SURFACE CONTAMINATION MAPPING

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ABSTRACT

A new application of laser standoff detection is being investigated, namely, the prediction and mapping of surface contamination. The hardware and software of an existing CO2 lidar was modified to allow improved scanning and real-time processing and display. The lidar was then used to demonstrate the capability of mapping surface contamination to a 1 g/m2 level by detecting aerosol and rain fallout from an airburst during field tests.

1. INTRODUCTION

Eyesafe Frequency Agile Laser (FAL) LIght Detection And Ranging (LIDAR) technology is currently being developed for standoff detection of airborne chemical vapors/aerosols/rains and bioaerosols, with application to fixed site and shipboard contamination avoidance and monitoring. This development effort is being executed under the Joint Service Warning and Identification Lidar Detector (JSWILD) program. Currently fielded standoff chemical detectors employ passive detection technology that provides advance warning of the presence of chemical agent vapors. Active systems (i.e. lidars) are being developed because they employ lasers that can provide added capabilities such as precise target ranging and real-time detection. These enhancements allow a standoff lidar detector to locate the agent threat and provide mapping information. Chemical agent rains and aerosols can be detected and located, and vapors can be mapped as well. Detection and possibly some discrimination of bioaerosols are also within the capabilities of the lidar detector. The existing FAL Lidar prototype can scan the atmosphere and terrain from a fixed location. The JSWILD system currently under development is being designed to rapidly scan the surrounding atmosphere and terrain in a hemispherical fashion from a central location.

The FAL Lidar applies a proven technique, known as DIfferential SCattering and DIfferential Absorption Lidar (DISC/DIAL). Eyesafe laser light at several different wavelengths is transmitted from a carbon dioxide (CO_2) laser in the 9-11 micrometer region and is differentially scattered and absorbed by CB agents. The detection and analysis of light which returns to the lidar system can indicate the presence of biological agents and uniquely identifies chemical agents, since each has a characteristic scattering and absorption spectrum.

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For the past several years, Edgewood Chemical Biological (CB) Center, formerly the Edgewood Research, Development, and Engineering Center (ERDEC), has been developing lidar technology for standoff detection. Before the recent emphasis on Joint Service applications, the focus was on the Army battlefield reconnaissance mission and the intended platform was a vehicle such as the M93A1 FOX. This platform placed severe constraints on lidar system specifications such as size, weight, and input power. In response to this, the FAL, a rapidly tunable CO_2 laser shown in Figure 1, was developed and is currently the world's most sophisticated infrared (IR) absorption spectroscopy laser for moderate range applications. Three identical, state-of-the-art FALs were produced and then integrated into three different lidar systems. These lidars have been demonstrated to be effective in realistic scenarios from ground as well as airborne platforms at ranges up to 15 km.

FY98 funding was made available to enhance the FAL Lidar[1] shown in Figure 2 and perform a proof-of-concept demonstration of surface contamination prediction and resulting threat mapping. This demonstration was to be performed by detecting liquid chemical aerosol fallout from a simulated airburst chemical attack. One very important application of this concept is to identify regions of contamination in order to make decontamination of large areas more efficient and accurate. The demonstration was highly successful, as described in the following sections. Field results, although very promising, indicate that further work and funding are needed to determine the minimum detection limits of this new capability and to insert this application into the JSWILD requirements.

Figure 1: Frequency Agile Laser, manufactured by Raytheon (formerly Hughes Aircraft Company).

Figure 2: FAL Lidar, manufactured by Raytheon (formerly Hughes Aircraft Company).

2. DEMONSTRATION PARAMETERS

Liquid surface contamination can result from aerosol/rain particle fallout from the overhead airburst of a liquid chemical munition. The FAL Lidar can measure this fallout and use the data to predict the location and quantity of liquid chemical contamination. The blast creates particles with diameters ranging from 10-2000 µm depending on the payload and detonation system. A demonstration was designed to simulate and measure such fallout, and predict where the liquid surface contamination was deposited. The challenge was a surface chemical concentration of 5-10 g/m^2 or greater.

