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Less-Than-Lethal Acoustic Devices for Law Enforcement and Corrections Applications

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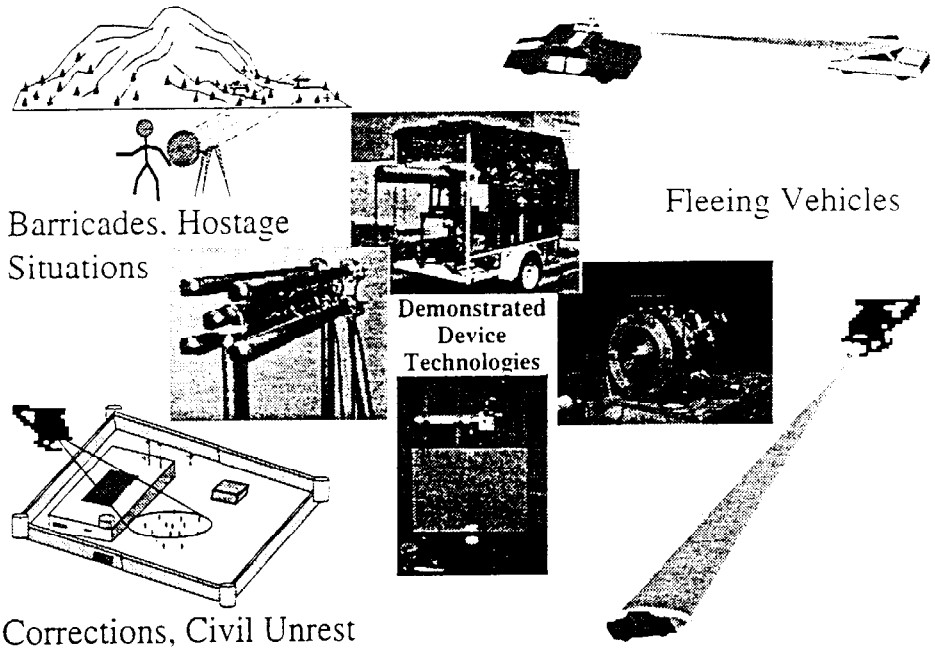

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Project Abstract

SARA is the leading US organization for the development of high energy acoustic sources and applications. We have developed this capability over the past five years for the Department of Defense and now propose to apply this promising technology to law enforcement applications. We have proposed to design, develop, and demonstrate three low cost prototype devices:

1. A high frequency (ultrasound), compact, hand carried device — designed for the individual law or corrections officer, it is an incapacitating weapon for controlling belligerent and fleeing suspects or aresstees in a corrections environment. Estimated price: <$500 in production.

2. A vehicle mounted high power audio band (0.5 to 5 kHz) device — designed to mount on an automobile, SWAT vehicle or helicopter. It would be capable of projecting a directional beam for use in defeating barricade situations, stopping fleeing vehicles and some civil unrest situations. Estimated price: $1000 - $5000 (platform dependent) in production.

3. A very high power, surface deployed, low frequency (10 to ~200Hz) sound generator — designed with a wider angle (forward area) beam pattern for control and suppression of civil unrest events and large scale outbreaks in correctional facilities. Estimated price: $1000 - $2000 in production.

During the development cycle we will work closely with several experienced active police officers as our consultants to make sure that each device can be deployed under realistic scenarios. If this proposal is awarded, the State of California intends to commit $250K of matching funds to be used for converting the prototypes developed under this program into production models. Therefore, we expect to quickly convert our prototype devices into production.

The total price for this effort is $1,404,702 plus the $250,000 State of California matching fund.

Scientific Applications and Research Associates, Inc. (SARA, Inc.) considers the technical information contained in this proposal to be highly competition sensitive and proprietary to SARA, Inc. In particular, the following areas are considered to be privileged, competition sensitive and proprietary to SARA, Inc.:

- *All combustion driver acoustic technologies,*
- *High Power and antenna beam forming concepts,*
- *Pulsed Periodic Stimuli - modulation, effects, effects data base,*
- *All high power acoustic device conceptual designs*

Executive Summary

SARA is the leading organization for the development of high energy acoustic sources and applications. We have developed this capability over the past five years for the Department of Defense and now propose to transfer this promising technology for law enforcement applications.

We have proposed to develop three low cost prototype devices: small hand held, medium vehicle mounted, and large trailer mounted systems. State of California will commit $250K of matching funds to be used for converting the prototypes developed under this program into production models. The price of these devices are expected to be $500 - $5000 per unit.

During the development cycle we will work closely with several experienced active police officers to make sure that each device can be employed under realistic scenarios. These officers have agreed to become SARA consultants for the duration of the effort. For most law enforcement applications, the proposed high intensity acoustic output levels can be made safe by limiting the exposure to OSHA safe levels — an advantage not matched by other competing LTL concepts.

1.0 Identification and Significance of the Problem

Nationally prominent events within the United States, over the past ten years have continually underscored the need for new options in dealing with urban crime, hostage stand-off situations and problems within correctional institutions. The present technologies for law enforcement are

clearly inadequate for dealing with the problems facing law officers. The preponderance of political and social concerns over the use of "excessive force" have placed an extreme burden on law enforcement and corrections officers.

Law officers are now placed in the difficult situation of maintaining civil peace, while taking the blame for any public or media perception of the use of excessive force. The result has been an actual diminishing of law enforcement effectiveness when dealing with violent crime, drug related crime standoff/barricade, hostage and correctional facilities scenarios.

1.1 Law Enforcement Community Team Members Briefed

As a result of successes on several DoD sponsored programs, we propose to transfer SARA's high intensity acoustic technologies to less-than-lethal (LTL) applications for the law enforcement community. SARA, Inc. has assembled an outstanding team, including several law enforcement officers, to support all phases of this proposed program. This team is dedicated to developing LTL technologies that will simultaneously 1) meet the law enforcement missions performance needs. 2) be easily operable with no collateral effects, operator safety or environmental contamination issues, 3) be engineered into an optimized/ruggedized design geometry for field applications. 4) be demonstrated at a level that satisfies all design needs to efficiently transfer the technology to production systems for use throughout the law enforcement and corrections communities.

In preparation for this proposal effort and as part of SARA, Inc.'s commitment to the dissemination of information on our acoustic beam weapon technologies we recently briefed several active and experienced police officers from local metropolitan police departments. Our briefing included a background perspective of the history of these technologies at SARA, Inc. beginning with our initial efforts in 1991. The technology aspects were covered and contrasted with the issues posed

by other LTL approaches that some have proposed. Key aspects of acoustic technology that our law enforcement team members pointed out included:

- Ability to vary the degree of effect by selective tuning of the source and it's intensity level.
- Control and suppression of a major civil unrest incident such as (Los Angeles experienced in 1992) by the use of low frequency sound wave generators of the type SARA, Inc. has already developed and tested for the US Army and ARPA.
- Application as a humane defense against vicious guard dogs used by drug dealers in Los Angeles against law officers conducting routine searches.
- Ability to use the sonic beam to clear a drug laboratory of suspects and drug dealers without subjecting the officers to the risks of toxic chemical fumes and the extreme explosion hazards posed by the use of firearms in such an environment.
- Ability to use the sonic flocculation (the rapid settling and precipitation of fogs and dust clouds by intense airborne sound waves) effect to trap and settle hazardous agents including the possible release of chemical or biological warfare agents by a terrorist group within an urban population center.

1.2 The Need for Improved Options in Law Enforcement:

Law officers and correctional officers are required to control hostile, belligerent and potentially dangerous individuals and ultimately accomplish this by having several technological means of forceful response and restraint available to provide the needed control.

This might be thought of as an effectiveness or force multiplication aspect of law enforcement technologies. In other words, the technologies allow the officer to subdue, control and contain a determined and sometimes significantly outnumbering hostile criminal force. Other scenarios

strongly highlight the critical need for less-than-lethal technologies. Barricade situations involving well armed individuals have become more common. Such barricade situations are extremely dangerous to law enforcement personnel owing to the advantage of protection and cover afforded to suspects hiding in the barricade. These situations have been further compounded by the presence of innocent individuals such as children and non-belligerent people mixed in with the perpetrators. The innocent parties are used as "political" shields by the violent and armed individuals. Again, these scenarios present an extreme challenge to law enforcement in trying to respond to the armed and violent individuals while ensuring the safety of the innocent victims.

1.3 The Less Than Lethal (LTL) Technology Option:

The response to violent and other situations by less than lethal force is the solution to many of the issues outlined in Category 1, LTL focus area, of the NIJ solicitation. LTL technologies would allow for a fundamentally new type of response by law enforcement and corrections officers to violent scenarios. Some benefits of the LTL response are:

- Breaking the escalation to violence cycle in uncertain scenarios, the LTL technologies eliminate the criminals' ability to escalate the situation to the need for forceful or lethal response (with the corresponding social/political implications).
- Application of the LTL technology in complex situations with by-standers and hostages. The use of a true LTL device eliminates the possible lethal effects of some conventional response options upon innocent victims and bystanders.
- Protection of buildings, personnel and borders with emplaced devices that can be operated only when necessary to respond to surrounding events.

The use of LTL technologies would *largely eliminate the social concerns about excessive force.* Clearly such a capability would greatly add to the overall utility of law enforcement.

2.0 SARA Inc.'s Approach - High Power Acoustics

Before discussing the applications of high power acoustic beam technology to specific types of law enforcement problem areas, let us consider some general aspects of acoustics.

2.1 The Effects of Intense Acoustic Energy

High power sound imposed on personnel and material can generate some unique effects. Acoustic effects can be varied from mild annoyance through incapacitation. These variations can be attained by adjusting intensity, frequency and other beam parameters.

Experiments conducted with high power acoustic sources have often revealed profound effects upon personnel. Table 1 lists the effects noted during SARA, Inc. acoustic testing and the benefit to the NIJ of these effects. Figure 1 summarizes the physiological coupling and effects of acoustics to the human anatomy. Less-than-lethal effects of high energy acoustic fields include incapacitation of personnel by excitation of acoustic resonances within body air cavities (e.g., lungs, sinuses, nasal passages); excitation of resonances or vibration modes within or between the internal bodily organs; and thermal effects resulting from absorbed acoustic beam power.

A promising new effect (being investigated by SARA, Inc.) is Pulsed Period Stimuli (PPS). Under certain frequency and modulation formats, pulse acoustic waveforms potentially have the ability to interfere with the nervous system, causing disorientation, or inducing a passive state within the targeted subject. Additionally, these effects may be produced at significantly lower intensity levels (well within OSHA exposure limits), thus significantly reducing the required device output power.

TABLE 1. Benefits of LTL Effects to the NIJ Program

Acoustic Device & Frequency	Power Level or (Intensity)	LTL Effects Reported	Benefits to NIJ Program
Pulsed Combustion Infrasound Source, **built & tested by SARA, Inc. for US Army 1993** (7 to 20Hz)	500 - 750 Watts (110 - 130 dB)	• Bodily discomfort. • Strong avoidance of intense zones. • Fatigue and disorientation	• Effects relevant to civil unrest control demonstrated. • Compact, highly mobile device
Combustion Driven Siren, **built & tested by SARA, Inc. for US Army 1994** (2 kHz)	Actual power output classified by US Army	• Short term disorientation and strong fatigue lasting several hours	• Demonstrated source technology for future weapon systems and LTL technologies.
Thermo-acoustic (combustion driven) resonator tubes, **built & tested by SARA, Inc. for ARPA 1994** (165 Hz)	Power level data sensitive (120 to 130dB)	• Strong bodily discomfort. • Strong fatigue and discomfort lingering	• Compact, highly rugged and transportable sources for civil unrest, fleeing vehicles and barricade situations
Combustion Driven Siren, very high power device **built & tested by SARA, Inc. for US Army 1996** (4 to 8 kHz)	60 kilowatts 120 to 150 dB	• Nausea • Sonic fatigue and other effects	• Transportable source technology suitable for multiple applications such as fleeing vehicle, barricade and prison unrest
Special high frequency antenna generated beat waves, **built and tested by SARA, Inc. for the US Army 1995** (4 kilohertz carrier, 5 to 10 Hz beat waves)	----------	• Ability to propagate beat waves into closed structure observed. • Strong interference/ stoppage of activities.	• Physical and psychoacoustic effects present. • Adaptable to multiple NIJ applications and LTL needs.
Pulsed periodic stimuli effects testing, **conducted at SARA, Inc. for the US Army 1996** (4 kHz carrier with special modulation)	110 dB	• Strong disorientation effects noted. • Perceptual changes induced. • Forced calm/lethargic states	• Physical and psychoacoustic effects present. • Adaptable to multiple NIJ applications and LTL needs. • Allows for strong LTL effects at low intensities.

