

The Benefits of Real Time Biological Agent Detection in Homeland Security Applications

Laszlo A. Retfalvi P.Eng PMP, Director, Craig Walker P.Eng, Principal Engineer
Integrated Sensor Systems, General Dynamics Canada Ltd, Calgary, Alberta T2E 8P2

Primary Contact: Laszlo A. Retfalvi P.Eng. PMP at laszlo.retfalvi@gdcanada.com

Abstract

Post 11 September 2001, awareness of global terrorism threats has significantly increased. The current Iraqi conflict has been based on the premise that Weapons of Mass Destruction (WMD) may be held and be used by Iraq or terrorist organizations. In the contaminated letter scenario at the US Postal Service in 2002, as well as the Ricin incident in the UK, the inability to accurately define contaminated areas led to widespread fears among the general population.

In light of these concerns, Governments as well as other agencies have stepped up efforts to develop and field Chemical, Biological, Radiological, and Nuclear (CBRN) systems to help protect homeland assets. The establishment of the US Department of Homeland Security, and the creation of the Homeland Security Advisory System as a means to disseminate information regarding the risk of terrorist acts to federal, state, and local authorities and to the American people, is a direct result of counter terrorism initiatives. Similar initiatives are also in place in other countries.

The ability to detect biological agents in real time is the cornerstone to an integrated approach to defending against biological agent attacks. Biological agent detection systems must be able to detect in real time (less than a minute) to warn potential victims before they are exposed, minimize the number of casualties, and to contain the threat. Further, in situations where there is no warning of an attack, real time detection is a critical tool to maximize effectiveness of consequence management activities.

The goal of this paper is to describe the benefits of real time biological agent detection and to assist the reader in understanding the concept of how to use this technology in homeland defence applications.

Background

Biological agents are classified as four types: spores, vegetative cells, viruses, and toxins. An example of a spore agent is anthrax. Spores are tough and environmentally durable, so they are prime agents of interest as offensive weapons. When evaluating equipment, the simulant used is *Bacillus globigii*, an innocuous spore. Vegetative cells are more common as agents, and an example is plague. Vegetative cells are less hardy in the environment, so are more difficult to use in an offensive capacity. The simulant for vegetative cells is *Erwinia herbicola*. Viruses require a host to replicate, and are a rising threat because many are very survivable in the environment. An example of a virus is

smallpox, and the simulant is MS2. The fourth class of biological agents is the toxins. Although less toxic than most organisms, the toxins are more easily produced in many cases (e.g. Ricin) and are very survivable. The most prominent toxin is botulism, and the simulant is ovalbumin.

Biological agents can be delivered through a munition or as an aerosol from commercial equipment such as crop dusters. The intent is to produce an aerosol of particles of 1 - 10 microns in diameter. This size range of particles can travel great distances suspended in air, is ideal for maximizing respiratory effects, and is invisible. Biological agent clouds have been modeled and shown to retain their lethality for over 100 km. Most threat analyses expect the release of biological agents to be clandestine to invoke the element of surprise and provide deniability to the aggressor. Thus detection is a key to mitigating the effects.

Introduction

A number of sensors that detect unique properties of biological aerosol particles are currently available. Most of these detectors use UV laser radiation to excite fluorescence from living organisms, and have demonstrated the ability to detect biological agent simulants in real time (seconds) in a variety of natural locations throughout the world. They have been particularly effective when combined with sophisticated algorithms that reduce false alarm rates in the presence of naturally varying biological backgrounds. Their main limitations have been generally their cost and optical/electronic complexity has limited their ruggedness. To address these issues General Dynamics Canada developed the Biological Agent Real Time Sensor (BARTS). A version of BARTS is shown in Figure 1. The BARTS retains the sensitivity of more sophisticated sensors, but uses a different technical approach to reduce the complexity of the optical/electrical subsystem, and allows for a more cost-effective, rugged, and configurable design that is more compact and field portable, making BARTS ideal for homeland security applications.



Figure 1 – BARTS configuration for Canadian military applications designed for severe environments.

Setting the Context

In order to ensure a common understanding and minimize confusion, the following definitions are applicable to this document.

Trigger – a process that determines any change in background indicating a *possible* biological aerosol. An example is particle counter based network systems currently in use in various locations in the world.

Particle detectors - or particle counters, are instruments used to measure the number of particles in a volume of air. They cannot distinguish dust, obscurants, or droplets from biological threats.