To simulate the scenario, small liquid-filled munitions were launched and detonated at heights of about 30 m. The lidar scanned the horizon downwind from the airburst (approximately 3-5 m above the ground) and measured the reflections from the particle fallout. Droplet sensitive cards were placed on the ground to measure the concentration of liquid deposition and validate the demonstration. The lidar data can then be correlated with the droplet card data to determine how well the system can predict the location of surface contamination. This methodology was used for field demonstrations of the lidar and is illustrated in Figures 3 and 4.

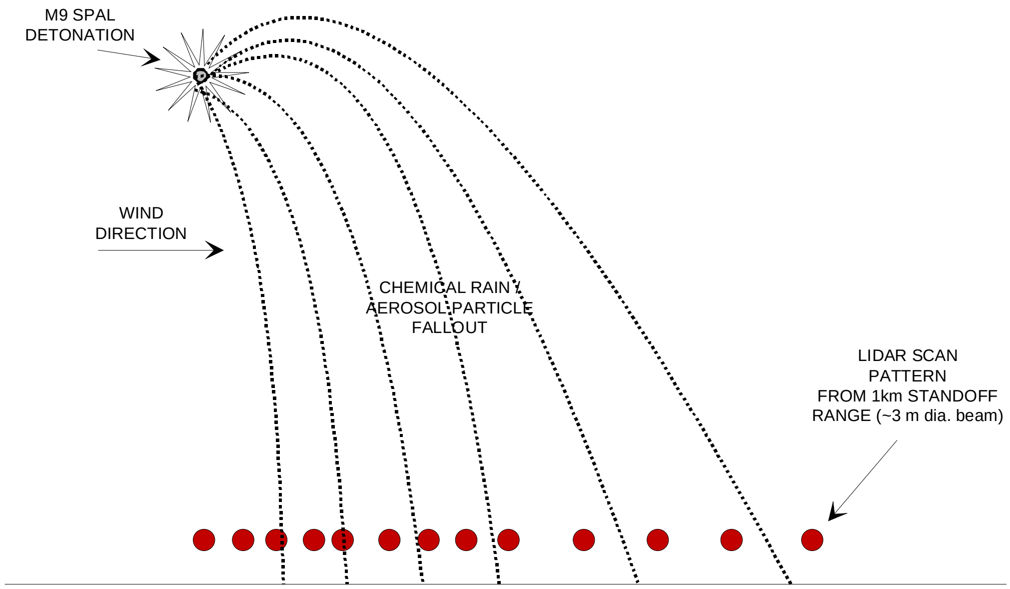

Figure 3: Schematic diagram of liquid airburst and particle fallout. Circles illustrate down-range laser beam footprint (~3m diameter @ 1km) as lidar scans underneath airburst release.