The susceptibility of personnel is strongly influenced by the acoustic beam's spectral content. Certain acoustic frequencies appear to have enhanced coupling efficiency to a target, as shown in Figure 2. To first order, this effect is a manifestation of resonance in which the acoustic frequency coincides with an acoustic (cavity) or mechanical oscillation made in the target.

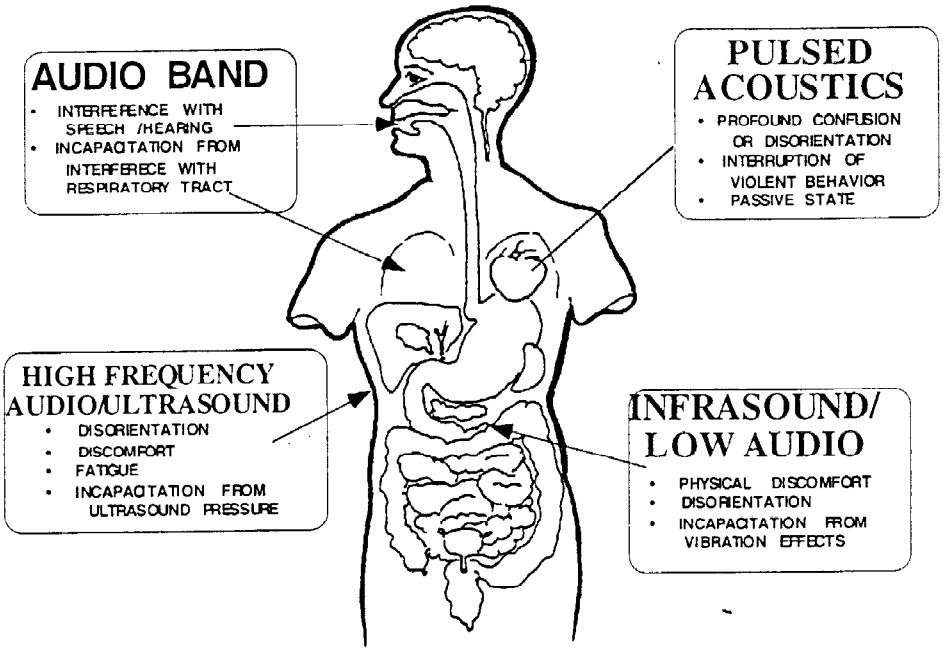


FIGURE 1. Physiological Coupling Mechanisms of Acoustic Energy

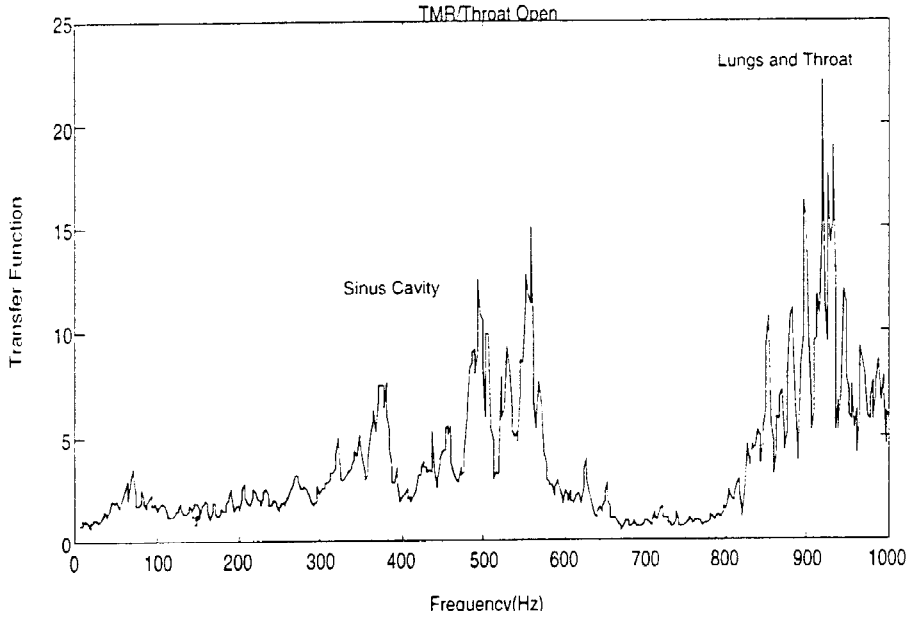


FIGURE 2. Transfer Function of Upper Respiratory Tract

2.2 Relevance of Acoustics to LTL Technologies

High power sound energy offers some very advantageous properties that directly support the goal of a viable LTL capability for law enforcement and corrections. Some of the more relevant aspects of sonic energy are illustrated in Figure 3 and outlined below with respect to LTL capabilities:

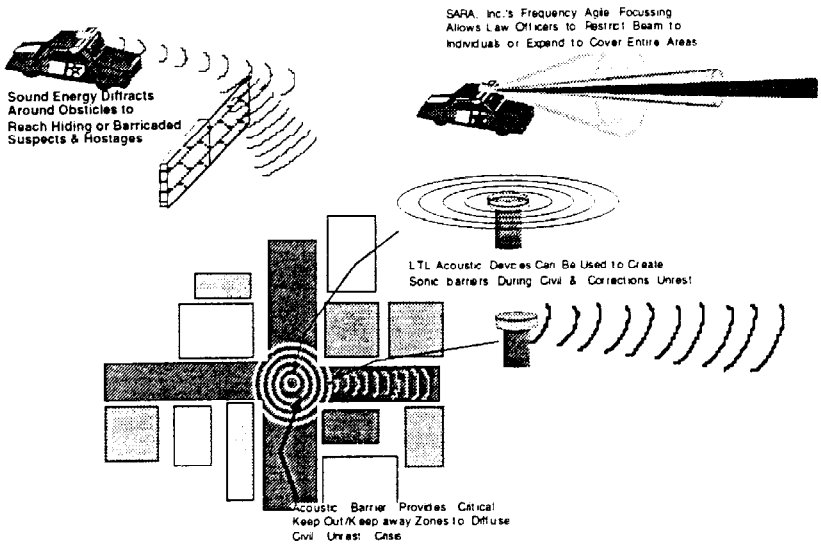


FIGURE 3. Acoustic Devices Provide Versatility in Law Enforcement Applications

Unlike tear gas, pepper spray or sticky foams the acoustic field does not leave a contaminating toxic residue requiring time consuming decontamination of suspects or operators, nor does acoustic technology release an environmentally hazardous material.

The acoustic field intensity level can be varied over a huge range, from a) mild annoyance, progressively through b) strong annoyance, c) physical discomfort (pain), d) disorientation, e) and finally physical incapacitation. Acoustic energy, at OSHA approved limits, may be used to produce a variety of physical incapacitation and other effects by selection of appropriate intensity, frequency and temporal waveform shape.

OSHA APPROVED LIMITS

One of the most important aspects of high power acoustics is the *incremental denial effect*. This occurs as the sound intensity level slowly increases either due to turning up the source power level or moving the source at fixed power towards the situation. Acoustic energy may be radiated as a large area omnidirectional field, a wide angle forward area directed beam or a relatively tightly focussed, directional beam, allowing for a) large crowd control, b) forward area sweep out control and c) small localized group or individual control.

Sound energy at incapacitating intensity levels may be propagated over short ranges (~100 meters) as for example an urban crowd control scenario. Acoustic energy may also be beamed hundreds of meters to multi-kilometers (using high energy acoustic sources) to remote locations such as isolated structures. Sound energy is airborne and can be transmitted via air ducts/air vents into enclosures where barricade situations may occur.

Sound wave energy can "diffract" around solid obstacles to reach hidden or barricaded suspects, and is efficiently transmitted through smoke, dust and fog.

Advanced acoustic beam control techniques in development at SARA, Inc. may give the device additional capabilities such as a) automatically selecting the most incapacitating frequency for a given suspect, b) extreme localization of any collateral effects and c) creation of low intensity "holding zones" surrounded by high intensity sonic barriers or walls that safely confine suspects for extended durations.

FORCE FIELDS

3.0 Methods of Generating High Intensity Acoustic Fields

Less than lethal applications of acoustic beam energy require sources capable of generating the power levels and spectral content needed for LTL effects. Although acoustic weapons have been proposed from time to time, it was SARA, Inc. that recognized the need for new acoustic sources as the first and fundamental step to weaponization of sound.

Conventional acoustic source technologies such as loudspeakers and compression drivers (high performance loudspeakers) are simply not capable of physically generating the sound energy levels needed for weapon applications. Indeed earlier acoustic beam incapacitation programs reached this barrier due to the lack of appropriate acoustic beam sources.

The problem can be illustrated by some simple examples based on effects modeling and analysis. SARA, Inc. has calculated that for incapacitation effects at even moderate engagement ranges, continuous output acoustic power levels of about 50 kilowatts are required. Conventional loudspeakers (even at peak performance levels) typically emit levels of only approximately 100 watts. Thus convention systems are nearly a factor of 500 below the required radiated sound power capability for weapon effects. This problem might be solved by arraying a large number of loudspeakers together. While this approach is theoretically possible it presents severe problems for practical application. Large numbers of individual loudspeakers require complex electrical and electronic control subsystems. In addition the typical electrical efficiency of the loudspeakers (~10% electrical to acoustic power conversion) would require prime electrical power sources in the megawatt range.

CONVENTIONAL SYSTEM

SARA, Inc. has developed acoustic sources that are highly compact, rugged and do not require electrical power sources to generate the sound energy (refer to Appendix A). We have recently demonstrated an acoustic power output of 60 kilowatts from a compact source. This device was one of a series of high power weapon prototype combustion driven acoustic beam generators developed and tested by SARA for the US Army and other government agencies. The following sections briefly describe some of the systems we are considering for NIJ applications. Appendix A gives greater detail on the background and operation of these device types.

3.1 Combustion Driven Siren (CDS)

This system currently holds the record for highest sustained continuous power output. This system uses a combustion process to generate a high pressure, high volumetric flow of gas from a combustion chamber. The combustion generated gas flow is outcoupled from the combustor plenum by a rotory mechanical system (rotor/stator assembly).

3.2 Super Charger Powered Air Siren;

SARA, Inc. has developed a variety of approaches to driving siren and siren like devices to very high sustained acoustic power outputs. Recently, for the helicopter based acoustic weapon program (funded by the Army AATD), we have created a system that uses a compact internal combustion engine to drive a series of high throughput air super chargers.

3.3 Unstable Combustion "Flame Resonators"

Another device technology that can be applied to the NIJ missions is the unstable combustion type device. These systems have been developed at SARA, Inc. for the very highest power applications for the US Army and other DoD customers. These systems can be scaled down to the more moderate NIJ power levels and are thus a potential approach for this program.

3.4 Super Charger Powered Whistle

The resonator type acoustic devices known as "whistles" offer a potential source for the development of a rapidly deployed source for crowd and riot control. In 1991 SARA, Inc. developed, under internal funding, a whistle device that operated at about 140Hz. This system was tested using electrically powered air-blowers for providing the requisite high power air stream.

4.0 Safety Issues

Our work has been the constant attention to all safety aspects of this technology for LTL use. In reviewing the application of intense sound and pulse periodic modulated sound sources for the law enforcement community we have identified the following critical areas for consideration in the design and usage phases:

1. Operator safety is clearly the principle concern as no LTL system will be practical if it poses a risk to the operator.

2. Collateral effects on nearby law officers or by-standers must be eliminated as well for the obvious reasons of general safety.

3. The effect upon the suspect must not be permanent and thus must be a temporary LTL effect.

To address these first two concerns SARA, Inc. has concentrated on the antenna, beam forming and frequency propagation characteristics for the sound weapon. SARA, Inc. has developed, modeled and successfully tested antenna designs for intense sound that have front to side emission ratios of over 1000.

The rejection ratio for the back lobe (sound projected backwards at the operator) is even higher and can exceed 10, 000. To further reduce the annoyance factor to the operator and nearby personnel ear protection would be issued. These antenna designs and potential further improvements will be incorporated into all aspects of this program. As part of our dissemination activities the safety aspects will be emphasized and explained to all potential users.

Low frequency sound energy, as we are proposing for the civil unrest device is also a safety advantage. At lower frequencies the human hearing tract becomes an increasingly inefficient acoustic antenna for capturing sound energy. At high intensities such as 120 dB the low frequency fields can incapacitate while the subject may not experience particularly significant hearing discomfort.

