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CONCEALED WEAPON DETECTION PROGRAM

Decision-Science Applications, Inc.

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13. ABSTRACT *(Maximum 200 words)*

This report discusses various Concealed Weapon Detection (CWD) efforts and technologies which have evolved over the past few years. Information provided in this final technical report summarized programs being pursued based on National Institute of Justice (NIJ) and DARPA Grants and contract awards to move toward safe and dependable sensors to address the concealed weapon problem. These weapons are a major threat to both military and law enforcement personnel. The capability for CWD is a critical operational need for the Military, Federal, State, and Local Law Enforcement communities in their various areas of operations, unique environments, and regulations each must operate under. The CWD technological challenge of the 1990's, and beyond, will include the detection of metallic and non-metallic weapons. Detection of concealed weapons posses severe technical challenges based on the target phenomenology, background and obscuring medium. Based on the maturity of the technologies and proprietary information restrictions, detailed information was not available to support our investigations and additional work will be required in the future.

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EXECUTIVE SUMMARY

Concealed Weapon Detection (CWD) can be defined as the various techniques used to detect and identify concealed weapons on individuals or, in essence, the remote covert frisking of individuals. Concealed weapons - predominantly handguns and edged weapons are a major threat to both military and law enforcement personnel. The need for CWD capability is critical to the Military, as well as, Federal, State, and Local Law Enforcement communities in their various areas of operations, unique environments, and to comply with regulations each must operate under. The CWD technological challenge of the 1990's, and beyond, will include the detection of metallic and non-metallic weapons. Detection of concealed weapons posses severe technical challenges based on the target phenomenology, background and obscuring medium.

Decision-Science Applications, Inc. (DSA) has been investigating Concealed Weapon Detection technologies for the past few years under IR&D, the SBIR program and most recently this task. Information provided in this final technical report summarizes the programs being pursued, based on National Institute of Justice (NIJ) and DARPA Grants and Contract awards, to move toward safe and dependable sensors that are able to address the burgeoning concealed weapon problem. *Based on the maturity of the technologies and proprietary information restrictions concerning ongoing research and development efforts, detailed information was not available to fully support the majority of our investigations. In fact, follow-on funding for the most promising technologies has only recently been provided As a result, the investigations will need to be continued as prototypes are tested in the laboratory and operational environments.*

The challenges of CWD have forced scientists to consider multispectral and multisensor techniques for assured CWD. In fact, the requirements have broadened to consider explosives and other illegal substance detection. Various active and passive techniques are currently being pursued including; detection of materials (metal detectors), imaging of items, chemical and substance detection (sniffing technologies) as well as tagging technologies. Each area covers a broad range of multispectral and other techniques for detecting various items (personnel, substances, weapons, explosives). Imaging technologies reveal objects concealed under layers of clothing, enabling security personnel to detect the presence of weapons or other dangerous objects. Tagging technologies utilize active or passive tags placed on objects which indicate or tip off the presence of a CW. One of the newer techniques utilizes trace detection devices with the ability to react to specific vapors or particles from illegal substances or materials.

Each CWD phenomenology discussed in this report has advantages and disadvantages for any specific mission. However, and depending on the items of interest, the CWD systems need to have various characteristics in order to be effective against the items to be detected. The operational environment and the needs of the user (size, weight, etc.) as well as acquisition and operation cost are determining factors. Other factors include; being unobtrusive, having a minimal impact on operations, portability and setup time, having flexibility to scan both small and large areas with high/sufficient spatial resolution, processing speed (capable of video-frame-rate (3D) imaging of moving humans), and safety in terms of danger to humans/animals. In addition, an individuals right to privacy must also be considered in terms of the fidelity of images. Automatic Target Recognition algorithms are considered critical to minimize the potential for human error.

1. INTRODUCTION

Decision-Science Applications, Inc. (DSA) has been investigating Concealed Weapon Detection (CWD) technologies for the past few years. Information provided in this final technical report summarizes our experience with various programs, as well as those being pursued based on National Institute of Justice (NIJ) and DARPA Grants and Contract awards, to move toward safe and reliable sensors that are able to address the burgeoning concealed weapon problem.

1.1 THE PROBLEM

CWD can be defined as the methods used to detect and identify suspicious items, potentially concealed weapons on individuals, or the remote frisking of individuals. Concealed weapons - principally handguns, and edged weapons (knife-type), are a major threat to military, law enforcement personnel as well as the private sector. CWD remains a critical need and top priority for the military, as well as Federal, State, and Local Law Enforcement communities in their various areas of operations, unique environments, and to operate within regulation. Events over the past few years have shown the need for CWD for military and law enforcement personnel with the requirements well publicized in both cases. These varied needs demand CWD capabilities which can be implemented in a variety of environments suitable for both the needs of the military and law enforcement practitioners.

