Biosensing in Urban Areas

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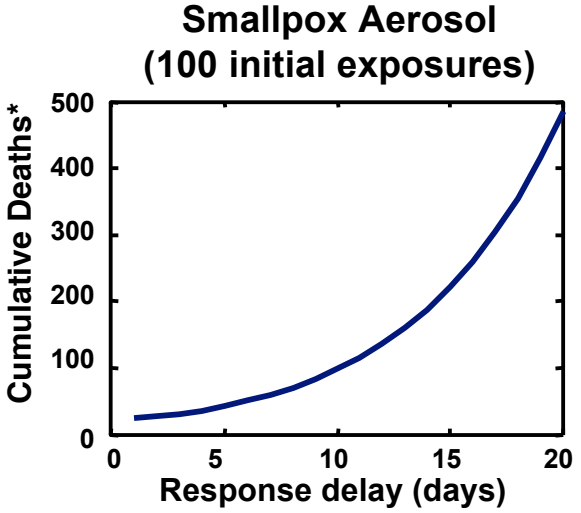
Outline

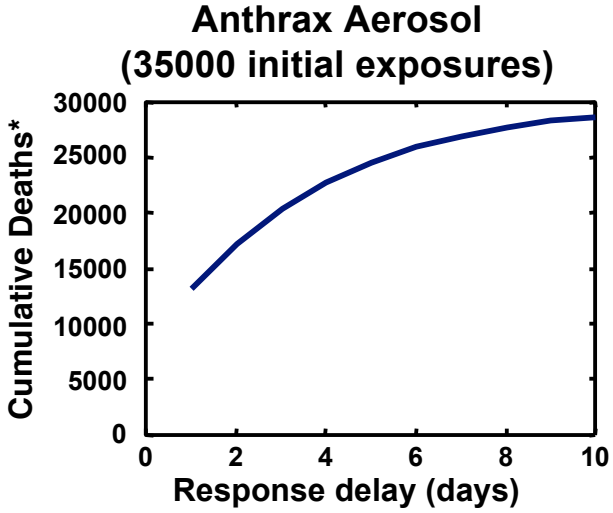
- Differences between military and civilian applications
- Value of biological sensors
- Sensing concepts of operation
- Trigger sensors
  - Value
  - Technical challenges
- MIT/LL urban measurement program

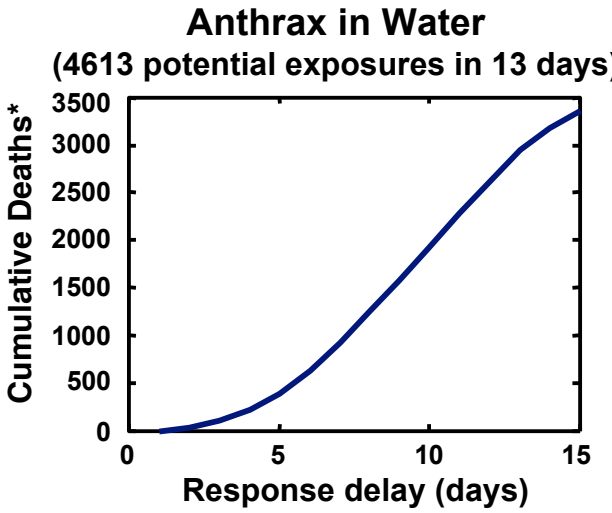
Aerosol Sensing for Urban Civilian Protection vs. Military Force Protection

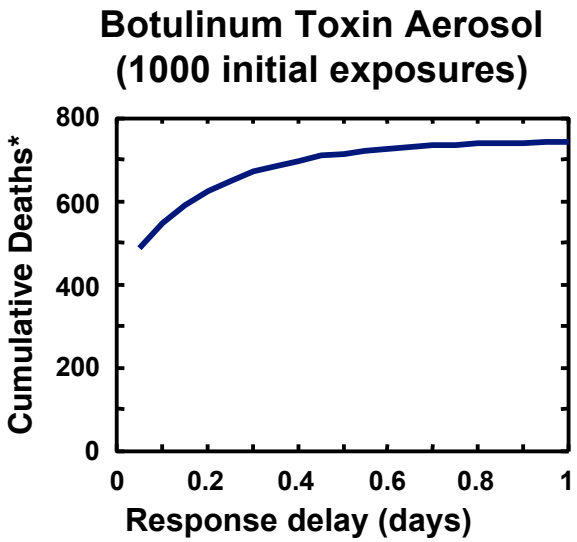
- Tolerance for costly systems with frequent alerts or maintenance needs is much lower
  - System cost, particularly O&M costs, may be the biggest current implementation obstacle
- Population is not prepared to act quickly or rationally if warned of imminent or ongoing attack
  - Detect-to-warn is currently impractical
- Urban aerosols (or other media) can be much different than many military environments
  - Inhomogeneous aerosol distribution, many local interferent sources
- Few areas access controlled – releases can be made anywhere

Delay Costs Lives









Variation of Gani and Leach disease progression model [Nature 414: 748-751, Dec., 2001]

