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COMPARISON OF ENCLOSED SPACE DETECTION SYSTEM WITH CONVENTIONAL METHODS*

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DISCLAIMER

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ABSTRACT

Enclosed Space Detection System (ESDS) is a fast, inexpensive, and reliable device for detecting human occupants hidden in vehicles. Operation requires less than two minutes. ESDS is used to foil attempts at smuggling illegal aliens, terrorists, and escaping prisoners. It is being tested at nuclear weapons facilities and has been operated at several prisons and international border crossings.

ESDS is the first practical electronic alternative to physical searches of vehicles for hidden passengers. At critical checkpoints, a thorough physical search of a single fully loaded truck requires a team of from two to six people, and may take as long as eight hours. Despite this level of security, experience has shown that the search can occasionally be foiled. Due to the enormous time and expense of thorough physical searches of vehicles, they are seldom conducted at any but the most critical of locations, simply leaving many sites vulnerable to crime and terrorism.

Prior to the development of the ESDS, the only other effective alternative to physical search was the use of specially-trained canines, which can be vastly superior to the physical search in both time and accuracy. However, as discussed in this paper, canine inspection is not really a competitive substitute for ESDS because canine reliability (80% at most) is not as high as that of the ESDS (99%+), while the costs, training requirements, and operator skill needed are significantly higher with canines than with the ESDS. In addition, the ESDS has straightforward self-diagnostic tests to ensure the system is operating correctly; such tests are not currently available with either canine or human inspectors. ESDS offers an attractive supplement or alternative to meet current security requirements for vehicle searches at portals at government, nuclear, industrial, and other facilities where concealed persons may pose a threat either by entering or leaving.

1. INTRODUCTION

The Enclosed Space Detection System (ESDS) is a fast, inexpensive, and reliable device to detect human occupants hidden in enclosed spaces in vehicles.[1] Vehicle inspection requires less than two minutes. Cost is approximately 3% of that of conventional methods. (Appendix I) Operation does not require specialized training. ESDS is sufficiently reliable that it eliminates the

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need for physical searches. It is used by law enforcement and security personnel to foil attempts at smuggling illegal aliens, terrorists, and escaping prisoners.

To appreciate why such a system is necessary, one need merely consider some of the likely security situations that involve the concealment of passengers in vehicles. The possibilities include (but are not limited to) vehicle portals at nuclear weapons facilities, international highway border crossings, prison sally ports, and sally ports at commercial nuclear power plants.

ESDS was originally developed for the US Department of Energy to be used at the vehicle entrance portals at nuclear weapons plants.[2] It was specifically developed as an alternative to the elaborate physical searches presently required at these extremely sensitive facilities. The first nuclear-weapons plant portal at which ESDS is being deployed is presently under construction. ESDS has been installed and will go into operation as soon as construction of the portal is completed.

The peril posed by an intruder sneaking into a nuclear weapons plant is the risk of a hostage incident inside the facility. A highly trained terrorist could conceivably evade the physical vehicle search and sneak inside the facility. If the terrorist has some knowledge of physics (many do) and is willing to die in the incident (many are), he/she could do such things as causing a criticality event that might kill hundreds of hostages. Presently this threat is countered by very elaborate physical vehicle searches. ESDS reduces the inspection time by a factor of as much as 250 for big trucks.

Another application in which ESDS would enhance current methods is the examination of vehicles for attempts at smuggling illegal aliens through international highway border crossings. Current procedure is based on the judgment and intuition of examining agent, sometimes assisted by a canine, and sometimes not. The examination might lead to totally dismantling the vehicle, or it might be cursory, taking only a few minutes.

The methods used to conceal passengers attest to the desperation of the illegal aliens, the ruthlessness of the smugglers, and the hopelessness of detection by a cursory search. One popular method is to hollow out the space behind the dashboard and hide a person in the space. In one case, US agents discovered two people wrapped around the engine of a Yugo. Some methods seriously challenge a physical search, no matter how carefully it is done. For example, a favorite trick is to pull the stuffing out of a seat, restuff it with several live illegal passengers, close it back up, and hide the whole business by having several legal passengers sit on the restuffed seat.

ESDS is a powerful tool for uncovering such schemes. Commonly used concealment tricks have been tested and do not foil ESDS. It will detect virtually all the aliens hidden in vehicles actually inspected, incidentally reducing the incentive to try to smuggle through a Port of Entry. It has been demonstrated at the Ports of Entry at San Ysidro and Otay Mesa on the California-Mexico border. Several national governments have inquired, and are considering how ESDS might fit into their border security schemes.