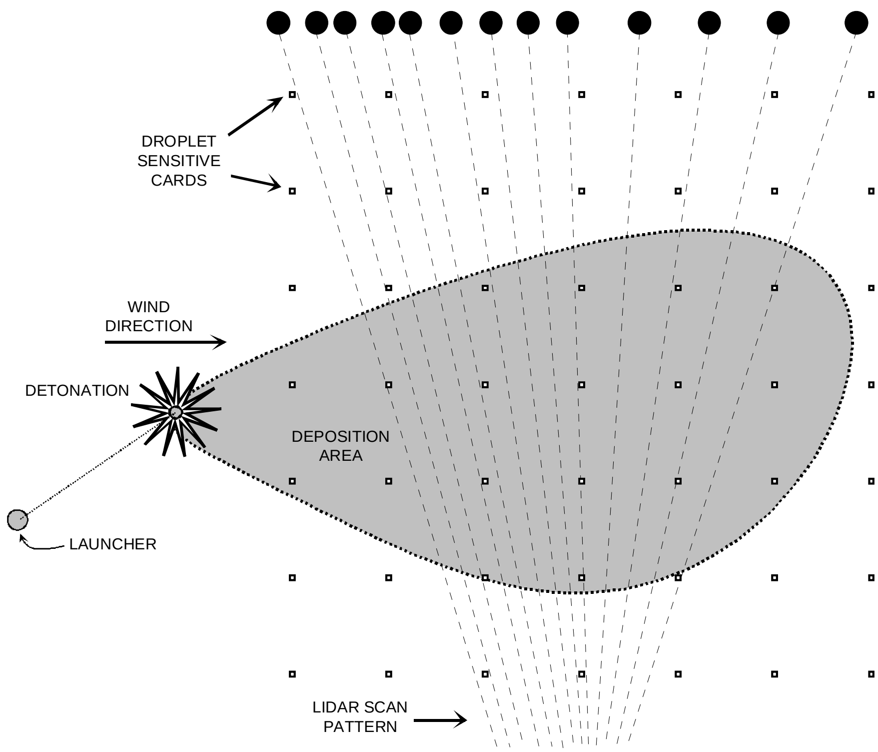

Figure 4: Arial view of test grid setup.

The Army has developed a training device for soldiers to use in chemical attack field exercises known as the Simulator, Projectile, Airburst, Liquid (SPAL): M9. The M9 SPAL, shown in Figure 5, is an assembly which contains a hard plastic bottle and an explosive charge subassembly with a dual-stage delay pyrotechnic time fuse. It can be filled with up to 1 liter of liquid simulant. Polyethylene glycol (PEG-200) is the standard simulant delivered with the standard M9 kit (5.5 liters of PEG-200 per standard kit of 20 SPALS). A launcher barrel is used to launch the projectile to an average height of 30 m. The specified dispersion area on the ground for a single SPAL from 30 m is 15 m x 75 m. Reports have shown data which indicate a 5-unit multiple launch configuration can yield ground dispersions of up to 75 m x 75 m. In this experiment, multiple lines of launchers were used to execute volleys of airbursts to give the lidar more time to sample the fallout event. Note that a 1 liter SPAL filled with the chemical agent simulant triethyl-phosphate (TEP) will create a ground concentration of 0.8 g/m^2. Simultaneous multiple launches of 5 to 15 SPALs were used to vary surface coverage amounts of both TEP and PEG-200.

Figure 5: Simulator, Projectile, Airburst, Liquid (SPAL).

A technique used by ERDEC in the past was to place droplet sensitive cards, shown in Figure 6, on the ground and to dye the chemical so that aerosol droplets would visibly mark the cards upon landing. Knowledge of the "spread factor" for different chemical liquids enables an estimation of particle size distribution and liquid concentration. Computer equipment exists which can scan the cards and count the droplets. This technique and equipment was brought to our attention by Dugway Proving Ground, Utah, West Desert Test Center (DPG-WDTC). Droplet sensitive cards were placed on a grid of 100m (downwind) x 100m (crosswind) at 10m intervals, resulting 100 cards total on the site. Card size was on the order of 8” x 10”. The full array of cards was not used for every trial since wind was often off-center and liquid tended to cover only portions of the array. Different patterns of card placement were relied upon, depending on the nature of each trial.

