Sensors for Chem/Bio Defense
- A Survey -

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Agenda

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

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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/duel 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**

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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.**

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Current Systems

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)**

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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**

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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**

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Biological Aerosol Detector Requirements

- + **Sensitive to bacteria (20,000 cfu/ml), viruses ($1x10^7$ 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**

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Biological Water Monitor Requirements

+ **Sensitive to bacteria (20,000 cfu/ml), viruses (1x107 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**

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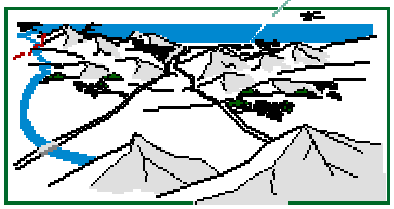
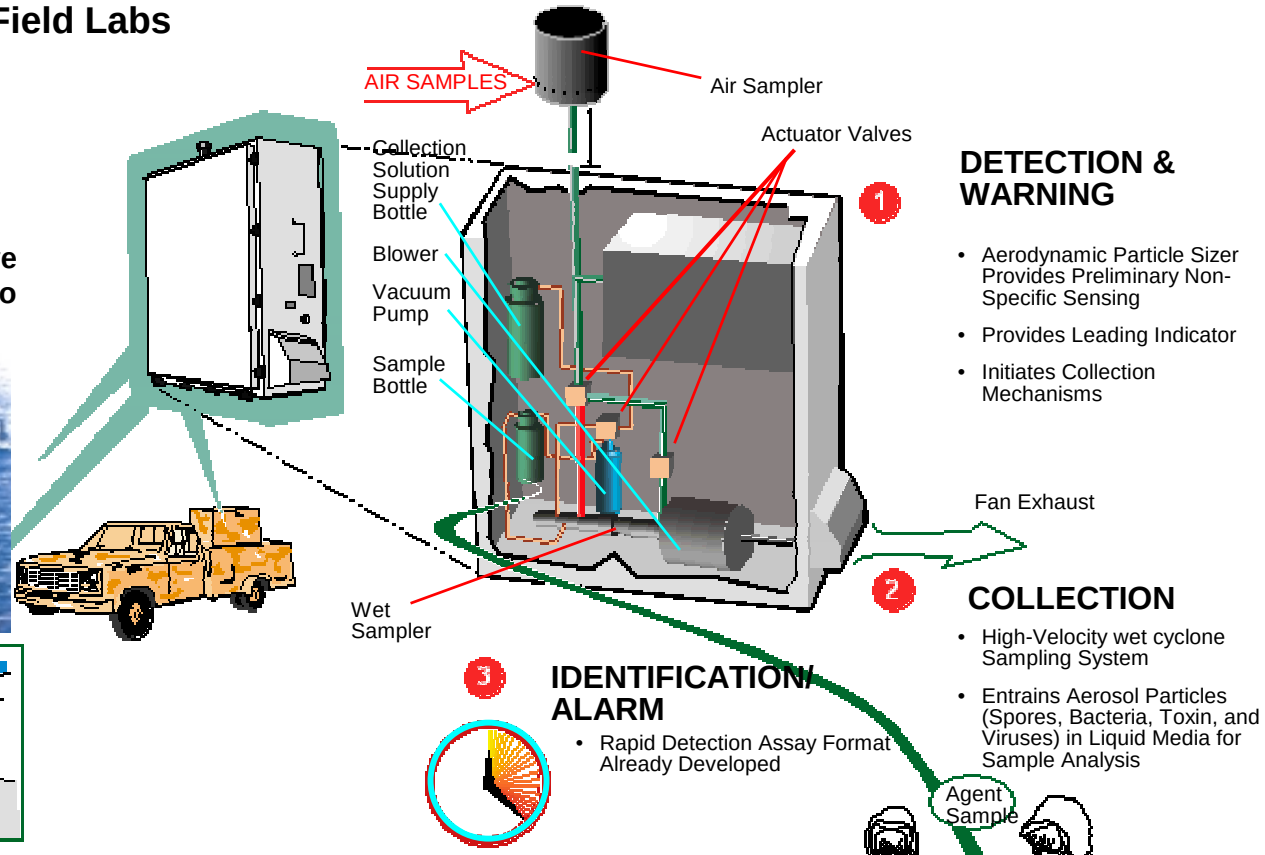
Interim Biological Agent Detector (IBAD)