ESDS has also proven itself in prison security. A favorite trick of prisoners is to hide in a departing support vehicle, and wait to be ferried out of the prison sally port by an unwitting truck driver. From informal discussions with prison authorities, it is a reasonable estimate that an average of one successful escape per year per prison uses this ploy. In a typical jailbreak, the prisoner is caught within a few miles of the prison, and according to GeoVox Security, the cost of the search is typically in the neighborhood of $100K.[3] (Note: Some prison authorities place the estimated cost at nearer $250K.)

ESDS has undergone long-term testing and evaluation at several prisons, including the Riverbend Maximum Security Institution in Nashville TN, and Centinela State Prison in California. One unit has been sold commercially to the Police Scientific Development Branch of the UK Home Office for use in the British prison system.

In addition to government applications, ESDS could greatly enhance security at commercial facilities, such as nuclear-powered electric generating plants. These are tempting targets for protesters wishing to stage an incident, or militant Greens and other terrorists. Furthermore, there is some risk to the public. A commercial nuclear power plant uses a high volume of low grade radioactive material. A single terrorist with a practicable amount of plastic explosive could cause an accident resulting in death and injury to plant employees, or a serious release of radioactive contamination into the environment.

Despite these perils, the level of security at commercial nuclear plants is not especially high. The typical inspection of a vehicle entering the sally port of nuclear power plant is cursory. Canines are seldom used. A guard looks under the hood, looks in the trunk, looks at the undercarriage with a long-handled mirror, and if he/she is feeling especially vigilant, may ask the driver to open some of the cargo packages. If the weather is less than ideal, the check becomes even more cursory than normal.

A check of two minute's duration by ESDS would provide a substantial improvement in the level of security at nuclear power plant sally ports. It would be virtually impossible to fool. Furthermore, it gives the same quality of inspection every time, ESDS would practically eliminate the risk of a terrorist hidden in a vehicle entering commercial facilities, and do so at a cost that the corporate security operations could easily afford.

2. OPERATING PRINCIPLE OF ESDS

The operating principle is detection of the ballistocardiac wave.[4] Each time the heart beats it generates a small but measurable shock (ballistocardiac) wave which propagates through the body. This ballistocardiac wave is coupled to any object with which the body is in contact. If a live human being is hidden in a vehicle, there will result, in step with the heartbeat, a small but detectable deflection (2.5-250μ) at the exterior of the vehicle. (Figure 1)

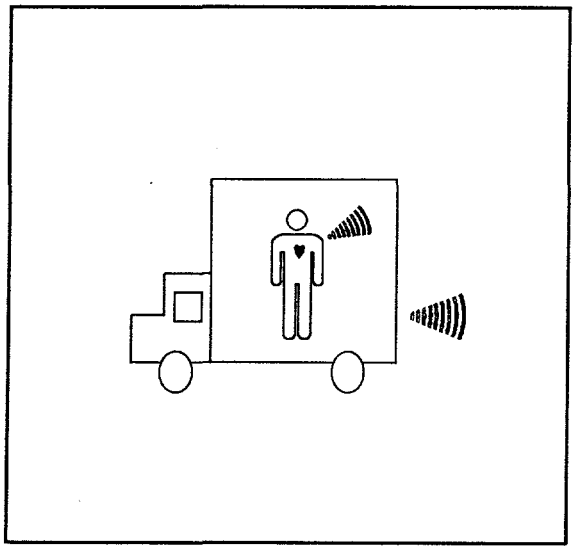

Figure 1. Ballistocardiac Wave

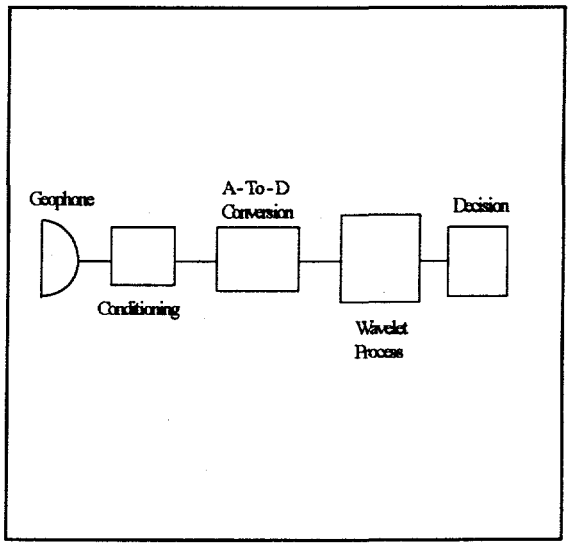

Figure 2. Block Diagram

Detection of the ballistocardiac wave requires several steps (Figure 2). Geophones are temporarily placed on the vehicle; these produce an analog signal proportional to the movement of the vehicle. The analog signal is amplified and low-pass filtered before being fed to an analog-to-digital converter. The data are analyzed using wavelet transform techniques to determine whether or not the features of a ballistocardiac wave are present.

