Appendix B
Explosives Detection: Dogs

This appendix and the following one will discuss two important areas of explosives detection that were only mentioned in passing in the previous OTA report on terrorism and technology.[1]

Introduction

The dog has been "man's best friend" since neolithic times, 10,000 years ago. As people learned to modify the dog's physical appearance and even its temperament through selective breeding, they were able to produce animals capable of performing a wide variety of services. These included refinements in the hunting process such as pointing, retrieving, tracking, and burrowing; herding; draft work (pulling and carrying); guard duties; providing companionship; and, more recently, assisting the disabled such as the blind or wheelchair-bound. Quite recently, police work has been added to the list.

In this last capacity, the dog has been making major contributions to the fight against terrorism, in no area more critically than in the search for hidden explosives. There is a lively debate between those who favor the dog as an explosives detector and those who place more faith in mechanical ''sniffers. " There are good arguments to support both sides. But to date, despite the best efforts of many talented scientists and technicians, there is no machine that is as widely used and accepted as the dog for the detection of explosives. This section will describe how and why the dog's nose has been applied to the task of detecting hidden explosives.

Disadvantages and Advantages

There are a number of disadvantages to using dogs as explosives detectors. First and foremost, adequately maintaining a canine operation, especially in the one-handler-to-one-dog mode preferred by many law enforcement organizations, is very expensive. Costs include initial acquisition of the animals, training for both the dog and the handler, veterinary and other maintenance expenses for the dogs, and the salary and other expenses associated with the handler, this last constituting the largest fraction by far.[2]

Explosives sniffer dogs do not and cannot operate by **themselves. They always function in tandem with their handler. The leash that connects man and dog is not so much a means of control as a channel for communication. This is both a strength and a weakness. When a team is in top form, the dog and his handler function with amazing** efficiency. But the dog works only as well as his master. Security searches are frequently boring, monotonous chores, the sort of task for which humans have trouble staying alert. If the dog senses a lack of commitment on the part of his human teammate, the dog's effort similarly diminishes. Also, it is inaccurate to say that the dog finds the explosive. It is up to the handler to recognize the sometimes subtle changes in the dog's behavior that signal interest in a faint scent. This reliance on the handler's judgment introduces a second opportunity for error.

Dogs have a number of weaknesses when compared to mechanical sniffer devices. Being a living creature, dogs cannot be worked as intensely as a piece of machinery. Depending on temperature and humidity conditions, a dog may be able to work only about 20 minutes before he needs a rest. Dogs are also vulnerable to distraction by loud noises, bright lights, new surroundings, fatigue, and alluring scents left behind by canine members of the opposite sex. Dogs have a limited attention span. They cannot be positioned beside a conveyor belt, even under comfortable conditions, and be expected to sniff luggage effectively hour after hour. They must be actively engaged in the search or their acuity will sharply diminish. They also are prone to personality quirks. Some dogs refuse to go in glass elevators. Some won't fly in helicopters. Some dogs bond very strongly to their handlers, some are more aloof. And it is the rare machine that produces the embarrassing "accidents" for which dogs are so infamous.

The dog also shares many of the shortcomings of the mechanical explosives sniffers. Because they rely on sensing airborne molecules or particles, dogs will not be able to detect an explosive that is perfectly wrapped. Also like machines, dogs can respond to the wrong thing. The U.S. Secret Service found that their dogs were reliably responding to the double stick tape regularly used to hold down small equipment in Air Force One. Perhaps a **cellulose nitrate was used in the adhesive. But this tendency to generate false alarms is apparently so unpredictable that the Irish Republican Army terrorists in the United Kingdom have been trying for years without success to devise a reliable masking odor for the bombs they plant.**

Probably the most serious liability of the canine approach is that it is largely unpredictable and essentially unquantified. How does the dog do his job? Is it just smell

[1]U.S. Congress, Office of Technology Assessment, ***Technology Against Terrorism: The Federal Effort***, OTA-ISC-481 *(Washington,* DC: U.S. Government Printing Office, July 1991).

[2]For some typical values, see the section of this appendix, below, in which the experiences of the U.S. Secret Service are discussed.

or are cues from other senses, such as vision or hearing, involved? Is it possible to tell, *before* **investing a lot of time and money, which puppies will make good sniffer dogs? These questions and others related to dog performance could probably be answered with some R&D effort.**

In the face of these disadvantages, why would anyone choose to use these animals? Basically, because they work. The primary advantage of using sniffer dogs over other methods of sweeping an area for explosives is that it has been shown to be effective. There is no mechanical device that is as accurate, fast, sensitive, mobile, flexible, and durable as a well-trained dog/handler team. Many organizations claim their dogs can even detect low-volatility explosives, such as TNT and the plastic explosives, RDX, PETN and Semtex.[3] No mechanical sniffer has been reliably shown to match this performance under field conditions. The dogs can go anywhere a human can go and can operate under any conditions tolerable to humans (although performance degrades with increasing temperature and humidity). They don't need electricity or batteries. They can be transported by helicopter, truck, car, or plane. They generally do not break. Service life is an average of 7 to 9 years. Thus, while they are expensive, they can be cost-effective for many uses. The dog/handler team operates in a real-time mode and thus can be much quicker than some sniffers that rely on sample collection followed by preconcentration and analysis steps. Also, the dog offers much more directional information than most mechanical sniffers and is usually better able to pinpoint the location of an explosive as opposed to merely alerting to its general presence.