Particle detectors are almost always used in a network of sensors to attempt to increase the probability of detecting biological agents as well as to attempt to decrease the false alarm rate. These systems exhibit a detection time, which is on average 30 - 40 minutes, and as such do not implement real time detection, a cornerstone to the protection from possible biological agent threats. By definition, implementation of detection as defined below requires sampling and identification, a very complicated and expensive process.

The approach to biological detection requires at least two or three sensors of the array to initiate an alarm. This is a function of required false alarm rate (FAR) and provided algorithm software. In almost all applications, this is neither adequate nor very reliable. Further, the alarm does not indicate that the threat is biological. This significantly reduces the overall efficiency due to the requirement to mask up every time an alarm occurs, even though it may not be biological in nature.

Detection – a process that determines and confirms an aerosol is a biological aerosol. This is the basis of the GD Canada 4WARN Biological Detection Systems, which are based on fluorescent particle detection. Particle counter based systems are not detectors.

Sampling - a process by which a sample of an aerosol is taken in either dry or liquid form.

Identification – a process by which a sample is analyzed to specifically identify the biological agent.

Minimum Requirements of an Effective Biological Agent Detector

An effective biological agent detection system must meet a number of minimum requirements in order to be effective and offer good value to the Customer. These minimum requirements are detailed below.

Reliable real time detection

In order to be effective, biological detection systems must offer reliable real time detection. Real time is defined as 30 seconds or less from the potential pathogen reaching the air intake until an alarm is issued.

Low false alarm rate

False alarms must be minimized for a biological detection system to be effective. This is applicable to both false negatives as well as false positives. Ideally, the system must not miss a real event.

Ability to take a viable sample

A viable sample is required for two major reasons. First, the sample must be available for the identification cycle to occur and must originate from the time the alarm occurred. Second, an uncontaminated sample of the detected event must be made available for evidentiary purposes. This is key to homeland defence applications.

Ability to monitor continuously

Detection of a potential threat is paramount. The ability to distinguish when the threat has left the scene is also of critical interest. To enable this, the detection system must be capable of continuous monitoring. This is of significance to homeland defence applications as tracking of the event can now occur, specifically when the sensors are configured in a network configuration.

Modular design for flexible deployment

Emerging technologies must be considered. Failure to design a system to accept emerging technologies will result in higher overall acquisition costs and reduced overall performance. This allows addresses the issue of component obsolescence.

Core design applicable to various platforms

Design reuse is critical to an effective solution applicable to various applications. The design must be flexible to allow it to be repackaged to address specific environmental or operation needs.

Automated operation, alarming and reporting

The best detector in the world is not effective unless it has the capability to communicate its alarm automatically and autonomously. This has a significant impact to effectiveness and overall operating costs.

Low logistics support requirements

The overall operating cost of any system or deployment activity is key. Biological detection systems must not have any liquid consumables as they are proven to be expensive and difficult to operate. This is particularly applicable to non-specialist operated homeland defence applications.

Integration with command, control, communication, and hazard assessment tools for decision aids

The significance of information dissemination to appropriate decision-making levels is key. This is an emerging area with no firm topology; however, the ability to integrate in network centric applications is an important factor.

Easily deployed and used

Finally, incorporation of the above design constraints must include the ability to be operated in a simple and effective manner in homeland defence applications. This must not be underestimated as a discriminator.

Benefits of Real Time Biological Agent Detection

Based on the threat analysis and the hazard assessments, detection systems must be able to detect in real time to warn, protect and minimize the number of casualties. In spite of the availability of medical therapies for some agents, they are still very toxic and deadly, so the best defense is to avoid exposure. The ability to detect viable organisms in real time is key to an integrated approach to warning and defending against biological agent attacks because it allows time to warn personnel before they are exposed.

Achieving this goal requires the ability to detect airborne organisms at very low infectious levels in the presence of the normal background aerosol that consists of both biological and non-biological particles. The small amount of information that is available in the scientific literature has been augmented recently by a variety of field tests with biological agent detection systems, and it indicates that the vast majority of particles in the respirable size range in natural backgrounds throughout the world (>95%) are inert.

Thus the ability to distinguish characteristics of living organisms provides a great advantage in detecting biological particles in natural background aerosols. The proportion of particles in natural backgrounds containing living organisms, however, is variable based on geographical location, meteorological conditions, seasonal variations, diurnal variations, and man-made activities. Thus, sophisticated algorithms and data fusion techniques in conjunction with real time detection allow the variability in the natural biological aerosol background to be discriminated from biological agent releases or man-made increases in the biological content of the air in real time.

For example, the performance of the BARTS during field trials is shown in Figure 2.