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**





DETECTION & WARNING

- Aerodynamic Particle Sizer Provides Preliminary Non-Specific Sensing
- Provides Leading Indicator
- Initiates Collection Mechanisms

COLLECTION

- High-Velocity wet cyclone Sampling System
- Entrains Aerosol Particles (Spores, Bacteria, Toxin, and Viruses) in Liquid Media for Sample Analysis

IDENTIFICATION/ ALARM

- Rapid Detection Assay Format Already Developed

In the Future---

- **Expansion for Additional Agents**
- **Increased Automation**
- **Integration with Shipboard Damage Control System**

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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)**

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Technological Progression

DESERT 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
- JBSDS

NBC Infrastructure

- JSLNBCRS
- JWARN

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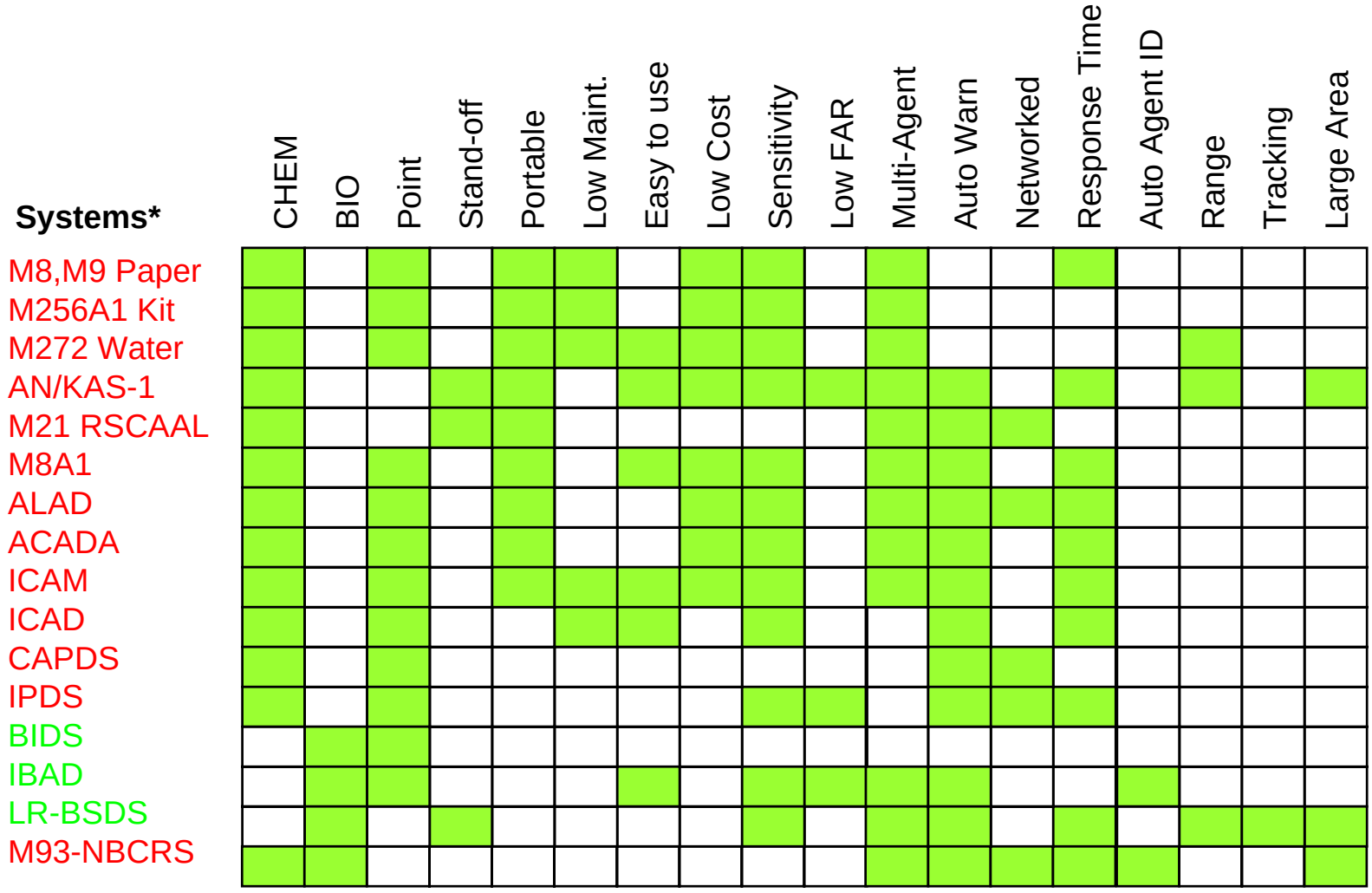
System Capabilities - Today