Legally, a canine search is not considered invasive under the fourth amendment in distinction to methods that use any kind of penetrating radiation. Thus the searches can be conducted without a warrant. Finally, dogs are socially acceptable, at least in this culture. People are used to being sniffed by dogs and do not take offense or become fearful or belligerent.

It looks as if there probably will be a place for dogs in security work for the foreseeable future. But considerable progress has been made in the development of mechanical vapor detectors. Some people in the field estimate that within 10 years, possibly fewer, technology will be able to challenge or even surpass the detection capabilities of the dog.

Technology is also being applied to the animal systems in order to ameliorate some of the problems mentioned above. A number of organizations are considering efforts to **better understand the operation of the dog/handler team and to optimize it. These efforts will be discussed below.**

The Sense of Smell [4]

Of all the dog's senses, it is the sense of smell that is most renowned. Humans have made use of the dog's olfactory talents in a wide range of endeavors. Dogs now are used routinely to hunt for contraband such as drugs or weapons. They track escapees and other criminals. They locate earthquake victims buried in rubble. They assist in the investigation of suspected arson by searching for accelerants typically used by the criminal to start a fire. They even are used to find termites lurking in dark basements. Yet despite having used and relied on the dog's sense of smell for millennia, man still has little understanding of how this sense works.

Even in humans, much less in dogs, the sense of smell is not terribly well understood. It is known to be a chemical sense, requiring physical contact between the stimulant and the sensory organ. There are three pathways for reception of stimuli generally called odor or smell: receptor cells, pain endings of the trigeminal nerve, and, for some animals, the vomeronasal, or Jacobson's, organ. Anatomically, in dogs, as in humans, receptor cells are located high in the nasal cavity. The receptor cells are long and thin, terminating in about 6 to 12 olfactory cilia (delicate hair-like structures) that extend into the mucus layer that normally covers the inner lining of the nasal cavity. The other end of the receptor cell narrows to a fine nerve fiber and, joining with others of its kind, becomes the olfactory nerve which passes through the bony roof of the nasal cavity and then connects with the olfactory bulbs, stem-like projections under the front part of the brain. From there, additional complex neural connections are made to centers higher in the brain. Typically, there are millions of receptor cells in the olfactory mucosa patch, but for some animals, such as the dog or the rabbit for whom scent is very important, there can be tens of millions.

The second channel for sensory input, the pain or "free nerve' endings of the trigeminal nerve, are found throughout the nasal cavity and are also activated by many of the same stimuli that trigger the receptor cells. For example, these cells respond to orange oil, a relatively mild odorant, as well as scents more obviously irritating, such as ammonia.

The third channel is the vomeronasal organ, typically located in the hard palate of the mouth or the floor of the nasal cavity of some animals. It is believed to be

[3] See, for example, *Counter-Terrorism & Security Intelligence,* Bethesda, MD, Sept. 24, 1990, p. 6.

[4] The information in this section is from "Sensory Reception," *The New Encyclopedia Britannica,* vol. 27 (Chicago, IL: Encyclopedia Britannica Educational Corp., 1986) pp. 170-171; "Olfaction," *McGraw-Hill Encyclopedia of Science and Technology, 6th* **cd., vol. 12 (New York, NY:** McGraw-Hill, Inc., 1987) pp. 340-344; and Lawrence J. Meyers, "Dysosmia of the Dog in Clinical Veterinary Medicine," ***Progress in Veterinary Neurology,*** vol. 1, No. **2, 1990, pp. 171-179.**

important in detection of nonvolatile compounds and, for some species, pheromones. Its function in normal conscious scent sensation is not well understood.

In terrestrial mammals, the physiological steps involved in detecting odors can be broken down as follows:

- **airflow and sampling of odors,**
- **concentration of odors in mucus,**
- **odor-receptor molecular interaction,**
- **transduction, and**
- **. neural coding.**

While the receptor cells are located surprisingly far from the main airflow path (it is estimated that only 1 to 2 percent of the odor molecules inhaled during normal breathing actually reach the receptor sites)[5], apparently eddy currents carry just enough stimulus to the cells to cause arousal, whereupon sniffing will occur. Sniffing changes the airflow pattern and dramatically increases the number of molecules coming in contact with the nasal mucosa.

Odor molecules concentrate in the olfactory mucus on the order of 1 to 10,000 times their concentration in air. An apparently general olfactory binding protein in the mucus or in the ciliary membrane immersed in the mucus is involved with a reversible binding of the odor molecules to the receptors.

The exact manner in which the odor molecule and the receptor interact is another area that is not well understood. Mammals have a relatively small number of different kinds of receptors, estimated to be between 7 and 30, and each responds to a broad range of odorants. Yet thousands of different odors can be distinguished.

Once the odor molecule becomes attached to the receptor cell, the cell generates electrical signals to be sent to the brain in a process called transduction. Again, the mechanism by which this takes place and determination of the critical elements of the signal (pattern, repetition rate, signal strength, and so on) are areas in need of investigation.

