

Patrolling a biological frontier

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Biological agent detection and countermeasures have always proved much more difficult than chemical agent detection. John Eldridge reviews developments

Countermeasures against nuclear, biological or chemical (NBC) weapons have rarely been a top priority in Western defense ministries, until recently. The former Soviet Union, on the other hand, saw NBC as a vital component of its warfighting plan several decades ago, and, consequently, countermeasures were an important consideration. In the 1970s, even the larger Soviet fishing vessels were fitted with pre-wetting/washdown networks. In those days, detection systems for liquid chemical warfare (CW) agent consisted of impregnated paper strips - indeed they still do - and there was no biological warfare (BW) agent field-detection capability at all.

The latter part of the last century saw the outlawing of NBC weapons by international treaty and, with the technological focus shifting to countermeasures in Europe and North America, the states involved in the continued production of offensive NBC weapons were exposed more starkly.

In recent years there have been two periods of accelerated countermeasures development. The first was in 1991 when coalition forces faced the very real prospect of operating in a contaminated environment. The Iraqi regime had seen the utility of CW when used against unprotected personnel (Iranian forces) during the 'war of the cities' (1980-88). CW helped to halt the Iranian onslaught and set the Iraqi leader on a personal campaign to refine and develop a significant CW capability, which he subsequently tested with devastating results against the Kurdish town of Hallabjah in 1988. Hence during Operation 'Desert Storm' (1990-1991), NBC detection and protection became a rapid and urgent priority, especially for the coalition ground forces whose command was certain that its personnel would face a real CW environment.

The second period of countermeasures acceleration is today. The aftermath of 11 September 2001 identified Al-Qaeda as the aggressor, highlighting its published intention to acquire weapons of mass destruction (WMD). The anthrax letters in the US a month later raised the public's baseline anxiety level still further, and made populations aware of their vulnerability to the use of BW agents in the domestic terrorism arena. The US government now senses a renewed vulnerability to nuclear weapons also, delivered by 'rogue states' such as [North Korea](#) or acquired by rich terrorist organizations.

Detection investment

The greatest Western technical and financial investment is now in detection - especially BW agent detection. Of the others, radiological detection remains the poor relation and the technologies underpinning it have changed little over the years. In the nuclear detection industry, Geiger-Muller tubes and scintillators still form the technological backbone. It has been a poorly funded area and, although the Chernobyl disaster of 1986 and Al-Qaeda's nuclear ambitions have raised the profile of nuclear detection, the emphasis remains on improving signal processing, data exchange and data presentation. On the other hand, in field-deployable CW agent detection there are several well-established competing technologies, with Ion Mobility Spectrometry (IMS) and its derivatives being the most popular.

It is perhaps surprising, therefore, that the leading contender for the US Joint Chemical Agent Detector program is based on Surface Acoustic Wave ([SAW](#)) technology rather than IMS. Nevertheless, BW detection is the current focus of effort and the area of fastest development. Not only is it the toughest technological nut to crack but it is also the most expensive. This feature will focus on BW agent detection.

The characteristic that differentiates CBW from conventional warfare is the terror it creates. CBW agents are, to all intents and purposes, invisible, except through the devastating effect they wreak on unprotected people. Whilst CW agents are essentially instantaneous in their effect, BW agents take an appreciable time to act. It is this that makes BW particularly hard to detect at the outset of an attack, and renders BW more a strategic than a tactical weapon. There is no trigger event to tie the investigative effort to a particular location or perpetrator. Fundamentalist terrorists appear to have developed an unhealthy interest in this feature of BW and there are three aspects that need to be addressed in developing countermeasures.

Firstly, it is easy to grow dangerous infectious diseases. Many are endemic in some parts of the world. These diseases are therefore capable of being harvested and used as weapons of terror against vulnerable urban populations with no immunity. The science, techniques and equipment required to achieve this are commonly available in hospitals, laboratories and universities across the world. With the right fermentation conditions, a single organism can multiply a billion-fold in 10 hours.

Secondly, many of these organisms are delicate and unlikely to survive for long outside their host. However, with the advent of fundamentalist suicide attacks, self-infected individual hosts could become the disease vectors.

Thirdly, in recent years biological know-how has become as available to ill-intentioned groups as it is to benign users, via the Internet. Although the human genome project represents a major step forward in understanding human disease, the open-source availability of such data also allows malign development to take place and hastens the advent of ethnic weapons.

