Sensors for Chem/Bio Defense
- A Survey -

Presented by:
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Science Applications International Corporation
McLean, Virginia

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Agenda

- Overview
- Operational Needs
- Current System Requirements for Sensors
- Active Research
Acknowledgements

Material for Paper Provided by:

- LTC Michael Lanphere - Joint Service Integration Group
- Eric Eisenstadt - ONR
- Mark Siever - NRL
- Cindy Swim - SBCCOM
Overview

- Three classes of sensor information:
  - detection
  - localization
  - classification

- Multiple robust solutions for chemical sensors
  
  **Point - Manual** - colorimetric paper; enzymatic-substrate based wet chem; ionization product diffusion;
  **Point - Automated** - electrochemical; single-cell/dual cell ion mobility spectrometry; baffle tube ionization cells;
  **Standoff/Early Warning** - forward looking infrared technology (FLIR); passive, Fourier transform infrared (FTIR) spectrometry;
Overview, Continued

- Current bio identifiers rely on detailed laboratory analysis
  - assays
  - electron and oil immersion microscopy
- Limited, but promising future solutions for biological sensors
  - **Point - Manual** - flow cytometry; ATP luminescence; UV aerodynamic particle sizer; mass spectrometry;
  - **Standoff/Early Warning** - LIDAR
- Detection based on features of biological activity i.e. tryptophan for bacteria
- Biological characterization requires (to date) fusion of information
  - particle #
  - size distribution
  - base pair constitution and sequence
Operational Needs

Enhanced detection, identification, mapping and confirmation of any standard/non-standard hazards including toxic industrial materials (TIMS).
Immediate notification of hazard existence/location.
Automated identification, plotting and hazard density mapping over time.
Obtain and preserve hazard samples.
- Point, aerial, shipboard (multiple platforms) and large area coverage.
- Water test capability.
- Integrated point and remote/early warning.
- Interface with joint C4I architecture.
Chemical Vapor Detector Requirements

- Small Lightweight (pocket size)
- Immediate detection time (seconds)
- Low maintenance
- Broaden from chemical agents to environmental
  - Immediate cleardown time (seconds)
  - No hazardous internal sources
  - Inexpensive
  - Ability to be networked
  - Short term (days) memory; long term download for historical record
  - Flexibility in applications
  - Ability to learn (neural)
Chemical Water Monitor Requirements

+ No false alarms
+ Detect ppb/ppt levels of CB agents and their hydrolysis sentinel compounds in source, treated, distributed and discharge water
+ In-line continuous and batch (<=10 minutes) detection and quantification
  - Low power, light weight, inexpensive
  - Upgradeable, prefer no disposables, few moving parts, easy to maintain and use
  - Modular system
Joint Chemical Agent Detector (JCAD)

**OPERATIONAL CONCEPT**
- Detect point and cumulative exposures of CW agents.
- Compatible with the Joint Warning and Reporting Network (JWARN).
- Operate from a variety of platforms to support contamination avoidance or reconnaissance.

**CAPABILITIES REQUIRED**
- Detect, ID and quantify nerve, blister and blood agent vapors.
- Liquid, particulate, specific agents and TIMs are objective requirements.
- Minimize false alarms (MTBFA > 168 hours).
- Capable of rejecting battlespace interferants.
- Will not exceed two (2) pounds and forty (40) cubic inches.

- Nerve and Blister Agent Detection
- Lightweight and Portable
- Expandable for Emerging Threat Agents
- Mass Spectrometry
- GC/SAW Combination
- Paper Size
Biological Aerosol Detector Requirements

+ Sensitive to bacteria (20,000 cfu/ml), viruses (1x10⁷ pfu/ml), toxins (1 ng/ml)
+ Rapid detection
+ Minimal setup time (zero to 1 minute)
  - Small, lightweight and ruggedized
  - Low maintenance
  - On-board filtration/eliminate interferents and dust
  - High specificity without loss of sensitivity
  - Fully automated; no skill required to operate
  - Long operation time and ability to be networked
  - Short term memory (days); long term download for historical record
  - Flexibility of applications
  - Adaptable to new threats
Biological Water Monitor Requirements

- Sensitive to bacteria (20,000 cfu/ml), viruses (1x10^7 pfu/ml), toxins (1 ng/ml)
- Adaptable to any water sampler
- Rapid detection
- Adaptable to new threats
  - Small, lightweight and ruggedized
  - On-board filtration/eliminate organic and inorganic interferents
  - High specificity without loss of sensitivity
  - Minimal setup time
  - Fully automated; no skill required to operate
  - Long operation time and ability to be networked
  - Short term memory (days); long term download for historical record
  - Flexibility of applications
**Interim Biological Agent Detector (IBAD)**