1.2 MILITARY

The military has been called upon many times in the past few years to perform peacekeeping or humanitarian aide roles. Somalia and Haiti are recent and vivid examples of the need for CWD to preserve peace, control personnel and provide for the safety of the peacekeepers. In many cases, a few soldiers are charged with monitoring and controlling a crowd with no way to determine if personnel are carrying concealed weapons short of searching each individual. Depending on the immediate mission and threat, it would be desirable to unobtrusively screen individuals to determine if any are carrying a concealed weapon and then take appropriate action. Knowledge of which individuals are carrying concealed weapons would allow the military personnel the ability to take the required action while being wary of the potential threat from the individuals.

Postulated MMW Radar CWD sensors are applicable to peacekeeping and humanitarian missions and would improve the safety of the military performing these missions. Also, there is the potential to use this sensor for through the wall imaging based on the specific makeup of some walls. With the addition of an adjunct sensor (visual/low light or infrared) slaved to the CWD radar, CWD detection would be linked to specific individuals. With the individuals displayed, the military personnel would be able to perform a safer approach to the individuals to take appropriate action. We also feel there is the potential for the implementation of cooperative tagging of weapons/personnel to identify persons authorized to carry concealed weapons.

1.3 LAW ENFORCEMENT

CWD has been described as the leading problem facing the Law Enforcement (LE) community. This problem has been widely publicized with regard to areas where the detection of concealed weapons is desired for the safety of the general public as well as the law enforcers. CWD surveillance of personnel on a street corner, attending a public function, or in and around government/public buildings is becoming more and more important. There are many other applications in the official (LE), private security, and business areas where unobtrusive and flexible CWD would be extremely valuable. Some examples include: mass transport (subway, airports); public buildings (banks, courthouses, schools); and, even shopping malls. In a recent

New York Times Magazine article, CWD capabilities were required to provide a method to identify potential weapons carriers to give police "reasonable suspicion" which allows them to stop and frisk suspects.

Obviously, all levels of law enforcement display the need for select sensors that would protect the public as well as ensure the security of the LE provider. In a broader scope, however, civilian/commercial use of these types of sensor capabilities would offer the largest market and shows tremendous potential. Businesses and industry would be able to screen employees, visitors and customers to identify personnel suspected of carrying concealed weapons. This screening could be expanded to look for other types of objects which might be used to address theft, etc. The technology is also amenable to the quality control and production world where products with certain characteristics could be screened automatically, and "templates" used to ensure all parts were included, in the correct place, and that no foreign objects were present.

1.4 CONVERGENCE

Because of the convergence of requirements of the military and the Law Enforcement communities, personnel from both now require similar CWD technology. The post Cold War era has driven the military and law enforcement missions to operate under similar rules and environments in many cases. Today, the military conducts peacekeeping missions in countries where it must operate under mandates comparable to the local policeman patrolling a small community. Likewise, the local police now must defend against criminals with high-tech weapons previously encountered only by military personnel. Today's military and law enforcement communities are faced with similar threats. A common threat suggests that the roles of the traditional military and law enforcement communities are metamorphosing, and technologies of use to one may be of use to the other. This common set of threats has advanced the use and tailoring of technologies, developed and funded by the military (DoD), for use by the civilian community.

2. TYPES OF CWD SENSORS

CWD Sensors are utilized in various environments and against a broad set of threats. Object detection and imaging technologies are currently the primary types under development or in use. Each technology covers a broad range of multispectral, multisensor and other techniques for detecting various items (objects, substances, weapons, explosives). Imaging technologies reveal objects concealed under layers of clothing, enabling security personnel to detect the presence of weapons or other dangerous objects. Tagging Technologies in terms of CWD utilize tags placed on the items to support detections. Trace-detection devices react to vapors or particles from explosive or other materials common to concealed weapons or other items of threat. CWD Sensors types consider the following:

- Passive Millimeter Wave
- Magnetic
- Electromagnetic
- Infrared
- Ultrasound
- Microwave

2.1 RADAR SENSOR CONFIGURATIONS

A variety of sensor types and configurations are possible, depending on the particular application. These sensor configurations would define the type of radar imaging problem undertaken, such as SAR, ISAR, tomography or real aperture. The SAR configuration is characterized by motion of a sensor to provide a spatial diversity with wideband frequency diversity. For the CWD problem, one might envision a sensor mounted on a police car that images street scenes as it passes. The ISAR sensor configuration is characterized by the motion of a target to provide spatial diversity with wideband frequency diversity. For the CWD problem, ISAR could be effectively used in areas that people walk through, such as lobbies, hallways and reception areas. Tomographic sensor configurations are typically characterized as having a very rich spatial diversity and low signal bandwidths or frequency diversity. A sensor of this type would require the placement of a large number of transmit and receive sensors throughout a room or other area to form a real versus synthetic aperture.