Neural coding refers to the processing of the signals from the olfactory receptors in the various areas of the brain and is not well understood. Of all the senses, the pathways of the olfactory system through the central nervous system are uniquely complex. Some paths, apparently carrying strictly sensory information, link three different parts of the brain. Others are connected to structures of the limbic system, which are closely involved with control of emotions, feeding, and sex. This is consistent with observations of a strong influence of odors on behaviors and physiological regulation.

What makes something have a smell? Typically, the stimulant is a volatile organic molecule (only a handful of the chemical elements have odors although, obviously, some inorganic compounds such as ammonia and hydrogen sulfide (H_2S) are fragrant). To be detected by smell, the material must be volatile and, typically, the volatile organic compounds are soluble in water or fats. There are about half a million such compounds. Apparently, the nature of the perceived odor is influenced by both the shape of the molecule as well as the character of the chemical groups of which the molecule is made. Perception also varies depending on what other odorants are present.

The sense of smell in humans is said to be 10,000 times more sensitive than the sense of taste but sensitivity to odors varies from individual to individual and from compound to compound. For example, humans can detect 3-methoxy-3-isobutyl pyrazine (green bell pepper odor) at concentrations of about 1 part per 10^{12} parts of air, but methanol is far less easily detected and must be present as 1 part in 10^4 to be noticed. Temperature, humidity, age, respiratory infections, phase of the female hormonal cycles, and hunger all seem to affect sensitivity to odors. Among mammals, rats and dogs are credited with being the most sensitive to olfactory stimulation, one test showing dogs able to detect an odor at concentrations 10^3 to 10^5 times lower than humans.[6]

Continuing Investigations

Scientific work continues in an effort to better understand olfaction in general and the sense of smell in the dog in particular. Several years ago, animal studies were conducted at the University of Pennsylvania under support provided by the FAA, but were not followed up after the death of the researcher. Some work with rats has recently been reinitiated at the same laboratory, again under the aegis of the FAA. But the research is too embryonic to have yielded reportable findings yet.

Another group professes to be ready, willing, and able to perform serious study of olfaction in dogs but is having trouble securing funding. The Institute for Biological Detection Systems (IBDS) of Auburn University (Auburn, AL) was created in 1989. IBDS is made up of a team of scientists, veterinarians, and engineers whose aim is to improve existing methods of odor detection and to develop advanced sensing technology. They also would like to coordinate similar efforts at other institutions and corporations. They have received contracts and other support from private industry, foundations, the Department of Defense, and the FAA, but are interested in expanding their operation. In October 1990, they were expecting a memorandum of understanding from the

[5]D.A. Marshall et al., ''Olfactory Sensitivity to Alpha-Ionone in Humans and Dogs,' Chemical Senses, vol. 6, No. 1, 1981, pp. 53-61.
[6]Ibid.

Department of State, the U.S. Secret Service, and the FAA that would provide funding, but as of this writing, the Federal budget situation leaves this arrangement unconsummated.

This group has put a good deal of thought into developing a list of areas in which research should be performed and in developing preliminary outlines of experimental protocols to support such research. The range of questions these investigators would like to look into is an indication of the depth of human ignorance about this topic.

In response to an expression of interest by the U.S. Secret Service (although almost all security organizations relying on dogs expressed a similar need), IBDS considered means to investigate how to optimize the dog/handler team. They saw this effort as breaking down into several subsections. First, IBDS would like to devise a way to quantitatively and reliably evaluate the dog/handler team's detection capability. They would also like to improve the system for selecting dogs to be trained as sniffers and they want to establish means to evaluate and improve the training process. Finally, they want to explore possible ways to enhance the olfactory function of dogs.

In order to optimize the dog/handler team, the IBDS researchers want to start with an investigation of the sensory function of the dog. As an example of the means by which one may investigate the limits of a dog's sense of smell and the factors that affect these limits, IBDS proposed the following series of experiments. A test substance would be analyzed, using gas chromatography and mass spectrometxy, to determine the number and nature of its volatile constituents. Some preliminary work along these lines has recently been conducted by the Transportation Systems Center of the Department of Transportation. Explosives would be hidden in various detection "scenarios,' simulations of real-life situations, and the concentration ranges of the volatiles in the air surrounding the hidden samples would be measured. Then, the detection thresholds of dogs to each of the major volatile constituents would be gauged. This would involve selecting a fairly large group of dogs (at least 10) matched for such factors as age, sex, breed, and response to predetermined concentrations of baseline substances such as eugenol.[7] The detection threshold of the dogs to the test substances would be determined by olfactory methods (electroencephalography[8] [EEG] and behavioral olfactometry[9]) and by operant conditioning methods.[10] These procedures would be repeated under different conditions to determine the effect of variables likely to influence the dog's performance, including such factors as gender, temperature and humidity, circadian rhythms, and number, order, duration, and intensity of stimuli presentation.

