## DEPARTMENT OF DEFENSE

# DEVELOPING CRITICAL TECHNOLOGIES/SCIENCE & TECHNOLOGY (DCT/S&T)

## *SECTION 5: CHEMICAL TECHNOLOGY*

**February 2000**

**Defense Threat Reduction Agency**
**Ft. Belvoir, VA**

# PREFACE

Developing Critical Technologies/Science & Technology (DCT/S&T) is a product of the Defense Critical Technologies Program (DCTP) process. This process provides a systematic, ongoing assessment and analysis of a wide spectrum of technologies of potential interest to the Department of Defense. DCT/S&T focuses on worldwide government and commercial scientific and technological capabilities that have the potential to significantly enhance or degrade U.S. military capabilities in the future. It includes new and enabling technologies as well as those that can be retrofitted and integrated because of technological advances. It assigns values and parameters to the technologies and covers the worldwide technology spectrum.

DCT/S&T is oriented towards advanced research and development including science and technology. It is developed to be a reference for international cooperative technology programs. A key component is an assessment of worldwide technology capabilities. S&T includes basic research, applied research and advanced technology development.

# SECTION 5—CHEMICAL TECHNOLOGY

***Scope***



***Highlights***

- Chemical weapons in the hands of rogue states and terrorist groups will remain a threat to U.S. national security.
- The United States will need to keep abreast of potential new agents and dissemination technologies to defend against their use.
- Full dimensional protection calls for new sensors that "…will be deployed to detect chemical or biological attack at great ranges and provide warning to specific units that may be affected."
- Obscurants offer adversaries methods of defeating and/or degrading precision weapon technology.

### *OVERVIEW*

This section addresses technologies related to the use of toxic chemicals, including the production of chemical agents and their dissemination; defense against chemical agents; and methods to detect, identify, and provide warning of their use. Also included are obscurants, that is, materials that limit or prevent reconnaissance, surveillance, target acquisition, and weapon guidance. Energetic materials (explosives and propellants) are in addressed in Developing Critical Technologies Section 2, Armaments and Energetic Materials.

The Chemical Weapons Convention (CWC) is now in effect and supported by a majority of nations of the world whereas further development of chemical agents is banned by this treaty, rogue states or extra-national groups may pursue development. Unfortunately, the Information Age has made available, and will continue to provide, the wherewithal for such entities to be dangerous in the context both of national defense and in the use of chemical warfare for terrorism.

Operation Desert Storm has shown that obscurants, both natural and man-made, can be a force multiplier if properly employed. Current obscurants can be effective in the visible through the far-infrared wavelengths. Newer obscurants will be effective from the nanometer through the 1-m wavelength of the electromagnetic spectrum.

As technology flows to less-developed countries, its use for military as well as peaceful purposes is inevitable. Information on the technology used to produce toxic chemicals for use in chemical weapons is available in the open literature. Some of the classic chemical agents date back over 150 years. Some of the nerve agents require production steps that are more difficult but still within the reach of determined proliferators.

Because of the potential use of CW on the battlefield, many nations are seeking technology to detect, defend, and defeat CW. Another concern is the impact on national security of toxic chemical use by terrorist organizations. Efforts are aimed at positive identification of chemical agents in time to avoid contamination.

# SECTION 5.1—CHEMICAL DEFENSE SYSTEMS

***Highlights***

- Capability to operate in a chemically contaminated environment is an important component of full-dimensional protection.
- Efforts to make protective clothing more wearable will reduce the degradation of operational efficiency.
- Decontamination of people and equipment is necessary to prevent continued exposure to toxic chemicals.
- Medical advances may provide relief from the effects of chemical agents.

## *OVERVIEW*

Defense has been the classic counter to the development of new chemical agents and weapons. As the agents have evolved to greater potencies with various ways of entering the body, individual protection, collective protection (protection for groups of individuals), and decontamination technologies have kept pace. Growth in defensive technology, however, has usually been incremental with no major breakthroughs. For example, the mask used today, while greatly improved for protection and comfort, still uses activated charcoal technology first developed in World War I. Moreover, the limits imposed by time and comfort are still the main problems of individual protection. Individual protection of civilians has been complicated by an insistence upon total protection, which leads to decreased comfort and thus severely limits wear time. Decontamination has likewise been complicated by a perceived necessity for total decontamination, coupled with the introduction of important equipment (e.g., electronics) that could be destroyed by current decontaminants.