Therefore the life-risk to the general population through the use of BW agents has overtaken its risk of success against well-prepared military personnel. In fact, the majority of so-called BW 'attacks' in recent years have been perpetrated by private individuals or small groups with a grudge against society. At present, technology cannot deliver warnings against this type of event, in the sense of offering time to take precautions. The realization that an attack has taken place may well come through the epidemiological study of a rising toll of cases. The initial symptoms are difficult to differentiate from many common diseases. As the immune system is stimulated by the onslaught, the initial flu-like symptoms in the case of plague, for example, or a stomach upset in the case of botulinum toxin, may not alert medical teams for several hours.

Detection at range

Two distinct but complementary approaches are being pursued in the BW detection arena, the first of which attempts to identify the physical characteristics of a cloud of agent at some range from the detector system. This works for any type of aerosolized agent: BW, CW or so-called 'mid-spectrum' agents such as toxins. Even passive infrared (IR) can provide an early indication that an aerosol has been released, and current electro-optic devices working in the mid-IR (3-5 μ m) or far-IR (8-12 μ m) bands can offer results against a coherent cloud. For example, the [M21](#) RSCAAL system, optimized for CW aerosol detection, has been in service with the US armed forces since the early 1990s. Interrogating an aerosol cloud using active methods (such as laser) offers much greater sensitivity, discrimination and range information. LIDAR (Laser Identification And Ranging) systems have been deployed for CBW detection or are under development in [Russia](#), the [UK](#) and the US.

Fibertek Inc, under contract to the US Department of Defense (DoD), fielded and tested a prototype LIDAR system at Dugway Proving Ground, Utah, in 1998 as part of the [SR-BSDS](#) program (Short-Range Biological Stand-off Detection System). Ranges of 3,000m were achieved against a coherent BW agent cloud. Since then, there has been a three-fold reduction in equipment size and weight. The Fibertek X-BSDS is due for test in 2003 under the auspices of the Joint Program Office for Biological Defense.

The Russian KdKhR-1N Chemical Agent Reconnaissance Vehicle uses a pulsed (50Hz) AIG:Nd laser system, delivering 100-500mJ at a wavelength of 1.06 μ m and 40-100mJ at a wavelength of 0.53 μ m (near IR). The reflected IR data is received via two channels through 0.03m² objective lenses (f = 1.5m). Using band-pass filters, channel 1 looks for the back-scattered light from the cloud and compares it with the background in channel 2.

Against VX, the Russian system claims a range of 7km at the moment of agent release, but this range capability decreases with more highly dispersed clouds. The biggest hurdle to the widespread acceptance of

this technology is its enormous cost. Ruggedized, vehicle-mounted tunable lasers are extremely expensive and it is arguable whether the investment is worth the return, considering the way in which BW agents are likely to be delivered either on the battlefield or in the domestic arena. This technology may, however, have some utility in offering warning to fixed installations or to ships at sea. The IR band gives greater range than ultra-violet (UV) against coherent CW agent aerosol clouds, whereas UV gives better discrimination, being able to distinguish viable (BW) from chemical agent. Nevertheless, this entire technology depends on the appearance of a coherent 'cloud' of agent.

The alternative to cloud-recognition technology is the installation of existing air-sampling sensors on platforms deployed in the direction of the threat. Whilst it is unlikely that valuable manned air or ground assets will be dedicated purely to CBW detection, unmanned platforms offer a solution. In particular, micro air vehicles could be sent as probes into a suspect area, providing digital information by datalink. In an amphibious scenario, air-sampling units could be mounted on floating buoys or low-velocity missile probes.

The [BAE Systems](#) ChemSonde is a [SAW](#) device, designed to be deployed by parachute from standard aircraft chaff dispensers to survey potential landing zones for evidence of CW agent. CW detection has reached a point of relative maturity, and the level of miniaturization is a feature of this. However, BW electro-mechanical sampling equipment is large and complex, making it a poor candidate for similar deployment at the present time.

