended distances is more problematic.

*Maturity Level: **Low***

6.3 Other Audio-Visual Technology Descriptions

6.3.1 Tesla Lightning Sources, Ball Lightning Sources

FUNCTIONAL DESCRIPTION

These sources could be used in concert with conductive free space waveguides created by SARA's ring-vortex projector under a "greased Lightning" concept. The vortex projector would populate the waveguide with conductive metal particles; a Tesla source (a coil that builds up a huge voltage at one end and puts out arcs of electricity at high frequency and high voltage) would then send an electrical discharge down the linear waveguide to produce a large visual effect. Alternatively, artificial ball lightning could be generated and discharged down a linear axis.

USE

The idea is to disorient targeted enemy units. The Tesla-source vendor, kVa Effects, reports that its Tesla discharges are extremely intimidating.

MATURITY

This concept has been explored by SARA in collaboration with kVa Effects, a special effects "boutique" specializing in large Tesla generators (high voltage static charge) for trade shows and other public events. SARA has also experimented with ball lightning and believes it is the first to produce it on demand.

*Maturity Level: **High** (Tesla source and ring-vortex projector), **Low** (ball lightning)*

6.3.2 Vortex Projectors

FUNCTIONAL DEFINITION

Developed by SARA, the ring-vortex projector accelerates repetitive "slugs" of air - along with any aerosol or particle material that can be entrained and seeded into the air slug - at speeds up to 0.5 Mach to distances of 50-100 yards with a high degree of linear control.

USE

Originally developed for non-lethal standoff control of hostile individuals or crowds, the vortex projector can entrain numerous ORBS-relevant materials: image plane materials, irritant or obscurant aerosols, smokes and multi-spectral obscurants, etc.

MATURITY

SARA is the only source known to this study. The vortex projector exists as a single prototype that has seen limited use.

*Maturity Level: **Low to Medium***

6.3.3 Optical Grenades, Stun Grenades, Pyrotechnic Aerosols

FUNCTIONAL DEFINITION

ORBS units need compact non-lethal sources of optical, acoustic and mechanical energy that can be thrown or launched as conventional projectiles or projected by ring-vortex projectors.

USE

Grenades that produce extremely bright light for temporary dazzling have reportedly been designed or developed for uses like non-lethal crowd control. Other “stun grenades” that combine light with sound and physical shock for hostage rescue situations involving terrorists have also been developed and used. Ring-vortex projectors could also launch aerosols of pyrotechnic particles that produce a dazzle effect.

MATURITY

These devices can be considered mature for purposes of non-lethal crowd or group control. However, more tailored applications may be desired for ORBS engagements.

*Maturity Level: **High** (in inventory)*

6.3.4 Strobes, Pulsers (including Acoustics)

FUNCTIONAL DEFINITION

These produce controlled pulses for communication or (potentially) for personnel incapacitation. Reportedly, flickering lights have also been tested in DoD programs to decoy anti-aircraft missiles equipped with techniques that allow them to “see through” IR countermeasures employed by U.S. aircraft. These lights alter the shape of the targeted aircraft.

USE

Strobes are currently in use by ground forces for communicating with aircraft. According to SARA and Col. John Alexander (USA, Ret.) of the Institute for Discovery Science in Reno, Nev., acoustic pulsers can disrupt the human brain stem’s “clock,” immobilizing the targeted individual or putting him to sleep. However, this incapacitation effect is ill-defined, as mapping it out experimentally would require human testing and may require a change in U.S. policy on weapons effects.

MATURITY

For communication in IR and visible regimes, strobes are well developed. For non-lethal incapacitation of individuals, they are immature.

*Maturity level: **High** (traditional use), **Low** (incapacitation)*

6.4 Olfactory Technology Descriptions

The type of olfactory agent to be used will depend upon the intended effect and on the culture of the opponent. Production of agents is, generally, a well-developed technology, although some development may be required for some specific uses. Delivery, in a manner that is consistent with the ORBS scenario being supported, may be the more challenging technological problem.