Finally, the actual components detected by trained dogs would be determined by using a setup such as that shown in figure B-1. A sample of the test material would be injected into a gas chromatography (GC) where the volatile constituents would be separated. The passage of each separated component past the exit of the device is recorded as a peak on the chromatogram. A dog trained to respond to the test material would be positioned at a "sniff port" at the exit of the gas chromatography and the dog's response would be correlated to the various peaks. Because it is likely that dogs cue on a mixture of scents rather than on any single component, the IBDS team also proposes performing this experiment while exposing the dog to a blend of peaks from the GC.

Obviously, even this fairly limited endeavor is going to involve a lot of dogs, a lot of time and effort to train and support them, and, critically, a lot of money. In April 1990, IBDS estimated that it would need $480,000 to perform these tasks. Even if all these needs were met, there is some question about how reliably the results of such artificially constrained experiments could be translated to the field. But the desire for quantification of the dog's performance is very strong among the organizations that rely on them and was a repeatedly expressed need. Experiments such as these were recognized as a necessary first step in the process of understanding, and thereby optimizing, the performance of the complex biological system that is the dog.

IBDS would also like to be funded to explore optimization of the selection process and the training routine for both the dog and handler. For example, they would like to develop a battery of assessment procedures that would predict a dog's physical suitability (that is to say, freedom from disabilities), its trainability, and its performance after training. They propose a $100,000 project aimed at determining what factors (e g., olfactory capability, motor capability, intelligence, trainability, temperament, and medical/veterinary factors) and what tests for measuring these factors are most predictive of a dog's future success in explosives detection work.

For example, a panel of experts might be able to assess a dog's temperament based on a review of a videotape of

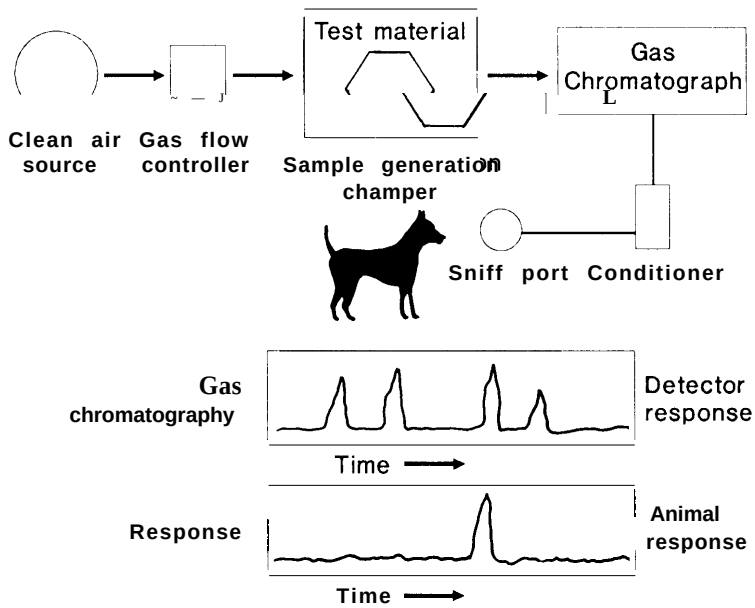
[7]The primary essential oil in clove oil.

[8]Electrodes attached to the animal's scalp record changes in electrical patterns in the brain in response to olfactory stimuli.

[9]Observation of an innate (perhaps reflexive) movement of the head towards or away from a stimulus red/Or sniffing or licking.

[10]The dog is trained to give a perceivable physical response upon detecting a sample. Then the concentration of the sample material would be lowered in stages until no response is given. This technique has the disadvantage of being extremely time consuming, taking about 8 weeks to adequately train a dog to give the proper response.

Figure B-I—Determining the Components of a Volatile Mixture to Which a Trained Dog Responds



SOURCE: Institute for Biological Detection Systems, Auburn University, April 1990.

an animal's behavior. Motor capabilities might be best evaluated by an analysis of gait and conformation, range of motion, or endurance tests. It is not easy to evaluate sensory capabilities in a nonverbal species. Some tests are based on detecting changes in electrical activity in the brain in response to sensory stimuli. Most tests rely on eliciting innate or reflexive behavior. Several means of assessing olfactory sensitivity already exist and may prove applicable. These include olfactory electroencephalograph and behavioral olfactometry that have already been mentioned.

Behavioral gustometry is a means of assessing taste acuity. Increasingly concentrated solutions of a taste compound are administered intravenously until a predictable response (usually a lick or a gag) is observed. This procedure can only be used to test sweet or bitter compounds because infusion of salty or acidic materials could adversely alter the dog's physiology.

Visual acuity can be assessed using the phenomenon of optokinetic nystagmus (OKN). In all species with moveable eyes, if the visual field is perceived to move, the eyes will follow the motion and then rapidly move back. To test **for visual acuity, the dog is presented with a moving grid pattern. The pattern is gradually made finer and finer. If OKN is observed, then it can be concluded that the animal can resolve the grid lines. At some point, the dog ceases to perceive a moving grid but sees only a constant grey** background and OKN stops. This threshold is an indication of visual acuity.