To make ESDS practical, the extremely poor signal-to-noise ratio of the geophone output had to be overcome. The heartbeat is in the vicinity of 2-16 Hz. Unfortunately, so are many other signals. The mere existence of a 2-16Hz component in the geophone output is insufficient to reliably determine whether or not the signal actually contains a ballistocardiac wave. Reliable determination requires the observation of the distribution of the 2-16 Hz energy as a function of time. Oak Ridge National Laboratory researchers discovered that a consistently good method of generating extractable features of a ballistocardiac wave in a noisy background is to take a continuous wavelet transform of the Fourier transform of the geophone output.

3. CONVENTIONAL METHODS

ESDS was developed as an alternative to physical vehicle searches by human inspectors. In current security practice, the only method widely used to detect passengers concealed in vehicles is the physical search. Sometimes the search is aided by canines, and sometimes not.

At critical checkpoints, a thorough physical search of a single fully loaded truck requires a team of from two to six people, and may take as long as eight hours. Despite this level of security, experience has shown that the search can occasionally be foiled by a trained intruder, cleverly concealed. Due to the enormous time and expense of thorough physical searches of vehicles, they are seldom conducted at any but the most critical of locations, simply leaving many sites vulnerable to crime and terrorism.

Most security experts agree that canine inspection is vastly superior to a physical search by unaided human inspectors. However, canine inspection is not really a competitive substitute for ESDS. If the best methods are used, a canine search for hidden people is about 80% reliable, nowhere near the consistently repeatable 99% reliability of ESDS. In addition, ESDS avoids many of the pitfalls common to canine security.

The first difficulty is that reliable security canines are hard to obtain, and demand far outstrips supply. Security canines require individual expert training and, unlike ESDS, are not amenable to mass production. Each canine is trained in only one of four possible jobs, drug detection, explosive detection, people detection, and arson investigation. (Note: Canines can be trained for multiple security tasks, but they become equally unreliable at all of them.)

Although there are a number of training facilities in the US, both public and private, the only facilities well known to produce reliable security canines are those run by the US Government, such as the US Military Working Dog Program, and by the Bureau of Alcohol Tobacco and Firearms (ATF). About 1100 high quality security canines are trained each year at US government facilities. Many of these 1100 are replacements for retiring canines. Few of these canines are trained to search for people. Very few are for sale to non-Federal users. The reliability of security canines from private trainers is notoriously poor, far below the 80% reliability obtained by the best US government trainers.

Even when it can be obtained, canine security is expensive. As demonstrated in Appendix I, the canine security to replace a single ESDS unit would have a life cycle cost of more that 30

times that of ESDS. Major elements that drive the cost are the facts that each canine requires a dedicated handler, and that canines have a very limited duty cycle.

The effectiveness of detection depends on the relationship between the canine and the handler. The canine and handler often respond to very subtle cues in each other's body language. It takes several weeks to several months for a canine to adjust to a new handler, and reliability of detection is lost until the adjustment is made. Consequently, canines and/or handlers cannot easily be interchanged in the long term, and cannot be interchanged at all in the short term. If either the canine or handler becomes sick, the day's work is finished for both. Thus, canine security is highly subjective.

Another pitfall in canine security is the limited duty cycle of the canine. Labrador retrievers, bred to arduous work, have the best endurance. They remain highly reliable through a cycle of two hours on, one hour off, repeated for several cycles per day. For a less robust canine, the reliability can drop in as little as 30 minutes. Some security canines work a much longer shift in practice, but their reliability drops dramatically (often unbeknownst to the security operation) as the shift wears on. The best canines, working an optimal cycle, are available about six hours per day, as contrasted with ESDS, which is available 24 hours per day. Thus, for a day's work it takes at least four canine/handler teams to do the work of a single ESDS system.