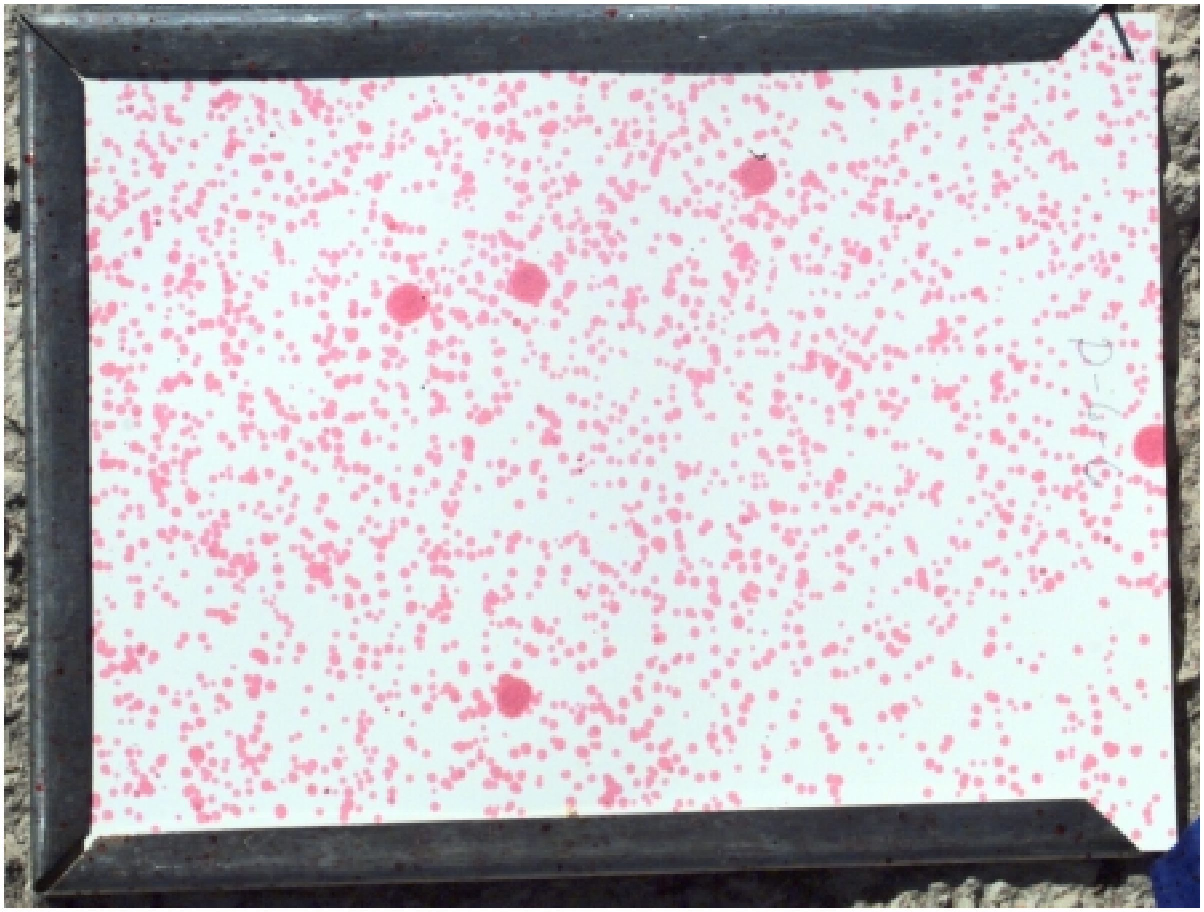

Figure 6: Droplet sensitive card.

3. RESULTS

The test methodology of airburst SPAL releases and droplet sensitive cards proved to highly effective. Trials were conducted using varied quantities of SPALs. Initially, three volleys of 15 SPALs, launched at 15 second intervals, were used to simulate a persistent attack. Later, trials were conducted using 10 SPALs, and one of the final trials examined the effect of a single SPAL launch.

The droplet sensitive card data was reduced and analyzed prior to departure from the test facility. Outstanding topographic maps of chemical concentrations and droplet particle size distributions were presented by the facility’s analysts. One significant problem with the quality of the card data, however, occurred because requests for 24-hour turnaround of the data went unheeded. This resulted in a post-demonstration realization that card placement could have been more effective. In any event, the card data did produce results which accurately described the particle size, area of coverage, and effective ground concentration.