Behavioral audiometry is a technique for measuring the threshold for sound detection. The dog is exposed to sounds of various loudness and pitch and a reflexive response such as ear twitching or startle is noted. Unfortunately, this technique is not very good for **determining minimum threshold sensitivity because the animal does not reliably respond to noises that are detected but apparently not considered as needing further investigation. The IBDS team would like to investigate whether electroencephalograph might be a more suitable test.**

A separate proposed study would investigate the suitability of several new physical screening methods. In particular, a number of musculoskeletal abnormalities (e.g., hip dysplasia, common in German Shepherds) render a dog unusable. Yet this particular problem is not necessarily visible using conventional x rays until the animal is several years old or the disease well advanced. Work recently completed at the University of Illinois has demonstrated that the technique of gait analysis is effective in predicting the onset of hip dysplasia at age 2 in dogs 6 to 12 months old. This technique measures the relative amount of weight the dog places on each limb as he trots over a pressure sensitive plate. The IBDS researchers would like to investigate whether this technique should be included in the battery of physical

examinations conducted on dogs who are candidates for explosives detection work. They would also like to follow up on work done at the University of Pennsylvania using a new radiographic technique that measures hip joint laxity.[11] There maybe a correlation between this phenomenon and the later onset of musculoskeletal diseases thereby allowing for early diagnosis of such problems. Finally, there is some evidence that changes in bone metabolism could also be predictive of dysplasia. These changes in growth and resorption can be monitored by following the movement of a radioactive taggant and using a high-resolution tomographic imager. Auburn estimates that it would need about $120,000 to develop these physical screening procedures.

Another study proposed by the Auburn team would involve investigating training procedures for both the dogs and their handlers. To do this, they would perform a survey of existing detection training techniques for dogs, analyze which of those techniques are effective (which, of course, would require development of some measures of effectiveness), and develop improved training techniques based on these analyses. They expect that a number of factors might influence the success of a training program. These would include:

1. **the number and duration of daily training sessions,**
2. **the sequence in which "subtasks" are trained,**
3. **the optimal proficiency required on one "subtask" before training is begun on the next "subtask"**
4. **the type and schedule of reinforcement for correct performance,**
5. **the type of consequences delivered for incorrect performance, and**
6. **the role of the handler in detection tasks.[12]**

IBDS estimates that $400,000 would be needed for this study.

There are several other avenues for investigation proposed by the Auburn team. One of these involves a proposed $180,000 study exploring the influence of drugs on behavioral measures of olfactory function in order to try to find some agent that could enhance odor detection. There is some speculation that drugs could be used to alter:

1. **olfactory sensitivity,**
2. **odor discriminatory capacity (e.g., by increasing the signal-to-noise ratio),**
3. **olfactory memory,**
4. **attention mechanisms, or**
5. **motivation. 13**

Some preliminary work along this line was done by R. Doty at the University of Pennsylvania and the researchers at IBDS. Some of this work suggested that, in rats, low doses of amphetamines enhanced odor detection capability. Of course, this approach runs the risk of altering the behavior of the animal due to the intoxicating effects of the drugs. Other very preliminary research, for which the IBDS team would like $10,000 to run a pilot project, suggests that the sense of smell in the dog could be enhanced by ingestion of the target odorant.

This discussion of proposed projects came from a paper prepared by the Auburn group. It was designed to spark the interest of various governmental agencies that would have an interest in improving the explosives detection capabilities of dogs. Some of these projects may not be feasible, some may cost considerably more than estimated. However, IBDS was, at this writing, the only facility attempting to address the question of canine sensory capabilities in such a comprehensive, scientific way.

Other Avenues of Investigation

Several other groups are looking at novel ways to make use of animal olfaction to enhance security. A group in South Africa is marketing a system that it hopes will prove to be the best of both worlds. They use a mechanical device to collect and concentrate vapor samples. A vacuum source draws large quantities of air through cartridges containing an adsorbant material. In this manner, large volumes such as freight cars on trains, shipping containers, airmail pallets, airplane cargo holds, and so on can be sampled quickly and efficiently without unpacking. The saturated cartridges are then presented to a dog specially trained to detect odors from contraband. The manufacturers claim that this process works faster and better than normal dog operation. Objective evaluation of their claims is not presently available. Others have suggested that odorants easily detected by dogs should be used as taggants in explosives.

Animals other than dogs have been suggested for use. Some rodents, notably rats and gerbils have already been tested for this role with less than satisfactory results. Pigs apparently have an excellent sense of smell but their use by law enforcement agencies has been ruled out for aesthetic and practical reasons.

Finally, 10 to 15 years into the future, research into the "artificial nose" may pay off. Again at IBDS at Auburn University, researchers have taken small bits of natural membrane from olfactory receptor cells and fused them onto an artificial lipid substrate. When odorants bind onto

[11] The amount of mobility in a joint.

[12] A Discussion Document on Enhancement of the Dog-Handler Team and Development of Antibody-Based Sensors, ' submitted to the U.S. Secret Service, by the Institute for Biological Detection Systems, Auburn University, April 1990, p. 11.