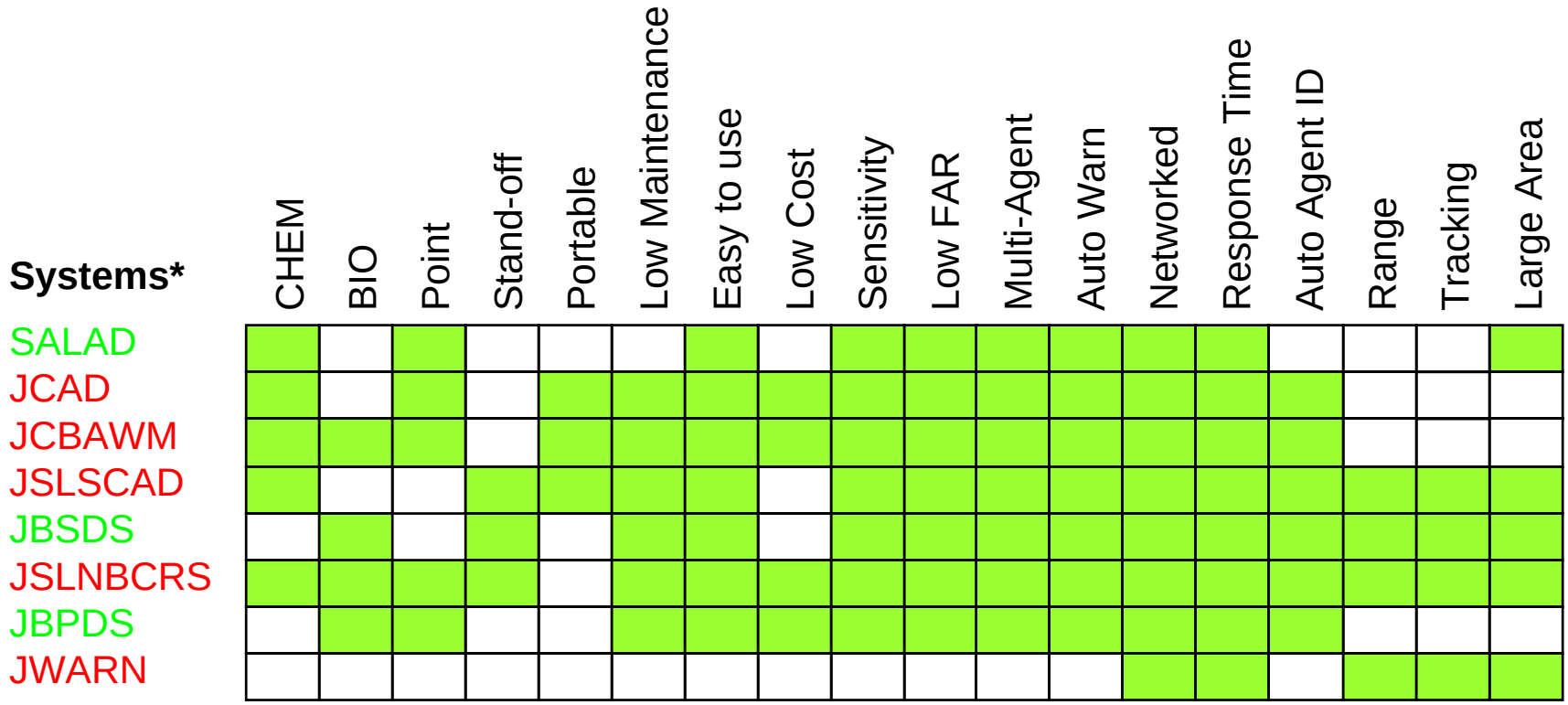


*** See list of System Definitions**

Limited or N/A

Applicable and Adequate

Future Systems Capabilities Objectives



*** See list of System Definitions**

Limited or N/A

Applicable and Adequate

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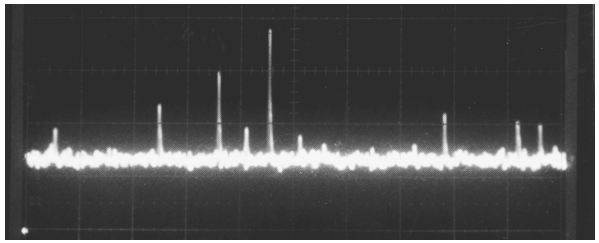
