Appendix D
Chemical and Biological Warfare Agent Detection

This appendix summarizes work done in detection of chemical and biological agents in recent fiscal years.

Biochemical Detector System

Sponsor: U.S. Army-Chemical Research, Development, and Engineering Center (CRDEC).

Status: Exploratory development of an automated Army field device.

Funding: Approximately $5 million per year.

Basic Operating Principles and Goals of Concept

This system is a "simple" point detection alarm that classifies and partly quantifies nerve and blister gases as well as pathogens and toxin agents. Detection is accomplished at levels consistent with human sensitivity to the agents. The device is to operate unattended and continuously. The system consists of an aerosol sampling subsystem, a sample preprocessor, and a detector.

Technical Description

This device is designed to be a 10-pound, l-cubic-foot object that operates continuously when unattended. A cassette feeds film through the sample stream drawn in by the aerosol sampling subsystem (a suction pump). In the preprocessor, antibodies from a storage system are directed towards the sample where they attach to any antigens that are present. The agglomerate sticks to the film at specific locations. The antibody has an attached radical that increases the acidity of a solution in which it is dissolved. If the antibody/antigen combination is present, the pH of the spot will then drop, due to the increased acidity, indicating the presence of the agent. The pH is measured indirectly through a simple measurement of the conductivity of the spot.

Status

This is a major Army development program designed to bring chemical and biological weapon (CBW) detection capability to field use, and is not directly aimed at the terrorist threat. The program is currently in exploratory development. The engineering development phase is slated to start in fiscal year 1993. Technology from this program could be utilized to produce some near-term, terrorist-specific hardware, which would not necessarily have the same degree of automation or the same weight specifications but might have the need for a more rapid response.

Potential and Shortcomings

This point detector is a local measuring device with a limited range. It responds only to those specific agents that it is designed to search for. This is a general weakness of all detection and analysis schemes that utilize anitbodies. Such systems are primarily useful when an attack by a specific set of agents is suspected.

Chemical and Biological Mass Spectrometer

Sponsor: U.S. Army-CRDEC

Status: Exploratory development—technology base studies.

Funding: $8.8 million through fiscal year 1990-$30 million projected through to production and deployment.

Basic Operating Principles and Goals of Concept

This device is a somewhat more sophisticated automated point detection system designed to detect, identify, and semiquantify chemical and biological materials in an air sample. It is designed to detect known chemical agents, toxins, and pathogens that are listed in an internal library.

In later versions, it is hoped that the device will be able to identify unknown agents based on stored characteristics and expert system software (i.e., software that allows the system to employ programmed methodologies, assembled from human pathologists, that are intended to evaluate an unknown threat).

Technical Description

This instrument is a major extension of an existing German mass spectrometer instrument, which can perform a limited detection and identification function. The specified improvements over the existing device include a quicker response time, a broader range of observable materials, increased resolution (i.e., ability to identify), a larger library of agents in the data bank, and reduced physical weight, size, and power requirements. This system is designed around a two-stage mass spectrometer for detection and identification. It consists of a biosampler unit, an infrared pyrolyzer that prepares the sample, and the mass spectrometer itself. The device is designed to weigh 40 pounds and have a volume of 2 cubic feet.

Status

This is a long-range development program for the Army, currently in the exploratory development phase. A

simpler and more modest version of this technology, possibly based on the German system, could be of some value to the terrorist detection problem and could be available at a much earlier date than the current Army program.

Potential and Shortcomings

Like other chemical and biological detection and identification concepts, this system depends on stored data on potentially harmful agents that are known to exist. The use of artificial intelligence techniques for implementing the process of identifying unknowns is in an early stage of research and its success cannot yet be forecast.

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The following are smaller projects, sponsored by the Technical Support Working Group (TSWG) and conducted by various laboratories and contractors under the technical and contractual supervision of the Naval Explosive Ordnance Disposal Technology Center at Indian Head, MD. In general, these programs do not develop brand new technology, but are applications of existing capabilities *specifically to the counterterrorist problem.*

Building Air Monitor

Sponsor: **TSWG—through the U.S. Army CRDEC**

Status: **Contractor efforts at Los Alamos National Laboratory (LANL) and at the Illinois Institute of Technology Research Institute (IITRI) during fiscal years 1988, 1989, and 1990. Systems demonstrated at CRDEC in 1989 and 1990.**

Funding: LANL—$120,000 **in fiscal year 1988; $198,000 in fiscal year 1989.**
IITRI--$351,000 in fiscal year 1988.