A real aperture sensor configuration is similar to a two dimensional phased array antenna. In this configuration, imaging can be three dimensional, thus providing down range, cross range and height. This sensor's multiple simultaneous beams provide angle discrimination in cross range and height. Range information would be provided through use of a wideband waveform. This sensor configuration can provide high quality images which are "clean" of artifacts due to the fact that little polar to rectangular grid interpolation was required in the spatial Fourier space. The particular CWD application, its operational requirements and dollar constraints would determine which sensor configuration is most appropriate for use.

Concepts for CWD have been identified which could image concealed weapons on people in open, unconstrained areas. Various concepts have been discussed for this application which would utilize microwave transmit and receive sensors distributed in various configurations to form images based on either real or synthetic aperture radar principles. The *real aperture concepts* require a large number of receive elements in order to develop images of small guns at moderate ranges, with sufficient resolution to identify the gun from other background returns.

Dealing with clutter or background returns from people, metallic objects (belt buckles, watches, keys, coins, etc.), and the surrounding scene is an essential part of the design for each sensor. In real aperture imaging sensors, a variety of techniques are applicable to minimize the level of these returns, and/or to clean the resultant images formed. A high quality sensor, with fine resolution and good point spread functions, is the fundamental feature required to determine discrete weapon returns from the aggregate of other background returns. The FM/CW sensor inherently has the capability to gate or filter out scene returns outside the range of interest. This feature is also used to suppress the direct signal in bistatic geometries. Spatial nulling of strong off axis returns is another technique which is used to reject strong returns from scene features which produce strong returns. In this case the sensor spatial transfer function is tailored to minimize the level of the background return in the resultant image. In addition, techniques are available to remove or clean residual background returns which are stationary over long time periods. These various methods have been successfully used in many DOD applications. Selection of applicable techniques is based on knowledge of the expected level of such returns in comparison with that of the concealed weapon. The ultimate sensor architecture is a careful balancing between implementing these background suppression techniques and the cost and complexity of implementation.

In ISAR sensors which utilize motion of the weapon to form the large synthetic aperture required for the image process, stationary returns from background scenes can be removed by a clutter filter in the frequency domain. The range/Doppler nature of the ISAR sensor is used to pass returns from moving objects while nulling zero Doppler returns from stationary clutter. This feature deals with part of the overall background problem. Returns from other metallic objects on the person moving through the scene will pass through the clutter filter and will appear in the resultant image. Rejection of these objects relies on Automatic Target Recognition algorithms based on distinguishing features between the weapon and other objects. These are typically learned as part of the testing and evaluation of the sensor in background scenes of interest.

Table 2-1 summarizes some key aspects of the various sensor configurations. It may be very desirable for the CWD problem to have 3-D imaging (down/cross range and height), which could only be provided by the ISAR and real aperture configurations. The ISAR configuration would be a hybrid aperture, part synthetic and part real as depicted.

Table 2-1

Key Aspects of Various Sensor Configurations

Sensor Configuration	Image Dimensionality	Bandwidth	Motion Requirements	Sensor Geometry
SAR	2-D	Wide	Sensor Motion	Monostatic
ISAR	2-D/3-D	Narrow/Wide	Target Motion	Mono/Bistatic
Tomography	2-D	Narrow	None	Multistatic
Real Aperture	2-D/3-D	Narrow/Wide	None	Bi/Multistatic

To be cost efficient when designing systems with real apertures, the numbers of array elements and receivers must be specified carefully. In an effort to reduce the number of array elements and receivers, techniques such as array thinning, modern spectral estimation (MSE) and receiver multiplexing may be useful. Array thinning techniques can provide a 10:1 element reduction ratio while maintaining the filled array's beamwidth at the expense of sidelobe levels.

MSE techniques have been applied to beamforming to achieve desired beamwidths with as much as a 4:1 reduction in aperture size. Receiver multiplexing is a way for array elements to share a common receiver. The number that could be multiplexed depends on motion effects limitations. Multiplexing could provide a 16:1 reduction of receivers.

Table 2-2 shows the results of a preliminary survey accomplished to determine the state of active microwave imaging techniques for CWD. The table provides some insight into the speed, quality and cost of the various methods. In many cases the performance would certainly be adequate to provide high quality CWD, but the cost of developing and implementing that system would be prohibitive. The overall trade space in this area must consider implementation cost, as in the law enforcement area, high budgets are not available to procure such items.