- **Relative cost of delay is scenario dependent**
- **Response can often be delayed a few days with minimal impact as long as the people infected can be found well after the fact**
  - **Not the case for transportation nodes**
- **Health monitoring cannot bring the rapid attack recognition needed to minimize casualties**
  - **Sensors (air, water, etc.) needed**

* Over the fist 120 days after attack

Sensing Challenges*

	Apply Treatment (Civilian, Military bases)	Prevent Exposure (Force Protection)
Indoor	**Cost** Latency Sensitivity	Cost **Latency** **Sensitivity**
Outdoor	**Cost** Latency **Sensitivity**	Cost **Latency** **Sensitivity**

Cost - $ cost, particularly for O&M

Latency – Available time after release to detect and take action

Sensitivity - Amount of material needed to achieve a reasonable false positive rate

** This is an oversimplified representation intended to demonstrate that there are a variety of technical solutions that depend on the environment and the objectives.*

Larger text in table represents more stringent requirements

Candidate Environmental Monitoring Strategies – Current Maturity

- Routine periodic sample collection and lab analysis
  - Expensive
  - Too slow for some agent releases
- Periodic sample collection or collection after device trigger, followed by lab analysis
  - More timely but still expensive
- Triggered sample collection and lab analysis
  - Timely and less expensive if trigger rates can be kept low
  - Currently, trigger rates are too high and triggers are too insensitive for some applications
- Triggered sample collection and automated analysis on site
  - Limited production military systems (currently very expensive)
  - Still must be followed by some confirmatory lab analysis

Potential Response Actions

- Modify HVAC operation
- Consult other surveillance sources (e.g. cameras, foot patrols)
- Collect additional samples for analysis

Reasonable actions as a result of trigger sensor alert

- Evacuate
- Alert public
- Decontaminate

Requires specific and confirmed identification sensors

Use of Triggers to Reduce System Operating Costs

- **Trigger**
  - Reduces cost of identification step
  - Improves timeliness of additional testing and provides tentative warning
  - Sets the system sensitivity!

- **Candidate ConOps O&M cost estimates ($K/yr/location/agent)**
  1. Auto identify every _ hour ($10/test) = $175K
  2. Identify 2 times/day in lab ($30/test) = $22K
  3. Identify in lab when triggered ($30/test)
     a. 10 triggers/day = $110K
     b. 1 trigger/week = $2K