The following are the principal development issues in this area:

- Improvements in wearability of protective clothing will continue to be a major issue. There is a conflict between the need for encapsulation and impermeability to agents (liquids and vapors) and the need for ventilation and heat stress relief. Current procedures involve either addition of significant weight for climate control or reduced impermeability.
- Permissible times for completely encapsulated personnel need to be increased significantly. Current doctrine in the civil environment when responding to a scene where there is a probable release of an unknown chemical agent (or a known nerve or mustard agent) calls for complete encapsulation of personnel together with a self-contained breathing apparatus. Using current equipment with normal donning and cleanup times, actual time on scene tends to be less than a half hour. In many situations this is not enough time for identification of the agents employed, let alone rescue and clean-up. Protective garments tend to impede coordination and restrict vision when moving and manipulating equipment. There is a similar conflict between complete protection in what may well be an oxygen-poor closed space and the ability to perform necessary tasks.
- The ability to provide medical prophylaxis against many types of chemical agents and to reduce protection requirements would be of value in many environments.
- The development of a nonaqueous decontamination procedure for water-sensitive devices to permit their continued use would greatly enhance continuity of military operations.

Chemical defense has experienced evolutionary rather than revolutionary change. New materials technology is a possible area where breakthroughs might occur. Since defensive technologies must be applied to large numbers of personnel and diverse situations, this technology must provide economic as well as technological advances.

## LIST OF TECHNOLOGY DATA SHEETS
## 5.1. CHEMICAL DEFENSE SYSTEMS

## DATA SHEET 5.1. PRODUCTION AND DESIGN FOR PROTECTIVE CLOTHING

| | |
|---|---|
| **Developing Critical Technology Parameter** | Semi-permeable, lightweight material, 20-percent lighter than the battle dress over-garment material system. It will allow selective permeation of moisture while preventing the passage of common vesicant agents, provide protection against penetration by toxic agents in aerosolized form, and provide at least the current level of protection against toxic vapors and liquids. |
| **Critical Materials** | Semipermeable membranes; polymers. |
| **Unique Test, Production, Inspection Equipment** | Simulated agents; particle-size analysis equipment. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | First responders. |
| **Affordability** | It will reduce the logistics burden as a result of improved launderability, lighter weight, and reduced volume (less bulky). |

## DATA SHEET 5.1. PRODUCTION AND DESIGN FOR COLLECTIVE PROTECTION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Protect against 100 percent of current and future threats. |
| **Critical Materials** | Impregnated charcoal filters; polyethylene; fluoropolymer/aramid laminate. |
| **Unique Test, Production, Inspection Equipment** | Simulated agents. |
| **Unique Software** | Airflow models. |
| **Major Commercial Applications** | First responders. |
| **Affordability** | Reduced logistics burden. |

## DATA SHEET 5.1. MEDICAL PROTECTIVE TECHNOLOGIES

| | |
|---|---|
| **Developing Critical Technology Parameter** | Development of practical prophylaxis for entire classes of chemical agents. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | First responders; hospitals for diagnosis and treatment of civil casualties. |
| **Affordability** | Not an issue. |

## DATA SHEET 5.1. REGENERATIVE FILTRATION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Need for protection with unlimited capacity to remove CB agents from air streams to generate breathable air. |
| **Critical Materials** | Pressure swing absorption (PSA): compressed air from vehicle or alternative source.<br>Temperature swing absorption (TSA): source of heat/energy from vehicle. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Software to detect system malfunction must be developed. |
| **Major Commercial Applications** | First responders. |
| **Affordability** | Regenerative filters would reduce the logistics burden of filters that must be replaced. |

## SECTION 5.2—CHEMICAL DISSEMINATION AND DISPERSION

***Highlights***

- Although there are many technologies for dissemination and dispersion of chemical weapons, new and/or unexpected means may be devised.
- Computer simulations may enable countries to "test" CW clandestinely.
- Advances in meteorological sensors might permit dissemination of CW with maximum effect.

### *OVERVIEW*

Rogue states and extra-national groups are the principal causes of concern over the use of chemical agents. Although traditional weapons systems remain a factor, smaller numbers of less conventional weapons are expected to constitute the majority of the chemical weapons threat. Developing technologies could assist in the dissemination and dispersion of chemical agents by making current methods more practical and efficient, not necessarily through novel means. Improved spray patterns, the ability to sense meteorological conditions in the target area, and remote control of unmanned systems could enable CW to be used more effectively.

Dissemination and dispersion in the future are more likely to be influenced by enhancements in information systems than advances in munitions. Techniques to disseminate chemical agents more effectively are contingent on sensing of local conditions and knowledge of dispersion patterns.

## LIST OF TECHNOLOGY DATA SHEETS
## 5.2. CHEMICAL DISSEMINATION AND DISPERSION

## DATA SHEET 5.2. URBAN MODELING

| | |
|---|---|
| **Developing Critical Technology Parameter** | Detailed urban architecture, with generic, interactive, three-dimensional modules capable of being adjusted to a specific scenario. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Image conversion to digital map; interactive virtual reality models; transport prediction codes. |
| **Major Commercial Applications** | Disaster preparedness. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

The dispersion of chemical agents on the battlefield is well understood; however, urban architecture changes the pattern that would be expected in the open. Models of urban areas are needed to understand chemical agent distribution and effects in built-up areas.

