APL Investigations with Counterproliferation Sensors: Guest Editor's Introduction

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This issue of the *Technical Digest* describes several APL efforts focusing on the development of sensors to combat the use of chemical and biological weapons in the traditional military and ever-vulnerable civilian environments as well as other sensor applications as part of the global war on terrorism. Chemical and biological sensor systems are often considered to be elements of defense against weapons of mass destruction (WMD). *Counterproliferation* and *counterterrorism*, respectively, are terms that have been used loosely to differentiate between activities to thwart the spread and use of WMD against military and civilian targets. We summarily use counterproliferation to describe our efforts in all these venues as a matter of convenience.

Chemical and biological sensors have a variety of applications such as screening people and their hand-carried items, inspection of packages and containers, operational defense of field deployment areas and buildings, and medical diagnoses, to name a few. The use of sensor systems differs according to the phase of threat encounter that is contained within an operational spectrum encompassing intelligence, surveillance, passive operational defense, consequence management, decontamination, and medical care. In intelligence activities, sensors are used to search for and discover threat agents and production products at various stages of weaponization. In surveillance, sensors are used to detect inadvertent leakage, misuse, or slow, subtle use of weapons and substances. In passive operational defense, sensors are used to consciously scan, detect, and avoid weapons and agents during an overt attack. After an attack has occurred, sensors are used to characterize the physical extent of contamination, check the health status of people, measure the effectiveness of decontamination procedures, and manage the health care of the contaminated population.

The multifaceted challenge for these sensor systems is that they be sensitive enough to measure minute quantities, specific enough for precise identification, rapid with low false alarm rates, portable, and inexpensive enough to be widely dispersed. Long shelf life, ease of use, and low maintenance are desirable.

During the past decade, motivated by shortcomings in Operation Desert Storm, there has been a surge of chem-bio sensor developments. For chemical substances, advances in gas chromatography, mass spectroscopy, ion mobility mass spectroscopy, and surface acoustic wave technology have led to a significant operational capability. For biological substances, enzyme-linked immunosorbent assay, affinity chromatography, flow cytometry, mass spectroscopy, and nucleic acid sequence and hybridization technologies are among the many approaches being recruited. Today, the recent anthrax attacks in the United States and the specter of widespread casualties from many candidate terrorism substances are focusing even greater attention on the sensor deficit.

Sensor system development is not just the exploration of transducer and sensing device subsystems for efficacy in physical, chemical, and biological response. The engineering of the electrical, electronic, mechanical, signal processing, and information subsystems, when integrated, is essential to bring the Laboratory's capability to the operational environment. As part of the systems engineering discipline, the sensor system is prototyped, operationally tested, evaluated, adjusted for operational interoperability, and transitioned to manufacturing. APL plays a major role in all these stages of counterproliferation sensor development, particularly in the areas of chemical and biological defense as described in previous issues of the *Digest* that introduced our work in the development of molecularly imprinted polymer (MIP) chemical sensors,[1] the Matrix-Assisted Laser Desorption and Ionization (MALDI) Time-of-Flight (TOF) mass spectrometer biosensor system,[2–4] the immunoaffinity fluorometric biosensor,[5] and the ESSENCE biosurveillance system.[6]

THE ARTICLES

APL work on MALDI-TOF mass spectrometer sampling, detection, and analysis technologies continues to play a prominent role in the systems approach to sensor architectures, as described in this issue. Jackman and Moss address the suitability of this sensor to rapidly analyze cytokines, which are small, secreted proteins with a modulatory effect on cells that react to infection. This development will help distinguish between those people who are actually affected by infectious agents from the "walking worried," thus greatly reducing the burden on medical resources after an attack and calming the excited population. Ecelberger et al. have developed a portable suitcase version of the TOF mass spectrometer that is tailored for use by first responders. In collaboration with the U.S. Army's Soldier Biological Chemical Command at Aberdeen Proving Ground, APL has tested the suitcase TOF to verify its specificity, speed, and broad agent range capabilities. Antoine et al. are establishing important sample treatment protocols for the MALDI process. Methods are being developed to optimize the extraction of key biomarkers, separate contaminants from the targeted analytes, and provide calibration for mass accuracy. Demirev et al. are investigating an alternative to mass spectral signature "fingerprint" matching, which is the exploitation of the expanding proteome (proteins in the microbial genome) database. Here, the statistical significance of matches of experimental masses by mass spectroscopy is compared against the sequence-derived proteomic masses to identify bacteria. This work helps to ratify the broad, rapid, mass spectral results with other microbial analysis standards.

Theodore et al. have further broadened APL's scope in handheld biological detection with their investigation into the Micro Arrays of Gel Immobilized Compounds on a Chip (MAGIChip) in collaboration with the University of Washington and Argonne National Laboratory. Using the ribosomal ribonucleic acid (rRNA) macromolecule as the target, since it is preamplified by bacteria with thousands of copies per cell, micro-based arrays are constructed that contain capture probes on a single sensor platform to help sequence potentially thousands of bacterial organisms in a much shorter time (hours) than techniques requiring amplification as well as excessive time and power. In collaboration with Texas Tech University, APL is exploring new applications of MIP technology for the detection of chemical warfare agents, other hazardous chemicals, and explosives. Boyd et al. describe new imprinting processes and the use of a new class of fluoropolymers that allow the creation and test of a versatile, low-power fiber-optic waveguide detection cell.

Remote standoff detection of aerosol biological agent plumes is an essential part of the sensor system architecture that provides early warning for avoidance and countermeasures. APL has been tasked by the Program Executive Office Chemical-Biological Defense (PEO CBD) to assist in the independent test and evaluation of several new aerosol lidar systems. Walts et al. are investigating the characterization of a key detection parameter of the biological target, the extinction cross section. APL uses transmissometer devices as part of an experimental protocol that may eventually be used to measure all biological target strengths. Fuechsel et al. describe the Laboratory's use of a tunnel enclosure at the Dugway Proving Ground test site to calibrate aerosol lidar systems with an accuracy unattainable using open-air disseminations. Increased testing efficiency is attained, which helps to rationalize the differences among several different lidar detection system end-to-end models and test data.

The use of nonconventional methods—improvised explosive devices; slow, covert-release biological sprayers; and infection spreading infiltrators—is of great concern. Two award-winning APL inventions address these issues. Nelson describes the Laboratory's time-domain method of metal detection (proven for land mine detection applications) that may provide an alarm for unconventional weapons. One application is the high-throughput, wide-area surveillance of areas such as airports, train stations, and business centers. In the context of bioterrorism, Sniegoski has developed, within the APL ESSENCE biosurveillance system, a method for the automatic classification of syndromes reported by emergency rooms. This work helps to systematically overcome the reporting problems associated with non-standard, free-form text fields that result from patient medical complaints.

FINAL THOUGHTS

Whether we are dealing with a warfare area such as counterterrorism, or everyday medical and industrial settings, the role of sensors is universally accepted as being vital to surveillance and diagnostics. The extent to which we can overcome the sensor challenges mentioned earlier requires the continual interplay between technologists and operators to develop requirements and concepts of operations, characterize the operating environment, and provide training. There must also be the realization that any overarching sensor architecture needs to be adaptive and flexible to accommodate changes in the threat spectrum and advances in the technologies. APL has demonstrated the ability to deal with these factors. This *Technical Digest* issue gives a brief glimpse into some of the sensor technologies supporting APL's contributions to military operations, civilian biodefense, mail security, and building protection.

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