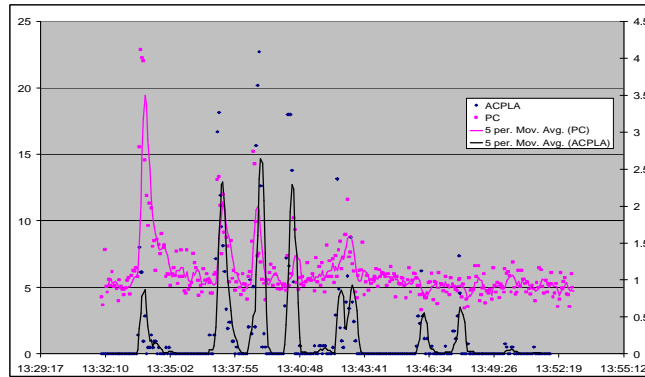


Figure 2 – Typical sensitivity of the GD Canada BARTS exposed to BG during field trials.

Notice the coloration of the referee data with that of the BARTS response. BARTS easily achieved 20 ACPLA sensitivity. The real time response makes the BARTS ideal for real time biological agent detection applications.

Homeland Security and Biological Agent Detection

In order to provide effective solutions to the homeland security market, the supplier must recognize the differences between military and homeland security applications and design the solutions with the differences in mind.

The traditional military application has the following thrusts:

1. Exposure avoidance to agents based on intelligence;
2. Medical pre-treatment activities;
3. Rapid detection and warning of biological threats; and
4. Post event hazard assessment activities.

Civilian or homeland defence applications differ significantly. Recognition of these differences is key to a successful solution. These applications have the following thrusts:

1. Focus on consequence management as the event has happened with no warning;
2. Rapid detection and warning to avoid the spread of contamination;
3. Treatment of casualties;
4. Monitoring of downwind hazards; and
5. Low overall acquisition and operational costs.

Real time biological detection is a very effective element in situations where there is no warning of an attack as it offers a critical tool to maximize the effectiveness of

consequence management activities. This is an ideal application of the General Dynamics Canada 4WARN technology.

Biological Agent Detection Challenges in Homeland Defence

A number of unique challenges exist when using fluorescent particles detection systems, like the BARTS, for the detection of biological agents in homeland defence applications. Key items include the following ¹:

High background particle counts

The background of an urban area is difficult to predict and has shown the ability to include widely varying high particle counts. Refer to Figure 3.

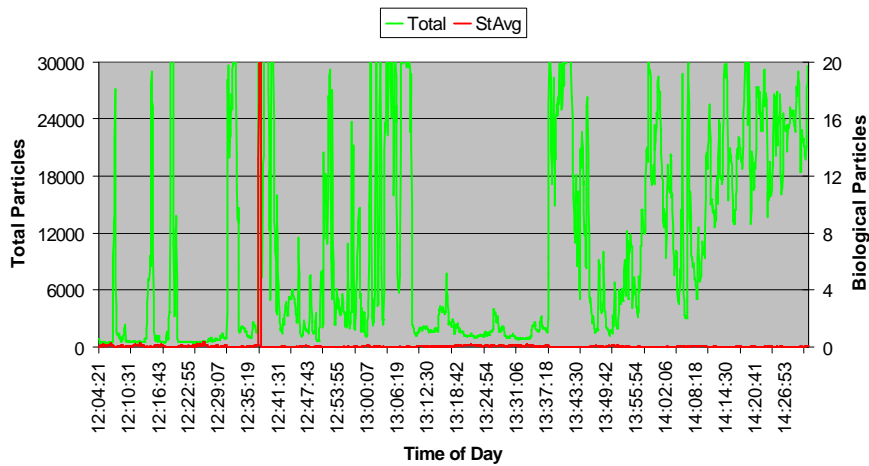


Figure 3 – An example of the variation of particle counts encountered during one test in the greater London, UK area. Note the widely varying background levels.

Unpredictable fluorescent materials from human activity

Tests to date have shown that the fluorescent content of aerosols vary significantly based on the location and the situation at hand. In certain applications, the changes in background as well as changes in fluorescence have made reliable detection a difficult task. Where releases are characterized by short bursts on wildly fluctuating backgrounds, the speed of response of the detector and the ability to eliminate interference are critical to success. In addition, the ability to sample the releases effectively plays a key role.

Realistic controlled tests hard to design

¹ “Development of a Small and Affordable Biological Agent Real Time Sensor (BARTS) – Field Trial Results from Porton, Battelle and Edgewood” Dr. Greg A. Luoma, Mr. Steve Herz, and Mr. Laszlo Retfalvi, General Dynamics Canada, November 2002.