Detection from samples

The other complementary approach is detection by analysis of samples. The liquid phase of CW agents is most efficiently field- sampled, even today, by the use of impregnated adhesive papers. However, CW vapor in the atmosphere has to be efficiently collected before it can be recognized by one of several technologies which, themselves, fall into two types. The first type splits up the molecules to reveal one or more of the constituent elements. The French [AP2C](#) and its derivatives successfully use flame photometry, for example. The second type measures other characteristics of the molecules under less harsh conditions. Their drift rates under a high potential gradient (IMS) or their effects on sensitive substrates ([SAW](#)) can be analyzed and measured. Technologies can be combined - Gas Chromatography with Mass Spectrometry (GC/MS), for example. However, the equipment required for GC/MS is quite large and is mainly used for CW agent detection and sampling in laboratories or reconnaissance vehicles.

BW agent organisms are likely to be widely dispersed in the atmosphere. Apart from the self-infected terrorist, BW delivery methods may include water contamination or aerosol release. Some of the viral hemorrhagic fevers only need a single airborne organism to cause a fatal infection, and such pathogens can be carried on the wind for extremely long distances. Particles measuring 1µm can drift for 1,700km in a gentle breeze and remain airborne for four days. The challenge for BW detection system designers is therefore enormous.

Any aerosol detection system must be capable of sampling vast quantities of the surrounding atmosphere continuously to gather enough pathogenic material to show up in a test. From minute quantities of sample, it has to identify precisely the pathogen and alert the operator.

A complete BW aerosol detection system comprises four phases. The first, collection, requires a large-capacity air-pumping system to gather air and agent. The second phase, concentration, seeks to remove the minute quantities of agent from the air and store them in a form that allows the identification process to begin.

In the third phase, categorization, parts of the sample are studied for their physical properties - viability, size or shape - to narrow down the range of agent types. Certain chemicals such as ATP (Adenosine TriPhosphate) occur in all living organisms and can be picked up chemically in the categorization process. Particles in the 1-5µm range are able to get right down into the lungs, but larger particles (7-20µm) can cause upper respiratory tract infection and should not be ignored in the categorization process. Those that fall into the target range of physical and chemical properties are then analyzed for their biochemical effects during the fourth, characterization process.

Defense laboratories continue to refine library data on the pathogens of greatest concern. At the top of the list are those that cause the most infectious diseases, such as Variola ([Smallpox](#)), Yersinia (also

Pasteurella) Pestis (Plague) and Francisella Tularensis ([Tularemia](#), also named Rabbit Fever or [Deer-Fly Fever](#) after its vectors). For detection system designers, toxins present a serious challenge. These are the chemical agents created by living organisms, but now capable of synthesis in the laboratory. They are large molecules and include venom from spiders or shellfish ([Saxitoxin](#), for example). Clostridium Botulinum (which causes Botulism) and Staphylococcal Enterotoxin B (SEB - 'food poisoning') are also identified as warfare toxins.

The whole BW detection process takes time, with characterization as the longest and most critical element. The precise strain of the organism must be identified accurately, as a misidentification may lead to a misdiagnosis of the disease and the application of treatments that could kill rather than cure the victim. Characterization is where the cutting-edge technology is being focused.

The heat is on to reduce both the time taken to deliver precise identification and the size of the equipment suite. The target is to offer, as nearly as possible, real-time agent identification by equipment that is reliable, with a low logistic burden, and which can be operated with the minimum of training. Ideally it should be hand-held - a tall order. Progress in this area is reviewed below.

Collection and concentration

There are two leading technologies in the collection and concentration field. The first combines the mass of incoming air with a water mist under a strong electric field. The field causes the wetted particles to migrate towards an electrode for collection. The second principle simply traps the particles from the airflow. Impactors with flow rates of 900 liters per minute are common in industry. Inhalable particles in the mass airflow are encouraged to impact on to a wetted surface.

One of the best examples of a field-deployable, hand-held collection device that works on the wetted-surface principle is the Mesosystems BioCapture range. The BT-500 and BT-550 are hand-held, battery-powered collector systems that can process 150 liters of air per minute. They collect particles in the 0.5-10µm range by drawing air across a wetted rotating arm.

In the BT-550, the particles can be collected in cartridges or applied to Tetracore's Guardian BTA test strips. TSI Incorporated fields what is called a Two-Stage Virtual Impactor - the RESPICON Model 8522 - which forces the airflow past an annular gap. The majority of the air escapes radially, transporting particles that are too small to be of interest in its slipstream and to atmosphere. The remainder of the flow 'impacts' on to a slower moving air mass inside the collection probe.