Perhaps even more important, ESDS does not give the false sense of security that might result from using a tired or sick canine. ESDS has a straightforward and objective self-diagnostic; the operator can easily determine if the system is working properly. In contrast, the canine provides no clear diagnostic for failure. If the canine catches a cold, it may show no external symptoms, but its sense of smell (and consequent level of reliability) may be greatly diminished, *and neither the canine nor the handler may be aware of it.*

4. CONCLUSIONS

ESDS is a breakthrough in security technology. It has been independently tested at the Thunder Mountain Evaluation Center at Fort Huachuca AZ. It has been shown to provide 99% reliability at detecting occupants hidden in vehicles. It is easily within reach of any security operation (government or corporate) that needs it. It provides a substantial increase in the level of public safety by foiling jailbreaks and denying terrorists access to their targets. It has the potential of neutralizing the present methods used for smuggling illegal aliens through highway Ports of Entry at international border crossings.

ESDS is important because it is the first practical electronic alternative to human or canine inspection of vehicles for hidden passengers. ESDS is dramatically superior to both human and canine inspection. An effective human inspection can take hours, possibly requiring the dismantling of the entire vehicle, and is not feasible in most practical settings. ESDS is significantly less expensive and more reliable than canine inspection.

ESDS is based on the highly counterintuitive discovery that the heartbeat of a human occupant can be detected at the exterior surface of a vehicle. It uses an innovative development in heartbeat feature extraction. Original algorithms in wavelet analysis, devised especially for ESDS, enable reliable heartbeat detection.

ESDS can dramatically increase the level of public safety and decreases the level of fear, by reducing the number of jailbreaks, terrorist acts and smuggling incidents. Because it reduces

the odds of success, it prevents many incidents from even being attempted. In addition, ESDS inspection is safer than conventional searches, both for the agent, and for the intruder.

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3. Informal discussion with Mr. Mark White, former Governor of Texas, and founder of GeoVox Security, Inc., 3 Remington Lane, Houston TX 77005 (Note: GeoVox markets ESDS commercially under the AVIAN trade name.)

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APPENDIX I. COMPARISON OF COSTS

A single ESDS unit is continuously available and can be used by regular guards in addition to their other duties. Physical search presumes two dedicated guards per eight hour shift who spend full time searching vehicles. Canine search presumes one canine and a dedicated handler per six hour shift. The comparison is based on a portal at which many large trucks must be inspected.

Physical search data are based on security procedures that are typical for Federal agencies, and on direct observation of security practices at commercial nuclear power plants. ESDS data are from testing performed by the ESDS development team, from the independent testing conducted by the Thunder Mountain Evaluation Center, and from the levels of performance that GeoVox is willing to guarantee to its customers for the AVIAN implementation of ESDS.

Financial rates are based on reasonable practice for government agencies. Discount rate is assumed to be 6.45%. This is the ten year Treasury Bond yield in early 1997. The rate of return of

an investment should cover the cost to borrow the money to pay for it. Operating costs are expected to inflate at 3.2% annually after the first year. This is the inflation rate used by Oak Ridge National Laboratory in early 1997 for financial projections.

The first step in determining life cycle cost is to estimate the comparative up-front costs of the three alternatives. Up-front price is the price the security operation must pay for the system before the first day of security work begins. For hardware, it is the selling price per unit. (Note: For consistency in the comparison, the estimated lower bound of the price for all three alternatives is given.)

For ESDS and physical searches, the up-front cost is straightforward. ESDS price of $55,000 is the GeoVox price per unit for the basic AVIAN implementation. It includes installation, software, training, upgrades, and the first year of maintenance. The physical search presumes zero up-front cost.

The up-front cost for canine security is more involved. A single security canine trained for 80% reliability costs $9000-12000, assuming that one could be found for sale. Take the bottom end of the range, and note that, due to the limited duty cycle of the canine, four canines are needed to do the work of one ESDS. The result is that $36000 is the low end of the range for the up-front cost for the "canine component" of 24 hour canine security. Cheaper canine security is available, but it falls far short of the 80% reliability provided by high quality canines.