6.4.1 Olfactory Sources

FUNCTIONAL DEFINITION

Since the largest portion of the human brain is devoted to smell, it is a useful vector for ORBS deception. Olfactories can be used to deceive, distract, or disrupt an ORBS-targeted enemy unit. Historically, dismounted infantry units (e.g., point men on patrols, reconnaissance units) employed smell to detect enemy presence (e.g., cooking fires, cigarette smoking). This behavior can be exploited for ORBS purposes. Olfactory sources would operate much more slowly than acoustic deception and thus, require pre-positioning.

USE

Olfactories could include manufactured scents that suggest human presence or other indicators. Enemy units may be expected to respond in advantageous ways when presented with olfactory evidence which gives false indications of the location, size, or composition of U.S. forces. At the least, enemy forces should be expected to slow or delay action while assessing the olfactory evidence. Olfactory cues may be particularly effective at causing delay since they are usually not closely linked to the location of the source. The presence of forces suggested by the olfactory cues is thus particularly difficult to confirm or refute. It may be possible to develop scents that cause behavioral effects under long exposure, and these sources could be dispersed and remotely controlled. An extension of olfactories is the psychoactive (mood-altering, consciousness-affecting) inhalant, which in illicit “street form” comes in three types: solvents (e.g., gasoline), aerosols (e.g., hair spray) and anesthetics (e.g., nitrous oxide). These inhalants produce wide ranging effects: nausea, ringing in the ears, sneezing, abnormal heart rhythm, nosebleeds, tiredness, double vision, lack of coordination, poor judgment, muscle and joint aches and coughing.

MATURITY

Olfactories are well characterized for many uses, as are inhalants. Convenient fieldable sources for some types of olfactory agent have not been developed.

*Maturity Level: **High to Medium***

6.4.2 Olfactory Delivery; Pre-positioned Olfactory Sources

FUNCTIONAL DEFINITION

ORBS units will need ways to deliver or pre-position olfactory sources at as early a stage as possible (possibly prior to an engagement), given that olfactory agents tend to spread from the point of origin, and therefore have impact, more slowly than acoustic or visual events.

USE

Use of olfactories entails “seeding” an area where the enemy is expected to advance or otherwise using covert delivery. Delivery methods for irritants can be expected to work with olfactories. Covert deployment and seeding by miniature air vehicles (MAVs) is one prospect. Pre-positioning sources on the ground is another technique. However, any deployment and use, including remotely controlled release, would require the ORBS unit

to ascertain wind direction and any terrain features that might channel or disrupt the desired propagation sought for these aerosols. These sources could be randomly deployed in a mix that could be remotely activated as needed to create the desired ORBS effect. The emphasis must be on covert delivery and pre-positioning methods.

MATURITY

Chemical dispersant canisters, such as those used for tear gas, are quite mature. Addition of timed or remote controlled triggers would not present a significant challenge. However, covert delivery (e.g., by MAVs) may be possible, depending on the weight of the olfactory source, and the size (and thus the acoustic and visual detectability) of the olfactory delivery mechanism.

Maturity Level: ***Medium to High***

6.5 Hiding Technology Descriptions

6.5.1 Active Camouflage in Multiple Sensor Domains for Fabrics and Coatings

FUNCTIONAL DEFINITION

To enhance their own deception operations, ORBS units ideally should maximize their own covertness. A deception that is projected from a covert/stealthy unit would be more effective than one projected by a unit that the enemy knew was in the area. Clothing fabrics and equipment coatings with active camouflage (AC) coatings and materials enable such covertness. “Active camouflage” adjusts autonomously to ambient terrain and settings; it can also be controlled by the ORBS unit itself.

USE

The Army is funding work on fabrics and coatings that are stealthy in multiple sensor domains – e.g., millimeter-wave RF, infrared, and visual. AC coatings and materials reportedly being developed for aircraft could be used in ORBS ground equipment. A May, 1994 “*Report of the Senior Working Group on Military Operations Other Than War*” called for camouflage uniforms, uniform coveralls, ponchos, blankets or multi-garment ensembles that could conceal soldiers over a wide range of the electromagnetic spectrum for use in counter-terrorist and reconnaissance operations [Ref. 1]. For ORBS operations, Blue units may wish on occasion to vary their signature to allow hostile detection.