The need for highly safe LTL acoustic devices may occur in certain scenarios. In this case SARA. Inc. proposes, as part of this program, the incorporation of pulse periodic stimuli (PPS) effects for LTL applications. These effects occur when sound in the audio band (the carrier frequency) is transmitted with a particular type of modulation format. This format essentially has a repetition

rate, duty cycle and pulse rise time that are intended to create interference effects with the natural rhythms and cycles of the human central nervous system. With the correct format this results in essentially a temporary, completely reversible upset in brain functioning leading to perceptual distortions and forced states of calm and lethargy.

5.0 Technological Approach to Law Enforcement Applications

SARA, Inc. has performed preliminary assessments of particular applications of interest to the NIJ. The highlights of these applications are shown in Table 2 and detailed in Appendix A. We have determined that acoustic devices have applications in the focus areas of 1) Riots, civil disturbances and crowd control, 2) Fleeing vehicles, 3) Arrestee, prisons and corrections, and 4) Barricade and hostage situations. Each focus area is discussed in the sections that follow.

5.1 Riots, Civil Disturbances & Crowd Control Focus Area

At present, we are envisioning a system that will employ "agile beam control". This will allow the peace officers to define a beam spread pattern that matches the area that needs to be subjected to a LTL acoustic beam. For this scenario, shown in Figure 4, the beam generator would be delivered into the area by surface vehicle and kept at a safe range (for the officers) from the crowd. Using the *incremental denial effect* to transition from moderate to high levels of discomfort and disorientation will result in the tendency for people to move away from the source to lower intensity acoustic zones. Thus the sonic beam can be used to clear an area and sweep out the more determined mob members. The source would then be operated in several possible manners, as detailed below, to initially gain the needed control.

TABLE 2. Benefits of Previous SARA, Inc. Acoustic Technology Programs to the NIJ

Project	Technology Description	Benefit to the NIJ	Project Contact (Organization)
High Power Acoustic Beam Technology DAAA21-92-C-0083	Infrasound Pulser Crew-Served Weapon Application	Source technology for crowd control and civil unrest	Harry Moore (U.S. Army ARDEC)
Non-Lethal Weapons for Helicopter Use DAAJ02-94-C-0019, and DAAJ02-95-C-0011	Combustion-Driven Siren, Flame Vortex Resonator Helicopter Non-Lethal	Source concepts for: crowd/riot control, fleeing vehicles and hostage/barricade situations	Charles Fikes (U. S. Army AATD)
Selective Facility and Area Denial Technologies DAAH01-94-C-R242	Resonant Flame Tube Non-Proliferation	Source technology at optimum frequency for civil unrest	Steven Flank (ARPA /ASTO)
Acoustic Weapons Development DAAE30-95-C-0006	Combustion-Driven Siren for Lethal and Non-Lethal Operations Other Than War	3 devices designed and produced. 2 delivered to date Two new technologies developed for long range use. Design/Fabrication/Test turnaround times improved	Cpt. Scott O'Neil (USAIS)
High Intensity Acoustic Fields for Access Denial DE-FG03-96ER82274	Access Denial for specific DOE Facilities	Initial work into Physical security for buildings. Concepts applicable to NIJ prison applications	Karl Veith (DOE-HQ)
Non-Lethal Devices DAAE30-96-C-0038	Acoustic Pulsed Periodic Stimuli from a Non-Lethal Device for Non-Lethal Operations Other Than War	Research provides an approach that eliminates the risk of any physical or permanent side or collateral effect from acoustic LTL devices	Lucian Sadowski (ARDEC)
Acoustically Enhanced Remediation of Contaminated Soil and Ground Water DE-AR21-94MC30360	Piezo-electric transducer generated acoustic field Soil and Ground Water Cleanup	Acoustic Source technology development which enhances the understanding of acoustics	Joe Iovenitti
Acoustically Driven Pest Control 20905193	Commercial Pest Control SARA Proprietary Program	Research providing further understanding of the use of acoustic devices for commercial applications	Proprietary Contact

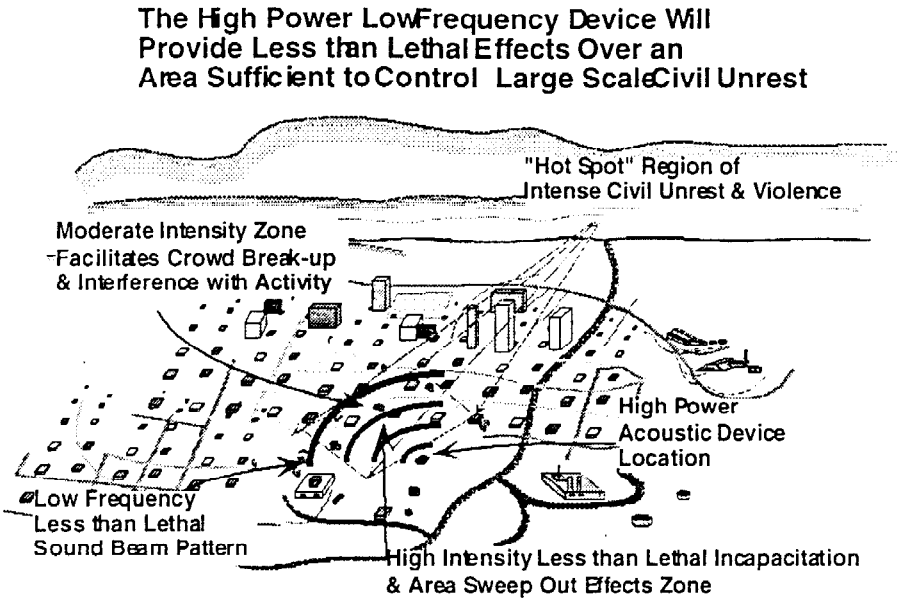


FIGURE 4. Large Scale Civil Disturbance Application of Low Frequency LTL Acoustic Device

- Wide area coverage to control large crowds. — Generation of an intense wide area coverage, forward directed beam that acoustically "illuminates" the entire mob.
- Communications Disruption — Initial illumination with high intensity, high frequency audio band sound (1 to 10 kilohertz) to produce attention getting discomfort, and interfere with communication (talking/shouting) between rioters.
- Area sweep out, Perimeter/barrier creation and access denial — Illumination with lower frequency audio or infrasound to produce significant bodily discomfort and somatic disorientation effects. The intensity is then increased (slowly) to begin pushing the crowd back.
- Disorientation of riotous mobs — A more complex waveform involving pulsed periodic stimuli (PPS) may be employed. The PPS effects can be profoundly disorienting and would enable the law officers to essentially shut down particularly dangerous areas of the riot.

- Control and break-up of riot flash points — Tightly beamed acoustic radiation at or near the strongly incapacitating level could be beamed into the crowd at selected individuals and groups. This would allow LTL applications on riot leaders or individuals within the crowd that were armed or acting as snipers against law officers, thus minimizing collateral effects on the surrounding crowd.

Figure 5 depicts a device concept to address these applications.

To assist in our design the SARA, Inc. team will use the expertise in riot dynamics provided by our members from the Los Angeles Police Department (LAPD). The LAPD is the only major metropolitan police department with very recent experience in a major urban unrest event.

SARA, Inc.'s understanding of the dynamics of acoustic beam interactions will be used to select the optimum frequency band for usable effect. Since this type of application will require a high average power source we will investigate the use of a scaled down version of the combustion

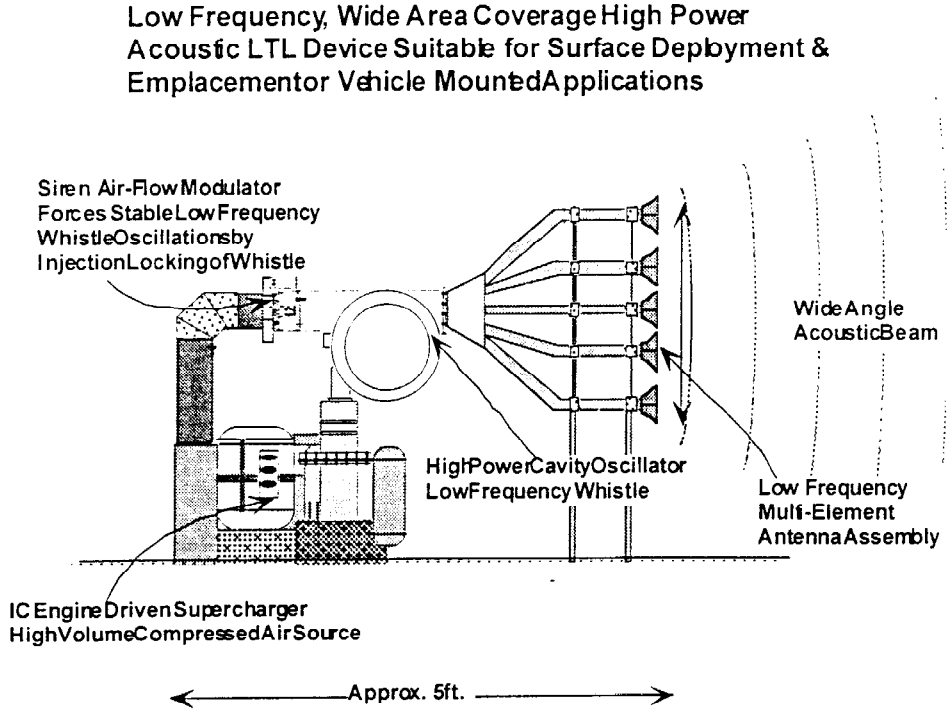


FIGURE 5. Low Frequency, High Power Acoustic LTL Device for Civil Unrest and Crowd Control Applications

driven phase change beam generators developed for the US Army. This device would also be effective for border patrol, control and access applications.

5.2 Fleeing Vehicle Focus Area

High power acoustic beam technology would also have important applications in the pursuit and stopping of suspects in fleeing vehicles. The advantage of the acoustic beam approach is that the power may be directed remotely from other police pursuit vehicles and helicopters (Figure 6).

The human response to an intense acoustic field results in an inability to carry on activities such as driving a vehicle. Intense sound (120 to 130dB) can create effects from annoyance to profound physical discomfort. Drivers subjected to an intense acoustic field would initially attempt to protect their ears, thus significantly interfering with their ability to continue driving or fleeing from pursuing law officers. A noted effect of intense sound is to interfere with the visual process. High intensity sound results in blurred vision due to the rapid vibration of the human eye ball created by intense sound waves.

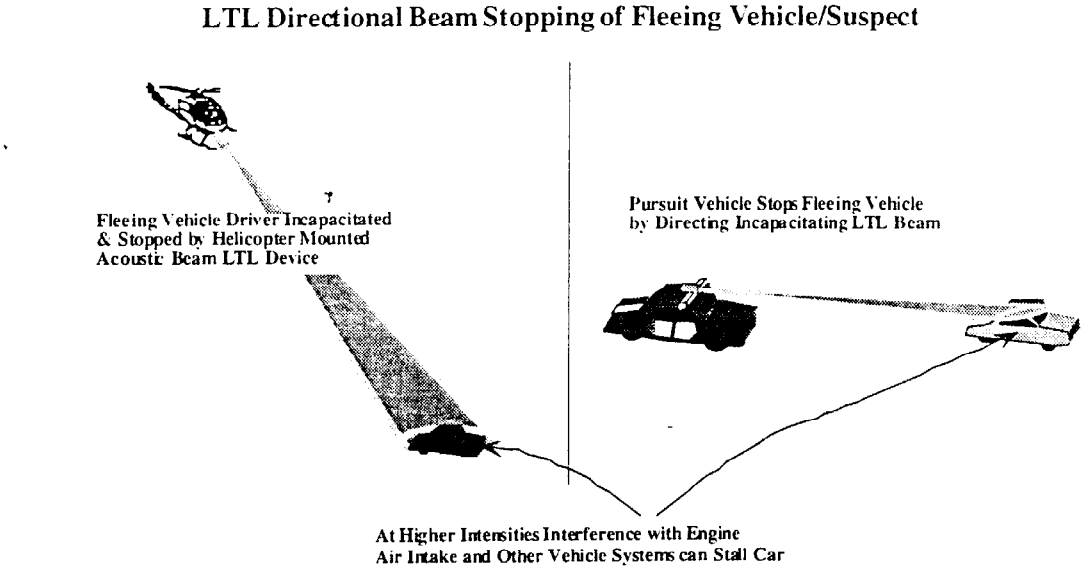


FIGURE 6. Application of Mid Frequency Directional Acoustic Beam Device to the Stopping of Fleeing Vehicles

At higher intensity levels (140 to 150dB) the sound field will produce effects that reach a level of profound physical (full body) discomfort. At such intensities the driver will be unable to concentrate or function in any way required to maintain driving.