Table 2-2
Survey of Active Microwave Imaging Techniques for CWD

Method	Description	Time to form Image	Image Quality	Cost	Remarks
Full 2-D array	2-D array of elements over 2 x2 meter aperture	fast	excellent	very high > $10 M	high quality but too expensive for CWD
Hybrid 2-D array	1-D linear array moved to synthesize 2-D aperture	slow	excellent	moderate < $1M	subject must pose in front of sensor
Strobed Hybrid array	1-D linear array strobed	very slow	good-excellent	< $500 K	subject must pose in front of sensor for long time
Hybrid ISAR array	1-D linear array with ISAR in 2nd dimension for moving subjects	depends on motion of subject	fair	< $500 K	limited to side aspect of subject - not good for front and back view angles
Strobed Hybrid ISAR array	Strobed 1-D array with ISAR	depends on motion of subject	fair	< $250 K	limited to side aspect of subject
Sparse 2-D array with conventional beamformer	Thinned 2-D array with FFT beamformer	fast	poor impulse response side lobes	< $750 K	inadequate for imaging of concealed weapon
Sparse 2-D array with adaptive beamformer	Thinned 2-D array with adaptive beamformer	fast	good	< $750 K	adequate but too expensive
Strobed sparse 2-D array with adaptive beamformer	Strobed, thinned 2-D array with adaptive beamformer	fraction of a second	good to fair	< $300 K	adequate and least expensive (no posing)

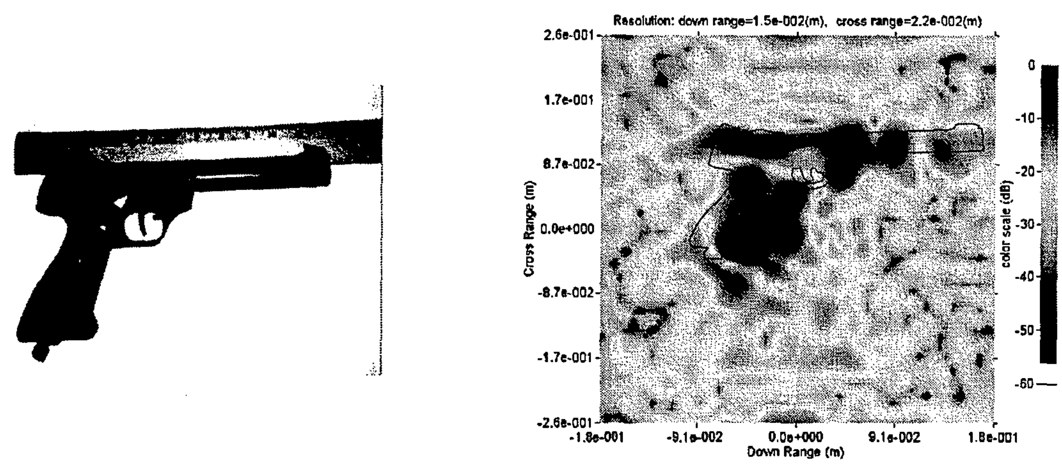
2.2 FREQUENCY/WAVELENGTH VERSUS CLOTHING PENETRATION

The ability to penetrate clothing improves with the use of longer wavelengths or lower frequencies, to the point in which clothing is virtually transparent at microwave frequencies. An optimum frequency for CWD would allow easy penetration, without excessive integration times, and provide the required spatial resolution for imaging. Based on surveys of existing CWD efforts, the 30 GHz millimeter frequency seems to meet these requirements. Results from other CWD developers have shown that at 30 GHz, common clothing is readily penetrated. This ease of penetration allows quality imaging in processing intervals that would support real time implementation.

2.3 SPATIAL RESOLUTION VERSUS RANGE

The CWD sensor will support 3-D radar imaging of a person being inspected for concealed weapons. A scene of interest could be described in terms of down, cross and vertical range extent. The down range extent is determined by the IF bandwidth in a deramp type radar. The cross and vertical range extents are typically limited by array element spacing in the horizontal and vertical arms of the cross array. The 3-D scene is composed of 3-D pixels that stack up like sugar cubes to fill the scene box. The dimensions of the 3-D pixels are given by down, cross and vertical range resolution. Down range resolution is determined by the radar bandwidth. The cross and vertical range resolution is determined by operating wavelength, aperture dimension and the range to the target. The cross and vertical range resolutions degrade as the range increases.

Previous work on imaging handgun size targets has indicated that it is desirable to have the handgun covered by several pixels to aid in the recognition of the gun in the image. A typical handgun and a corresponding X band radar image of the gun is shown in Figure 2-1. This result is indicative of the need for resolutions on the order of 2 centimeters. This translates to system requirements of 6 to 7 GHz of bandwidth and aperture sizes of 2 meters for a 30 GHz operating frequency and range of 8 meters.