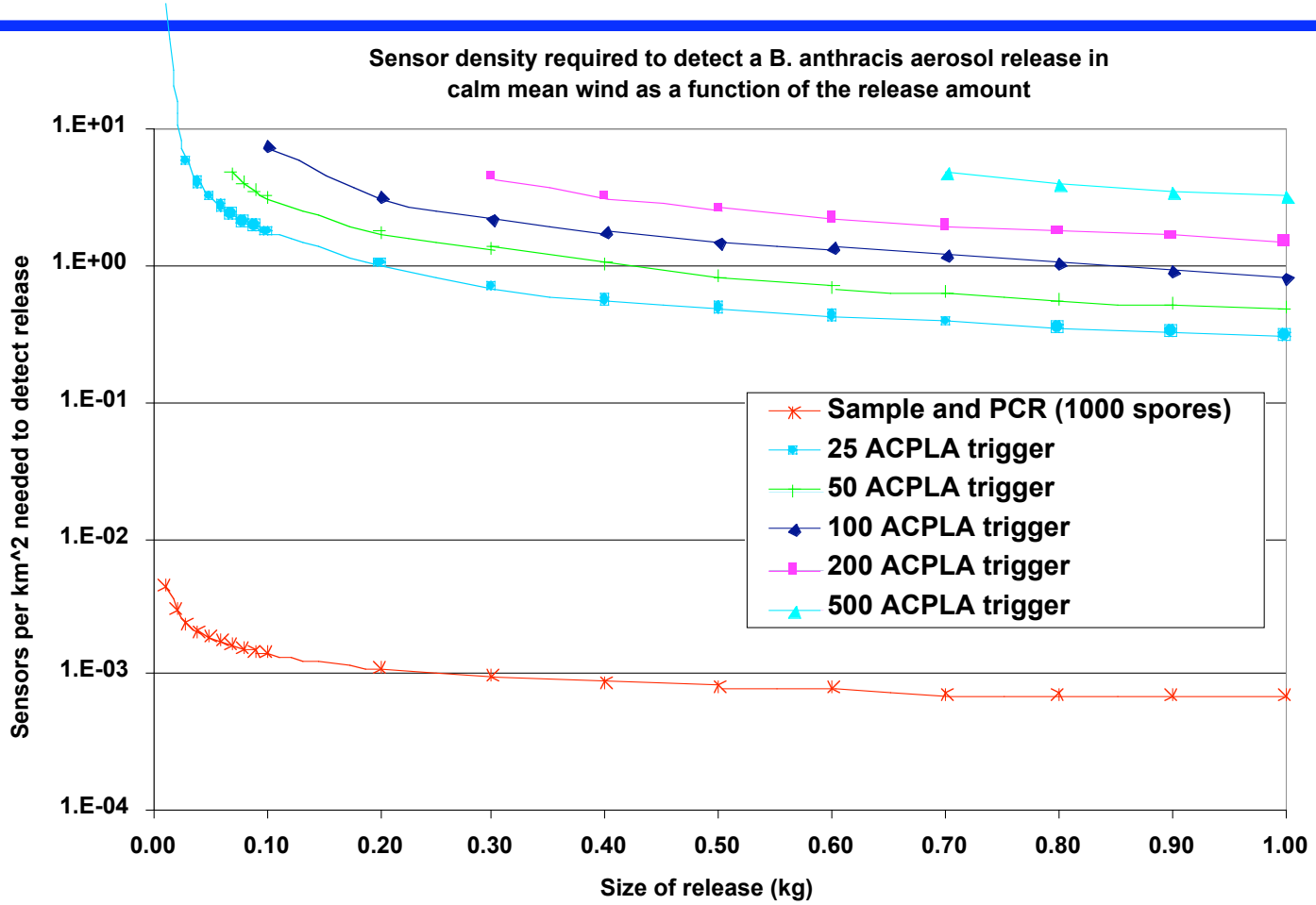
Potential Aerosol Constituents

- No Urban sites
- Some Urban Sites (examples given)
- Most Urban Sites

Potential Particle Sources	Outdoor	Indoor
Fuel Combustion remnants		Airport, Buildings near highways
Cooking	Near kitchens	Near kitchens
Fungal spores		Subway Some buildings
Skin cells		
Human activity	Outdoor public gathering	Sporting Arena, Theater, Convention center
Machine activity		Subway
Man-made fibers (clothing, paper, carpet, etc)		Postal facility

- Particles can come from a variety of natural sources
- The indoor aerosol composition is different from outdoor
- The spatial and temporal frequency characteristics also differ

Outdoor Sensor Density Requirements*



High sensitivity is needed for wide area outdoor surveillance. Lower cost, less sensitive sensors may not decrease system costs unless detectability is sacrificed.

* Worst case estimates for a *B. anthracis* release are shown

MIT/LL Urban Testbed Project Goals

- Initiated in Spring, 2001 to examine the unique aspects of urban biosensing
- Understand aerosol backgrounds and sensor responses
  - Initial emphasis on triggers
- Develop technology testbeds
  - Test evolving technology in realistic settings
- "System of Systems" approach
  - Improve automated data interpretation
    - Algorithms, including sensor fusion
  - Develop system requirements
    - Understand responder needs
  - Low cost a priority
  - Engineer for improved maintainability

Examples of Urban Testbed Measurements

Sporting Arena

- **Measurements over 3 days**
  - Three different events
  - Air handler return, mixing box

- **Instruments**
  - BAWS III
  - MetOne 2408 particle counter
  - PAH
  - Aethalometer
  - VOC
  - CO2
  - HVAC filter sample
  - Viable/nonviable fungi
  - Mycelial fragments
  - Air velocity
  - Damper settings
  - Temperature, humidity

Airport

- **2 terminal air handlers over 4 days**

- **Instrument data available to MIT/LL**
  - Triggers
    - BAWS III
    - MetOne 2408 particle counter
  - Potential Interferents
    - PAH
    - HVAC filter, electrostatic collector samples (PCR interference analysis)
    - Viable/nonviable fungi
    - Mycelial fragments
  - Operations Data
    - Damper settings
    - Air traffic operations

Measurements are to understand cause/effect as well as assess trigger performance

Recent MIT/LL Background Measurement Locations

Metro Boston

- Subway
- Major public events
- Hospital
- Postal sorting facility
- Office buildings
- Bus station

Across U.S.

- International airport
- Sporting arena
- Salt Lake City
- Military installations

Long-term measurements

Field data are essential to finding problems and developing solutions

Example Sensing Strategies

- **Subway**
  - Large area to cover; many sensors are needed
  - High background levels relative to other settings
  - Particulate levels driven by train function
  - Air motion affected by outside weather

  Strategy:
  - Inexpensive sensors
  - Fuse together with information about train movements and air flows
  - Engineer to keep optical devices clean
- **Sporting Arena**
  - Few zones
  - Aerosol composition widely varied depending on event

  Strategy:
  - Willing to use more expensive but more discriminating sensors
  - May need to use a few different types of sensors to keep high sensitivity
- **Office Building**
  - Many air handling zones; air handlers may be near one another
  - More consistent day-to-day background composition and flows

  Strategy:
  - Use inexpensive sensors or multiplex more expensive sensors
  - Use sensor fusion techniques to improve sensing performance within or between zones

Conclusions

- Cost is the most stringent requirement for civilian protection systems
  - Triggers with low trigger rates can reduce operating costs
- Unique characteristics of facilities lead to different sensing designs
- Biotrigger devices can reduce cost, but
  - False positive rate of sensors must be low
  - Sensitivity must be high for outdoor use