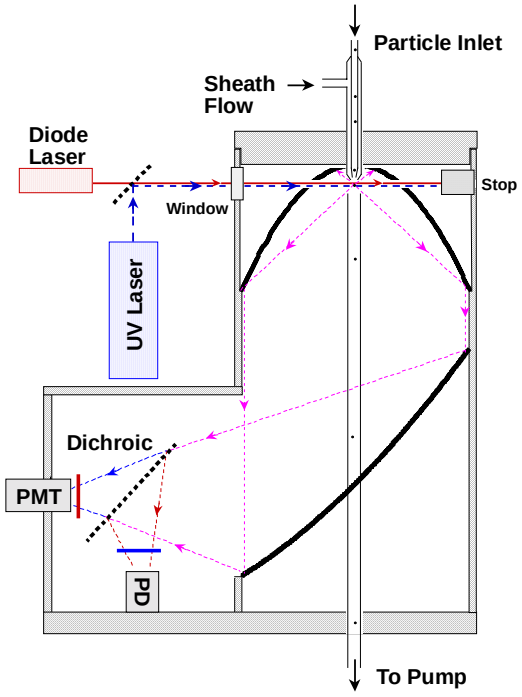
Future Directions and Issues

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.





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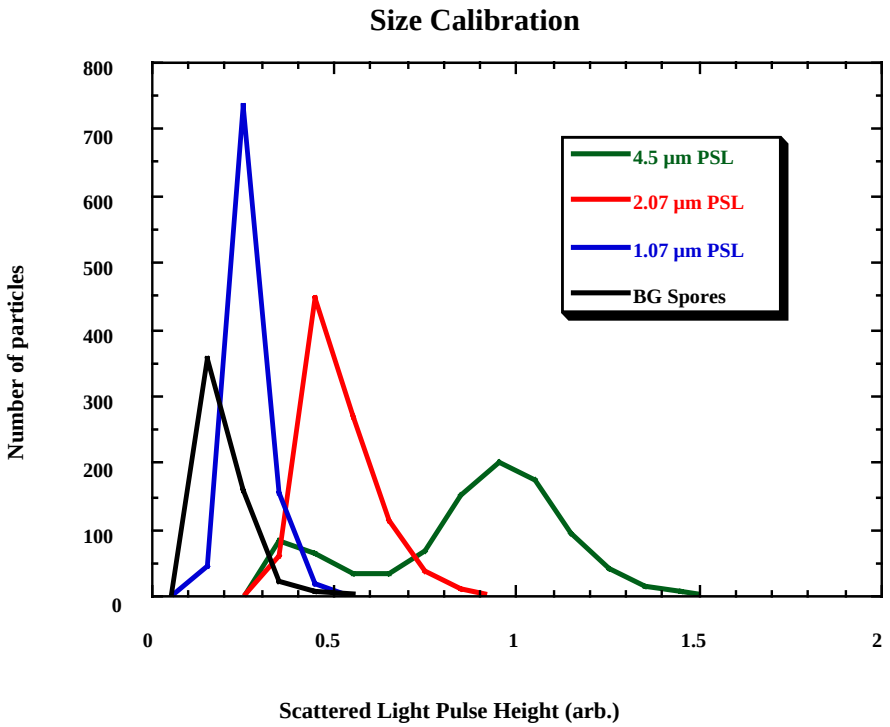
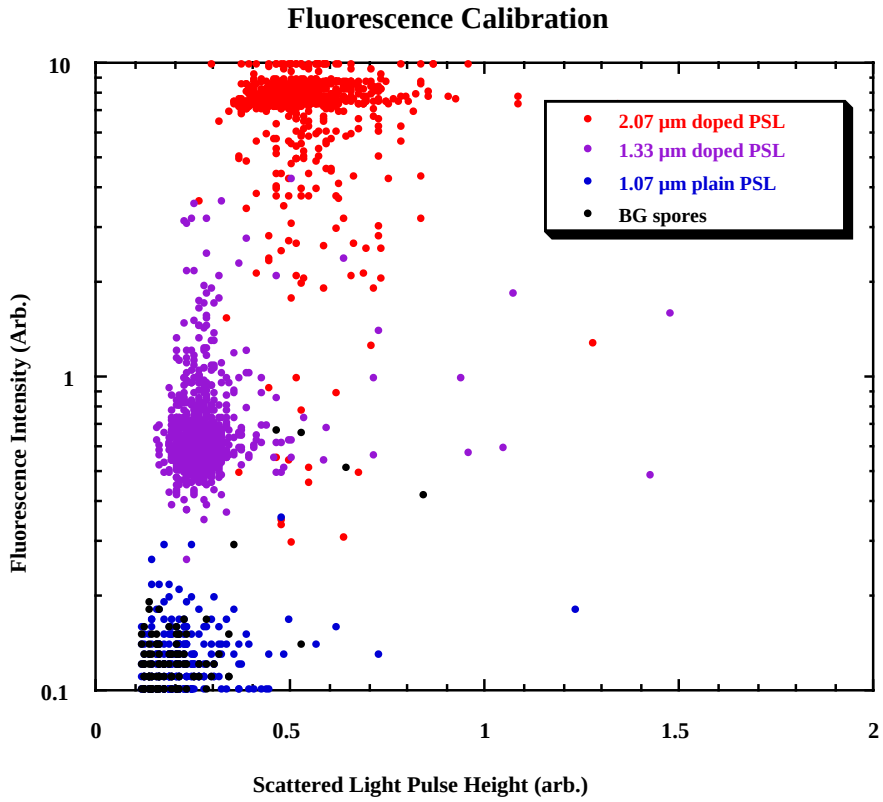
Calibration with PSL