Typical testing involves the use of chamber or field trials to determine biological detection performance. In homeland defence applications, these tests do not adequately characterize the environment where the detector will be used. Therefore, urban field trials are key to development of a reliable biological detector as it allows for the collection and analysis of the background data. This data is used to improve the software algorithms.

The Importance of Alarm Algorithms

The ability to distinguish biological particles from other particles based on fluorescence reduces the potential for false alarms significantly but not completely because there are many natural and man-made materials that fluoresce in a manner that is similar to biological particles. The background fluorescence encountered in most locations can be reduced by choosing the excitation and emission wavelengths specific to biological particles. The excitation and emission frequencies in BARTS were chosen to minimize the amount of natural background interference, but major sources of interference remain. Without software methods to eliminate them or reduce their levels, unacceptable false alarm rates would occur. Refer to Figure 4. The graphs show overlap of the fluorescence response from the BARTS with the referee ACPLA data. Note the determination of the alarm that occurs at the same time as the referee data in a varying background.

The four major sources of interference for BARTS and other fluorescence particle detectors are:

- natural fluctuations in the biological background fluorescence in various geographic and climatic locations;
- deliberate attempts to mask releases with interference such as signal smokes;
- human activity that causes unpredictable changes in the background particle levels;
- man-made fluorescent materials, particularly in urban environments, such as fluorescent dyes or brightening materials.

General Dynamics Canada has invested a significant amount in the effort to develop and to improve alarm algorithms to address the above scenarios.

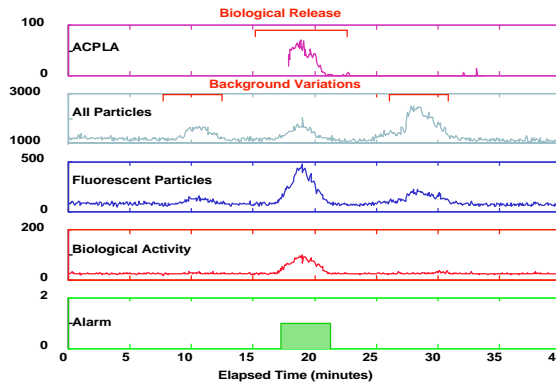


Figure 4 – Response of the BARTS detector during field trials.

The 4WARN Family of Biological Detection Systems

General Dynamics Canada has developed a family of biological agent detection systems for both military and non-military applications based on the BARTS technology. The 4WARN products designed for non-military applications, such as homeland security and consequence management, include the following:

1. 4WARN Sentry - a fully automated, portable and readily deployable, briefcase-sized, real-time biological agent monitoring system that can be utilized as a stand-alone detector or within a scalable biological agent detection network. Refer to Figure 5;



Figure 5 – 4WARN Sentry during field trials shown with referee equipment

2. 4WARN Scout – a fully automated, battery-powered detection and sampling system based on field-proven fluorescence particle technology for the real-time detection of aerosolized biological agents and “white powder” incidents. Refer to Figure 6; and,



Figure 6 – 4WARN Scout for use by HAZMAT personnel.

3. 4WARN Urban - a vehicle-integrated, fully automated biological agent detection and identification system designed to defend against, and manage the consequences of, terrorist use of biological agents. Refer to Figure 7.



Figure 7 – 4WARN Urban during field trials

Mobile Biological Agent Detection

It is well recognized that detection systems must be strategically placed on and near high-value assets, in order to provide rapid warning in the event of biological attack. The approach most widely promoted to date involves deploying a network of remote point detectors upwind of personnel and assets, to perform this task. Ideally, these detectors are stationary, and capable of automatic (i.e. unmanned and unattended) operation, and require little or no routine maintenance.

Because conditions change dynamically, there also needs to be a solution, that provides high mobility for these point detectors. Thus, the need for a vehicle-mounted system comes into play. A vehicle-based system can be used as a remote point detector, as a command post as well as implement a reconnaissance role, to survey terrain in order to identify problem areas.

As a result, it is highly desirable to consider systems that have a common core capability, which can be easily adapted to either stationary or highly mobile deployment situations. This is the approach GD Canada adopted when developing the 4WARN Urban.

The 4WARN Urban is an excellent solution for homeland defence requirements as it offers the ability for remote detectors to be integrated and networked to a central mobile location, which acts as a command post for the analysis and controlled dissemination of information. Refer to Figure 8.



Figure 8 – Inside view of the 4WARN Urban showing the control console. The console can control a scalable network of detectors. Installation kits for other vehicles are also available.