## DATA SHEET 5.2. MICROMETEOROLOGY

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to predict local effects of wind and temperature gradients within 10 m of the surface as they continually change. Ability to make critical measurements that permit continuous predictions. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Interactive virtual reality models; transport prediction codes. |
| **Major Commercial Applications** | Disaster preparedness. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

To properly map contamination from chemical attack, it is necessary to know the meteorology of the battlefield where the agent was employed.

## DATA SHEET 5.2. COMPUTATIONAL FLUID DYNAMICS

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to predict airflow patterns within and immediately adjacent to structures and to model the interchange between interior and exterior fluid mass transport phenomena. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Interactive virtual reality models; transport prediction codes. |
| **Major Commercial Applications** | Disaster preparedness; pollution abatement. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

Pollution control modeling and hazardous materials (HAZMAT) spill modeling are the drivers of this technology. Lessons learned in this application could be applied to military operations, particularly in urban areas.

## DATA SHEET 5.2. ENHANCED DERMAL PENETRATION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Techniques for (1) enhancing skin penetration of percutaneously toxic materials so that penetration occurs rapidly (within minutes), (2) penetrating protective masks in physiologically significant amounts and in logistically deliverable quantities, or (3) circumvention of the protective mask. |
| **Critical Materials** | Penetrating agents, mask-breaking agents. |
| **Unique Test, Production, Inspection Equipment** | Effective heavy gas models (i.e., models describing the behavior of gases several times the vapor density of air). |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Not an issue. |

## DATA SHEET 5.2. NONTRADITIONAL INSERTIONS

| | |
|---|---|
| **Developing Critical Technology Parameter** | Use of nonconventional delivery means such as UAVs to overtly or covertly disseminate chemicals that attack other than the "traditional" neurotransmitter sites. |
| **Critical Materials** | Materials that block alternative neurotransmitters and/or cause disruption in vital body functions. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Map of human genome; neurotransmitter models for newly discovered/defined substances. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Not an issue. |

## DATA SHEET 5.2. SOLIDS DISPERSION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Techniques for effective dissemination and dispersion of solid particulates efficiently in the inhalable size range (0.5–5 µm). |
| **Critical Materials** | Possibly deagglomerants. |
| **Unique Test, Production, Inspection Equipment** | Effective and reproducible measurement technology for aerodynamic particle size of dispersed solid particulates. |
| **Unique Software** | Particulate dispersion models for nonspherical solid aerosols. |
| **Major Commercial Applications** | Dispersion of agricultural and pesticide products. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

The majority of incapacitants and probably those materials affecting neurotransmitters will exist normally as particulate solids. Solids naturally tend to agglomerate and are difficult to effectively disseminate as inhalable aerosols.

# SECTION 5.3—CHEMICAL MATERIAL PRODUCTION

***Highlights***

- Although production technologies for chemical agents are widely known, the use of combinatorial chemistry in conjunction with new screening methods could lead to the discovery of toxic chemicals unknown at present.
- Chemical agents can be tailored to affect target populations (lethal and nonlethal).

### ***OVERVIEW***

This subsection addresses the production of toxic chemicals for use in war. Although a majority of the nations in the world is expected to abide by the ban of chemical weapons embodied in the CWC, some may not, and others will not become parties to the convention.

The most potent lethal chemical agents discovered to date are those which directly influence neurotransmitters in one way or another. Neurotransmitters are chemical substances that transmit nerve impulses across the synapses (junctions) between certain types of nerve cells. Although a large number of them have been identified, their precise role and the mechanisms of their actions have been determined for only a few.

The principal chemical warfare agents postulated and/or produced since World War II have affected the actions of the neurotransmitter acetylcholine by inactivating the enzyme acetylcholinesterase and thereby interfering with the regular sequence of nerve impulses. Tabun (GA), produced by the Germans in WW II, and sarin (GB) and soman (GD), synthesized and readied for production are in this category. Similarly, the GB and chemical nerve agent (VX) produced and stockpiled by the United States and GB, GD, and a variant of VX produced and stockpiled by the former Soviet Union were anticholinesterase agents. In the Iran-Iraq War, GA and GB/GF nerve agents were used; GB/GF was prepared (although not used) by the Iraqis in the Gulf War. The Aum Shinrikyo employed GB in their terrorist attacks. Both rogue states and extra-national groups are thought to have experimented with VX.

VX and its analogues are among the most toxic organophosphorus poisons, and there is thought in some areas that these compounds represent close to the practical limits of toxicity for the anticholinesterase agents. Another neurotransmitter, gamma-aminobutyric acid (GABA), used for channel blocking has probably reached its maximum efficacy.