Detection and mapping of liquid surface contamination was demonstrated to a level of 1 g/m^2, or less, pending detailed analysis of droplet card data. Note that, as a proof-of-concept, no attempt was made to determine the lowest detectable level. However, 1 g/m^2 exceeded the demonstration challenge of 5-10 g/m^2. Preliminary calculations indicate that a level of 0.01 g/m^2 is achievable. The detections and mappings were performed and displayed on a real-time basis, as shown in Figure 7, which was a significant improvement over previous off-line analysis methods. The figure illustrates a horizontal lidar scan over a 30-degree range in which liquid aerosol fallout is detected at approximately 600 meters. This plot is a false-color representation of the total liquid deposition intensity over the area.

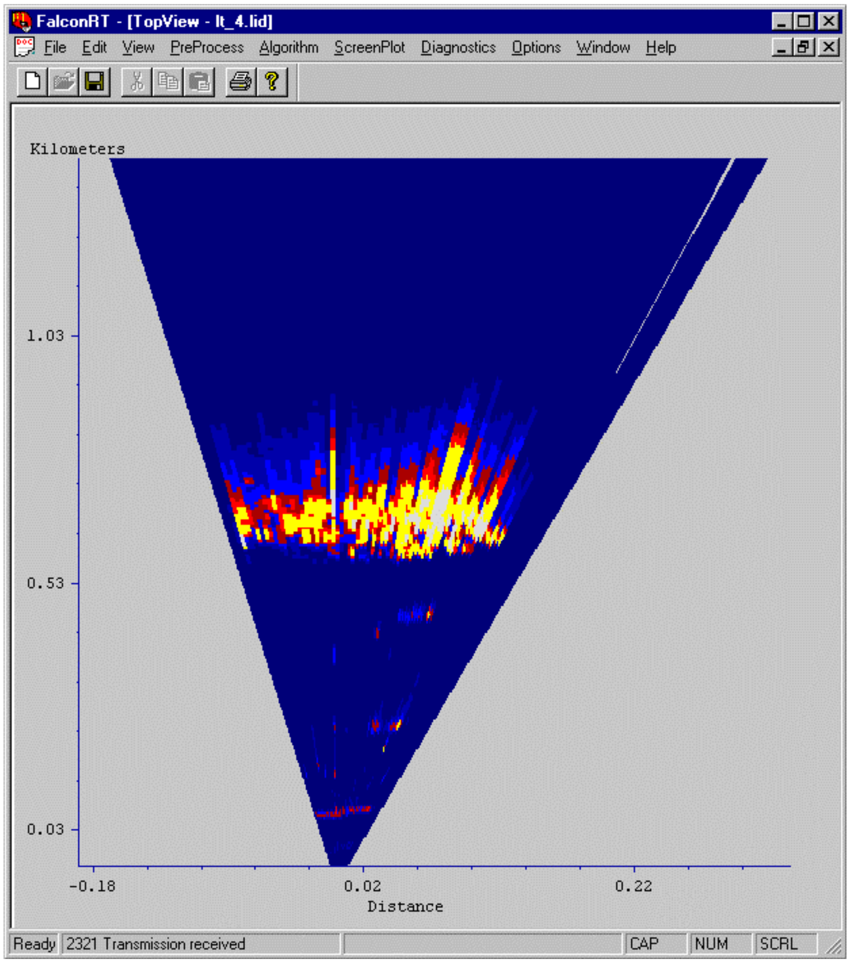

Figure 7: Real-time screen display map of predicted surface contamination.

CONCLUSIONS

As shown in the proof-of-concept demonstration, real-time standoff detection and mapping of surface contamination is possible and highly effective. By using data collected in the field test demonstration and performing additional data collection as necessary, this new standoff capability can be fully characterized. What remains to be shown with additional funding is the minimum concentration level which can be detected and how well these detections and mappings can be corroborated with dispersion and system performance models. This capability, once fully evaluated, can be adapted as a requirement for the JSWILD, a multifunctional standoff CB detector.

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