MATURITY

The Army is funding work in multi-spectral fabrics and coatings. DARPA-DSO (Defense Systems Office) recently (November 1998) issued a Broad Agency Announcement (BAA) for “biomimetic systems” that will study biological systems’ performance in active camouflage and IR, optical and acoustic detection.

Most of DoD’s AC work appears oriented to tactical aircraft. According to one press report, the Air Force and other DoD organizations are developing special lights, coatings (e.g., electrochromic coatings) and other technologies to hide tactical aircraft from visual acquisition in daytime. The account claims that the original design of the “Have Blue” prototype for the F-117 stealth fighter called for light apertures on 2-foot centers on the

aircraft's sides and underside. Connected to a central light source by fiber optic lines, the apertures' output would be controlled by light sensors on the aircraft's upper side that would "read" the background light and adjust the skin's luminance to mirror it. The article claimed that an Air Force test aircraft, FISTA II (Flying Infrared Signature Technology Aircraft), is testing visual stealth with IR imagers and a visual imaging system [Ref. 10]. Potential for application of this technology to ground forces is not clear.

Besides DARPA-DSO, AC developers include FMC Corp. (subcontractor: TARDIS Systems, Inc.), University of Ohio (subcontractor: University of Florida), University of Texas - Dallas, and the U.S. Army Engineer Waterways Experiment Station. Particular attention is going to electrochromic polymers. For example, EIC Laboratories, Inc., is teamed with University of Florida in developing three-color, matrix-addressed, environmentally robust appliques of electrochromic polymers for variable camouflage.

Assessing the maturity of AC technologies and the availability of classified aircraft-oriented AC techniques for ORBS use is complicated by classification issues.

*Maturity Level: **Low***

Under an Army SBIR award, Physical Sciences, Inc., is developing a "light electro-optical active reflectivity device" (LEOPARD) system of variable color electrochromic (EC) devices and sensors to actively sense the background environment of an object and adjust its reflectivity in visible wavelengths to minimize its contrast with the environment. LEOPARD employs a large number of panels covering the object surface, with each panel comprising several EC devices and one or more high resolution color CCD cameras. For variable reflectance over visible wavelengths, LEOPARD would use mechanically rugged, low cost EC polymer thin films on flexible kapton substrates. The panels' color would be controlled by the camera's input.

*Maturity Level: **Low***

6.6 Supporting Technologies

6.6.1 Power Sources

FUNCTIONAL DEFINITION

ORBS equipment requires high performance refuelable or rechargeable electrical power supplies that can draw power from soldier backpacks or can operate as autonomous embedded systems.

USE

Electrical power for image or acoustic projectors may be the most technically stressing requirement for ORBS. Possible solutions for small sources include micro fuel cells (including fuel cells that can run on local fermentation fuels like alcohols), micro (MEMS-based) gas turbines, and "mesoscale" (coffee cup size) fuel cells and micro fuel reformers being developed by the Department of Energy's Pacific Northwest National Laboratory (PNNL).

For general “soldier backpack” power, power candidates include DoE-PNNL’s fuel cells, “direct carbon fuel cells” developed under a DoE Phase 1 Small Business Innovative Research (SBIR) award, and backpack fuel cells developed and commercialized by H Power Inc. Other power sources for ORBS units include energy scavenging from human motion (especially “heelstrike” generators) and Seiko’s motion powered watch), human body heat (e.g., Seiko’s thermoelectrically powered watch) and windup electrical generators (e.g., those from Baygen/Freeplay in South Africa).

MATURITY

Portable power systems today are at varying levels of maturity, with commercial systems the most mature.

Maturity Level: Backpack fuel cells: **Medium to High** (COTS); Human energy/motion scavenging: **Low** (heelstrike); **High** (thermoelectric, limb motion); Solar, wind: **High** (COTS); Windup (human motion): **High** (COTS); Micro fuel cells: **Low to Medium**

6.6.2 Automated Speech Translation, Speech Synthesis

FUNCTIONAL DEFINITION

Automated speech translation allows realtime identification of enemy commands or speech that may employ various languages. Speech synthesis refers to the generation of realistic sounding human speech in a target language.