The goal of this task area will be to identify how high power acoustic devices can be used to stop fleeing vehicles. We will rely upon the expertise and large experience base of the LAPD to define requirements for this device application.

This device would also be effective in border pursuit applications where violators flee across international borders into the United States. Figure 7 shows the concept as implemented on a police vehicle.

5.3 Arrestee, Prisons and Corrections Focus Area

This area of applications for sonic LTL technology would look at the general need to control suspects during the arrest process. Related to this is the critical need for the control of large and potentially violent populations in correctional institutions. Prison riots and unrest can lead to

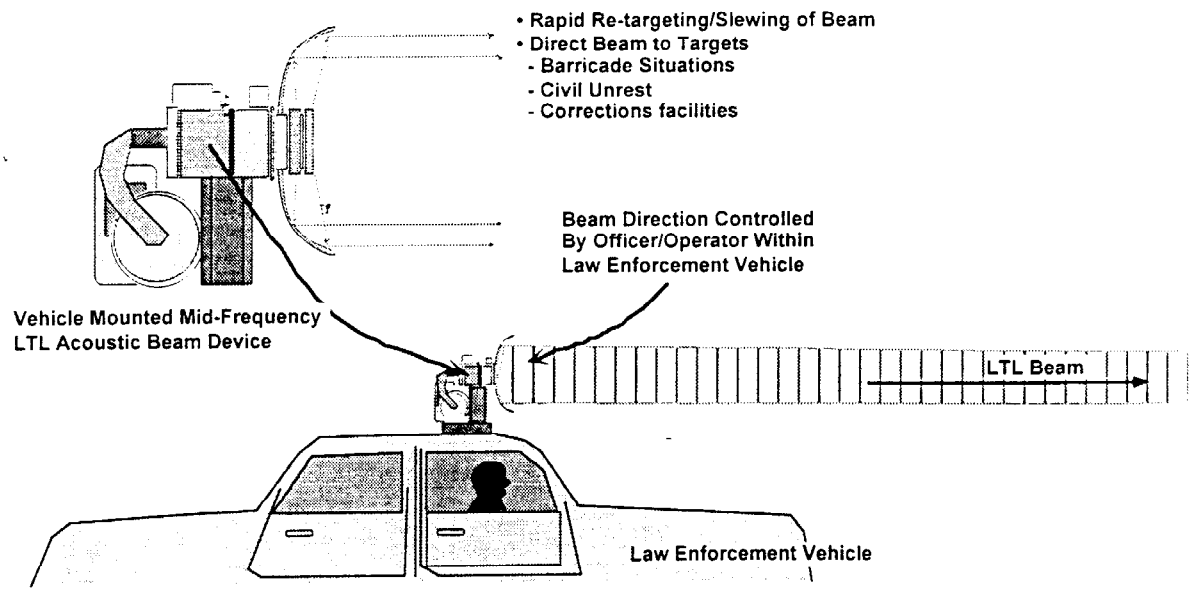


FIGURE 7. Mid Frequency High Power Acoustic Device with Optional PPS Effects for LTL Applications

highly dangerous situations resulting in the injury and death of corrections officers and prisoners. As with other areas of concern in this proposal, the prison unrest scenario (Figure 8) often involves a small number officers attempting to control a large and belligerent prison population. For this scenario, high power acoustic technology offers the LTL solution by allowing the following strategies:

- Control of prison riots

  Disorient/subdue violent inmates and prisoners

  Provide physical security barriers for officers and other non-inmates
- Prevent communication between prisoners
- Disorient/subdue violent or uncontrollable suspects

The variable degree of effects that can be selected with high power acoustic LTL systems offers very significant potential for such applications. The ability to either tightly beam and direct the acoustic power or flood a wide area is critical in supporting these criminal arrest and corrections facility situations.

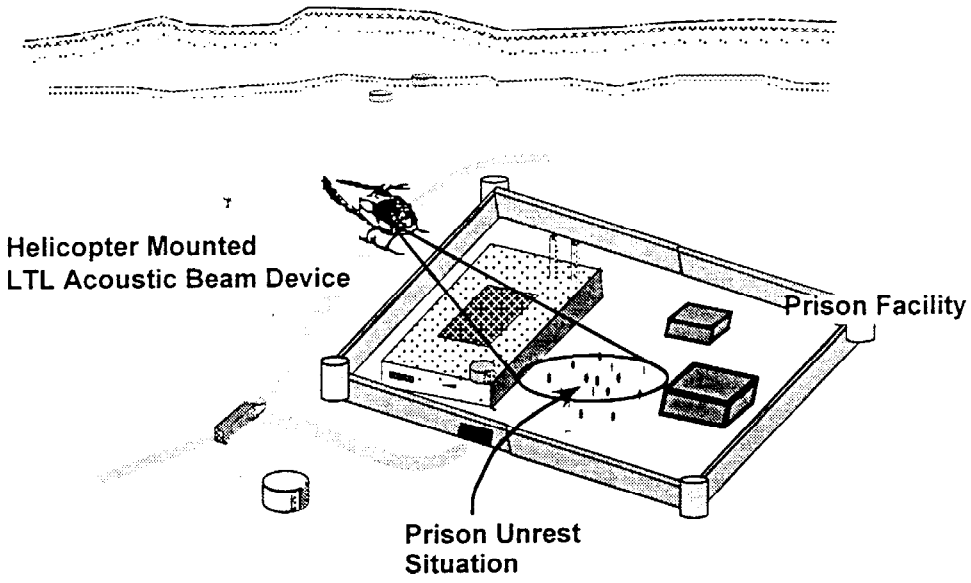


FIGURE 8. Possible Corrections Application of a Helicopter Mounted LTL Device

In an arrest scenario the arresting officer could be equipped with a compact sound weapon as conceptualized in Figure 9. Suspects that choose to flee from the officers or offer resistance to arrest could be targeted. The small device would be operational at a high ultrasonic frequency (from 25kHz to possibly as high as 100kHz). The device would be configured to operate much like a common flashlight allowing for a directional central beam to directed onto a particular suspect.

The choice of the high frequency ultrasound beam offers additional benefits. At sufficiently high frequencies the beam will be strongly attenuated in transmission through the air. It will thus be possible to select a beam that would only propagate to a distance of tens of meters before being absorbed by the air. Thus collateral effects with unwanted or stray beam power are eliminated at any range of more than several tens of meters from the officer.

5.4 Barricade & Hostage Situations Focus Area

The use of an intense sound generator LTL weapon will open an entirely new type of response to this crisis. Figure 10 depicts a high gain (highly directional) mid-frequency acoustic beam LTL

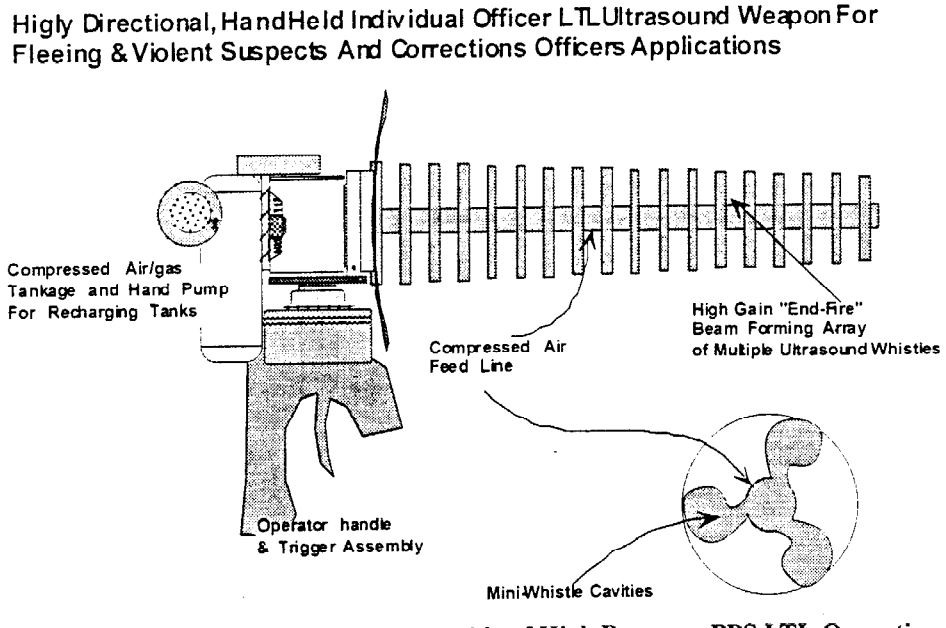


FIGURE 9. Individual Officer Device Capable of High Power or PPS LTL Operation

device. This device would be capable of projecting a narrow angle incapacitating beam distances of hundreds of meters to kilometers. The location of the barricade situation can be illuminated with the sound beam for extended periods as may be needed to force a resolution. It must be recalled that the effects we are basing our weapons upon can not be eliminated by simply covering or plugging ones ears.

- At high intensities the sound field has numerous coupling "paths" into the human anatomy to create the LTL effect.
- Low frequency sound waves (frequency ~ 10 to 200Hz) are extremely difficult to shield against, such frequencies easily penetrate through walls and into enclosures.
- To completely minimize collateral physical effects upon children that may be present, the device may be operated in a PPS mode intended to be disorienting and incapacitating to adults.

For barricade situations that are in remote or complex terrain, a directional beam device can be used. This would allow the officers to direct a beam (much like a search light beam) to acousti-

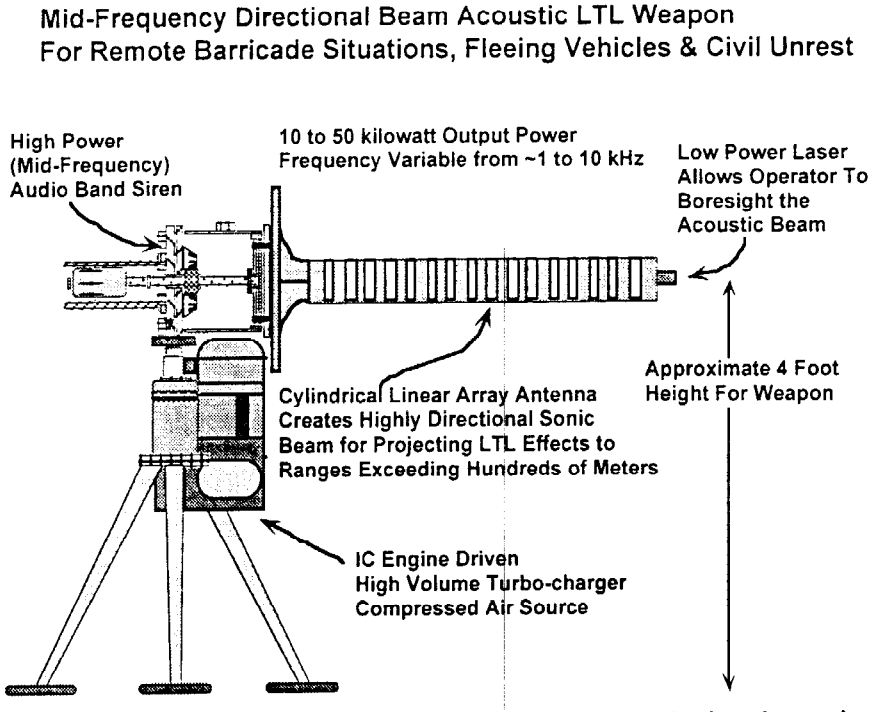


FIGURE 10. High directionality acoustic LTL device for remote barricade situations using a high gain linear array antenna developed by SARA, Inc.

cally "illuminate" the structure in question. Thus the main high power lobe will not be directed upon officers, observers or bystanders that happen to fairly near the barricade structure (Figure 11).

In an urban environment the sources may be placed near the structure or dwelling by transporting it to the location attached to a vehicle. Clearly a helicopter may also be used to direct the incapacitating beam down from above onto the structure or barricade location. SARA, Inc. will work closely with our law enforcement team and the NIJ to fully define and map out all options for this and other applications of acoustic LTL systems.