"New" agents are less likely to be the organophosphorus agents of today, but rather combinations which block multiple sites or which block neurotransmitter functions not understood at present. Neuroscientists are currently unraveling the functions of the other neurotransmitters. It is virtually certain that this information will be in the public domain and thus be available to the undesirable nations or groups to tailor different, more effective agents. It is anticipated that knowledge of the biochemical actions of the neurotransmitters may enable tailoring of agents that are potentially more dangerous as well as more difficult to counter.

Several types of toxins are among the most toxic nonliving substances known. Toxins have high molecular weights and the full structural conformation of many of them has not been fully determined. Botulinus toxin, a mixture of eight 135 to 170 kD (kilodaltons) proteins, acts by inhibiting the release of acetylcholine in a cell. Which of the proteins responsible for the inhibition is not known for certain. During the coming decade the ability to map the proteins' molecular structures may provide the ability to create relatively simple "molecular fragments" that could be readily incorporated in larger molecules and would exhibit the essential toxic properties of the toxin.

The mapping of the human genome (and the subsequent public release of this information in the next few years) could provide the unscrupulous with useful information needed for designing genetically tailored chemical agents that would attack specific sites in the body or selectively attack specific individuals or groups of individuals of a common genetic type.

Despite the prohibitions under the CWC, the wording and definitions regarding incapacitating agents remain necessarily vague because they encompass specific biological effects, as well as a multitude of commercial pharmaceuticals. History seems to show a recurring impetus to revert to more "humane" forms of warfare. Toward this end, it is believed possible that forms of nonlethal but physically incapacitating agents may be developed and used. Particularly interesting would be materials created for "police" efforts internal to advanced nations that become known and/or available to extra-national groups or rogue states. Among the conceivable incapacitating agents are those that could result in overt or covert mood altering, the modification of hormonal systems, or the interference with bio-molecular kinetics.

Given the probable world situation in the next 5–10 years, it is anticipated that chemical agent production even in the rogue states may be covert and may represent essentially bench-scale processes that can be easily concealed. Contrary to popular belief, neither the United States nor the Russian production facilities for their respective stockpiles were ever what could be construed as large scale. As a result of ongoing improvements in process control and automated processes, a high degree of automation would be expected for future production facilities. They would likely be tailored to a "fill just before use" concept and generally difficult to locate.

For agents that attack two or more neurotransmitters or for those intended for attacking genetically defined sites, a pharmaceutical-like manufacture would be expected.

In the realm of terrorism, in addition to the above, it is envisioned that potential "chemical agents" could also result from the use of industrial chemicals against an unprotected civilian population.

A description of chemical production techniques sufficient for a country/group to produce chemical agents for chemical weapons exists in the open literature.

## LIST OF TECHNOLOGY DATA SHEETS
## 5.3. CHEMICAL MATERIAL PRODUCTION

## DATA SHEET 5.3. BIOCHEMICAL MODELING

| | |
|---|---|
| **Developing Critical Technology Parameter** | Identify key physiological sites based on knowledge of neurotransmitters and sites in the human genome. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Biomolecular kinetic modeling algorithms. |
| **Major Commercial Applications** | Medical and pharmaceutical. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

Knowledge of the functions and structure of neurotransmitters and the human genome would allow for the modeling and subsequent creation of chemical molecules that would react at selected sites for a wide variety of effects. The information on the human genome and much derivative data is expected to be in the public domain and thus readily accessible to those who would use it for other than beneficial purposes.

## DATA SHEET 5.3. DESIGNER CHEMISTRY

| | |
|---|---|
| **Developing Critical Technology Parameter** | Molecular structures that bind on two or more specific sites and/or molecular structure based upon fragments of toxin structure to take advantage of high potency of the toxin. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Interactive chemical and biochemical modeling. |
| **Major Commercial Applications** | Possible medical and pharmaceutical. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

Combinatorial chemistry allows the screening of thousands of chemical compounds in a short period of time. The same efforts are used by responsible countries and groups for developing new drugs and medicines.

## DATA SHEET 5.3. RELATIONAL TOXICOLOGY

| | |
|---|---|
| **Developing Critical Technology Parameter** | Using data from the human genome, the physiological effects are tied to a genetic trait so that the agent only affects specific individuals. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Interactive chemical and biochemical modeling. |
| **Major Commercial Applications** | Medical and pharmaceutical. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

Once the human genome is mapped, it will be theoretically possible to attack a specific group of genes that control various functions or are unique to individuals/ethnic groups. This would be the ultimate specific agent, which could be tied to as narrow or broad a genetic definition as desired.

## DATA SHEET 5.3. BIOREGULATION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Development of chemicals which modify hormonal systems or serve as mood-altering agents. |
| **Critical Materials** | Specialized drugs with unique hormonal modification properties. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Interactive chemical and biochemical modeling. |
| **Major Commercial Applications** | Possible medical and pharmaceutical. |
| **Affordability** | Expected to be large, complex, and difficult-to-synthesize molecules and hence rather costly. |

### *BACKGROUND*

Agents of this type could serve as subtle and possibly covert incapacitating agents used to control the response of large segments of a population.