Basic Operating Principles, Goals of Concept, and Technical Description

The object of both these efforts is to develop a real-time chemical vapor and biological detection system to monitor fixed-site air supply systems. The LANL system utilizes a Zeeman interferometer that detects the change in the index of refraction of air or water when a contaminant is present. The measurement is not very sensitive or very specific, but is instantaneous. This is a major advantage for an early warning system. The IITRI program uses modified, off-the-shelf, flame photometry equipment.

In the LANL system a commercial Zeeman laser[1] shines through a reference chamber and into a photodetector. A phase shift between the two lines is measured and related to the refractive index of the medium. For a 5-centimeter path length, the refractive index can be measured to 1 part in 10^9. In practical terms, the sensitivity is about 1 part per million (ppm or 10^6) for air and gases and about 1 part per billion (ppb or 10^9) in water (the change in index is much greater for water). Since the only observable is the change in index of refraction, the device can only note that the baseline content of the air or water has changed. The project has been completed and a final report is nearly complete. No hardware has been delivered.

The IITRI system uses a liquid chromatography and a standard flame photometer to identify GB, VX, and DFP (nerve gases) concentrations at parts per trillion (ppt or 10^{12}) levels in a 7-minute analysis cycle. In a flame photometer, the sample is passed through a flame that excites the molecules present. These excited molecules then radiate light at characteristic frequencies, which can be used to identify the molecular species. The work on this project was initiated in fiscal year 1989 and is continuing through 1990. Demonstration of the capabilities of the system is expected at CRDEC in the near future.

Real-Time Water Monitor

Sponsor: **TSWG—through CRDEC program.**

Status; *Program* **scheduled for completion soon. Project is being carried out with the support of the Environmental Protection Agency (EPA) by a contractor.**

Funding: $510,000 in **fiscal year 1988; $486,000 in fiscal year 1989.**

Basic Operating Principles, Goals of Concept, and Technical Description

The object of this program is to develop a highly sensitive and specific monitoring device capable of measuring chemical and biological contaminants in surface and ground water supplies.

The system consists of a sampler and preconditioned module, which gathers a sample from the water supply piping. The sample is heated uniformly to a set temperature and its pH adjusted to a set level. The sample is then processed to remove excess minerals. The conditioned sample is then fed to two sample modules, one to detect chemical contaminants and one to detect pathogens.

Currently this system is partially developed and tested, with the pathogen unit lagging behind schedule. Operating and detection software are also being written and tested, with the pathogen system again behind the other.

[2]That is, the frequency can be shifted rapidly among many different lines that arise from transitions between energy levels of a multitude of rotational and vibrational states of the CO_2 molecule.

Combination Detector System

Sponsor: **TSWG—through CRDEC program.**

Status: **Demonstration of feasibility soon.**

Funding: ***$521,000 in*** **fiscal year 1988; $270,000 in fiscal year 1989.**

Basic Operating Principles, Goals of Concept, and Technical Description

The objective of this program is to develop an on-line air and water monitoring system for chemical (nerve) and biological agents using a laser fluorometer to detect changes in the fluorescence of a sample. The work is being undertaken at LANL. The system can detect one ppt of nerve agent and 0.1 ppt of biological protein in aerosols, with a sensitivity of about a factor of 100 lower in water. Detection times are quick.

A sampler collects either a gaseous or a liquid sample into a continuous flow system. A pulsed laser (KrF excimer laser) fluoroscope irradiates the sample. To detect nerve agents, immobilized acetylcholinesterase (the actual target of nerve agents) is exposed to the sample and is then monitored using a substrate that fluoresces under illumination by the ultraviolet (UV) laser light. A change in activity indicates the presence of a nerve agent. To detect bacterial particles, the system observes the fluorescence emitted by aromatic amino acids and proteins (usually tryptophan) when excited by the uv light. The fluorescence-based chemistry for these compounds has been developed under this program.

This system is nonspecific and is intended as a "first alarm." The hardware consists of state-of-the-art laser and other components and weighs on the order of 45 kilograms.

Remote Agent Detector

Sponsor: **TSWG—through CRDEC.**

Status: **Feasibility demonstrated in fiscal year 1990.**

Funding: **At Stanford Research Institute (SRI)—*$428,000 in* fiscal year 1988; $0 in fiscal year 1989; $405,000 in fiscal year 1990. CRDEC contributed $50,000 in fiscal year 1989.**
At LANL--$497,000 in fiscal year 1988; $450,000 in fiscal year 1989.