USE

Automated translation allows ORBS units to translate enemy unit speech in realtime, while voice synthesis allows them to synthesize deceptive voice commands in realtime for spotbeaming to the enemy unit. Enemy unit speech could be represented by synthesized voice or print display and would allow ORBS units to ascertain enemy intent.

MATURITY

Automated voice translation is commercially available from several vendors (e.g., Language Systems Inc. and Dragon Systems). A device such as Language Systems Inc.’s (LSI) two-way realtime translator/voice synthesizer, developed under DARPA’s Technology Reinvestment Project (TRP) would be useful to disrupt interactive speech (i.e., between two or more persons) within an enemy unit in realtime by generating deceptive speech. Now being commercialized, the portable LSI device translates in realtime from the target language (currently Spanish, Arabic and Russian) into synthesized voice English. It can also translate in realtime from English to the target language.

Maturity Level: **Medium to High**

6.6.3 Detect Disruption

FUNCTIONAL DEFINITION

An ORBS unit must be able to detect (ideally in realtime) behavioral indicators of disruption in enemy units exposed to ORBS deception (e.g., via acoustic spotbeaming). Without such indicators or signatures, ORBS units have no way of knowing whether their deceptions are working.

USE

It is probable that an enemy unit that has been successfully deceived or manipulated by ORBS units – e.g., through such measures as spotbeaming deceptive signals to an enemy unit’s leader –will produce signatures of uncoordinated action or confusion that include “milling around”, or (in poorly disciplined enemy units) shouting and vocal arguments. Sensing such disruption will require active and passive optical sensors and microphones.

MATURITY

These signatures exist but tend to be captured only as “soft” knowledge that is tied to an individual soldier’s experience in small unit or special operations forces (SOF) operations. However, for ORBS purposes, such signatures ideally would be collected and displayed semi-automatically.

*Maturity level: **Medium to High***

6.6.4 Gesture and Face Recognition

FUNCTIONAL DEFINITION

Gesture recognition allows characterization of human gestures from standoff ranges of tens of feet (current) to greater ranges, using optical (passive) or lidar (active) sensors. Gesture recognition is being pursued by numerous universities for “smart rooms” that can sense and respond to a person’s presence. It is also used by physicians to assess limb motion disorders and injuries. Face recognition differs from gesture recognition in that it is not motion based but feature based.

USE

For gesture recognition in the field, ORBS units require lightweight optical sensors that can be non-emitting/passive (e.g., smart cameras) or active (e.g., lidars). The former is restricted to daytime operation; the latter can operate at night and in all weather. When employed against a hostile unit, gesture recognition can detect characteristic motions of a squad leader (e.g., hand signals, body motion), thereby identifying him. It can also be used to deter hostile actions like raising an aimed weapon (e.g., rifles, shoulder-fired weapons) to firing position, allowing a Blue force to quickly target that individual either lethally or non-lethally. Body recognition draws on similar classification techniques, albeit at a larger scale. Face recognition extends to identification of individuals for targeting by ORBS units, particularly in urban warfare operations.

MATURITY

Gesture recognition techniques have been developed by companies like Interval Research and Holoplex, as well as by several universities, as “soft interfaces” to computers and for interactive games and displays. Holoplex, which employs passive cameras, is marketing several interactive games that employ gesture recognition. In face recognition, a recognized leader (Visionics) claims that its commercial systems can identify individuals by analyzing the upper half of their face (although it can be defeated by individuals wearing dark glasses). Its systems, which can process 12,000,000 faces per minute using Pentium processors, can recognize individuals who have grown facial hair or wear glasses to

change their appearance. Interval Research has tested lidar for standoff gesture recognition. University research includes use of Doppler radars and imaging cameras.

*Maturity Level: **High***

6.7 Operational Enablers

The routine tactical employment of military deception techniques for small unit ground operations will be a substantially new capability for U.S. forces. Accordingly, new doctrinal approaches and the supporting tactics will be required to implement the capability. The technologies discussed above will then become enablers for the new tactical approaches to warfighting operations. Development of novel tactics may be significantly advanced through the use of human stimulus/response models. A team from Honeywell and the James Randi Institute has proposed using models of this type which have been developed within the portion of the entertainment industry most closely connected with deception - stage magic. Magicians typically use very low level technology and considerable presentation skill in the creation of their illusions. The Honeywell/Randi team has presented concepts to reverse this balance (to low skill and high technology) while still employing the basic elements of deception to provide minimally trained military personnel with the capability to use deception techniques.