(a) Handgun

(b) X band Radar Image

Figure 2-1: Handgun and Image

3. CWD PROGRAMS

In early 1995, a number of CWD programs were initiated and contract awards (or grants) provided to various contractors. These programs included active and passive techniques for CWD. In addition, DSA was awarded a Phase I SBIR contract investigating active radar techniques for CWD.

A list of ongoing and completed CWD programs addressed within this report follow:

- Passive Millimeter Wave
- Magnetometer
- Low Frequency Electromagnetic
- Millimeter Wave and Long Wave Infrared
- Radar and Ultrasound
- X Ray

The section to follow provides a brief description of each of these programs.

Our investigations were limited by the maturity of the technology, release of proprietary information as well as the status of the ongoing research and development efforts. In fact, the programs were halted for a number of months based on lack of funding. Understand that the description of a particular technique may not be indicative of the current or final configurations or even the final concept for a particular application.

3.1 PASSIVE MILLIMETER WAVE

Passive Millimeter Wave (MMW) is a technology being explored by the Millitech Corporation which offers the potential for rapid and remote detection distances of up to 12 feet without a direct physical search for metallic and nonmetallic weapons, plastic explosives, drugs, and other contraband concealed under multiple layers of clothing.

This technology is based on the fact that all objects naturally emit a broad spectrum of electromagnetic radiation. The human body emits millimeter waves which facilitate the use of this energy for sensing images obscured by some medium (cloaked in fog, darkness, poor weather and even clothing). Heat generated by the body in the infrared region is most familiar; less well known is the fact that humans are especially good emitters at millimeter wavelengths. When a person is scanned using technology with sensors sensitive to this wavelength (Millimeter-wave radiation lies around 100 GHz), any concealed item shows up as a dark image against the lighter background image of the individual. This difference in image brightness is due to the differences in electromagnetic radiation emitted by the object and the individual. Because this purely passive imaging technique relies solely on existing natural emissions from objects, it does not require outside/additional illumination. For contraband detection, the MMW system relies on the convergence of 3 key factors, adequate resolution in a reasonable sensor size; the high transparency of virtually all clothing to MM waves; and the extraordinarily high emissivity of human flesh compared to the vast majority of other materials. Passive MMW systems do not expose the subject to any manmade electromagnetic fields or radiation from the imaging system and do not pose any health risks to the person being observed. Observations can be made remotely and with discretion as required. Although passive millimeter wave imaging devices do literally see through clothing, the resulting image display does not reveal intimate anatomical details. Passive MMW systems can be used to frisk large crowds, i.e. political demonstrators. It can also detect metallic or non- metallic firearms as well as non-metal grenades; plastic explosives; electronic listening devices; explosive timers; remote detonators; dry powders or liquids in centimeter or larger-size plastic bags, vials or other containers.

3.2 MAGNETOMETER

The concealed weapons detection initiative being explored by Idaho National Engineering Laboratory (INEL) utilizes a proven, existing technology currently used in mineral exploration, environmental characterization, military navigation, and submarine detection.

This technology is based on passive sampling of the Earth's magnetic field. Local aberrations in the magnetic field produced by ferromagnetic objects, such as guns and knives, can be detected by extremely sensitive magnetometers. This is a new application of an existing technology in magnetometer sensors, which are commercially available. INEL's approach is to construct a more reliable scanner that can be used as a stand-alone unit, much like an airport scanner system, or be incorporated directly into building doorways or hallways. Sensors in the system will simultaneously collect the data, thus providing a top-to-bottom magnetic profile of an individual. Reasonable suspicion will be dictated by the location and magnitude of the recorded magnetic anomalies. An electronic catalog of magnetic signatures will be established through the collection of magnetic profiles of a variety of weapons in differing locations and a number of non-weapon personal artifacts. These signatures will later be used in analysis schemes that will determine the presence, location, and potentially, the type of weapon carried. However, this technology is limited to the detection of ferromagnetic materials.

3.3 LOW FREQUENCY ELECTROMAGNETIC RADIATION

In development by The Raytheon Company, this concealed weapons detection technology involves illuminating an individual with a low intensity electromagnetic or heaviside pulse and then measuring the time decay of the re-radiated energy from the metal objects carried by the person.

The intensity and the time decay of the secondary radiation can be characterized and the signatures identified as a gun or non-threatening metal object. Much of the basic development work has been completed by Raytheon. In the NIJ project, the company will conduct an experiment testing the system's feasibility and provide performance data on probabilities of detection and false alarm rates. The experiment will establish whether sufficient discriminating ability exists to meet police probable cause requirements for a physical search for weapons. When fully developed, the system is expected to have a low probability of false alarms. Possible locations to use this technology range from large gathering places such as shopping malls, schools, meeting places, and airports to small stores and banks.