[13] Ibid., p. 15.

receptor sites in the membrane, electrical impulses are given off. In the living creature, these would be transmitted to the brain, which would decode the signals and identify the odor. In the 'artificial nose' these signals are detected by sensitive electrodes and processed by a computer. The "nose" is very sensitive, responding to very low levels of odorant. But so far it is not very specific. "It cannot yet distinguish between different odors," says main researcher Vitaly Vodyanoy. Future research is aimed at improving selectivity. The researchers speculate that different odors may cause different electrical patterns to be produced. Alternatively, receptor cells may be differentially sensitive to different kinds of odorants.

The U.S. Secret Service Canine Explosives Detection Teams

Many organizations rely on dogs for part of their physical security routine. The Federal Aviation Administration, the U.S. Customs Service, all military services, the U.S. Park Police, the U.S. Capitol Police, many State and local law enforcement agencies, and numerous foreign organizations, such as the Royal Canadian Mounted Police, and the Royal Ulster Constabulary in Northern Ireland, use canine teams.[14] Since 1975, the U.S. Secret Service (USSS) has also trained and maintained a canine unit, the largest single canine bomb detection squad in the country. The background and operation of this organization are fairly typical and give a good insight into the pros and cons of using dogs.

The USSS is charged with protecting a long list of notables **including the President and Vice President, their families, visiting heads of state, and other dignitaries. They also provide security at the White House complex, other Presidential offices, and foreign diplomatic missions.[15] Part of this security involves searching structures, vehicles, and individuals for threats including explosive devices. For this task, the USSS employs dog/handler teams. It should be noted, however, that the USSS never relies on these teams as the sole means of explosives detection. They are always used as part of an overall Explosive Ordnance Demolition Unit and in conjunction with another search technique, either manual or mechanical, although the decision as to which search means is primary and which is backup depends on the situation. The dogs' place is as a tool for use by the security professionals.**

The USSS canine corps currently consists of about 30 dog/handler teams. Generally, these teams spend about 80 percent of their time doing detection work with the remainder spent performing patrol functions. It is uncommon, for cost and operational considerations, for any organization to dedicate dogs solely to detection work and so, frequently, the same animal is used for both detection and patrol duties. This cross use is not necessarily bad. The obedience training that is a necessary part of the patrol training process, improves the control and operation of the animal in the detection mode. The USSS dogs are trained to detect only explosives. They are not cross-trained to detect both explosives and narcotics (or other drugs). This is for safety reasons. If a dog were trained to give the same response to both types of contraband, the handler would never know which type of threat he was dealing with. If the dog were trained to give different responses, there still would be the lingering doubt about whether he was giving the proper signal. Because the courses of action following detection of these two types of contraband are drastically different and because the consequences of making the wrong response can be so dire, the USSS did not want to risk having their dogs give an improper alert.

Many breeds of dogs are probably suitable for detection work but patrol and guard dogs must be large and trainable to present credible attack behavior. For this reason, German Shepherds are frequently the breed of choice although several factors count against them. These include a difficulty getting physically sound dogs because careless breeding, especially in the United States, has resulted in the proliferation of animals genetically predisposed to physical disorders such as hip dysplasia. Also, German Shepherds, while controllable, are not as easy to work with as other breeds. Labrador Retrievers, for example, are less expensive, longer lived, more tractable, have good noses and (to date) no predisposition for debilitating diseases. However, their generally genial disposition renders them not particularly suitable for criminal apprehension[16] work Beagles, even poodles, have been considered for use as detection dogs but to date, no scientific comparison of the olfactory capabilities of various breeds has been undertaken.

The USSS is a great believer in the use of dogs and they are willing to pay quite a price for the privilege. Their expenses start with acquisition of the animals. The USSS relies on a breeder in the Netherlands who selects young (1- to 3-year-old) dogs, usually German Shepherds or

[14] This list is far from complete.

[15] The USSS is part of the U.S. Department of the Treasury and investigates many varied currency-related offenses such as forgery, violations of the FDIC Act, and those pertaining to electronic funds transfer frauds, credit and debit card frauds, false identification documents, computer access fraud, and misuse of U.S. Department of Agriculture food coupons. But these activities do not involve the use of dogs and so will not be further discussed.

[16] A euphemism for "attack."

Belgian Malanois.[17] The Service has found that this individual is their most reliable source of high-quality dogs. Because the dogs will also be used for patrol work the generally larger males are preferred. The dogs usually have had preliminary obedience and patrol training and cost about $2,000 apiece. Shipping adds another $400 to $500.

The handlers are selected **from the ranks of uniformed USSS** officers. They are chosen based **on an** evaluation of how well they work with the dogs and their general seniority in the ranks.[18] The only physical **requirement, beyond those normally associated with the Service, is the ability to pickup and carry 80 pounds, the average weight of a dog. Both men and women serve as handlers. The canine corps is considered desirable work among the USSS officers. At the very least, there is the free use of a car and the opportunity for improved income. Dog handlers are considered "technicians" which, by itself, justifies a pay raise of about 6 percent. In addition, considerable travel is inevitable, which translates into considerable overtime pay and, for care and feeding of the dogs, the handlers receive 2 hours of overtime pay every day for as long as their dogs are alive and working.**

Training is conducted at the USSS Canine Training Facility in Beltsville, MD. Small groups of new dogs and rookie handlers, typically four or five at a time, are trained as the need arises, about every 2 years. Deciding which dog to assign to which handler is more art than science. Some assessment of size (the larger dog goes to the larger handler) and home situation (the touchier dogs are not assigned to officers with small children) is made.