Each canine requires a dedicated handler. Conventional wisdom among security experts is that handler training costs more than canine training. It costs $6000-12000 to train a year-old canine. Taking the low end of this range as the lower limit of the handler training cost, assume that $24000 is the training cost for four handlers. In addition, assume that the handlers are paid a regular salary during a three month training course. The assumption of a fully burdened cost of $50,000 per year for salary, benefits, employer taxes and overheads for each handler is probably low. Thus, the wage costs for a quarter year of training each for four handlers has a lower limit of $50000. The sum of training expenses plus salaries during training for four handlers is $74,000. The lower limit of the up-front costs for four canines and four handlers is $36000 and $74000 respectively, or $110000 total. This is the most optimistic reasonable estimate of the up-front expense to buy the same amount of canine security that is provided by one ESDS. (Note: It is not valid to argue that the canine serves several functions. An individual canine/handler team is trained in one and only one of the four security functions. A canine/handler team trained in people detection does exactly what ESDS does.)

The annual cost that results from each choice is determined as follows. The lower bound on the cost of physical search presumes three shifts of two full time dedicated guards per shift. The assumption of a fully burdened cost of $50,000 per year for salary, benefits, employer taxes and overheads for each guard is conservatively low. This works out to $300,000 per year.

ESDS annual upkeep is mainly replacement of geophones and hardware maintenance. This is taken as $2000, after the first year. (First year's upkeep is included in the purchase price.) This estimate is based on experience at Centinela State Prison in California. Since it can be used by guards without special skills, and in addition to their other duties, no increment of cost is included for the operator.

Upkeep for the canine is typically $3000 per canine for food, kennel expenses, and vet bills. Since four canines do the work of one ESDS, the total upkeep of canine security for a full duty cycle is $12000. Each canine requires its own handler. The assumption of a fully burdened cost of $50,000 per year for salary, benefits, employer taxes and overheads for each handler is

probably low, but it makes the point. Four canines require four handlers, and $200000 is the lower limit of the annual cost. Hence, the ongoing cost to use four canine/handler teams to do the work of one ESDS for a year has a lower limit of $212000. The typical handler works a 5-day week, but the smuggler works a 7-day week. Multiply the foregoing by 7/5 to obtain $297800, accounting for a 7-day week.

These figures are for a canine security system operated at the level of quality required for the canine to achieve 80% average reliability. There are cheaper canine security schemes. However, to obtain an average reliability of 80%, it is necessary, *at bare minimum*, to meet *all* the constraints, and pay *all* the costs, described above. Tricks like using cheaper canines, or working longer shifts, will result in levels of reliability substantially below the 80% reasonably expected for high-quality canine security operations.

To summarize, the basis for the analysis of cash flows is as follows. Up-front costs are $55,000 for ESDS, $110,000 for canines, and 0 for physical search. Annual costs are $2000 for ESDS, $297,800 for canines, and $300,000 for physical search. After the first year, operating costs increase at 3.2% per year, and the net present value of cash flows are discounted at 6.45% per year.

TABLE I-1. NET PRESENT VALUE OF ESDS VERSUS ALTERNATIVES

				Discount	Discounted Costs:		
	ESDS	Canine	Physical	Factor	ESDS	Canine	Physical
Up-front	55000.00	110000.	0	1.0	55000.00	110000.	0
Year 1	0	297800.	300000.	1.0	0	297800.	300000.
Year 2	2064.00	307330.	309600.	0.939408	1938.94	288708.	290841.
Year 3	2130.05	317164.	319507.	0.882488	1879.74	279893.	281961.
Year 4	2198.21	327313.	329731.	0.829016	1822.35	271348.	273353.
Year 5	2268.55	337787.	340283.	0.778785	1766.71	263064.	265007.
Year 6	2341.15	348597.	351172.	0.731597	1712.77	255032.	256916.
Year 7	2416.06	359752.	362409.	0.687268	1660.48	247246.	249072.
Year 8	2493.38	371264.	374006.	0.645625	1609.79	239697.	241468.
Year 9	2573.16	383144.	385975.	0.606505	1560.64	232379.	234096.
Year 10	2655.51	395405.	398326.	0.569756	1512.99	225284.	226949.
Life Cycle Sum					$70464	$2710452	$2619662

The resulting sums of the net present value of discounted cash flows over a ten year life cycle are thus computed to be $70464 for ESDS, $2,710,452 for canines, and $2,619,662 for physical search. Since all three numbers are lower bound estimates, and not precise costs, it is appropriate to round them to three significant figures, so as not to give an illusion of a precision that is not justified by the analysis. It is a fair comparison to claim that the life cycle costs for the three alternatives are $70.5K for ESDS, $2710K for canines, and $2620K for physical search, or that the cost of ESDS is approximately 3% of the cost of conventional methods.