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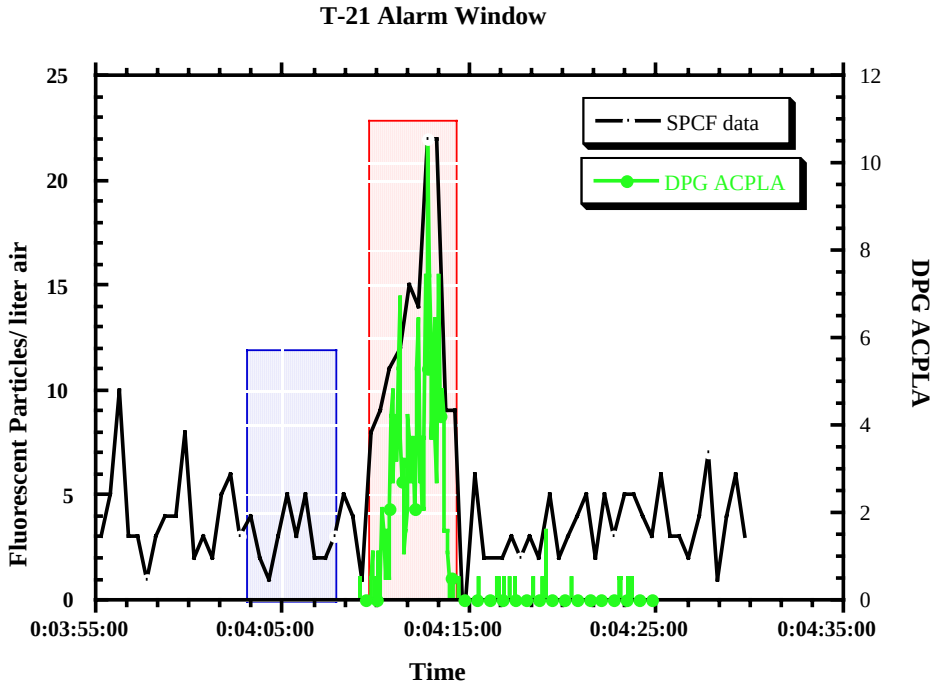
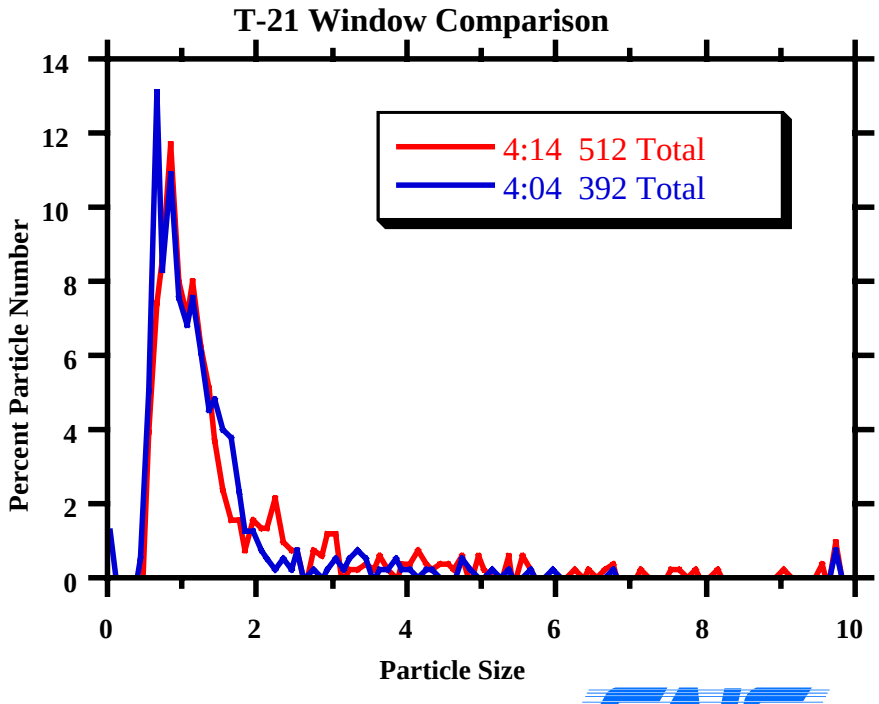
Fluuorescence with Paticle Number Fusion