The USSS currently uses four dog trainers who are civilian employees of the USSS. Initial training lasts 20 to 26 weeks (40 hours per week) during which time, the teams are drilled in obedience, criminal apprehension, and detection techniques. For the obedience work, both on and off the leash, the dog is schooled to respond to the commands ''heel" (maintain a position at its handler's knee at any pace and through changes in direction), "stay' (remain in position even while the handler walks away or walks past), "down" (lie down on command, even if the handler is some distance away), and ''come" (return to the handler). To test and improve agility, the dogs are taught to cope with a variety of obstacles such as fences, windows, tunnels, broad jumps, ladders, and elevated cat walks.

Criminal apprehension training involves teaching the dog to chase and grab the arm of a suspect and to hold on until the handler arrives. On command, the dog must release the suspect and return to his handler. The dog then stands guard as the handler searches the suspect for weapons and will reengage if the suspect makes a threatening move. The dog must also obey a command to stop a chase, even if he is in full flight, and return to his handler.

For detection, the dogs are taught a three-step sequence: smell a target compound, alert, receive reward. To do this, the dogs are exposed to the scent of one of the target compounds, then the handler manually positions the dog into the "alert" posture, then the reward is provided. After an adequate number of repetitions, the dog comes to realize what is expected of him. The dogs must also be taught to follow the 'scent cone" to the site of the strongest odor. Training the handler to observe the environment and interpret the dog's behavior is critical here for the strength and location of the scent is strongly influenced by any air currents and eddies. The handler must be able to work the dog in a search pattern that takes best advantage of the air movements and he must be able to recognize when his dog is interested but not yet sure enough to alert. Commands are given verbally, with body signals (a wave of the arm, a sweep of the hand), or by using both modes simultaneously.

The USSS trains its dogs to signal detection of an explosive (alert) by sitting. Drug-detecting dogs are frequently trained to bite, scratch, and otherwise attack a suspect package. The passive "sit" response is clearly more appropriate when dealing with a potential hazard such as an explosive. The dogs learn to look for scents on the ground, in the air, and coming from objects, and they are trained to search for both humans (with the command "find him") or explosives ("search"). The dogs are trained to find about 13 of the most common military and civilian explosives including TNT, RDX, Semtex, and black powder. They do not train on peroxides which are considered too unstable to work with.

This seems like an impressive list of accomplishments. Yet, some dog-training experts estimate that a single dog can learn 150 tasks. A complex operation may involve a number of tasks but the USSS dog trainers believe that their dogs are asked to perform at a level of only about half their maximum capability.

Dogs require 70 to 130 iterations of a task before they can be considered trained in it. This time might be shorter for a very intelligent, talented animal or if the task is related to one already learned. For example, to learn to respond properly to the detection of a first explosive might take the full number of repetitions but to learn another explosive (where all that is required is to

[17] A breed developed in Europe during the early years of this century by crossing German Shepherds with hounds. The USSS finds them more suitable than German Shepherds because they have abetter 'nose,' they have abetter drive to work, especially in hot weather, their bite is about 100 psi stronger than a Shepherd, and they area little smaller and a lot faster.

[18] A minimurn of 5 years on the force is required.

recognize the new scent, the response procedures being already familiar) would be quicker.

Motivating the dogs is a supervisor's dream come true. The dogs generally will work to please their handlers who are lavish with praise when it is due. Furthermore, for criminal apprehension work, the dogs find biting the subject very rewarding in itself. Also, when they have performed successfully, the dogs are allowed to play with a ball. Usually this play is allowed to go on only for a few seconds before the handler removes the ball but it seems to satisfy the dog.[19] Food is used as a reward only as a last resort. The dogs are never punished for a false alert. They may not be rewarded if the handler feels the dog is "faking," but he won't be punished. False positives are tolerable, false negatives are not. The USSS does not want the dogs or their handlers to feel constrained about alerting.

At the conclusion of initial training, the dogs and their handlers are ready to join the canine patrol corps (although, as a practical matter, it may take an additional 6 to 18 months of experience before the dog and his handler become really comfortable working together). But formal training does not end at this point; in fact, it never ends. During regular working hours, the handlers repeatedly challenge their dogs by hiding ''training aids" scented with different explosive compounds. This not only gives the handlers a chance to test and hone their dogs' skills, but it also is very satisfying to the dogs, who, like people, can get very frustrated and bored if their work never seems to accomplish anything. All influencing factors are varied as much as possible. Therefore, the locale in which this training takes place, the kinds of explosives used, and the concentration of the explosive are randomly altered.

Additionally, on a weekly basis, every dog returns to the Beltsville facility for a full day (8 hours) of continuing training as part of a recertification process. During this time, he is tested against three or four explosives other than those used by the handler during the course of the week such that, over a span of a month or two, the trainers can be assured that the dog is still properly responding to the whole range of explosive threats. Should an animal fail recertification, it would return to Beltsville for additional training. This USSS recertification routine is much more stringent than that of many agencies. The FAA for example, recertifies their dogs only four times a year. Of course, the FAA generally uses their dogs for narcotics detection and if they should fail to perform correctly the consequences are not as immediately disastrous as a failure to detect an assassin's bomb.