The RESPICON has two virtual impactors arranged concentrically and three collection filters. Dycor Technologies Inc manufactures the XMx aerosol concentrator, which uses a similar principle. It can be connected to a Liquid Impingement Module to collect aqueous samples of agent and, in turn, the samples can be passed to automated categorization and characterization systems.

Categorization

The physical properties of the aerosolized agent offer a number of clues as to its identity. BW agents vary enormously in size, from the largest bacteria through viruses and rickettsiae to the tiny prion (Variant CJD is generated by a prion). Useful characteristics of BW particles include their shape, size, surface texture and color. The way they back-scatter polarized electromagnetic radiation or their speed of migration through a medium in an electric field (electrophoresis) differentiates between them and serves to narrow down their type. First-generation, high-efficiency particle counters included the BAM 1020 from Met One Instruments Inc, but current developments seek to detect several characteristics simultaneously.

TSI Corporation's Model 3312A Ultra-Violet Aerodynamic Particle Sizer (UV-APS) measures not only the size but also the distribution of sizes within a potentially BW agent-laden air sample, and also the fluorescence of the particles. A collimated diode laser is used to determine particle sizes from their times of flight and light-scattering signatures. If the size falls in the range of interest, a UV laser is triggered causing the particles to fluoresce. If the fluorescence characteristics also fit the BW agent template, all the data is analyzed, together with the time history. The suspect sample is then passed on to where its biological constitution can be examined - in the characterization process. UV-APS data can be exported for

downstream automated handling or interpreted via the TSI proprietary MS Windows-based Aerosol Instrument Manager software.

In the US, Lockheed Martin also developed a detector based on fluorescence particle analysis as part of the [BAWS](#) (Biological Aerosol Warning System) Project. UV-APS and the TSI Fluorescence Aerodynamic Particle Sizer (FLAPS) are systems that grew from a 1993 Canadian initiative to develop a combined agent detector system called CIBADS (Canadian Integrated [Biological Agent](#) Detection System). This in-service system continues to evolve and has generated the 4WARN system, which is aimed at the commercial first-responder market by [Computing Devices Canada](#) (part of General Dynamics [Canada](#)).

Laser technology is expensive and the design team has been looking for more cost-effective adaptations that could deliver a similar capability to these first-generation systems. As part of the US 'Portal Shield' WMD defense system, the company is continuing to refine a follow-on categorization system, the [Biological Agent](#) Real-Time Sensor (BARTS, or PS-BARTS for the Portal Shield version). With upgraded electronics, it combines a MesoSystems MicroVic particle concentrator with a Nanolase 355nm pulsed laser to measure viable particles directly by fluorescence, with similar efficiency but lower cost than earlier versions.

There are other categorization technologies that detect the chemicals present in every living organism (ATP or adenylate kinase [AK]) through luciferase markers using flow cytometry techniques. In other words they measure the bioluminescence of both the sample as a whole and of individual organisms, but none of these techniques can yet precisely identify the agent. Identification is the province of the characterization process.

Characterization

Efficient collection and categorization of aerosolized BW agent particles is difficult enough, but precisely identifying and characterizing the organism is the toughest challenge of all. It is here that the biotechnology industry is in fiercest competition. The large-scale technology of the laboratory has, somehow, to be miniaturized, automated, made faster and be battery-powered to make it field deployable.

The industry has responded and the size of effective samplers has come down from Portakabin size in 1991 to filing cabinet size, and is decreasing all the time. It still has a long way to go but the speed of the process will reach an irreducible point until another, entirely new technology emerges. The minimum viable entity that can react is the Colony Forming Unit (CFU) and samples are described by biologists in CFUs. The problem is that the organisms can only work at their natural speed, forcing operators to wait whilst the process runs to a conclusion. Also, most identification processes are specific to the organism's precise type and strain. An organism can mutate (or be artificially altered) and even a slight mutation reduces significantly its chances of being spotted. In any case, the living organism has to be stimulated to react and then probed biologically to give up its identity.

There are several tests including bioassay (intervening chemically) and immunoassay, where a pathogen-antibody reaction is created. In the latter technique, pathogen-specific monoclonal antibodies are bonded to markers that only reveal themselves when they land at receptor sites on the pathogen. There are several types of marker, including radioactive, bioluminescent, fluorescent and colorimetric. The last two are probably the most popular.