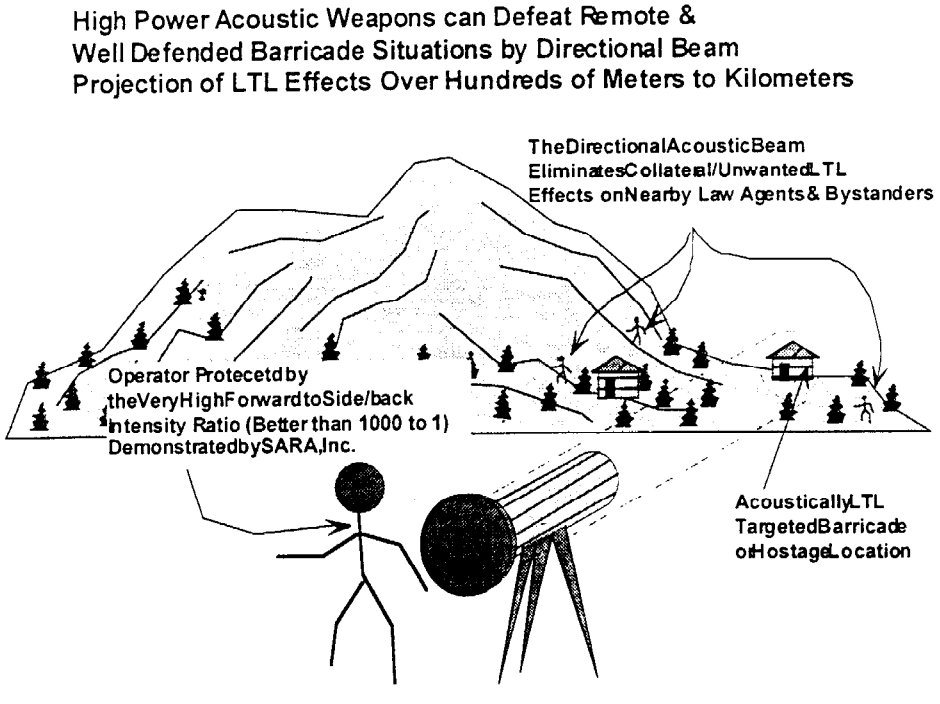


FIGURE 11. Acoustic Device Application to a Barricade Situation

6.0 Statement of Work

The overall goal of this program is to develop, fabricate and test three prototype, high power, acoustic beam devices that address the Less-than-Lethal (LTL) focus area in Category 1 of the NIJ solicitation. These devices will provide a truly Less-than-Lethal technology that is compact, easy to use and low cost. Concepts under consideration are:

- A high frequency (ultrasound), compact, hand carried device — Designed for the individual law or corrections officer, it is an incapacitating weapon for controlling belligerent and fleeing suspects or aresstees in a corrections environment.
- A vehicle mounted high power audio band (0.5 to 5 kHz) device — Designed to mount on an automobile, SWAT vehicle or helicopter. It would be capable of projecting a directional beam for use in defeating barricade situations, stopping fleeing vehicles and some civil unrest situations.
- A very high power, surface deployed, low frequency (10 to ~200Hz) sound generator — Designed with a wider angle (forward area) beam pattern for control and suppression of civil unrest events and large scale outbreaks in correctional facilities.

Based on these concepts, a statement of work has been developed and is outlined below.

6.1 Task 1 - Evaluation of LTL Acoustic Requirements

During this phase of the program SARA, Inc. will evaluate and perform analysis of several critical LTL law enforcement and corrections applications of intense sound. Based upon our extensive programmatic experience we will define acoustic intensity and frequencies for each mission type. Included in this task will be computational modeling (using our proprietary acoustic antenna and beam codes) of the beam footprint patterns.

6.2 Task 2 - Device Analysis & Design:

This task involves the detailed design of the high power acoustic sources for LTL applications. The design philosophy will emphasize four critical areas:

1. Compact and low weight integrated package for ease of transport and operation.
2. Control and elimination of operator hazards as well as unwanted collateral effects on bystanders.
3. Design for maximum operator ease and agility (such as rapid beam focus/defocus and power control).
4. Prototype device design for rapid transition to a low cost production version for use by government and civilian law enforcement and corrections.

6.3 Task3- Device Fabrication:

During this task the high power acoustic LTL prototypes will be fabricated. SARA. Inc. will closely monitor all phases of fabrication to ensure that all design requirements are met. We have a *100% success rate in fabrication* of functional, very rugged and cost effective high power acoustic systems for less than lethal applications.

6.4 Task 4 - Device Verification Testing

During this phase of the program substantial checkout tests on the three fabricated, prototype devices will be conducted to verify basic device performance levels and operational characteristics before moving onto scenario testing. These tests include:

1. Functionality
2. Power measurements

3. Spectral content

6.5 Task 5- Limited Effects Device Testing

During this phase, the devices will be tested under a variety of simulated engagement conditions including 1)demonstration of beam agility from a common device including tight focussing, variable beam divergence, beam slewing and rapid retargeting for selected areas, 2)testing in large areas with complex structures and other urban features to characterize the beam effects in conjunction with buildings, trees etc.,3) interaction of the acoustic source with hallways, corridors and large enclosed areas as would be involved in prison, correctional facilities and some hostage scenarios, 4) intensity measurements inside of buildings or other structures that may be targeted by law enforcement from outside locations (such as during hostage/bank robbery scenarios), and 5) intensity measurements inside of moving vehicles targeted by the sonic beam.

6.6 Task 6 - Human Response Testing

In order to expand the effects data base of the highly promising Pulsed Periodic Stimuli (PPS), we will test more volunteers during this phase of the program. The tests will be conducted by the team who performed the original tests during our Army Phase I program described in Appendix A. All tests are performed with volunteers at *OSHA safe sound levels*. These tests will give NIJ a better understanding of the type of affects available for use in LTL scenarios.

6.7 Task 7- Project Management

Quarterly progress reports will provide the customer with the latest updates on the program and will include current schedule, budget, relevant conceptual and fabrication drawings, data, and consultant inputs.

SARA, Inc. will provide periodic briefings to the NIJ based on schedule requirements. These include the CDRs for Device 1, 2 and 3, and after the completion of Tasks 4, 5 and 6, a final briefing will be prepared and presented to the NIJ showing the results of all test efforts and analysis.

The final report will be prepared based on the results of our analysis, test results and briefings. This report will be used to disseminate the results of the program to other individuals and institutions. *The full dissemination plan is discussed in Appendix A*

6.8 Task 8 - Optional Item- *State of California Matching Funds*

Based on input from Mr. Rohit Shukla of the LA Regional Technical Alliance, letter enclosed in Appendix A, SARA Inc. will apply for cost sharing funds of $250,000 from the State of California. These funds will be used to begin the process of converting the prototype devices to production. Once the funds have been awarded, a detailed plan will be developed.

7.0 Expected GFI/GFM

We currently have access to a remote test range at USMC Camp Pendleton through our ARDEC sponsored Acoustic Weapons Development Program. We would require support from NIJ in requesting continued access to Camp Pendleton. Of special interest would be the use of the combat towns to support some of the scenario testing outlined in Task 5

8.0 Management Plan, Schedule and Deliverables

8.1 Management Plan

The SARA, Inc. team was conceived to allow for the highly valuable input from a major metropolitan law enforcement agency. SARA, Inc. selected the Los Angeles Police Department (LAPD) as the prime member of it's law enforcement advisory team. The LAPD team will consist

of distinguished representatives from several critical offices and divisions within the LAPD. Each of these representatives has many years of experience in areas that are directly related to the LTL technology goals of this contract.

Mr. Jeffrey Baxter will head and coordinate the LAPD advisory and consultant team on this program. Mr. Baxter is a consultant and special advisory and intelligence to the LAPD. He has coordinated and selected an outstanding panel of LAPD members representing the following functions within the LAPD:

- Special Weapons and Tactics (SWAT)
- Special Security Investigations (SSI)
- Anti-Terrorism

Additional input will be provided by having law enforcement veterans on the team that will directly relate the requirements for LTL from the perspective of the "officer in the streets". This input is essential to give our acoustic weapon engineering team the insights needed to correctly engineer for the ultimate end user.

Figure 12 shows the management structure for this effort. Individual task managers and other performers will report directly to the program manager. Refer to the Curriculum Vitae for summary resumes of the key individuals.

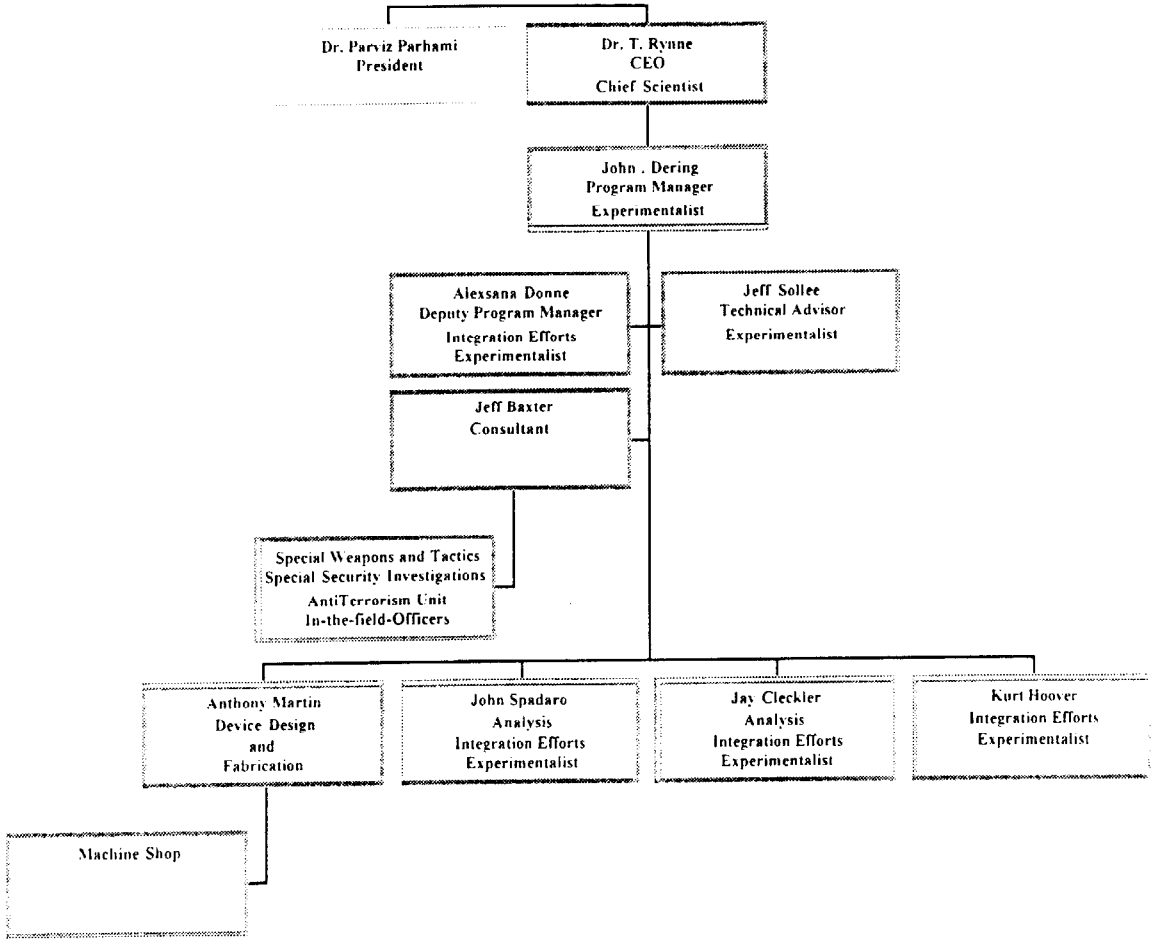


FIGURE 12. SARA, Inc. Organization for the NIJ Effort

Projects are regularly reviewed by senior executives of SARA, Inc. to ensure adequate performance with respect to technical, cost, and schedule aspects, as well as adequate support to the program. Cost and schedule information for CDRL items are provided on a weekly basis to the program managers by our administrative staff. The cost information is available each Monday for the previous week, allowing for near real time management of costs and schedules.

8.2 Schedule

Based on the Work Breakdown Structure (task breakdowns) and our experience in design, fabrication, test and delivery of acoustic hardware for previous development programs, Figure 13 shows the top-level schedule of tasks we have developed for this program.