**Yesterday** - Only Forward Field Labs
**Today** - IBAD Can Provide:
- Immediate Capability to Support Contingency Force Deployments
- Responsive in Sea and Land Environments
- Full Detection Capability on the Move
- Timely Threat Warning Notification to Force Command and Control

**In the Future---**
- Expansion for Additional Agents
- Increased Automation
- Integration with Shipboard Damage Control System
**Joint Service Warning and Identification Lidar Detector (JSWILD)**

**OPERATIONAL CONCEPT**
- Provide a laser standoff integrated chemical and bioaerosol detection capability for protection of fixed sites, ships, and possibly for recon.
- Standoff CB detection of aerosols/rains/particulates/liquids in addition to vapors, in real time.
- 20 km range and precise ranging information.

**CAPABILITIES REQUIRED**
- Max Range: 10 km now, 20 km in 2000
- Provides precise location of threat
- Vapor (nerve): 20 mg/m²
- Vapor (blister): 500 mg/m²
- Aerosols/rains: 20 mg/m² or less
- Surface prediction: 0.01 g/m²
- Bioaerosol detection, discrimination?
- 99.6% probability of detection
- Detects in a few seconds or less (real-time)
Technological Progression

**DESERТ STORM**

**Chemical**
- M8/M9 Paper
- M256A1 Kit
- M8A1 CW Alarm
- M272A1 Water Kit
- CAM
- CAPDS
- M21 RSCAAL
- AN/KAS-1

**Biological**
- SMART tickets

**TODAY**

**Chemical**
- IPDS
- ICAM
- SALAD
- ACADA
- M93A1 NBCRS

**Biological**
- IBAD
- BIDS
- Portal Shield
- LR-BSDS

* including all Desert Storm Capabilities

**FUTURE**

**Chemical**
- JSLSCAD
- JCAD
- JCBAWM
- JSWILD

**Biological**
- JBPDS
- JBDS

**NBC Infrastructure**
- JSLNBCRS
- JWARN
## System Capabilities - Today

### Limited or N/A

- M8, M9 Paper
- M256A1 Kit
- M272 Water
- AN/KAS-1
- M21 RSCAAL
- M8A1
- ALAD
- ACADA
- ICAM
- ICAD
- CAPDS
- IPDS
- BIDS
- IBAD
- LR-BSDS
- M93-NBCRS

### Applicable and Adequate

- Point
- Stand-off
- Portable
- Low Maint.
- Easy to use
- Low Cost
- Sensitivity
- Low FAR
- Multi-Agent
- Auto Warn
- Networked
- Response Time
- Auto Agent ID
- Range
- Tracking
- Large Area

*See list of System Definitions*
# Future Systems Capabilities Objectives

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* See list of System Definitions

[SAIC](https://www.saic.com) - An Employee-Owned Company
Future Directions and Issues
**Single Particle Fluorescence - Detection Operation (Siever, NRL)**

- Particles cross red beam & scatter light. Pulses are proportional to particle size and also trigger the UV laser.
- 1 µsec later, UV laser excites the particle. Its fluorescent intensity indicates particle composition.
- Scattered and fluorescent pulse heights are captured in data record.
Calibration with PSL

Size Calibration

- 4.5 µm PSL
- 2.07 µm PSL
- 1.07 µm PSL
- BG Spores

Fluorescence Calibration

- 2.07 µm doped PSL
- 1.33 µm doped PSL
- 1.07 µm plain PSL
- BG spores
Fluorescence with Particle Number Fusion

T-21 Alarm Window

T-21 Window Comparison

- SPCF data
- DPG ACPLA

4:14 512 Total
4:04 392 Total

Percent Particle Number

Particle Size

An Employee-Owned Company
Calibration with Bacteria

(Individual Bacteria - Lab data)

APS 3320

E. coli
BG spores
Erwinia

Fluorescence (arb.)

scattered light (arb.)

Number of Particles

Aerodynamic diameter (µm)
Bacterial Fluorescence Comparison

![Graph comparing fluorescence and scattered light of B. thuringiensis and B. subtilis](image)
Distinguishing B. anthracis from Its Nearest Neighbors (Leighton, LBNL; Long, NMRI)

Organism

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Chromatographic Assay 50 ng; 30 min

Ba Bt Bc Bm Bs Bg NT Cont
Conclusions

- Lasers have been employed for detection (point ® limited range)
- Lasers have been used for gross features determination
- Gene-oriented characterization techniques are current research rage for rapid characterization
- Novel active (laser) ideas are ...