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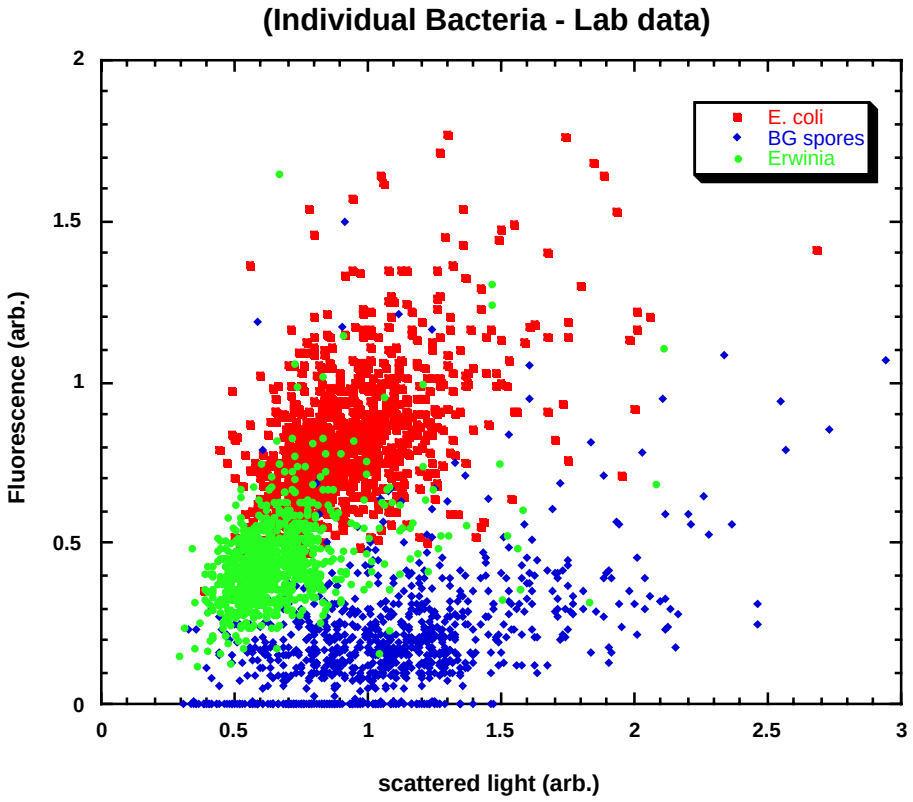
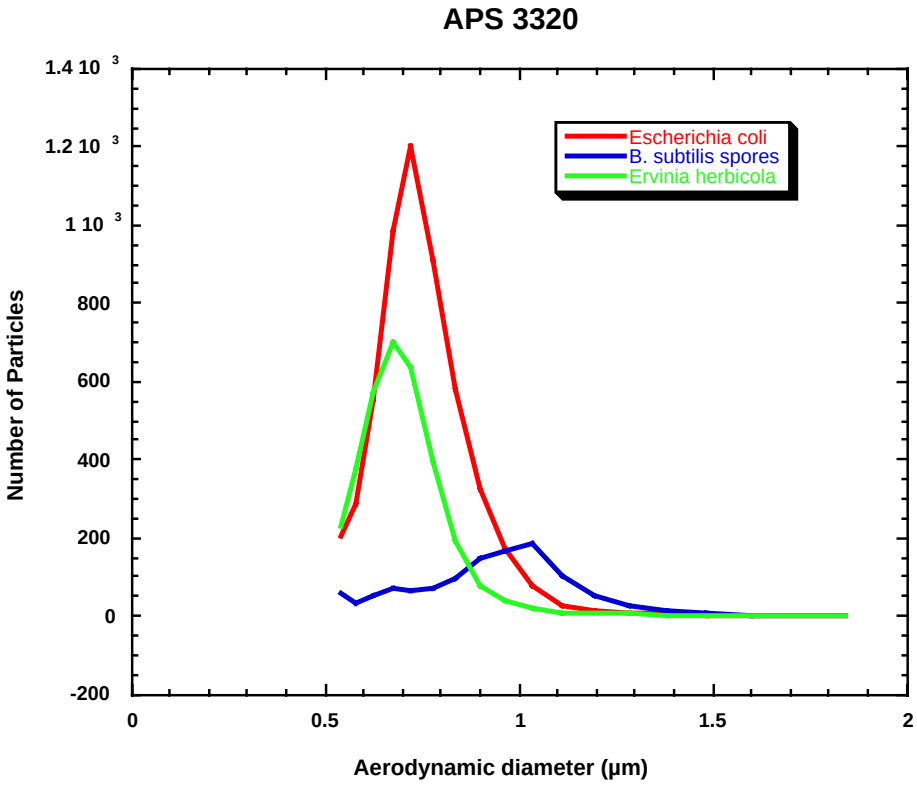
Calibration with Bacteria