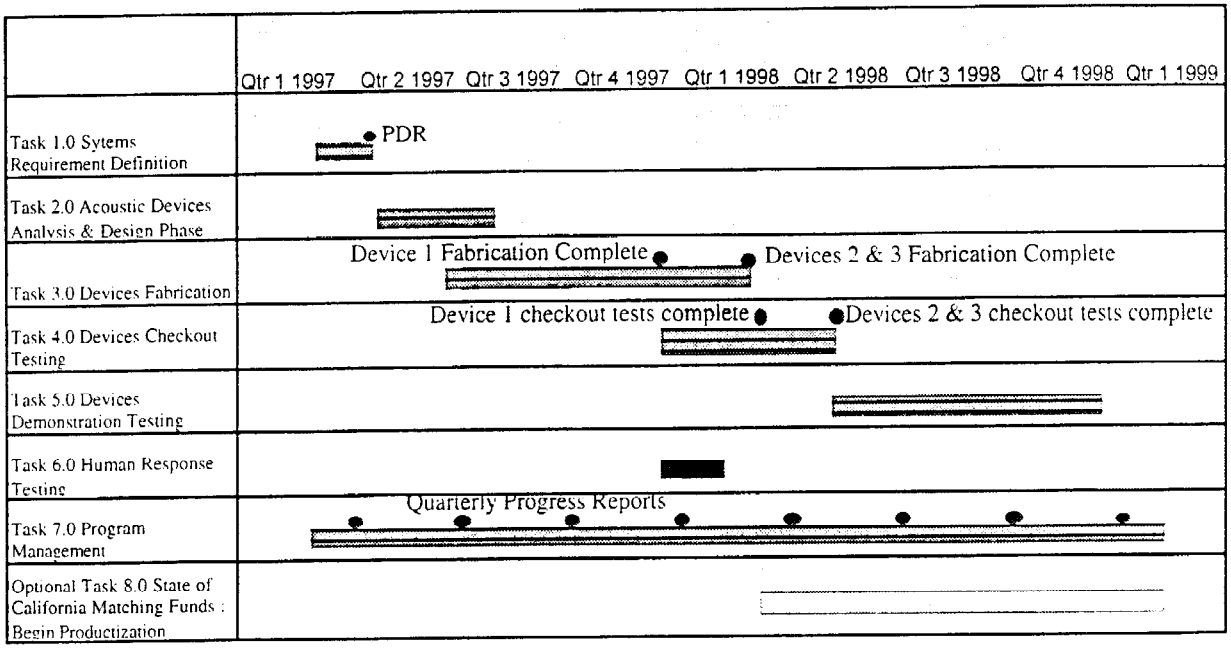


FIGURE 13. Task Schedule Based on the Work Breakdown Structure

Appendix A

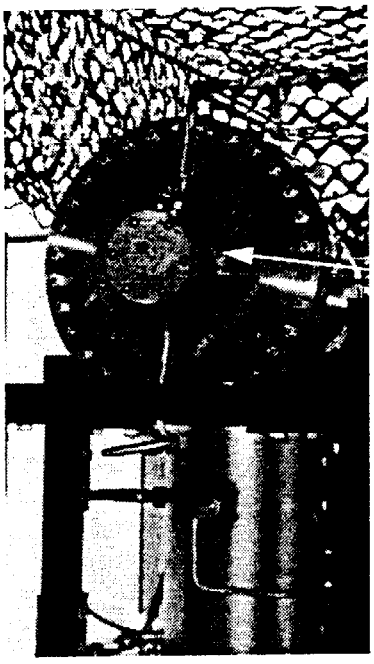
- Related Contract Experience
- Information Dissemination Plan
- Services, Products, Facilities and Equipment
- Supporting Documentation for Optional Task 8

1.0 Related Contract Experience

1.1 Acoustic Weapons Development Program

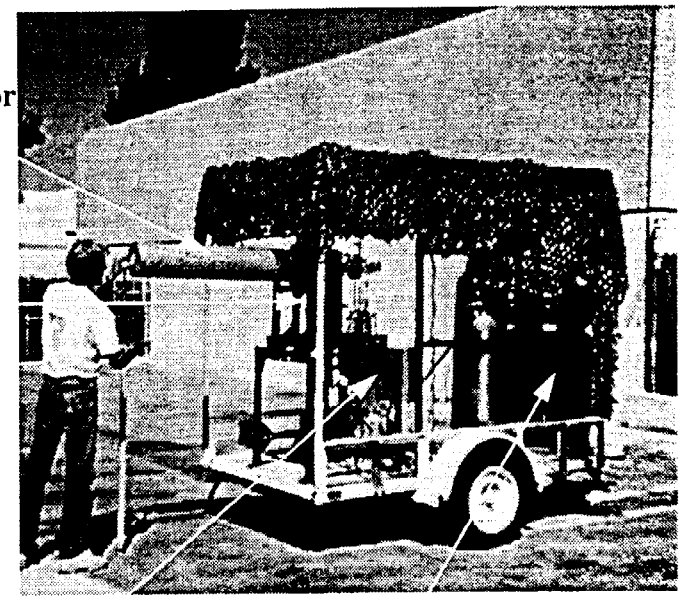
The High Power Acoustic Weapon Technology Program (contract # DAAE30-95-C-0006) was awarded to SARA, Inc. under the FY'95 Advanced Concepts and Technology II sponsored by the Army Research Office.

The program is specifically aimed at providing the individual soldier and small forces new methods to enhance war-fighting capability in dismounted battlespace. This includes both lethal and non-lethal options. The High Power Acoustic Weapon Technology Program has developed a portable demonstration device,Figure 1, which has been characterized in a series of field tests at Camp Pendleton Marine Corps Base in California. Demonstrations and outdoor effects test programs are pending. In addition to developing high power source technologies (Figure 1, Figure 2, and Figure 3) this program also developed key analytical tools and a unique method of providing a directional acoustic beam while maintaining a compact device profile.



Beam Director

Combustion Driven Siren



Instrumentation and Readouts Reactant Supplies

FIGURE 1. SARA, Inc. Combustion Driven High Energy Acoustic Source

Frequency Range of 2.5 kHz to 10.0 kHz

Continuously tunable

Power level of ~ 2 kWatts

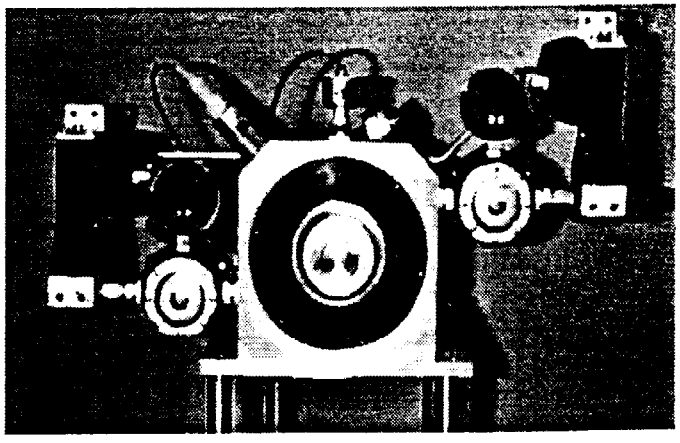


FIGURE 2. SARA, Inc. Compact High Power, High Frequency Acoustic Test Source

Frequency Range of 450 Hz to 2.5 kHz

Continuously tunable

Power level of ~ 2 kWatts

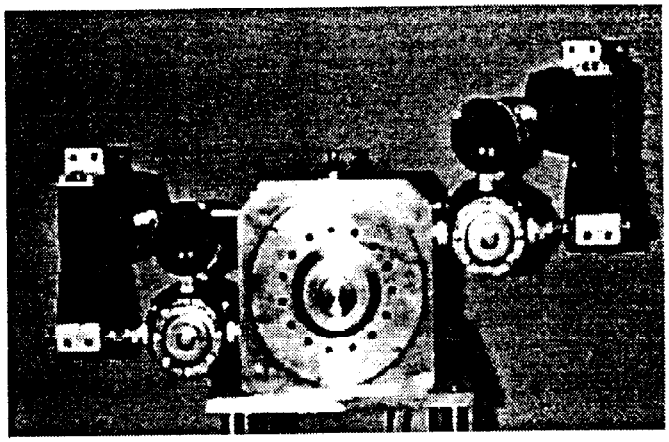


FIGURE 3. SARA, Inc. Compact High Power, Audio Band Acoustic Test Source

1.2 High Power Acoustic Beam Program

During this Phase I BAA, SARA, Inc. looked at the requirements for building an acoustic crowd control demonstration device. A number of issues currently applicable to the NIJ were researched and are highlighted below:

- The main objective with respect to large area crowd control is providing an area denial capability, enforcing a keep-out zone, or cause an advancing group to turn back. In this case, it may be advantageous to set up a non-lethal acoustic device to turn back a crowd advancing down a street. This requires that the area of coverage equal typical human height (2 meters) by typical street width (10 meters). For cases where non-lethal devices would be useful (i.e., the crowd is armed only with things they can throw), a useful keep out range would be in excess of 50 meters. Multiple devices could be used to separate or drive back unruly crowds, or sweep them in a desired direction.

- In the above case, the power requirements for a combustion-driven acoustic source could be rather modest. Taking the area of coverage desired (2 X 10 = 200 square meters) and multiplying by a non-lethal, incapacitating intensity of 130-140 dB (10 - 100 w/m^2) we find that the

power requirement at the source is between 2 and 20 kW. We have demonstrated laboratory scale sources well in excess of the 2 kW level, and are currently working on designs for other applications that are well in excess of the 20 kW level.

The device built for this program is pictured in Figure 4.

Frequency Range of 1 Hz to 17 Hz

>130 dB at 10 m

The Infrasonic Pulser is based on repetitive detonation of methane and oxygen or other fuels. It generates intense low frequency emissions. A modification allows for the generation of intense toroidal vortices. It is intended for the investigation of the effects of intense infrasound energy.

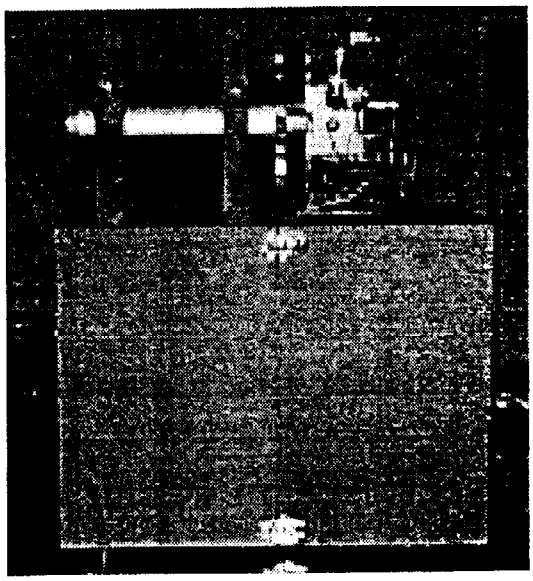


FIGURE 4. SARA, Inc. Infrasonic Acoustic Pulser

1.3 Non-Lethal Weapons for Helicopter Use

The purpose of this ongoing program for the Army is to develop two high energy acoustic source technologies that can be mounted to and used from a helicopter platform. Among the mission concepts for such a crew served weapon are:

- Control of large surrendering forces
- Riot/mob control
- Rapid response perimeters

- Area incursion denial
- Hostage/barricade crisis
- Smuggling interception

The device being built for this program is an advanced design combining both the antenna and siren into one unit. The benefits of such a design are:

• The siren allows a more compact power scale up aspect by utilizing the surface area of a cylindrical form (i.e. the cylindrical rotor stator).

• The cylindrical siren with it's periodically arrayed planes of outcoupling holes provides the antenna/beam forming function as well.

• The siren design minimizes the overall weight envelope by combining the actual acoustic power generation system and antenna into one integrated package.

Since the antenna is an endfire type system it has performance characteristics similar to the endfire and related multi-element antenna concepts in RF engineering. One benefit that our analysis has shown is that beam forming functions such as projection of a wide angle or tightly directional beam can be accomplished by simply varying the frequency of acoustic output. This permits the siren to have the following range of operations abilities:

- In a full angle mode the siren is tuned so that the diffractive antenna structure acts as a broadside array. This launches beam power essentially into a pattern that radiates out as a divergent cylindrical pattern (i.e. power radiated more or less in all direction). This capability might be used to create an initial warning or strong "attention getting" effect in hostile/riotous crowd control.

- As the frequency is swept the diffractive beam forming effects collect the primary beam power into a narrowing forward directed cone of sound radiation. This allows for the creation of a large footprint intense beam for area control, sweep out and targeting of selected zones in a conflict situation.
- The narrow directional beam is created as the siren frequency is now tuned to coherently diffract the siren output into the most tightly focussed "diffraction limited" sonic beam. At this mode of operation relatively small target zones can be subjected to high intensity non-lethal incapacitating acoustic pressure levels.

1.4 Selective Facility and Area Denial Technologies

Figure 5 depicts a risk reduction experiment configuration with a high power acoustic source and a linear beam former/antenna developed at SARA, Inc. on a Phase I SBIR for ARDEC. The hardware set up is generally representative of the size and configuration of an acoustic device that might be implemented for crowd control. The main device components are the siren, the beam forming antenna, and the reflector.