New techniques for genetic analysis in recent years have accelerated the identification process and made it much more sensitive. Polymerase Chain Reaction (PCR) is a common method for amplifying sections of DNA. It is about 10⁶ times quicker than natural culture methods and speed of reaction is improving all the time ('fast PCR'). Restriction Fragment Length Polymorphism is a very sensitive technique that allows differentiation of strains of a sample species. It utilizes the capability of restriction endonuclease enzymes (the type of enzyme that helps bacteria to fight attacks) to cut out fragments of DNA at specific points, thereby allowing them to be analyzed.

The world of genetic engineering and 'DNA fingerprinting' has allowed the advent of new, user-friendly techniques. Colorimetric test strips, similar to the commercially available pregnancy test kits, allow users to carry out field tests to narrow down the agent type and point more sophisticated analysis at it, but the agent still has to be efficiently collected to give enough material to analyze. New Horizons Diagnostics Corporation produces the Profile microluminometer which, together with its SMART test ticket, allows bacteriological detection of a range of specified pathogens.

PCR is a process that goes right to the DNA and is therefore appropriate for any living organism. DNA fragments are heated, causing denaturation (a permanent change in structure - boiling an egg is a denaturing process). A primer (a 'starter' molecule for the polymerization process) is attached to the denatured DNA. This process is then cycled several times (the more the better) and, each time, the number of DNA strands doubles, which is how the process 'amplifies' the DNA.

The sample then needs to be 'read' and compared with library data on known BW agent types. To move this process out of the laboratory has been a huge technical challenge, and a good example of an automated fast PCR system is the LightCycler from Roche Applied Science. There are a number of LightCycler features which make it a successful system.

- Temperature cycling is achieved using hot air, which makes the process significantly quicker than other methods such as water baths or thermal blocks (the change rate is 20°C per second). Also the temperature can be more accurately controlled ($\pm 0.3^\circ\text{C}$). This allows 30-40 PCR cycles to be achieved in 20-30 minutes.
- The PCR process occurs in specially treated borosilicate glass capillaries that offer better optical properties, hold minute quantities of sample (20 μl) and offer the highest practical surface-to-volume ratio.
- Polychromatic detectors in the 530-, 640- and 710nm bands pick up the fluorescence generated by the reactions of probes in the samples, using an LED light source.
- The samples can be measured against different agent comparators. A motor-driven carousel is designed to hold 32 sample-filled capillaries, which move past the fluorimeter in steps.
- The data is sent to a PC-based analysis application developed specifically for the LightCycler.

Ruggedized for field use, this technology is now incorporated into the RAPID (Ruggedized Pathogen Identification Device) from Idaho Technologies Incorporated. Development of the RAPID system came to the ears of the US Air Force in furthering its aim to set up a better response to epidemics, using web-based information exchange. The Lightweight Epidemiology Advanced Detection and Emergency Response System (LEADERS) now deploys 12 RAPID systems, rising to 35 by 2005. RAPID packs the PCR system into a 22.5kg man-portable transit case, together with a notebook PC for statistical analysis of test results.

Cepheid and ETG (now owned by Smiths Detection) are collaborating to produce an integrated DNA testing system, based on the Cepheid Smart Cycler II system, another fast PCR device. Smiths Detection has also just fielded a new, fast PCR-based product called Bio-Seq, which featured at the BioSecurity 2002 conference at Las Vegas in November. It offers six simultaneous detection modules and a test time of 20 minutes (depending on the test protocol used). It is designed to be extremely easy to use with the minimum of training, and is aimed at the fast-growing first-responder market.

European research and development has co-funded the creation of BLOWARD 1. This is a joint venture between [France](#) (Giat Industries, NBC Sys) and the [Netherlands](#) (TNO), under the European EUCLID project (RTP 13.7). Currently at the field prototype stage, BLOWARD 1 utilizes Surface Plasmon Resonance (SPR) technology (the Texas Instruments Spreeta).

SPR makes use of the fact that waves of charge (plasmons) propagate along the surface of a thin metal membrane. The metal is lit with a powerful LED which, polarized and incident at an angle to the thin gold surface, sends an evanescent wave through the metal to create plasmons on the other side. BW agent sample media placed in contact with the gold membrane influence the frequency at which resonance occurs. Varying either the angle of incidence of the light beam, or its frequency, alters the point at which the reflected light drops sharply (ie resonance is occurring). The refractive indices of the samples are unique, giving an indication of agent type. This technique is very quick to respond and the BLOWARD 1 claims a three-minute response time to an assay sample. In addition, SPR does not depend on the viability of the sample and therefore, additionally, allows toxins to be detected. A sensitivity of 10ng/ml is typical with this equipment for SEB.