7.0 Conclusions

Throughout the ages, military operations routinely employed deception and disinformation on the tactical level. This use continues today because of the benefits of destabilizing and influencing enemy actions. Current tactical deception techniques lack the vision and advanced technology that are characteristic of other modern weapons systems, and are generally used at longer ranges or against more specialized sensors than should be expected in future small unit operations. Although focused on a completely different objective, deception technologies are being developed for concepts that serve the entertainment industry, rather than in the DoD. We have found persuasive evidence that there are potential benefits to be gained by leveraging these concepts and focusing them on military operations. But, this strategy will be fruitful only if it is combined with other key technologies resident in the military sector, with novel operational approaches towards military engagements. This must, of course, begin with the acceptance of these unconventional approaches by the military use.

A successful program to create an ORBS capability will require three elements. The first is the demonstration that ORBS techniques can provide a robust and effective tactical element. The second is a set of fieldable technologies that can be routinely used by military personnel to produce the desired effect in opponent behavior and capability. The third element is the acceptance and adoption by U.S. forces of ORBS, supported by appropriate doctrine and tactics, as a viable capability for future military operations.

DARPA is the DoD agency of choice for this ambitious undertaking for a number of reasons. First, vision and advanced technology are DARPA's domain within the DoD and the effort described in this paper will require lots of both. Next, a creative partnership with a segment of the commercial sector must be established and leveraged.

That segment, the entertainment industry, has historically been uninterested in partnering with the DoD. Of all its agencies, DARPA has the most experience and has been most successful at attracting and collaborating with the commercial sector. Finally, as discussed earlier, DARPA has committed itself to developing innovative concepts that will eliminate the need for and attractiveness of antipersonnel landmines - an appropriate and worthy focus for modernizing the art of tactical deception.

8.0 Acronyms

AC	Active Camouflage
APL	Antipersonnel Landmine
APL-A	Antipersonnel Landmine Alternative
AT	Antitank
BAA	Broad Agency Announcement
CCD	Camouflage Concealment and Deception
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
DEPSECDEF	Deputy Secretary of Defense
DMD	Digital Micro-mirror Display
DSO	Defense Systems Office
EC	Electrochromic
FISTA	Flying Infrared Signature Technology Aircraft
IR	Infrared
LEOPARD	Light Electro-Optical Active Reflectivity Device
LEOS	Lasers and Electro-Optical Systems
LOS	Line of Sight
MAV	Miniature Air Vehicle
MEMS	Micro Electro-Mechanical System
OPSEC	Operations Security
ORBS	Organic Realtime Battlefield Shaping
PNNL	Pacific Northwest National Laboratory
RF	Radio Frequency

SBIR	Small Business Innovative Research
SOF	Special Operations Forces
TRP	Technology Reinvestment Project

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10.0 Appendix C: List of Contractors

No technical assessment to the validity of the claims by any contractor was performed. The discussion with each contractor was purely for information mining purposes only. Full technology assessment was beyond the scope of this research project. If you would like additional information regarding points of contact, please contact Mr. John Bosma at the Potomac Institute for Policy Studies.