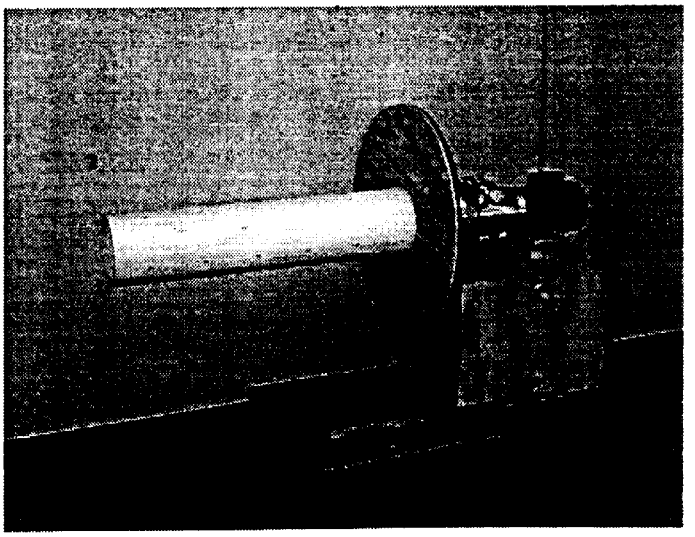


FIGURE 5. Risk Reduction Experimental Configuration with High Power Acoustic Source and Linear Beamformer

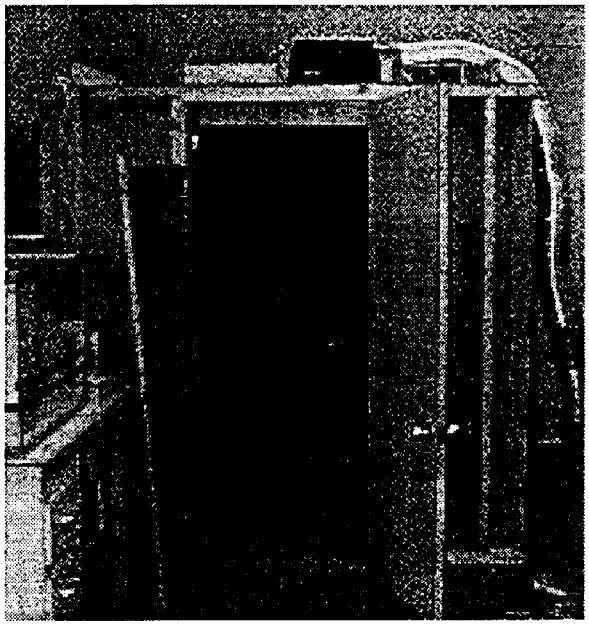


FIGURE 6. Anechoic Chamber

1.6 Commercial Acoustic Contracts Summary

1.6.1 Acoustically Enhanced Remediation of Contaminated Soils & Ground Water

Phase I was a laboratory scale parametric investigation to demonstrate the feasibility of using acoustic sources to alter the porosity of the soil matrix and/or physical properties of the fluid thus increasing the rate of flow of the contaminant within the soil. Phase I included laboratory tests and analysis to provide evidence of the viability of the approach.

Phase II of this successful program was to experimentally prove that an acoustic excitation field could be utilized to increase the remediation rate at a contaminated site. This program consisted of a laboratory scale investigation using a 2 dimensional model based on the Phase I experimentation as well as planning for a field test for Phase III.

SARA Inc. successfully developed and implemented an acoustic source capable of exciting a contaminated region within the 2 dimensional test cell. The acoustics package has been delivered to University of Colorado, Boulder/Weiss Associates where the actual remediation experiment is being conducted.

1.6.2 Acoustically Driven Pest Control

The goal of this ongoing proprietary research program is to develop a non-chemical means of pest control using high intensity acoustic energy to eliminate three classes of pests. Realization of this goal will yield a new, environmentally safe, user friendly, pest control system.

1.6.3 Acoustic Enhanced Oil Production

A team consisting of SARA, Inc., Weiss Associates of Emeryville, California, and Core Laboratories of Bakersfield, California have proposed to the Friends of the Tulare and the Friends of the Diatomite (FOT and FOD, respectively) testing a new technology for enhanced oil production. This technology involves the use of acoustic excitation fields directed into an oil reservoir to increase the sediment/rock permeability and the pore fluid (i.e., oil) mobility. The basis of this acoustic oil production (AOP) proposal lies in work conducted (1) between the 1960s and 1990s principally by Russian researchers, and (2) since 1993 by SARA, Inc. and Weiss Associates under a U.S. Department of Energy (DOE) environmental research and development contract involving the use of acoustic excitation fields in enhancing the remediation of contaminated soil and ground water.

The proposal is to conduct (1) laboratory proof of principle testing of the technology for oil field production in the Bakersfield area and (2) other required acoustic source testing to validate a viable oil field production technology. It is expected that Phase I one the testing will begin in Sep-

tember of 1996. Source technology testing will begin in January of 1997. SARA has also presented a proposal to interested Bakersfield oil companies to determine the potential of forming a Bakersfield Oil Consortia to further the develop and evaluate AOP.

2.0 Information Dissemination Plan

The results of this project will be made available to the individuals directly involved in the program and to the general law enforcement and corrections public. To facilitate information access the following steps will be taken:

- Three briefings will be presented at conferences of the NIJ's choice.

  Travel for these briefings has been budgeted in this proposal.

- A user friendly version of the final report will be placed in a professional magazine such as "The Corrections Professional".

This magazine has already carried an article about SARA, Inc.'s involvement with LTL technologies and is willing to add an update article about our work.

- SARA, Inc. homepage on the World Wide Web (http://www.sara.com)

  A page will be dedicated to the results of this program with a URL to the NIJ home page. The final report will be made available in Adobe Acrobat.pdf format for direct download via ftp from this dedicated page. Using the existing NIJ supplier page, a URL to the SARA, Inc. page will also provide direct access to the information.

- Directors of the Western and Midwestern Regional Centers

  We have previously provided Mr. Jim Keller and Mr. Robert Pentz with current SARA, Inc. capability brochures and briefing charts showing our existing and in progress work. They will be invited to all briefings during the course of this program and provided with sufficient support to allow them to disseminate the information to their contacts.

- Border Research Institute

  As the program we have proposed provides solutions for border patrol applications, personnel from the Border Research Institute will be invited to all program briefings. A copy of the final report will be sent to them.

- U. S. Congressman 45th District Dana Rohrabacher

  Congressman Rohrabacher has received numerous briefings from SARA, Inc. on all areas. He is an active proponent of LTL use and continues to provided support and contacts for our efforts.

- Ken McKellar, South Carolina Department of Corrections

Mr. McKellar contacted SARA, Inc. in response to the article in "The Corrections Professional". He has asked to be kept up-to-date on our advances in the areas of prison and riot control applications.

- Col. John Moffett

  Col. Moffett is the Chief of Staff for Lt. General Zinni of The First Marine Expeditionary Force which continues to be involved in the use of LTL technologies. They have had direct experience with the use of LTL technologies in Somalia and Bosnia.

- Col. Dennis Scanlon, USMC Quantico

  The U.S. Marines have recently become the executive agency for nonlethal weapons within the DoD. Colonel Scanlon is the cognizant officer at USMC headquarters, Quantico.

- Jerry Edwards

  Mr. Edwards is the R&D manager for the US Army Physical Security Equipment Management Office. This office deals with security issues for the triservices. Mr. Edwards has been briefed at SARA and continues to be updated on our LTL technology developments.

3.0 Services, Products, Facilities and Equipment

Scientific Applications & Research Associates (SARA) Inc. was incorporated in June 1989 by three aerospace scientists. SARA, Inc. headquarters is currently in Huntington Beach, Ca with approximately 18,000 square feet of office and laboratory space. This facility has a DoD clearance of work up to the Top Secret classification level. We are also evaluating permanent acquisition of remote test areas to support field testing for programs anticipated and currently in-house. As part of two ongoing Army contracts, we have access to a remote location at USMC Camp Pendleton

for testing our high power acoustic devices. This access will continue for the next two to three years.

The charter of SARA, Inc. is to perform state-of-the-art research on a number of high potential technical areas and to transform the developed technology into successful commercial products. SARA, Inc. has already developed and is marketing a 1 GHz bandwidth RF measurement system (CASSPER) for performing transfer function and spectrum measurements.

SARA is currently involved in a number of research and development activities and has business areas that include

- Future Military Technologies
- Law Enforcement Technologies
- Detection and Tracking
- Signal Processing and Instrumentation
- Electromagnetic Engineering
- Energy Sources
- Environmental and Geophysical Sciences
- Data Engineering

Including the original three founders, SARA, Inc. has 29 full time and 2 part time employees and will continue to grow due to significant contract awards in the above key areas. SARA Inc. has also established a network of academic consultants with Georgia Institute of Technology, California State University at Long Beach, University of Southern California, University of California at

Los Angeles, University of Illinois and Illinois Institute of Technology to aid in key research areas.

SARA, Inc. has an offsite laboratory where our mid-scale and high energy acoustic devices are assembled and initial lowpower checkout tests performed. This laboratory provides a machine shop, fuels and other tools for device integration and test. SARA has committed substantial capital funds to provide B&K microphones and PCB pressure transducers in order to make acoustic measurements at all frequency ranges necessary to characterize the broad range of devices we have built to date. We currently maintain and operate, for at least the next three years, a remote test site at USMC Camp Pendleton where all high power acoustic beam power and propagation tests are performed. The Marines are highly enthusiastic about the results of our acoustic technology testing and have prominently emphasized this work in articles in Marine Corp and other defense publications.

SARA, Inc.'s main laboratories have all the basic tools for fabricating, diagnosing, and testing electronic circuitry (up to 1 GHz) and fabricating various experimental hardware and test jigs. We have multichannel digital acquisition systems, high voltage power supplies, pulse power equipment, and the necessary instrumentation for performing high voltage engineering and physics investigations.

To support our charter we have an ongoing commitment to invest a high percentage of our capital expenditures for expanding laboratory resources. The recent purchase of Pacific Applied Research Corporation increases our company capabilities in the Laser area.

SARA has purposely kept its management organization simple and relevant. This approach has resulted in an ideal research and development environment, *with low overhead*, thus enabling SARA to quickly adapt to the needs of its customers.

4.0 Supporting Documentation for Optional Task 8

In the SOW, Task 8 an optional item for *State of California Matching Funds* was included. The support letter from Mr. Rohit K. Shukla, Executive Director of the Los Angeles Regional Technology Alliance is included as page A16.

Curriculum Vitae

1.0 Key Personnel

The SARA, Inc. concept for all programs is kept simple and relevant to the goals of the contract. All tasks and key subtasks are assigned to a Program Manager, who takes full responsibility for the successful completion of the assigned work within the budget and schedule allocated. Because of the importance of this program to SARA's growth and its implications for law enforcement and peacekeeping forces, we have assigned John Dering, as Program Manager. Mr. Dering was the program manager for the High Power Acoustic Beam Technology Phase I program, Selective Facility and Area Denial Technologies Phase I program, and Non-Lethal Weapons for Helicopter Use Phase I and Phase II. Dr. Timothy Rynne is also a key technical performer and will lead the analytical task efforts in conjunction with other analysts at SARA. Mr. Jeff Sollee will provide valuable input based on his technical and programmatic experience as the program manager/technical lead for the High Power Acoustic Beam Weapons Program.