Gas Chromatography and Mass Spectrometry, used together, can reveal a vast amount of information about the BW agent. Both of these systems have evolved in recent years from large-scale cumbersome laboratory

equipment, sensitive to vibration and requiring expert management and interpretation of the results. Now such systems are carried in vehicles and offer on-site analysis of samples.

The US DoD's BIDS (Biological Integrated Detection System) program includes a Chemical-Biological Mass Spectrometry (CBMS) element, and Block II of this program included the development of a spectrometry system by a team including Oak Ridge National Laboratory and Orbital Sciences Corporation. The system comprises a tandem mass spectrometry technology (MS/MS) that successfully weeds out the interferants that caused so many false alarms in earlier systems.

Bruker Daltonics of [Germany](#) fields the CBMS Block III system. It is an ion-trap MS that uses pyrolysis to generate the species for detection and therefore requires no liquid consumables. Fourier Transform IR (FTIR) spectrometry is a technique whereby a coded IR beam is passed through the sample and compared with the background. Several such interference-pattern results are combined and Fourier-transformed to generate unique spectra. This technology is useful in sampling water sources for BW agent in its FTIR-ATR (FTIR - Attenuated Total Reflection) form. There are other techniques that show promise also, such as Raman spectroscopy.

Many of these techniques are combined in different ways to give faster reaction, higher sensitivity or to reduce the size of the equipment. However, most of the processes still involve complex fluidics and electromechanical components, imposing a finite physical limit on the ability to miniaturize or ruggedize them for field use beyond a certain point.

Simply known as Bio Detector, Smiths Detection's compact unit is also part of the BIDS program and combines a Light-Addressable Potentiometric Sensor (LAPS) that reads data from an Immuno-Ligand Assay (ILA). Developed by Molecular Devices Corporation, LAPS detects the minute changes in electrical potential from a silicone-based sensor next to the ILA-captured sample, and delivers results inside 15 minutes.

Another important and relatively new combination technology that has been brought to bear on BW detection uses a technique known as Matrix Assisted Laser Desorption/Ionization together with a Time-Of-Flight mass spectrometer. Referred to as MALDI-TOF, the MALDI element is clever in that it overcomes the dissociation risked by bombarding an extremely large and complex molecule with a laser (this process is often referred to as 'soft ionization'). The mechanism is not fully understood but the matrix itself is an organic acid into which a small amount of the analyte is added and mixed (normally in the ratio 1:103 to 1:104 of acid). The matrix appears to absorb the UV laser light, converting it into energy, which prompts the required desorption and ionization without causing dissociation. Typically, 2,4-dihydroxy benzoic acid or alpha-cyano-4-hydroxy cinnamic acid are good general matrix candidates. The TOF MS looks at the velocities of the energized ions (their velocity is a function of their atomic mass, as the ionization energy and the field strength are fixed) and generates unique spectra. Another similar 'soft' process is Electrospray Ionisation.

The future

At the 7th International Symposium on Protection against Chemical & Biological Weapons, held at Stockholm in June 2001, Captain Sebastian Meyer-Plath (Bruker Daltonics) looked at all of the characteristics of potential BW agents and toxins, with the aim of identifying features common to both. He challenged science and technology to focus on the two properties that provide the most generic details - the proteome and the genome. One or other feature will identify the agent. However, it is not so much the actual detection process that needs the most help. With the extremely low concentrations likely to be encountered in a BW situation, scientists need to focus on the collection and concentration processes in order to reduce the quantities required to trigger a response, whilst also maintaining downward pressure on false-alarm rates.

It seems extremely unlikely at the moment that the natural processes can be increased much further (antibody-antigen reactions, for example), but technology may emerge to assist. Science has not solved the problem of detecting the self-infected terrorist in time to prevent him causing an epidemic. This is clearly the most feared scenario and its solution will require a wide mix of disciplines, including psychology, public communications, interpretation of intelligence and tissue sample collection. It also requires that better information on the most feared diseases and their morbidity be made available in such a way that outbreaks are picked up much earlier by busy general practitioners, paramedics and hospital staff.