1. A Basic Services, Ruidoso, NM: Designs next-generation interactive rides (e.g., roller coasters) and is examining special effects for outdoor environments.
2. Advanced Information Processing and Analysis Steering Group (AIPA-SG), Ft. Meade, MD: Coordinates all information technology R&D in the intelligence community. ORBS-relevant R&D includes automated image processing and manipulation; image recognition, feature extraction and classification; high-density image storage and transmission; high-bandwidth transmission links; collaborative man-in-the-loop analysis; automated document understanding, theme abstraction and summarization; and cross-lingual voice understanding.
3. Allan Yasnyi & Associates, Los Angeles, CA: Consultant to the entertainment industry, specializing in topics like information technology and information security for wireless and internet-carried entertainment.
4. American Technology Corporation, San Diego, CA: Developed a family of ultrasonic-mixing speakers that can produce localized zones and linear channels of sound that cannot be heard outside those zones. The company has tested its devices for deception purposes at ranges up to 200 yards and finds that the reflection of its speakers' sound off walls and other flat surfaces creates highly credible acoustic illusions among listeners. The company believes it can create free-space "virtual sources" through cooperative beams from two or more portable or handheld projectors, which can be designed to fold up like umbrellas.
5. Apple Ventures, Los Angeles, CA: Technology scout for major entertainment companies.
6. Arete, Los Angeles, CA: Specializes in near real-time rendering of ocean and atmospheric effects.
7. Army Research Institute, Alexandria, VA: Specializes in soldier psychology on the battlefield. ARI's October 1990 newsletter published an article on "*The Art of Deception: Attacking the Enemy's Decision Processes*."
8. Army Research Lab, Survivability and Lethality Analysis Directorate, Aberdeen, MD: Manages all Army obscurant research and experiments.
9. Army Research Laboratory, Adelphi, MD: ARL is developing a Mobile Acoustic Source (MOAS) pneumatic loudspeaker system that allows scientists to verify acoustic models with atmospheric effects. It generates sound sufficient for testing acoustic propagation of sources up to 15 km away. It develops 20,000 acoustic watts of power (>160 dB) and can reproduce realistic signals simulating any sound at various ranges and under controlled conditions. ARL also is developing an

Acoustic/Seismic Countermeasure Vehicle, a modified 5-ton stake-bed truck that can evaluate acoustic and seismic countermeasures by functioning as an acoustic/seismic decoy and an acoustic jammer. It is being used to examine the effects of decoying and jamming on the Wide-Area Mine System.

10. Boeing Lasers and Electro-Optical Division, Santa Suzanna, CA: Company specialties include lasers, nonlinear optics, liquid crystal displays, diamond thin films, and electrically tuned lithium-niobate crystals (LiNbO₃) for very fast, very rugged spatial light modulators. The company also developed a "Pancho suit" for all-spectral camouflage that can blend soldiers with their surroundings and fool hostile electro-optical sensors. The company also has investigated using active camouflage on ships, e.g., manipulating sea and sky blue colors to mask the discrimination of ship from the horizon. It has also examined illusioning methods such as image projection and laser and holographic projection, including relay optics for multi-hologram video projectors. Boeing has tested "second-harmonic generation" of light patterns on surfaces to create illusions at select locations. These include linear illusions (e.g., the kind one sees in the air/water interface, where there is a linear displacement of the image) and non-linear illusions, which exploit the non-linearity of a turning mirror.
11. Capstone Systems Inc., Colorado Springs, CO: Chaired SIGGRAPH 98 Enhanced Realities Committee, which evaluated SIGGRAPH submissions in interactive games, gesture recognition, image projection, illusions, and other forms of art.
12. Catholic University of America, Washington, DC: Principal Investigator for joint project in home/workplace-centered rehabilitation and living sponsored by FDA (Food and Drug Administration) and NSF (National Science Foundation). Project is interested in possible applications of gesture recognition and body/posture recognition for monitoring motion-related disabilities and for therapeutic analysis of patient motion.
13. Charles Kiselyak, Burbank, CA: Independent filmmaker and consultant, worked with Dale Dye and Oliver Stone in documentary on Stone's film "Platoon".
14. Cinebase, Los Angeles, CA: Company specializes in management of large (100's of terabytes) imagery files, and in indexing, image-recognition and retrieval of such imagery. Also expert in real-time compositing and synthesis.
15. Consortium for Real-Time Digital Synthesis of Real-World and Virtual-World Sounds, distributed: Members include Princeton University, University of Illinois at Urbana-Champaign, University Pompeii Fabra (in Italy), and Sandia National Laboratories.
16. Department of Energy Ames Laboratory, Ames, IA: Developed state-of-the-art rendering software (Photon) allowing photo-realistic imagery.
17. DKL Safeguard, Washington, DC: Developed a proprietary portable detector that can detect human electrical fields at distances of several hundred feet. It has detected earthquake survivors buried in rubble.
18. Dreamworks, Los Angeles, CA: Dreamworks is working on advanced compositing and rendering methods for animated, photo-realistic films.