Basic Operating Principles, Goals of Concept, and Technical Description

Two concepts, based on different operating principles, are being pursued by two contractors (one at SRI and one at LANL). Both are lidar systems, i.e. radar-like systems using pulses of light instead of microwaves. Each operates by sending out a pulse of light and measuring the backscattered energy and time of arrival. The intensity gives some indication of the strength of the scatterer, i.e., its concentration, and the time of arrival gives the range to the backscatterer, i.e., its location. Consequently, lidar systems can map the location and concentration of a cloud containing an agent.

The SRI system uses a frequency agile, pulsed, infrared (CO_2) laser operated in a differential absorption mode (DIAL). In a lidar system some light must be reflected back to the detection telescope; the source of the reflection can be a topographical object (the ground, trees, any reflector behind the cloud to be observed), or it can be the aerosol particles of the cloud itself. In either case two (at least) pulses of different wavelengths are emitted in rapid succession, one at a wavelength where the agent in the cloud absorbs and one at very nearly the same wavelength but where the agent does not absorb. The differences between the two signals can be used to determine the concentration and in some cases the location of the agent cloud.

Laser DIAL techniques for atmospheric measurements have advanced to a fairly high state of technology, using both air- and land-based mobile platforms. The SRI program is an application of the state of the art to CBW detection. The U.S. Army has an aggressive research program aimed at developing mobile (moving) detection capability with ranges out to 10 kilometers (km), with both aerosol and surface contaminant capability. The system under development for TSWG is designed for a range of only 1 km but permits automatic, unattended operation. It is closely related to much larger Army-sponsored efforts and employs very similar technology. A system demonstration is scheduled soon.

The remote agent detection system being developed by LANL is based on measuring fluorescence induced by the absorption of ultraviolet (UV) photons from a pulsed uv (KrF excimer) laser. The uv light pulses excite fluorescent radiation of amino acids in the protein of toxins or bacterial spores or cells. The measurement is not specific. A telescope detects the fluorescence and, utilizing appropriate computer software, the system determines the location and pattern of the cloud and produces a map. At present, the system has a demonstrated range of 1.2 km. The system was field tested in October 1989 to demonstrate the feasibility of the concept.

Mobile Laboratory

Sponsor: **TSWG—through CRDEC program.**

Status: **One of two modules complete in fiscal year 1989; the second to be completed in the near future, funding permitting.**

Funding: $611,000 in **fiscal year 1988; $0 in fiscal year 1989; $645,000 in fiscal year 1990.**

Principles of Operation, Goals of Program, and Technical Description

The objective of this program is to develop a fully transportable, rapid response, analytic laboratory, capable of sustained operation in a contaminated environment, to detect, identify, and quantify the spread of chemical and biological agents released by terrorists into the water or air. The program is being conducted with support from the Environmental Protection Agency (EPA) by a contractor, Engineering Computer Optecnomics (ECO), Inc.

The significant characteristic of this concept is that the lab is readily mobile, that is, it can be transported by helicopter, aircraft, truck, rail, or ship. It is designed to respond to an emergency call and be onsite and ready to function within a few hours of a decision to deploy. The laboratory is a fully self-sustained, closed ecological system; containing its own water, electricity, fuel, and waste disposal; protective gear for the operators; and airlocks for entry and egress without contamination. It is designed as a positive over-pressure air system with intake air filtration. It has analytic capability for both chemical and biological agents, including a gas chromatograph, a mass spectrometer, various chemical agent test kits, immunologic test equipment, and sample culture apparatus. It also contains a modified glove box with sample pass-through arrangements and decontamination capability.

The analytic laboratory (an 8 x 20 foot van module) has been completed. A coupled unit containing living quarters has been designed but not completed due to a lack of funding in fiscal year 1989. It is scheduled for completion soon.

Improved Expedient Hood

Sponsor: **TSWG--through CRDEC,**

Status: **Prototypes available.**

Funding: **$122,000 in fiscal year 1989.**

General Principles of Operation

The objective of this program is to develop a low-cost, disposable, limited-time-duration (5 to 15 minutes), ocular and respiratory protection system for key human beings in case of an unexpected terrorist attack using chemical or biological agents. The device is simply a hood with an integral breathing apparatus (with an activated charcoal filter) and an air seal at the neck, which provides a temporary, lightweight, sealed environment for the wearer.

This development is an upgrade of current chemical agent protective gear to make it lighter, easier to store, and cheaper to manufacture. Its chief advantage is that it is a very small package that will enable potential targets, or their guards, to carry it easily for rapid use. The program will test various designs that have been fabricated in fiscal year 1990 and select a final design for future acquisition.