3.4 MILLIMETER WAVE AND LONG WAVE INFRARED

A passive multispectral approach to CWD under development by the Lockheed-Martin Corporation would use a millimeter wave (MMW) receiver and a long wave infrared receiver, either individually or together, to measure the difference in temperature between a concealed weapon and an individual's body. When the two types of receivers, which are still being developed, are used in tandem and linked with a computer imaging system, it is expected that the probability of detecting a concealed weapon will increase substantially. Initially, the MMW receiver is planned for fixed-site operation only; however, it is expected that the long wave infrared receiver will be suitable for fixed-site and handheld use.

3.5 RADAR AND ULTRASOUND

An active approach that combines radar and ultrasound is being explored by JAYCOR. The system operator will have to be trained to interpret ultrasound images. It is expected that the radar component will be suitable for fixed-site operation and that the ultrasound component will be suitable for either fixed-site or handheld use.

A breadboard ultrasound sensor has been developed for remotely detecting and imaging concealed weapons. The breadboard sensor can detect metallic and non-metallic weapons concealed on a human body, under heavy clothing, at ranges up to 8 meters and can image concealed weapons at ranges up to 5 meters. This breadboard sensor has produced the only remote ultrasound images of concealed weapons ever published, including lexan (plastic) knives and a handgun concealed under a heavy sweatshirt at 15 feet. The remote imaging by ultrasound was made possible by several new technological developments. The sensor includes a novel, highly efficient source of high-power, tunable ultrasound radiation suitable for remote imaging in air. Together with millimeter-sized, highly sensitive ultrasound detectors and high-gain transceivers, these advances make possible the centimeter-resolution imaging of concealed weapons at ranges between 1 and 5 meters. Yet to be developed is a brassboard sensor with an imaging array of ultrasound detectors, capable of real-time, video-frame-rate imaging of weapons concealed on moving humans.

3.6 X RAY

Under development by Nicolet Imaging Systems of San Diego, California, this technology uses extremely low doses of scattered x-rays, in conjunction with advanced computer image processing techniques, to detect weapons, explosives, illegal chemicals, and other contraband concealed under a person's clothing.

An individual being scanned stands in front of the system for approximately 3 seconds. Almost immediately a computer-enhanced image appears on a monitor displaying the outline of the person and any concealed objects. Multiple views such as front, rear, and sides require individuals to turn their bodies for additional scans. The system is suitable for fixed-site configurations in controlled areas, such as prisons. This technology requires only a fraction of the radiation level previously thought necessary to detect concealed objects. Each 3 second scan exposes a person to 3 microRem of radiation. This level compares with the 10 to 20 microRem per hour that a person receives from naturally occurring background radiation, 500 microRem per hour received during a commercial airline flight at 35,000 feet above sea level, and 30,000 to 300,000 microRem received during medical x ray examinations.

Through a process known as Compton scattering, the low-dose x-rays collide with and bounce off electrons in the body or another object. When the x-rays penetrate materials composed of elements with a low atomic number, such as body tissue, they are more likely to bounce back, causing the image on the monitor to appear light. However, when x-rays pass through materials with a high atomic number composition, such as metal or bone, the radiation is more likely to release energy through the photoelectric effect, producing a dark image on the screen. Thus, a concealed handgun would appear as a dark mass against the light background of a person's body. Because of the low dose used in this method, most of the radiation reaches only the skin or penetrates a few centimeters into the body. The bones of the lower legs are the only internal structures likely to show up on the monitor, because they are so close to the skin.

3.7 PROS AND CONS

This section attempts to address possible strengths and weaknesses of CWD technologies. Based on the maturity and ongoing research and development efforts, detailed information was not available to support the majority of our investigations. Understanding that technical performance of a particular technique is described in available data and documentation may not be indicative of the current or final architecture, concept or performance.

Table 3-1

Passive Millimeter Wave

Pros	Cons	Comments
Maturity of development		• Matured over eight year period
Passive detection		• Passive detection is a plus when dealing public perception • Clothing appears transparent will not reveal anatomical details
Reasonable resolution	• Profile must be favorable • Stop and Pose	• Adequate to distinguish handguns and/or other weapons based on profile
Size		Simplicity and portability
Sensing capability	May sense uninteresting objects increasing false alarm rate	• Sensing of metallic, non-metallic weapons • Need to study different MMW signatures • Amenable to ATR to minimize false alarms
Phenomenology		Fairly well understood
	Pre-screening requirements	Determination of probable cause to perform more extensive search
Processing		• Algorithm performance for real time imaging/object determination • Requires more information
Countermeasures		TBD
Cost		TBD