19. Entertainment Design Workshop, Sheffield, MA: Specializes in the design and production of interactive-ride systems, computer graphics, and visual effects for entertainment and entertainment related customers.
20. Epidemic, Paris, France: Epidemic is a live audience-interactive European "techno-event" whose organizers also sponsor and direct the "Via Festival" series of new technology festivals for electronic arts.
21. Federal Communications Commission Chief Technologist Office, Washington, DC: Manages FCC regulation of new technologies such as impulse radios. Impulse-radio links could transmit the imagery proposed by groups like Cinebase for local projection of synthetic imagery that blends archival and real-time imagery for deception and illusioning purposes.
22. Georgia Tech Research Institute, Atlanta, GA: Developed a system for tracking and recognizing multiple people with multiple cameras, including static and pan-tilt-zoom cameras. The underlying visual processes rely on color segmentation, movement tracking, and shape information to locate target candidates.
23. Holoplex, Pasadena, CA: Gesture recognition for interactive games using passive cameras (visible). The gesture recognition sensor requires no artificial background such as a blue screen in order to map the players' gestures. The gesture recognition sensor performs 3D profiling of the object, tracks it, and identifies what it is doing. The company's sensor is a FPGA (field programmable gated array). For ORBS, Holoplex's optical memory stores 200 gigabytes and can be read at 1 gigabyte per second.
24. Honeywell Technology Center (HTC), Minneapolis, MN: HTC has proposed to DARPA an internally funded proof-of-principle experiment in battlefield deception.
25. Interval Research Corporation, San Palo Alto, CA: Interval has demonstrated techniques for gesture recognition of individuals and small groups. It can also interactively "morph" these groups or individuals in real-time, as demonstrated in its "Mass Hallucination" SIGGRAPH Project. Interval is unusual in using active sensors (lidar) for gesture recognition.
26. Iwerks, Burbank, CA: Combines motion-base simulators with 3D and virtual reality effects for rides, theme parks, science centers, and other entertainment venues. It is considered to be state-of-the-art in software and 3D effects for mass-immersion effects, albeit in constructed environments that include the outdoors, e.g., outdoor display ads.
27. KPMG, Los Angeles, CA: Organized EnterTech 99, which discussed the impact of Internet sourcing and distribution of low-cost multimedia films, games and interactive simulations on the entertainment industry and the "Big Three" major networks.
28. kVA Effects, Los Angeles, CA: Employs Tesla Coils for dramatic exhibits.
29. Laser Magic, Playa Del Rye, CA: Teamed with Hughes/JVC to develop a laser-illuminated light-valve projector that eliminates the extremely inefficient, high-temperature arc lamps used in conventional light valves.

30. M2 Associates, West Hyannisport, MA: Specializes in non-lethal warfare (NLW) and was instrumental in the formation of DoD's NLW Directorate, which is staffed by the US Marine Corps. The company is constantly seeking new NLW techniques and concepts and is interested in deception as a non-lethal option.
31. Mee Industries, Huntington Beach, CA: Specializes in producing image planes of <10-micron water droplets for laser shows and ad displays.
32. MIT Media Lab, Cambridge, MA: Developed an "acoustic spotlight" at MIT that converts an ultrasonic beam into an audible sound to produce an extremely narrow, focused sound source that does not spread like a traditional loudspeaker. The beam, with a width of only 3 degrees, can be used as (a) directed audio -- only those within the beam hear it; or (b) as projected audio, in which the beam is projected off a surface like light.
33. National Ground Intelligence Center (NGIC), Charlottesville, VA: NGIC may be tracking foreign activity in acoustic obscurants.
34. National Research Council- Committee on Power for the Dismounted Soldier, Washington, DC: Produced a 1997 report that summarizes options for soldier-portable electrical power.
35. New York University, New York City, NY: Developing projection techniques, including volumetric projections and other immersive methods.
36. Obvious Technology Inc., Paris, France: Introduced the first video software modules - i.e., video-software in the form of "building blocks" for assembling multimedia entertainment products. The software can be downloaded from the Internet.
37. SARA, Inc., Huntington Beach, CA: SARA has tested acoustic non-lethal weapons and believes it can extend its technology to distributed arrays of acoustic mini-sources. By operating cooperatively and phasing their output to a specific point in space, these acoustic sources could cause clumping or localization of ambient aerosols (water droplets, dust), thereby creating a diffuse by effective image plane. The company is also working on concepts for extremely directional acoustic lasers, as well as ensonified "zones". SARA is also working on ring-vortex projectors that can project an annular vortex of air - along with entrained obscurants, image-plane materials, conductive metal powders, and other natural or engineered aerosols - to distances of 50-100 yards. Lasers, electrical energy and particle beams can then be sent down this "waveguide-on-demand" to stun or disorient an enemy.
38. Silicon Graphics, Inc., Mountain View, CA: Develops most of the processors used for high-end special effects, including real-time compositing and rendering, used to make Hollywood films.
39. Sonotech, Developed a "Diver Alert and Tracking System" (DATS) that allows underwater diver self-positioning accuracy approaching differential GPS (i.e., several centimeters). DATS can be re-engineered for covertness and has been proposed for navigation of Underwater Unmanned Vehicles (UUVs).
40. Technology-Entertainment-Design (TED) Conference series, distributed: TED conferences highlight trends and new technologies for multimedia entertainment.