# SECTION 5.4—CHEMICAL DETECTION, WARNING, AND IDENTIFICATION

***Highlights***

- Sensors that detect chemical attack at great ranges and provide warning to specific military units that may be affected are part of full-dimensional protection.
- Adequate warning may allow forces to avoid contamination.
- Point detectors with significantly improved specificity and sensitivity will allow increased protection for exposed troops and improved capability to avoid localized chemical contamination.

***OVERVIEW***

This subsection reviews forecast changes to current technology and predicts how these advances might be applied to problems and shortfalls in the detection and identification of chemical agents. The assessment takes into consideration both combat operations and the application of detection technology to terrorist events where the military is likely to be involved.

The range of operations includes actual combat situations where U.S. troops are deployed against a discrete enemy force during actual hostilities or in an international peacekeeping operation. The application of detection and identification also extends to civil operations where an act of suspected chemical terrorism has taken place and military forces have been deployed to provide assistance to local authorities.

The following are the principal issues in the detection arena:

- Improvements in sensitivity to all significant threat agents to permit detection down to or below the respective threshold limit values. In this manner not only could the agents be effectively detected but a "safe" level for removal of protection be determined.
- Improved specificity in agent identification becomes crucial when agents might be employed in an urban or industrial environment. Current detection schemes are more or less fail-safe and yield many false positives, but generally preclude false negatives. This works reasonably well in a battlefield environment, where there are few interfering substances, but can become a major problem where extraneous substances abound. Generally, multiple procedures and comparisons are required for specific identification, which is critical in urban sites where treatment and assured cleanup are dependent on knowledge of the material involved. The complexity and logistics of this task has limited development.
- The inability to conduct tests in open-air conditions with real materials places limits on the realistic evaluation of many sensors, particularly "stand-off" detectors.
- The inability of a sensor to purge previous "sensings" and rapidly be available for additional tests is an operational limitation. The ability to clear sensors almost immediately or to provide an alternative path for sensing would provide a significant improvement in detection operations.
- Remote sensing at low levels is another area where progress is needed. For example, it is currently difficult, if not impossible, to detect terrain or other materials contaminated with a low-volatility substance such as VX without direct contact with the liquid.

Fortunately, the technologies that underlie improved detection and identification have undergone an accelerated development in the last decade, in large degree due to the explosive growth in photonic and electronic technologies and miniaturization. These changes have permitted adaptation of instruments that were in the recent past only suitable for research applications in the laboratory to field applications. These trends are expected to continue, partially as fallout from increased computational capabilities. The sensitivity of instruments has increased at a similar rate.

## LIST OF TECHNOLOGY DATA SHEETS
## 5.4. CHEMICAL DETECTION, WARNING, AND IDENTIFICATION

## DATA SHEET 5.4. ION MOBILITY SPECTROMETRY (IMS)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Hand-held, lightweight<br>Sensitivity at <1 µg/$m^3$ for nerve agents with sample preconcentration, <1 mg/$m^3$ for blister agents.<br>Sensitivity at 0.1 mg/$m^3$ for nerve agents in <1 sec, <20 mg/$m^3$ for blood agents. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. |
| **Major Commercial Applications** | Environmental monitoring. Process control. Contraband detection. Fire sensor (IMS using variable field strength). |
| **Affordability** | Moderately expensive. |

### *BACKGROUND*

IMS systems such as the chemical agent monitor (CAM) offer the capability of point detection of general classes of agent in the field and ascertaining if decontamination has been effective. This is normally accomplished using a radioactive source to ionize chemical substances drawn into the instrument and measuring the time it takes the particular ionized particle to traverse a drift tube and register on a detector. Each ion type has a characteristic mobility time and can be measured semiquantitatively. Although the technique directly measures the material in the air drawn into the system, it is affected by the humidity, temperature, and composition of the substances in the air. Because the technique looks at a generic part of the molecule it is subject to false positives. IMS instruments can theoretically be of high sensitivity and, if combined with a different sensor type, could be a tool for determining specificity to a high probability for the agent or agents involved.

## DATA SHEET 5.4. MASS SPECTROMETRY (MS)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Miniaturization (field-portable units) especially for peripheral equipment; one-man portable; ability to ruggedize. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. |
| **Major Commercial Applications** | Environmental monitoring. Process control. Contraband detection. Analytical chemistry. |
| **Affordability** | Expensive. |

### *BACKGROUND*

MS uses an ionizing source to split the measured molecules into a number of charged components. These are measured on a detector as a characteristic spectra and compared with known spectra of substances of interest (e.g., chemical agents). The spectra, when combined with another detection tool, can result in a high sensitivity and a probability of specificity. It does, however, rely on a previously generated spectral library.