High Value Asset Protection

The definition of high value assets is those places, people, or things, which are considered to be of significant value and must be protected against potential biological threats. These include:

1. VIPs;
2. Airports;
3. Event protection (large assemblies, football games, etc.); and
4. Transit protection such as subways.

In order to provide effective protection for such items, a network of real time biological detectors must be used in a network configuration situated in a fashion, which surrounds the asset under protection. Refer to Figure 9.

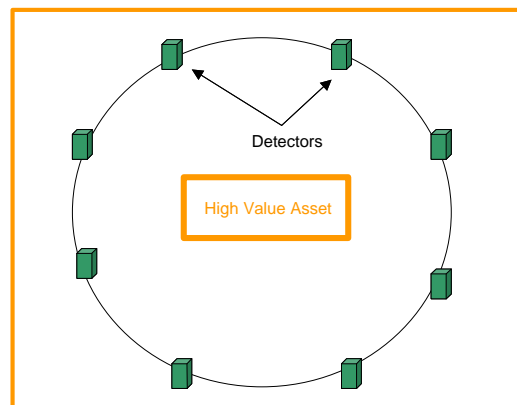


Figure 9 – Diagram showing an example of detector layout topology

The 4WARN Sentry provides the capability to establish a network of remote detectors. Control and monitoring for each of these is performed from a single Command and Control Station (CCS). The operator monitors each, represented by a green icon, from the main CCS window. If a detector detects an agent, the icon turns red and a warning window appears. Refer to Figure 10.

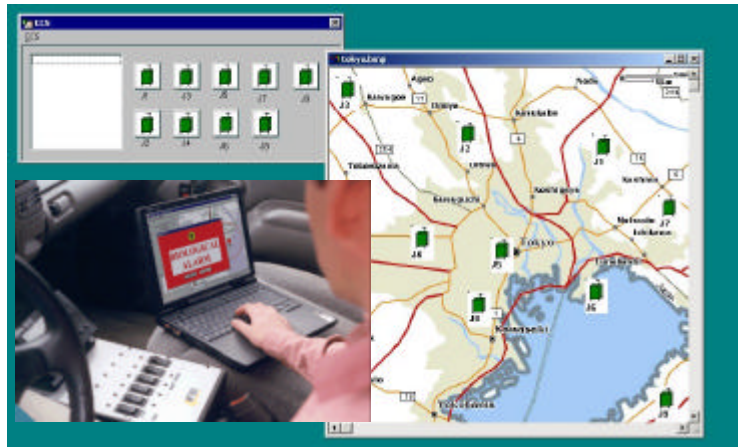


Figure 10 – Example 4WARN Sentry CCS Display

The number of detectors to be networked depends on the deployment scenario and must be carefully planned for maximum effectiveness. For example, networking several detectors along a front line offers protection from an attack from one direction whereas placing detectors around the perimeter of an area being protected offers protection from all directions.

Reconnaissance Monitoring

Biological terrorist attacks are characterized by a lack of advanced warning, and success in dealing with the consequence of an attack is critically dependent on taking the correct actions quickly. In terrorist scenarios, first responders such as firemen and police officers must have detectors for reconnaissance so they can isolate the contaminated area, identify potential casualties and avoid secondary contamination. Further, they need detectors that allow them to monitor contaminated areas so they can determine the effectiveness of decontamination procedures.

In a contaminated letter scenario in the US, the inability to accurately define contaminated areas led to widespread fears among the general population, slow implementation of medical countermeasures, and excessive remediation costs.

Thus, there is an identified critical need among emergency first responders for an affordable handheld real time biological aerosol detector.

In order to address this need, General Dynamics Canada has developed the 4WARN Scout, the world's first battery powered handheld real time biological detector for use by First Responders. Refer to Figure 11.



Figure 11 – 4WARN Scout for reconnaissance applications.

The 4WARN Scout has been designed with the operator in mind and offers a very simple GO/NO-GO visual alarm, which promptly identifies to the user that a biological substance has been detected at its intake nozzle. The unit also takes a sample for verification purposes.

Conclusion

The threat of biological attacks by terrorist organizations continues to be of grave concern. Real time biological detection systems are key to providing advanced warning and/or mitigating the effectiveness of a biological attack. Minimum requirements for an effective biological detection system include reliable real time detection, low false alarm rate, ability to take a viable sample, automated operation, alarming and reporting, and low logistics requirements.

Various configurations of biological detection systems are required to address different scenarios. Software algorithms play a critical role in the reduction of false alarms. GD Canada is a recognized world leader in the area of biological agent detection and GD Canada offers the field-proven 4WARN product suite, which represents the most advanced biological agent detection systems available today.