Table 3-2

Magnetometer

Pros	Cons	Comments
Maturity of Development		Technology has been demonstrated in several areas other than law enforcement
Passive Detection		Passive detection always a plus when dealing with human subjects
Sensitivity and Resolution	Stop and Pose	Potential to show better performance than conventional metal detection systems
Size		• Probably not easily portable.
Ferromagnetic sensing Small objects	Can only detect ferromagnetic objects	False alarm rate should be greatly reduced but non-metallic weapons will not be detected
Phenomenology		Fairly well understood
Pre-screening requirements		• Determination of probable cause to perform more extensive search • Requires more information
Processing		Algorithms may be less complex
Countermeasures		TBD
Cost		TBD

Table 3-3

Low Frequency Electromagnetic Radiation

Pros	Cons	Comments
Maturity of development		More information required
	Active detection	Active detection a minus when dealing public perception
Good resolution	Somewhat stop and pose	Adequate to distinguish handguns and/or other distinguishable metallic weapons
Size		More information required
Sensing capability	Only senses metallic, weapons	Mission limited
Phenomenology		Well understood
	Pre-screening requirements	Determination of probable cause to perform more extensive search
Processing		Algorithm performance for real time imaging/object determination
Countermeasures		TBD
Cost		TBD

Table 3-4

Millimeter Wave and Long Wave Infrared

Pros	Cons	Comments
	Maturity of development	Requires more information
Passive detection		Unobtrusive implementation.
Good resolution		Should distinguish handguns and/or other weapons
Size		Required more information
Sensing capability		Multiple receivers in different bands
Dual Phenomenology		Well understood
	Pre-screening requirements	Determination of probable cause to perform more extensive search
Processing		Algorithm performance for real time imaging/object determination
Countermeasures		Requires more information
Cost		Requires more information

Table 3-5

Radar and Ultrasound

Pros	Cons	Comments
	Maturity of development	Requires more information
	Active detection	Concern with safety and potential challenge from legal community
Good resolution		Should distinguish handguns and/or other weapons
Size		Required more information
Sensing capability		Multiple receivers in different bands
Dual Phenomenology		Well understood
	Pre-screening requirements	Determination of probable cause to perform more extensive search
	Processing	Algorithm performance for real time imaging/object determination Ultrasound interpretation
Countermeasures		Requires more information
Cost		Requires more information

Table 3-6

X- Ray

Pros	Cons	Comments
Maturity of development		
	Active detection	Active detection poses health concerns and challenges on safety
Good resolution		Should distinguish handguns and/or other weapons
Size		Required more information
Sensing capability		
Phenomenology		Well understood
	Pre-screening requirements	Determination of probable cause to perform more extensive search
Processing		Algorithm performance for real time imaging/object determination
Countermeasures		Requires more information
Cost		Requires more information

4. COMPLEMENTARY TECHNIQUES

4.1 TAGGING AND TAGGANTS

Tagging Technologies cover a broad range of multispectral and other techniques for detecting and/or beaconing various items (personnel, substances, weapons, explosives). We are currently looking at the range from RF Infrared to methods of detecting chemical residue in the air. Tagging Technologies in the field of CWD attempt to identified a target item by the items unique signature. This unique signature is either a natural occurrence, is placed within the object in the manufacturing process or is placed on the object at some other time. This signature is distinguished by utilizing various methods such as:

a) Embedded Bar codes
b) Biometrics
c) Codes
    - Temporal
    - Spatial
    - Amplitude
    - Hybrids

Embedded Bar codes involve resonant objects (taggants) mounted on thin films (invisible to eye), embedded within dielectric or concealed on the surface of metallic item. Biometrics involve the signaturizing of different parts of the human body that distinguish one individual from the other, i.e. finger prints and retina scans. Coding involves methods such as frequency or spatial scanned illumination modulated uniquely based on given pattern of taggants. These taggants are ordered in space, polarization, resonant frequency, or somewhat random arrangement. Ordering allows creation of unique "serial numbers" and coded sequences.

Applications include the ability to remotely monitor movements of personnel, weapons and contraband, and would be useful in tracking friendlies in battlefield or training exercises. In the area of substance detection, Tagging Technology allows for the detection chemical residue in air. Examples of recent development include the demonstration of Drugwipe - a trace detector developed by Securetec Inc.

The maturity of this technology is in the low to medium range. Currently applications are limited to short range, medium to long-range applications require additional development. The phenomenology must be well understood to minimize false alarms. Sensor performance needs augmentation for difficult scenarios such as through the wall surveillance.