## DATA SHEET 5.4. GAS CHROMATOGRAPHY (GC)-ION MOBILITY SPECTROMETRY (IMS)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Low power consumption GC. Smaller, shorter, faster GC columns. Sensitivity at <1 μg/m$^3$ for nerve agents, <1 mg/m$^3$ for blister. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. Multivariate data models. |
| **Major Commercial Applications** | Environmental monitoring; process monitoring; pesticide analysis; leak detection; stack monitoring; worker exposure determination; quality assurance and quality control; food industry for use as an “electronic” nose. |
| **Affordability** | Moderately expensive. |

### *BACKGROUND*

The combination of GC with IMS will provide partial identification of low levels of chemicals in the field, provided GC and IMS spectra are available.

This detection technology addresses the need to detect toxic chemicals in the field. Full-dimensional protection in *Joint Vision 2010* includes the ability to detect the chemical agents to enable forces to take protective measures.

# DATA SHEET 5.4. GAS CHROMOTAGRAPHY (GC)-MASS SPECTROMETRY (MS)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Lower power consumption GC. Smaller, shorter, faster GC columns. One-man portable. Ruggedization. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. |
| **Major Commercial Applications** | Environmental monitoring. Process control. Field analysis. Analytical chemistry. |
| **Affordability** | Expensive. |

***BACKGROUND***

The combination of GC with MS allows the detectors to measure compounds that have eluted from gas chromatograph column at specific elution. The combination of recorded and compared spectra and GC elution temperature provides a high probability of specific identification of a substance.

There is a need to detect toxic chemicals in the field. Full-dimensional protection dictates the capability to identify the use of toxic chemical agents. "Fast" GCs exist, but size and power consumption are issues. The airport security swipes of hand-carried luggage is an example of fast GC analysis.

# DATA SHEET 5.4. SURFACE ACOUSTIC WAVE (SAW)

| | |
|---|---|
| **Developing Critical Technology Parameter** | New coatings to interact with target materials. Sensitivity at <1 μg/$m^3$ for nerve agents with sample pre-concentration; <0.1 mg/$m^3$ in <1 minute for nerve agents, <1 mg/$m^3$ for blister agents. |
| **Critical Materials** | New coating materials. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition, neural networks. |
| **Major Commercial Applications** | Monitoring hazardous chemical vapors, potential fires and environmental pollutants. |
| **Affordability** | At present, moderately expensive. |

***BACKGROUND***

System detection limits for SAW are in the parts per trillion area. The system operates autonomously with a simple gas sampling system and without the need for support gases. Individual SAW devices operate by generating surface mechanical oscillations in piezoelectric quartz with frequencies in the megahertz range. Coating the SAW devices with different polymeric materials that selectively absorb different gases allows gas detection by changes in SAW frequency. Arrays of polymer-coated SAW devices detect different gases, and pattern-recognition techniques interpret data and identify unknowns.

# DATA SHEET 5.4. FIELD ION SPECTROMETRY (FIS)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Improved selectivity by separating compounds. Improved scientific understanding. Able to analyze subparts per million and in some cases subparts per billion. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. |
| **Major Commercial Applications** | Environmental monitoring. Contraband detection. Fire sensing. |
| **Affordability** | $20,000 for a single component analyzer, plus an additional $1,000 per extra component. |

## *BACKGROUND*

FIS is a new technology (less than five years old) that has been developed for trace detection of narcotics, explosives, and chemical warfare agents. This technology incorporates a unique ion filter using dual transverse fields, which allows interferences to be electronically eliminated without the use of GC columns, membranes, or other physical separation methods.

FIS is related to IMS in that it is a technique for separating and quantifying ions while they are carried in a gas at atmospheric pressure. In addition, both methods use soft ionization methods that yield spectra in which the species of interest produce the main features.

The sensor has no moving parts except for a small recirculation fan and no consumables except for the replaceable calibrator and gas purification filters. The size of the instrument is 0.8 $ft^3$ excluding a computer for control and display. The sole manufacturer of the FIS has reported limits of detection in the low picograms for common explosives such as RDX, PETN, and TNT. In addition, a response time of 2 sec for a single component and approximately 5 sec for each additional component is advertised. To date, there are no independent test data available for the FIS.

## DATA SHEET 5.4. GAS PHASE ION CHEMISTRY

| | |
|---|---|
| **Developing Critical Technology Parameter** | Improved ion sources (nonradioactive) for complex matrices, e.g., soil and water samples. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Unknown, perhaps pattern recognition if coupled with traditional specroscopy. |
| **Major Commercial Applications** | Soil and water monitoring. Analytical chemistry. Environmental monitoring. |
| **Affordability** | Moderately expensive. |

### *BACKGROUND*

Since many detection techniques require the sample to be in the gaseous state, there is a need to provide a sampling and preparation technique to generate a gas phase sample from complex soil and water sources that then can be measured by some of the techniques previously mentioned.