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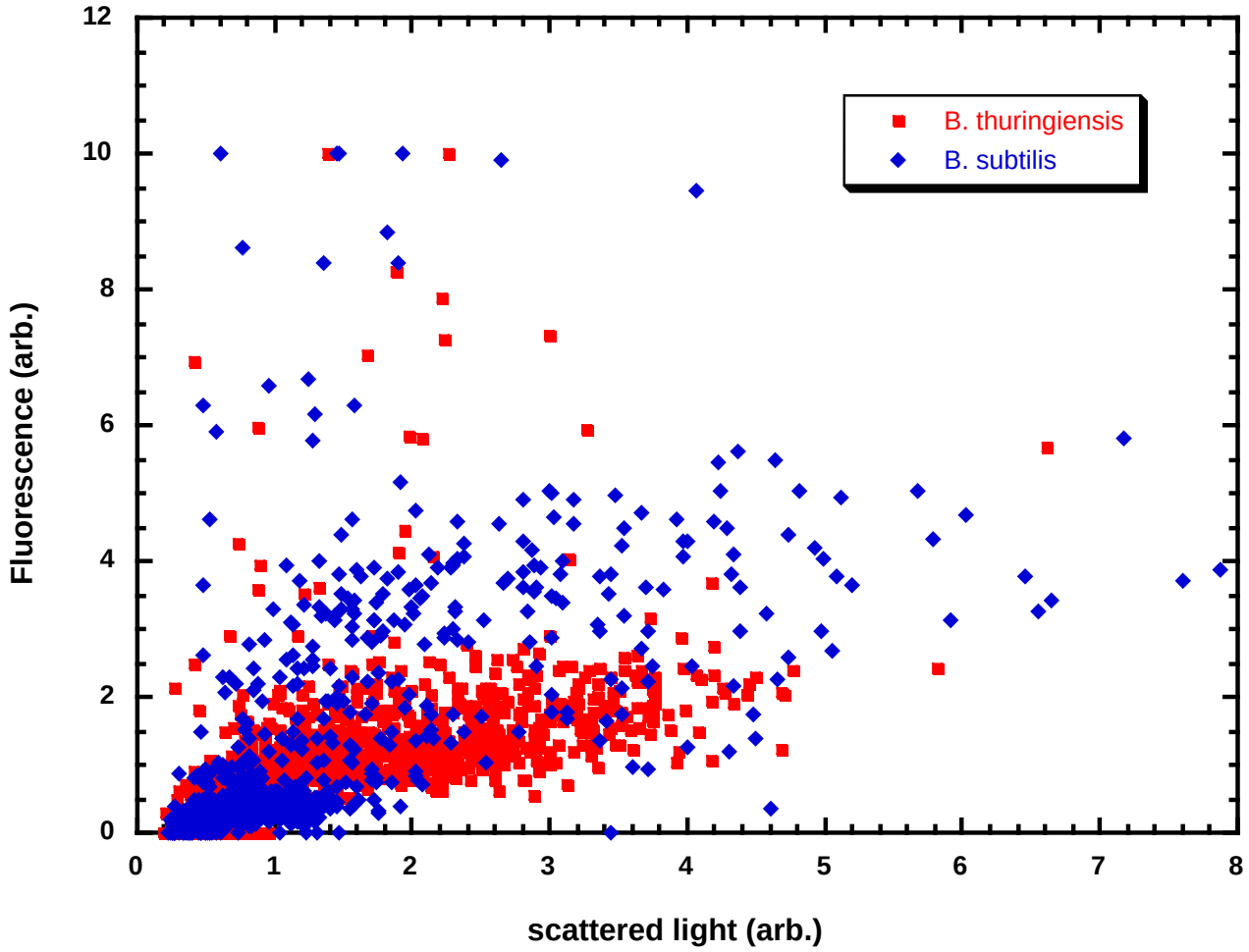
Bacterial Fluorescence Comparison