This technology remains under development in a number of areas and its full utility remains to be completely explored. Tags, sensors, platforms and methods of implementation and tag exploitation remain in work. Platforms need to be evaluated for cost and covertness multi-phenomenology fusion feasibility determination from codes to sensors.

5. TEST AND DEMONSTRATION OPTIONS

5.1 INTELLIGENT POLICE VEHICLE

The IPV concept and evolving prototypes are targeted on a number of LE requirements to include CWD. Progress of the evolving CWD sensors is being tracked to identify sensors which would be amenable to use in an IPV.

5.2 SCHOOLS

Violence, both nationally and locally, has negative impacts on the sense of well being in the community, and on public safety. The violence in our society has now spilled over into our schools, forcing states to pass tough laws about the consequences of bringing weapons on school properties. There is certainly the need for CWD sensors in our schools and use there would serve as a test and sensor validation.

An important part of the anti-violence prevention strategy aimed at youth is increasing the efforts to detect weapons in schools. While most schools are already vigilant about responding to individuals when specific knowledge is available about weapons possession, this approach has not addressed concerns and perceptions that a number of weapons are present in schools and undetected. A CWD system in the school would augment efforts already in place.

5.3 PUBLIC BUILDINGS

In the wake of the bombing of the Murrah Federal Building in Oklahoma City, the Justice Department reviewed security at federal facilities around the country. The review resulted in some 8,500 countermeasures now being implemented by the General Services Administration.

Building planners, architects, and managers must consider CWD systems in the early stages of design since foresight can mean significant rewards. Making a building secure does more than protect occupants and the contents of buildings. Determining the threats to a building is the first step and federal government guidelines can help. Federal buildings are rated in five security levels. Level 1 buildings have minimum security needs and are typically leased offices with 10 or fewer occupants. Level 5 sites are those critical to national security and have a large number of occupants. The Murrah building was a Level 4 structure.

Regardless of the purpose or size of a building, a CWD system can serve to restrict access to controlled areas, prevent incidents, and monitor/record activity to facilitate intervention and investigation if a security breach occurs. Other benefits of a CWD system would include; reduction of personnel costs, and increased morale and productivity. Equally, an effective CWD can reduce an owner's liability for damage. Courts have held building owners or managers liable for assaults and other criminal acts committed on their properties. Evidence of a CWD system design to prevent such acts can mitigate the damages awarded by proving that reasonable care was taken to prevent such occurrences.

6. SUMMARY

Detection of concealed weapons and contraband has historically been a serious problem. Airline hijackings in the 1970's focused the problem of the detection of metal firearms and knives. The technological challenge of the 1990's, and beyond, will include the detection of non-metallic weapons, explosives, and illegal drugs. Not only has the target phenomenology grown, but the background and obscuring medium have grown as well. Added to the need for CWD in airports, will be a need for CWD in virtually every aspect of the public and private sectors. CWD will be needed by the cop on the street, at sporting events, and even hospitals. The 1990's and beyond will demonstrate CWD expanding its mission driven technical requirements to include through-the-wall surveillance and location/status of objects. The need for CWD is real and present.

Traditional inspection systems, such as metal detectors and x-ray imaging systems, may have limitations for the detection of concealed weapons. Metal detectors are limited because they cannot detect plastic weapons and x-ray imaging systems may be limited in use due to radiological health considerations. While metal detectors and chemical sniffers may be used for the detection of larger metal objects and certain chemical substances, no system is currently available that can detect a wide variety of concealed objects and materials. Security personnel are often limited to hand searches of persons suspected of concealing many kinds of threats. Traditional inspections were limited in portability and required a large staff of trained operators. This approach is not only expensive, but subjects the public to an additional screening processes and consumes a considerable amount of valuable floor space. CWD systems that are fully integrated into the existing security system save time and space. A single operator can effectively man each line, thereby significantly reducing recurring costs.

Designers must consider how a CWD system is to be integrated into particular applications. Background phenomenology must be included in this integration. CWD systems must be able to communicate. Designers must consider how "dead zones" - areas where detection will not propagate - will affect detection. A good CWD system allows varying components (sensors) to complement each other. Proper sensor placement will facilitate effective surveillance. Sensors, Taggents, and biometric devices must all be compatible with the "head end". The head end records and processes the data, providing tracking and audit capabilities. The head end should be able to direct remote or secondary sensors, including cameras, visual alarms, pagers, and isolation locks, which seal an area.

In order for CWD systems to be effective they must possess factors such as being unobtrusive (with minimal impact on normal operations), portable (with a short setup time), possess ability to scan both small and large areas with high spatial resolution, have a video-frame-rate 3D imaging of weapons concealed on moving humans, be harmless to humans, implants, and the environment, function as an unattended operation using Automatic Target Recognition algorithms, and perhaps most importantly have low initial and operating costs.

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