The dogs go everywhere the USSS protectees go. The dogs are transported all over the country and, occasionally, all over the world. They ride like other animals, in travel kennels in the pressurized, but dark and noisy, baggage compartment. Despite this travel arrangement, most of the dogs seem to enjoy the excitement of being on the road and willingly enter their travel kennel. The dogs can suffer from jet lag, though, and several have washed out of the program from an inability to cope with travel.

An important feature of the USSS program is that the handlers have absolute authority to determine the fitness of their dogs for use on any given day. If the officer does not feel that the dog is performing properly, he or she can withdraw the animal from service without concern about being overruled by a supervisor.

Atypical day finds the dog and his handler reporting for the day shift (6 a.m. to 2 p.m.) at USSS headquarters in Washington, DC, where they receive their assignment. They might be sent to work 4 hours at the White House where the dog would be used to sniff a motorcade and then spend the next 4 hours on patrol around the embassies and other foreign missions.

The performance of the dog at explosives detection depends on several factors: the temperature, the humidity level, the amount of air movement, and, most critically, the skill of the handler in reading changes in the dog's behavior that signal a possible detection. As an example, for a search of a line of cars conducted outdoors, the handler would start the search downwind so that the dog would have the best chance to pickup odors. Handlers are issued small smoke generators to help them gauge wind direction. The animal is walked to the first car and given the command to search. The dog and the handler then circle the car. If the dog seems interested but does not alert (sit), the handler will note the behavior and continue the search, returning to the suspect spots later for a recheck. Ironically, newer cars are so tightly sealed around the doors, windows, and trunk that it can be hard for odors to seep out. Therefore special attention is paid to ventilation outlets and locks. Frequently, drivers are required to open the trunk to allow a closer inspection.

On cool, crisp days, the dogs can do sniffing work for an hour at a time, sometimes longer, before a break (on the order of 20 minutes duration) is needed. On hot, humid days, they may be able to work only about 20 minutes before they are exhausted. This behavior is quite the opposite of mechanical sniffers, which operate better under warmer conditions because more target molecules are evaporated and therefore are available for detection. Pavements are a particular problem. By catching and retaining the heat of the sun, the temperature around pavement level, where the dog's nose and feet have to do most of their work, can easily reach pain levels.

[19]Separating the dog from its orb is not always a trivial operation. Sometimes it is necessary to lift the dog by its collar until blood flow to the brain is choked off enough to cause partial unconsciousness before the dog can be persuaded to relinquish its grip.

Another distinction of the USSS program is that they dedicate one handler to one dog and the animals actually live with their handlers. Some organizations maintain a central kennel where the dogs are all housed communally. In some cases, there is not even any effort made to maintain a constant dog/handler team. Despite these apparent liabilities, some of these dogs still manage to work quite well. But given the mission of the USSS they cannot afford to have animals who are not well acclimated to humans in all their variations. They feel this is best accomplished by maintaining the dogs in a family environment complete with small children and other pets.

The bond between the team members seems to be a strong one. When the dog is retired from service, he is usually offered to his handler. Despite the necessity of signing mountains of paperwork acknowledging the risks of assuming ownership of a trained attack dog, most handlers choose to accept their teammates. One officer even delayed his own retirement in order to have it coincide with that of his dog so the two could stay together.

The average service life of the dogs is 7 to 9 years. Typically, when the dog retires, the handler also leaves the canine corps, either to retire himself or to assume other duties. The USSS generally has not recycled handlers through the program. This allows the maximum number of officers to participate, although some argue that this is a waste of a valuable resource, namely the trained handler.

In the end, has it been worth all the effort and expense? By maintaining the program, the USSS has clearly voted in the affirmative. But objective data is hard to come by. The problems of quantitatively assessing the dogs' performance have already been discussed and the USSS **is not immune to these problems. To date, the sniffer dogs have never found an explosive that would have actually threatened a protectee (apparently, they have not missed one either), although they have detected various weapons. No dog has been killed or wounded in action. Under training conditions, a detection rate of 75 percent is considered very good. A machine offering similar performance might not survive on the market. But finding plastic explosives 75 percent of the time is still a lot better than finding them none of the time. And as long as this performance level is acknowledged and the dogs are not relied on as the sole means of explosive detection, the Service is still ahead of the game.**

Furthermore, there is an undeniable deterrence factor in the use of dogs, especially in their guard and patrol functions The USSS feels this has inhibited the curious, and others with darker motivations, from trying to penetrate security boundaries.

Conclusion

As explosives detectors, dogs are about in the same boat as the FAA's thermal neutron analysis (TNA) device: they do not work very well, but they work better than anything else, at least so far. Again like TNA the competition is moving up fast.

There is some promise that research will enhance the dog's usefulness by: 1) improving our understanding of how the dog functions thereby making the dog's performance more predictable, and 2) by actually improving the dog's acuity. But research into mechanical sniffers is also proceeding apace. Devices capable of matching the dog's performance, at least in some respect, are nearly perfected.