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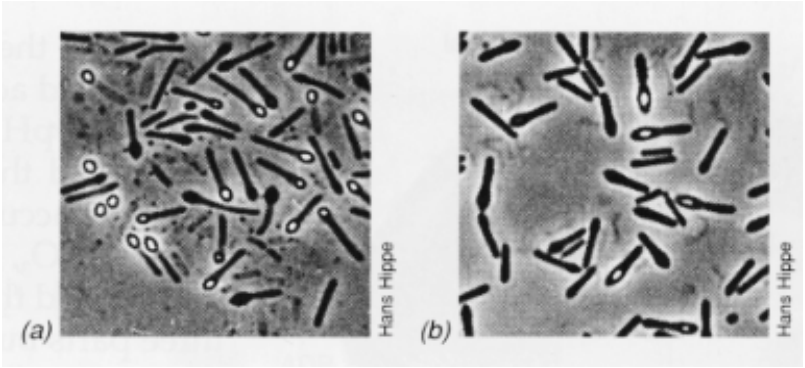
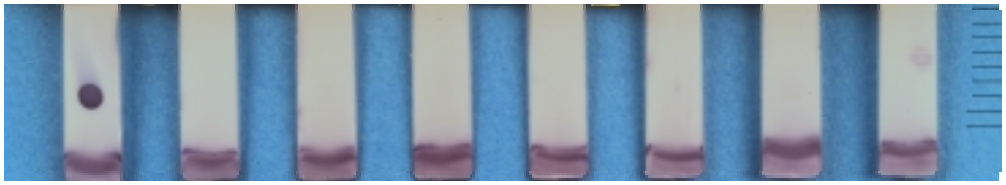
Distinguishing B. anthracis from It's Nearest Neighbors (Leighton, LBNL; Long, NMRI)



B. anthracis *B. cereus*

Organism	**Spore Protein Amino Acid Sequence**
B. anthracis	**TEFATETNVQAVKQANAQSEAKKAQASGASIQSTNA**
	: : : . : : : . : X : . : :
B. cereus	**TEFSTETDVQAVKQANAQSEAKKAQASGA--QSANA**

Chromatographic Assay 50 ng; 30 min



Ba Bt Bc Bm Bs Bg NT Cont

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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 ...**