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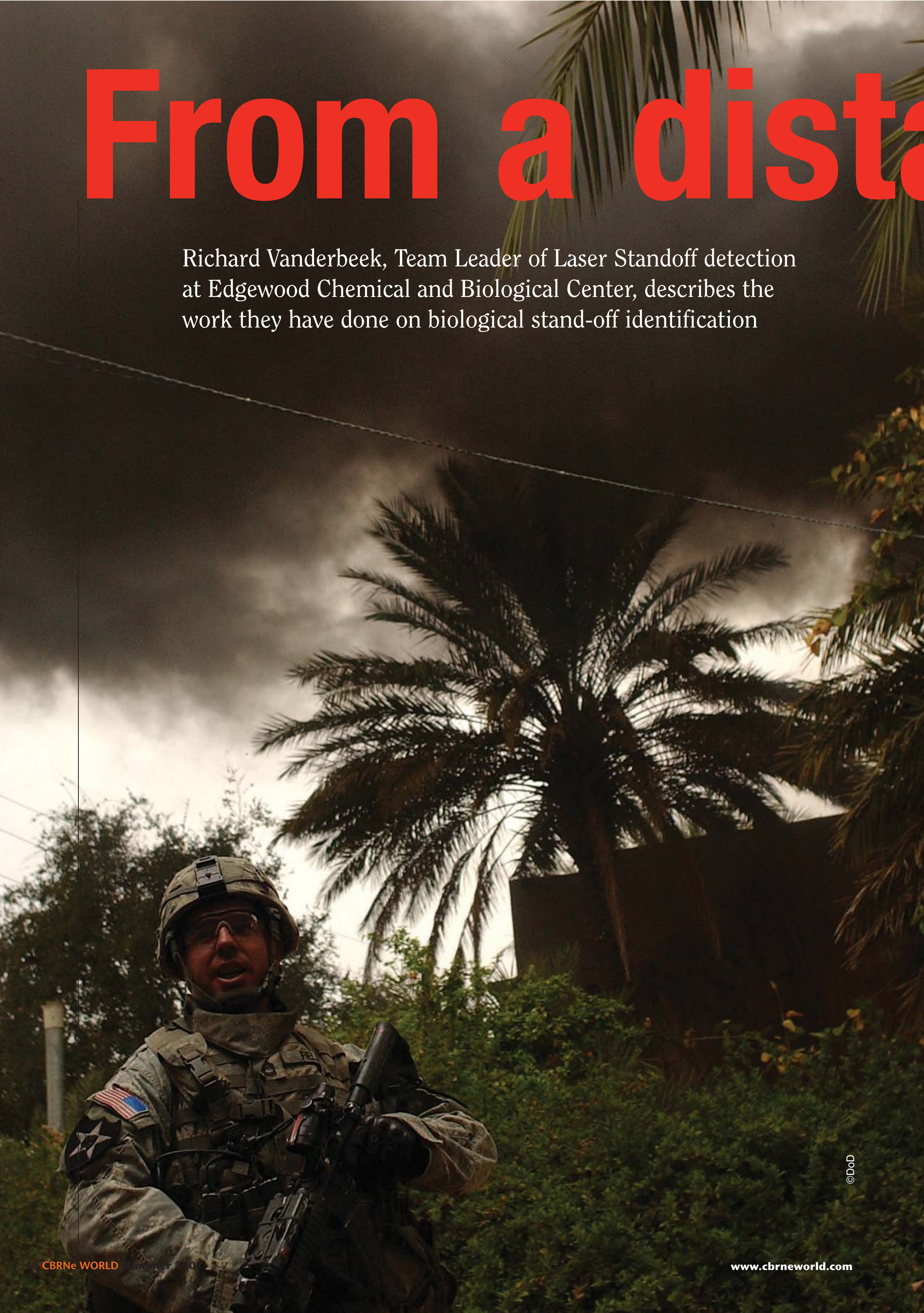
Richard Vanderbeek, Team Leader of Laser Standoff detection at Edgewood Chemical and Biological Center, describes the work they have done on biological stand-off identification



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Left: *The greater the distance detected the more likelihood that soldiers can get in to MOPP gear*

Right: *The US is already working on stand-off biological detectors*

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BIOLOGICAL weapons have become an increasingly important potential threat in today's military and civilian arenas. They are relatively inexpensive to produce and can yield a significant impact as a terrorist weapon. For these reasons the need to develop methods to remotely detect and discriminate biological aerosols from background aerosols, and ultimately, to discriminate biological warfare agents from naturally occurring aerosols, is paramount. Through significant international co-operation, including at least three Nato groups , many technologies have been evaluated. One promising technology currently being evaluated by Edgewood Chemical Biological Center (ECBC) is Long-Wave Infrared (LWIR) Differential Scattering (DISC) Light Detection and Ranging (Lidar).

Positive discrimination

Lidar has been widely used in atmospheric remote detection, and specifically chemical and biological (CB) agent detection, for over two decades. Lidar is a remote sensing technology which is used to measure the optical properties of distant targets. A laser is used to transmit light at one or more wavelengths. The light that is scattered back is collected and analysed to determine the optical properties of the target. These properties can then be used like fingerprints to identify the target. In some cases, however, the available information is more akin to partial fingerprints and can only be used to either exclude or include the target within a larger set of materials that contain the threat agents. The latter approach is referred to as discrimination. While discrimination is less specific than identification (ID), it still provides valuable information that can save lives. Standoff identification of bio agents was previously thought to be impossible, but would provide even more info in early warning, or detect-to-warn, situations .