Technically there are a number of developments on the horizon that focus on the detection process. The US Defense Advanced Research Projects Agency (DARPA) is undertaking a multimillion-dollar biodetection program to examine phenomena such as upconverting phosphors and the elusive 'detector on a chip'. SRI International, with DARPA funding, has focussed on UPT (Upconverting Phosphor Technology) as a breakthrough in the tagging, and therefore identification, of BW agents. Mixed rare-earth oxides are used in the labeling process. These man-made materials show properties that do not occur in nature. For example, they emit visible light when stimulated with IR wavelengths (ie they 'upconvert' the frequency). By doping microscopic ceramic spheres with these rare-earth materials and adding gene probes to their surface, they can bind to the target antigen as it is captured by the BW agent-specific antibody. Each particle can be given a mix of these phosphors that is unique to a particular agent.

The detector on a chip is the subject of work at several US laboratories including Sandia, Lawrence Livermore and Argonne National Laboratories. The aim is to do away with the complex fluidics and electrochemical components, conducting the entire assay process on a suitable treated chip. Examples include the Argonne MAGICChip and the biocavity microlaser developed by Sandia. The latter is a 1cm - diameter miniature laser that pumps cells through the microlaser, making them part of the 'lasing' process itself. It is currently being used to identify cancerous cells during surgery but clearly has an application in BW detection.

There is a huge amount of money being pumped into biotechnology and the race is on to find solutions, but there is no 'golden bullet' in BW detection. The industry faces a long haul to combine the large range of different technologies available, in ways that both reduce the time taken to identify pathogens and provide true warning in time to enable precautionary measures to be taken by exposed troops and the general population alike.



The Fibertek [SR-BSDS](#) uses the laser-induced fluorescence principle for BW agent detection.

(Source: Fibertek Incorporated)



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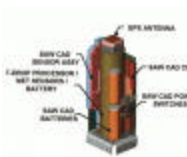
Tetracore Guardian BTA ('Bio [Threat Alert](#)') test strips are agent-specific colorimetric testers using a colloidal gold immunoassay process.

(Source: Tetracore Incorporated)



Four-finger exercise: collection, concentration, categorization and characterization.

(Source: John Eldridge)



The [BAE Systems](#) ChemSonde is one way to deploy existing CW detection technology for site reconnaissance or to probe a suspected release of chemical agent.

(Source: [BAE Systems](#))



The MesoSystems BT-550 can collect air samples and store them in fluid reservoirs (left) or apply them to Guardian BTA test strips (bottom right).
(Source: John Eldridge)



Smiths Detection has recently fielded the Bio-Seeq, which can simultaneously process six separate PCR assays, returning results inside 20 minutes.
(Source: John Eldridge)



Test strips can yield more data than the naked eye when 'read' by the **Alexeter** Guardian Test Strip reader.
(Source: John Eldridge)



The Canadian 4WARN system incorporates technology from the CIBADS project. 4Warn Urban is a version aimed at the 'first responder' market.
(Source: John Eldridge)



The Sceptor Industries Inc [SpinCon](#) is an advanced portable air sampler that can handle 450 liters of air per minute and particles down to 0.2µm.
(Source: Sceptor Industries)



The Russian KdKhR-1N is a mobile CW agent reconnaissance vehicle that uses LIDAR.
(Source: Rosoboronexport)



TSI Corporation's Model 3312A Ultra-Violet Aerodynamic Particle Sizer (UV-APS) does a lot more than just measure particle size.
(Source: TSI Corporation)



This UK-developed [PBDS \(Prototype Biological Detection System\)](#) evolved from a capability fielded during Operation 'Desert Storm'. The US BIDS (Biological Integrated Detection System) has a similar capability.
(Source: Insys)



The Bruker Daltonics CBMS Block III is a mass spectrometry system designed for next-generation NBC reconnaissance vehicles.
(Source: Bruker Daltonics)



Micro Air Vehicles could take detection payloads but technology has a long way to go to make BW detection sufficiently compact.
(Source: [Singapore Technologies](#))



The Bio-Haz reader forms part of a comprehensive field-portable kit from EAI Corporation. The kit allows fluorescence, luminescence and color to be read from aqueous samples.
(Source: EAI Corporation)