## DATA SHEET 5.4. PASSIVE INFRARED (IR)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Faster signal processing (terabytes/sec). Smaller, faster systems. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. |
| **Major Commercial Applications** | Environmental monitoring. |
| **Affordability** | Expensive. |

### *BACKGROUND*

IR detection measures the characteristic absorption bands for a gaseous substance. By ascertaining the wavelength and strength of these bands, vapors can be detected and partially analyzed or identified.

## DATA SHEET 5.4. ABSORPTION LIDAR

| | |
|---|---|
| **Developing Critical Technology Parameter** | Backpack system; gigabytes/sec processing speed. Increased sensitivity to detect low level vapor concentrations in aerosol clouds. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | Pattern recognition. |
| **Major Commercial Applications** | Environmental monitoring. |
| **Affordability** | Expensive. |

***BACKGROUND***

LIDAR measures the composition of a cloud by firing a laser or lasers into a cloud and measuring the characteristic absorption or backscatter from the vapor components. When the clouds consist of particulates of low volatility (for example, VX droplets), LIDAR is ineffective. In the future, however, it may also be possible to aim a LIDAR at surfaces to identify deposited substances, whether solid or liquid.

## DATA SHEET 5.4. SPECTROSCOPY [ELECTRO-OPTICAL (E-O) PROPERTIES]

| | |
|---|---|
| **Developing Critical Technology Parameter** | Remove spectrum gaps for solid, liquid, and gas phases. Establishing a surface-enhanced resonance Raman spectroscopic signature. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | Environmental monitoring. |
| **Affordability** | Not an issue. |

***BACKGROUND***

Spectroscopy is the next generation of detection technology. Spectroscopy would enable detection of CW and BW simultaneously.

# DATA SHEET 5.4. SAMPLE COLLECTION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Aerosols and particulates—air, liquids, solids—surfaces. Increased sensitivity; reduced bias. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | Environmental monitoring. Process control. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

Effective and accurate means of identifying materials and determining their concentrations are highly dependent upon accurate and reproducible sampling procedures across broad spectra of chemical compounds and different physical states.

## SECTION 5.5—OBSCURANTS

### *Highlights*

- If used properly, obscurants can negate the value of high-technology reconnaissance, target acquisition, and precision-guided munition systems
- Obscurant R&D, which resumed in 1972, is still being well funded in many countries.
- The effectiveness of technologies used in U.S. military systems can be degraded with obscurants at a fraction of the cost of the U.S. technologies.
- Historically, employment of obscurants has not been complex.

### *OVERVIEW*

This subsection covers obscurants that degrade or defeat sensors that operate in any part of the electromagnetic spectrum. An obscurant is defined as:

- Any gas, liquid, or solid particle, either man-made or natural, suspended in the atmosphere that affects any part of the electromagnetic spectrum by: scattering, absorption, radiance, reflection, or refraction.

Obscurants are identified by their application in the various parts of the electromagnetic spectrum: visible, visible and near-IR, visible through far-IR, mid- and far-IR, millimeter wave (MMW), centimeter wave (CMW), visible and MMW, visible and CMW, visible through millimeter wave, MMW, and CMW.

## LIST OF TECHNOLOGY DATA SHEETS
## 5.5 OBSCURANTS

## DATA SHEET 5.5. MILLIMETER WAVE—SCATTERING AND ABSORBING

| | |
|---|---|
| **Developing Critical Technology Parameter** | Packing density >75 percent of the material density; dissemination efficiency for large area systems >80 percent and for projected systems >50 percent; $Ext_{mm}$ significantly greater than 2. |
| **Critical Materials** | Metal microwires; metal-coated fibers. |
| **Unique Test, Production, Inspection Equipment** | Aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | Obscurant modeling; transport and diffusion. |
| **Major Commercial Applications** | Ram for high structures, electronics. |
| **Affordability** | Inexpensive, especially in relation to the assets that are protected. Also a very cost-effective means for an adversary to negate precision weapons systems. |

## DATA SHEET 5.5. MID AND FAR INFRARED—RADIANCE

| | |
|---|---|
| **Developing Critical Technology Parameter** | Emissive obscurant effectiveness parameters; methods for direct comparison with enemy smoke effectiveness. |
| **Critical Materials** | Activated metals; reactive metals; pyrophoric materials. |
| **Unique Test, Production, Inspection Equipment** | Field instrumentation; production quality control; aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | Obscurant modeling (new models required). |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Inexpensive, especially in relation to the assets that are protected. Also a very cost-effective means for an adversary to negate precision weapons systems. |