Frequency agile LWIR Lidar technology capable of automatically tuning to over 60 wavelengths between 9.2 to 10.8 microns at 200Hz was developed over a decade ago by ECBC via contract with Raytheon, El Segundo, CA for remote chemical detection. More recently, however, this technology has been investigated for detecting and discriminating biological aerosol clouds. This work was originally inspired by the results of laboratory measurements of the infrared spectral signatures of biological materials conducted at ECBC. These results indicated that signatures did exist in the LWIR region. Significant questions remained, however, with regard to the sensitivity and specificity of the technology. A series of field tests utilising the ECBC Frequency Agile Lidar (FAL) as a test-bed of the LWIR DISC technology were initiated in 2004. In addition, the development of advanced state-of-the-art algorithms for LWIR detection and discrimination of biological aerosols using the DISC phenomenology was started.

Field testing of Lidar technology for the detection of CB agents requires the extensive use of surrogate materials that have similar optical properties to the agents. These surrogate materials, referred to as simulants by the CB community, are safe to disseminate but appear similar enough to the Lidar to be used in evaluating the technology. Many standard biological simulants exist that represent each of the four major classes of biological threat materials. These threat classes include spores (such as anthrax), vegetative cells (such as the plague), viruses (such as smallpox), and toxins (such as botulism). Simulants from each of these classes have been evaluated during field testing as well as a variety of natural (pollens, dust, etc) and manmade (diesel exhaust, smoke grenades, etc) aerosol clouds. Testing was conducted in an outdoor semi-controlled environment. The concentration, particle size distribution and location of the cloud were controlled through the use of chambers and dissemination tunnels. The cloud was characterised and the concentration was accurately measured by aerodynamic particle size instrumentation. The test was semi-controlled because the environmental conditions, being outdoors, were not controllable. Standard atmospheric parameters, however, were recorded.

Evaluating the LWIR DISC technology in particular presented additional testing challenges. The FAL Lidar transmits a pulse of light that is about 150 meters long. This pulse is scattered off the aerosol cloud and measured by the Lidar. Traditional chambers utilise windows to contain the aerosol while allowing the laser light to pass. The light does, however, scatter off these windows. Since the FAL laser pulse is so long, the scatter from these windows would greatly degrade the desired spectroscopic information from the low concentration biological aerosol cloud inside the chamber. This challenge required the development of a new detector evaluation facility, called the "Vortex Chamber," at ECBC. The resulting windowless Vortex Chamber utilises air curtain technology and creates a cloud that safely simulates a chemical or biological threat cloud. The 20-foot diameter simulated threat cloud is held in suspension by a vortex created within the chamber and is contained by a pair of aerodynamic windows. The truly novel feature is the aerodynamic windows, which make this chamber completely invisible to the system under test. From the perspective of the chemical or biological detector the cloud appears to be suspended in midair. This chamber also allows control and accurate measurement of the cloud characteristics, such as concentration and particle size distribution. The chamber was built under contract with Raytheon, El Segundo, CA. In addition to testing with the Vortex Chamber at ECBC in Maryland, testing was conducted using the Joint Ambient Breeze Tunnel at Dugway Proving Ground, Utah.

Proof of the pudding

The results of these field investigations are highly encouraging and the current iteration of the FAL Lidar has demonstrated detection and discrimination of biological simulants at operationally significant ranges and concentrations during day and night testing. Further optimisation of the FAL Lidar is being completed by Raytheon, El Segundo, CA and ECBC, which is expected to improve the sensitivity by another factor of ten. While the sensitivity results are important, the most significant achievement is the increased specificity that has been demonstrated. With a test set of ten aerosol materials, including five simulants and five interferents, standoff identification was achieved. These results are largely due to the advanced algorithms that have developed. The robustness of the ID results in the presence of a greater variety of simulants and natural and manmade aerosols is still being investigated.

The traditional algorithmic approach to estimating the concentration of an aerosol cloud from Lidar backscatter measurements requires prior knowledge of the wavelength dependent backscatter coefficients. In applications where those parameters are well characterised a priori, the traditional approach is well suited. In the present application of detecting a biological threat cloud that was produced by an unknown source, using an unknown process in the presence of a complex background, the traditional approach is not feasible. For these reasons it is necessary to estimate the spectral structure and concentration from the same data. The algorithm that has been developed in collaboration with Russell Warren of EO-Stat estimates the aerosol backscatter wavelength dependence and concentration range dependence in parallel, as opposed to estimating concentration based on a "library" of backscatter spectra . The backscatter and concentration estimates are used to construct a test statistic to detect the presence of the aerosol. Once the presence of a material is detected and the spectrum is estimated, the discrimination algorithm is applied. Several discrimination algorithms were evaluated. These included the Linear Fisher Discriminant, Multilayer Perceptrons, and Support Vector Classifier (SVC). The SVC significantly outperformed the other approaches because it identifies and utilises only the data most important to making the classification decision, as opposed to using the entire data set. Traditional approaches utilise all the data and lack the selectivity of SVC .

In summary, the advanced algorithm development, Lidar optimisation and advances in test methodologies have led to a critical break-through in standoff biological aerosol detection that offers the first-ever possibility of standoff biological identification. In addition, LWIR DISC Lidar technology has been previously proven for standoff identification of chemical aerosols and vapours, which means that a single technology can potentially provide comprehensive chemical and biological standoff detection and ID. Finally, as a result of this work, an important new detector evaluation facility has been established at ECBC that will benefit future projects and lead to the improvement of other detection technology products for the warfighter.

Accurate identification can speed up the delivery of all important medical counter measures

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