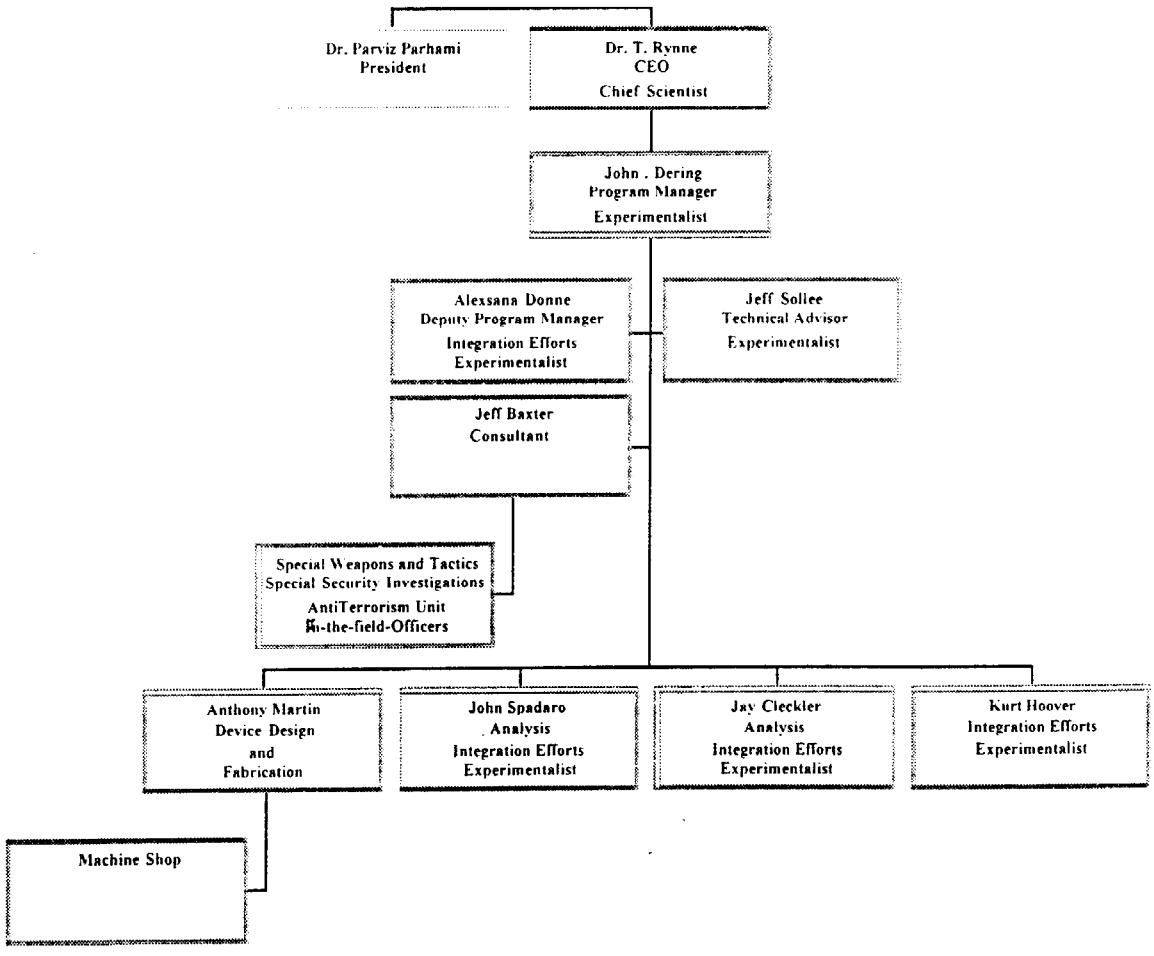


Figure 1. SARA, Inc. Organization for the NIJ Effort

Figure 1 depicts the project organization of the proposed effort.

Table 1 provides an overview of the program team and skills. T

TABLE 1. SARA, Inc. Team Provides a Broad Spectrum of Experience

Team Member	Acoustic Source Requirements	Acoustic Source Development	Acoustic Source Design	Acoustic Source Integration	Acoustic Source Testing	Acoustic, Thermal, Mechanical	Law Enforcement Experience	Program Management	Signal Processing
John Dering	X	X	X	X	X	X		X	
Dr. Tim Rynne	X	X		X	X	X		X	
Jeff Sollee	X	X	X	X	X	X		X	
Alexsana Donne	X			X	X			X	
Jay Cleckler	X			X	X	X			
John Spadaro	X			X	X	X			
Kurt Hoover	X			X	X				
Anthony Martin	X		X			X			
Dr. Parviz Parhami	X							X	X
Mike Marino								X	X
Jeff Baxter	X		X		X		X		
LAPD Consultants	X		X		X		X		

1.1 John P. Dering

Mr. John Dering has over 20 years of experience in the science, engineering and project management of advanced technology programs including all categories of directed energy weapons and related intense beam source technologies. Mr. Dering has a B.S. in Physics from California State University at Hayward and an M.S. in Optic Physics from the University of Arizona. Mr. Dering is presently the Technical Manager for the Power Systems Technology Operations.

- Since joining SARA, Inc. in 1991 Mr. Dering has developed several innovative technologies that have since grown into significant business areas at SARA. Mr. Dering is the originator of the combustion driven high energy acoustic beam source technologies at SARA. Inc. These innovative devices have been funded and developed on a series of critical government programs investigating the use of intense sound beams as an advanced weapon for limited effects and unconventional warfare missions.
- Mr. Dering has successfully managed the High Power Acoustic Beam Program (HPAB) funded by the Army Armament Research and Development and Engineering Command. Mr. Dering Has also managed the Phase-I and Phase-II small business innovative research (SBIR) programs developing non-lethal acoustic weapons for helicopters, funded by the Army Applied Aviation Technology Directorate (AATD). Mr. Dering was also manager and principle scientific investigator of a Phase-I SBIR investigating acoustic weapons for area and weapon of mass destruction (WMD) facility denial and neutralization sponsored by the Advanced Research Project Agency (ARPA).

- Mr. Dering continues to develop advanced acoustic source and beam control technologies for high power acoustic weapons as part of SARA, Inc.'s ongoing internal research and development program.
- Mr. Dering has also worked with the senior technical staff of SARA, Inc. in the investigation of fundamental physics for very advanced long term projects. Mr. Dering is currently the technical manager of several of the advanced research projects and topic areas at SARA, Inc.

1.2 Dr. Timothy Rynne

Dr. Rynne is a founder of SARA, Inc. and is presently the CEO and Chief Scientist of the company. He has 24 years of professional experience in a broad number of technologies including applied electromagnetics, applied optics, astrophysics, acoustics, and theoretical, experimental, and applied physics. He holds a B.S. and M.S. in Physics from Florida Atlantic University, and a Ph.D. in Physics from the Illinois Institute of Technology. He holds a DoD Top Secret Clearance as well as other EBI based clearances.

- Dr. Rynne was the Principal Investigator on a recent Army SBIR program which examined the possibility of using acoustical pulsed periodic stimuli for influencing human performance factors. The results of these tests have direct baring on using high power acoustical devices in riot and crowd control. The results of these experiments show the possibility of using relatively low intensity acoustical waves on influencing human performance at intensity levels that will not cause any damage (permanent or temporary) to the human physiological system.
- Dr. Rynne has been the principal scientist on all acoustical programs at SARA, Inc. His analysis efforts have been on acoustical beam formation, acoustical source designs, acoustical beam propagation, and acoustical coupling to facilities and targets. Dr. Rynne is a co-inventor (patent applied for) of a concept for using high power acoustics in the remediation of contaminants in the environment.
- Dr. Rynne has been the Principal Investigator on a SARA, Inc. IR&D program which examined the coupling of acoustical waves to the human physiology. This analysis included validation against experimental results obtained on humans at low illumination intensities. This analysis has resulted in an excellent understanding of the complete resonant coupling enhancement to the naso-pharynx, larynx, aural, and lung/trachea system.
- Prior to coming to SARA, Inc., Dr. Rynne was a Technical Fellow at TRW. His areas of expertise were in nuclear and conventional electromagnetic pulse, pulse power systems, and advanced nuclear power systems. He also has a great deal of experience in systems engineering of ICBM and other hardware development programs.

1.3 Jeffrey L. Sollee

Mr. Sollee joined SARA Inc. in June of 1993. He brings with him over 19 years of experience in numerous areas, including acoustics and lasers. He holds the B. S. and M. S. degrees in Physics from the University of California at Los Angeles. He also holds a DoD Top Secret Clearance.

- Mr. Sollee is currently the manager of the High Power Acoustic Beam Weapon Program. This work is sponsored by U.S. Army Dismounted Battlespace Battle Lab and ARDEC. Mr. Sollee was responsible for supporting the hardware design analysis and test planning

on the Phase I Nonlethal Weapons for Helicopter Use Program. He also supported the testing of the infrasound pulser on the ARDEC High Power Acoustic Beam Program

- Mr. Sollee also has a significant background in environmental acoustics. He participated for three consecutive years (1984 - 1986) in the Arctic Environment Acoustic Survey field tests, sponsored by the Navy. This work involved deployment of numerous acoustic sensors and sources beneath Arctic ice to characterize the propagation of sound beneath the polar ice pack. He is proficient in the planning and execution of field tests wherever they may occur.

Mr. Sollee has managed a variety of combustion-driven chemical laser programs. Prior to joining SARA Inc., he was the manager of the Army/BMDO-sponsored Overtone Laser Technology Development Program at TRW, where he led the design of a modular, regeneratively-cooled advanced chemical laser system. This work required extensive knowledge of the dynamics and thermodynamics of compressible fluid flow, along with knowledge of chemical kinetics, quantum electronics, and optics. He has a great deal of experience in hardware fabrication, integration, and testing of combustion-driven laser hardware, from subscale laboratory devices to weapons-class systems.

1.4 Alexsana Donne

Ms. Alexsana Donne holds a M.S. in Technical Management from West Coast University and a B.S. in Physics from the University of California at Los Angeles and has over 15 year of experience in high energy lasers and acoustics. She has an extensive background in the integration and test phases of programs including design, procurement, buildup, test, data acquisition and reduction. Ms. Donne has both laboratory, large test stand and remote site test experience. She has a current DoD Top Secret Clearance and has held a Special Access Clearance.

- Ms. Donne is currently the Program Manager/experimentalist for a commercial acoustics pest control research project.
- Concurrently, she is the Deputy Program Manager for the Nonlethal Weapons for Helicopter Use program and is providing experimental support for in-house and remote testing of the high energy acoustics devices on both this program and the Acoustic Weapons Development program.

Prior to joining SARA, Inc, Ms Donne worked at Rocketdyne as a junior Project Engineer on the resonator/diagnostics task for the Chemical Oxygen Iodine Laser (COIL) program.

1.5 Anthony Martin

Mr. Martin joined SARA Inc. in February of 1995. He possesses over 8 years of experience in mechanical engineering, including such fields as fluids, thermodynamics, stress analysis, materials, and dynamics. He holds a B.S. and M.S. degrees in Mechanical Engineering from the University of Michigan at Ann Arbor. He also holds a DoD Top Secret Clearance.

- Mr. Martin has extensive experience in developing the practical and real applications of advanced technologies, turning theoretical and experimental concepts into practical cost effective hardware.

- Mr. Martin provided the key inputs at SARA, Inc. for the design, development, and fabrication of a variety of acoustic devices, along with general mechanical engineering support for other programs, and has unique skills in the area of acoustic technology based on both this experience and his skill base. He has performed critical and original work in the analysis of air and combustion driven acoustic devices, their design, and cost effective manufacture. His efforts have addressed maximizing utilization of off the shelf hardware, low cost materials, and cost effective manufacturing techniques. He has developed a unique siren design that show promise for significantly enhancing inherent device beam forming and directionality capabilities.
- Prior to his employment at SARA, Inc. he worked for Rockwell International, Inc. and the diverse experience base developed there includes such work as structures analysis, materials, manufacturing, and project support for the National Aerospace Plane, Single Stage to Orbit Rockets, International Space Station, and a variety of other advanced programs.

1.6 John Spadaro

Mr. Spadaro attended Drexel University where he obtained a BS in Physics and California State University, Long Beach where he received a MS in Physics. Mr. Spadaro brings with him experience in high energy acoustics stemming from his involvement in several different government and commercial programs.

- Mr. Spadaro has worked with the US Army on several programs including, the High Power Acoustic Beam Weapon Program, the Non-Lethal Devices program and the Non-Lethal Weapons for Helicopter Use. He is responsible for integrating hardware, performing required tests and data analysis.
- Mr. Spadaro is also currently working on a phase II effort for the Department of Energy entitled Acoustically Enhanced Remediation of Contaminated Soil and Ground Water which is now in the process of being extended to the commercial sector as a oil recovery system. He performed all technical and data analysis tasks on this program.

1.7 Jay Cleckler

Mr. Cleckler joined SARA Inc. in December of 1995. He graduated Magna Cum Laude in Physics from the University of Colorado in the Spring of 1995. In addition to his experience in acoustics and electromagnetics he brings with him three years of experience in superconductivity and solid state research.

- Mr. Cleckler has significant experience field testing acoustical weapons, and is well versed in the techniques and protocols of such testing. He continues to participate in the field testing of the high energy acoustical beam weapon under development for DBBL and ARDEC.He also assisted in experiments designed to measure the neurological effects of pulsed periodic acoustical stimulus on humans.
- Mr. Cleckler has extensive experience in scientific programming. He has written codes for data acquisition and test automation for a number of experiments, as well as having developed automation and data retrieval code for the high power acoustical beam program. He has also been