## DATA SHEET 5.5. MULTISPECTRAL (VISIBLE, INFRARED, MILLIMETER, AND POSSIBLY CENTIMETER)

| | |
|---|---|
| **Developing Critical Technology Parameter** | Packing density >50 percent of source density; dissemination efficiency >50 percent; extinction coefficient >2. |
| **Critical Materials** | Conductive fibers or a mixture of materials that are used for the various wavelengths. |
| **Unique Test, Production, Inspection Equipment** | Field instrumentation; obscurant modeling; production quality control; aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | Obscurant modeling. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Inexpensive, especially in relation to the assets that are protected. Also a very cost-effective means for an adversary to negate precision weapons systems. |

## DATA SHEET 5.5. SPECTRAL DIRECTION SELECTIVITY

| | |
|---|---|
| **Developing Critical Technology Parameter** | Limit screening to specific regions of the spectra. |
| **Critical Materials** | Specially controlled sizes and shapes of conductive and semiconductive particles or techniques for polarization of an obscurant cloud. |
| **Unique Test, Production, Inspection Equipment** | Aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | Battle modeling. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Not an issue. |

## DATA SHEET 5.5. TEMPORAL SELECTIVITY

| | |
|---|---|
| **Developing Critical Technology Parameter** | Precisely select amount of time (e.g., five minutes or five days). |
| **Critical Materials** | Irradiated clouds; using slow heating which would allow selection of screening times in the infrared; degrading coatings. |
| **Unique Test, Production, Inspection Equipment** | Aerosol test chambers, transmissometers, test ranges, nephelometers. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Not an issue. |

## DATA SHEET 5.5. ENVIRONMENTAL

| | |
|---|---|
| **Developing Critical Technology Parameter** | Signaling and screening obscurants that are environmentally benign, i.e., zero damage to the environment. |
| **Critical Materials** | Environmentally benign substance that still provides significant attention-gathering characteristics. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Not an issue. |

## DATA SHEET 5.5. TECHNOLOGY COUPLING

| | |
|---|---|
| **Developing Critical Technology Parameter** | Concurrent application of use of obscurants, camouflage, and electronic obfuscation to enhance battlefield operations. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | None identified. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Not an issue. |

***BACKGROUND***

The application of multiple technologies has the potential for enhancing each individual effect.

## DATA SHEET 5.5. PRECISION PARTICLE PRODUCTION

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to uniformly create specific particle shapes and sizes within a narrow range. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | Particle size and shape distribution measurement. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | Paint pigments; microwires; electronics. |
| **Affordability** | Reduce logistics burden. |

## DATA SHEET 5.5. CREATION AND PACKAGING OF NANOMATERIALS

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to create specific particle shapes with dimensions less than 100 nm. |
| **Critical Materials** | Conductive or semiconductive materials that can be made as specifically shaped nano-particles. |
| **Unique Test, Production, Inspection Equipment** | Accurate measurement of particle size and shape as well as standardized measurement of extinction coefficient. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | Catalytic reactions. |
| **Affordability** | As the technology develops, costs will decrease. |

### *BACKGROUND*

The creation of nano-sized particles with diameters between 40 and 70 nm theoretically permits the attainment of extinction coefficients much higher than currently thought possible. This appears to be especially true if the particles are charged.

## DATA SHEET 5.5. MEASUREMENT

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to separately measure in the field location, extent, concentration, path length and extinction coefficient. |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | Aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | Data bank related to correlation of measurement techniques and errors of measurement. |
| **Major Commercial Applications** | EPA monitoring; weather monitoring. |
| **Affordability** | Not an issue. |

### *BACKGROUND*

Current techniques permit a field measurement of extinction coefficient only by inference based upon concentration measurements and calculated path length to yield an approximate value. Enhanced measurement would provide a better picture of what is being developed, how it works, and the performance of sensors.

## DATA SHEET 5.5. PROJECTED OBSCURANTS

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to project and successfully disseminate infrared and millimeter-wave material. |
| **Critical Materials** | Carrier fluids that would greatly decrease or eliminate particle clumping and agglomeration in launch and dissemination environments. |
| **Unique Test, Production, Inspection Equipment** | Aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | None identified. |
| **Affordability** | Potentially expensive. |

### *BACKGROUND*

Currently capabilities exist for IR and millimeter-wave screening only with self-protection smokes and large-area screening smokes. Projected obscurants would “blind” a remotely placed enemy. This would extend their use and open new possibilities for full-dimensional protection as espoused in *Joint Vision 2010*.

## DATA SHEET 5.5. OBSCURANT CLEARING

| | |
|---|---|
| **Developing Critical Technology Parameter** | Ability to use particle subsidence or other methods to create “holes” in obscurant clouds; ability to use energy to create “holes.” |
| **Critical Materials** | None identified. |
| **Unique Test, Production, Inspection Equipment** | Aerosol test chambers; transmissometers; test ranges; nephelometers. |
| **Unique Software** | None identified. |
| **Major Commercial Applications** | Fog clearing at airports. |
| **Affordability** | Variable. |

### *BACKGROUND*

Although total cloud clearing appears logistically infeasible, it may be possible to create selective, albeit relatively short-lived, “holes.”