41. Themed Entertainment Associates (TEA), Los Angeles, CA: TEA is the trade association for vendors, developers and operators specializing in theme parks, advanced rides (including motion-base simulators), immersive audience environments, outdoor events (e.g., fireworks shows), high technology displays, and other uses of "themes" in mass entertainment.
42. Time Domain Corporation, Huntsville, AL: World's leader in impulse radio technology. It has field-tested a covert Special Operations Forces (SOF) radio that cannot be detected at 100-foot range by state-of-the-art Army SIGINT (signals intelligence) and ELINT (electronic intelligence) sensors. Impulse radios operate at <1% of the power levels of conventional radios, can transmit at data rates of one gigabit/second (gbps), and can be engineered to fit on two chips. An inherent feature of the impulse radio is its extremely accurate self-location, which is better than GPS geopositioning accuracies by several orders of magnitude. TDC has designed another variant as a through-the-wall radar.
43. University of California - Los Angeles Entertainment Technology Center, Los Angeles, CA: Works with larger consortium of film and entertainment companies and specialty companies on various projects: e.g., "virtual state", distributed film-making with wireless transmission of imagery to central processing site for rapid editing, information security for digital art and other topics.
44. University of California - Los Angeles School of Art, Los Angeles, CA: Researching virtual reality for location-based entertainment and other 3D venues.
45. University of California Digital Media Innovation (DIMI) Program, Santa Barbara, CA: DIMI hosts Industry-University Technology Workshops on various University of California and industry-developed digital processing and image processing methods for possible use in entertainment. DIMI has examined all aspects of image manipulation including acoustic spot-beaming for live stage performances.
46. University of North Carolina, Chapel Hill, NC: Under DARPA sponsorship, UNC is developing a deformable-mirror device (DMD) imager that can also operate simultaneously as a projector. The imager can theoretically "null out" select parts of an image by retro-reflecting an image of the scene that omits the selected part.
47. University of Southern California, Santa Barbara, CA: Developing a MEMS-based acoustic source for DARPA that can be used for propulsion and other purposes.
48. University of Southern California's Integrated Media Systems Center, Los Angeles, CA: Specializes in all aspects of multimedia technology. A specialized IMSC spinoff is USC's Entertainment Technology Center (see separate citation for the ETC).
49. Virage Inc., San Mateo, CA: Specializes in imagery fusion, image recognition, real-time conversion and manipulation, and high-density storage. Its clients include the Intelligence Community.
50. Visionics, Jersey City, NJ: Visionics has developed face-recognition software that can process 12 million images per minute.

51. Visual Effects Society, Sherman Oaks, CA: Overview of state-of-the-art visual effects. Introductions to major studios, e.g., Industrial Light and Magic, Pixar, Digital Domain, etc.
52. Warriors, Inc., Northridge, CA: Specializes in providing military special effects for film producers and movie set designers. Instrumental in creating the special effects in Oliver Stone's film "Platoon".