Tools and Apps to Enhance Situational Awareness for Global Disease Surveillance

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August 21st, 2014
Situational awareness - The perception of elements in the environment within a given time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1995)
Situational awareness in infectious disease surveillance

Important for both early warning and early detection of a disease outbreak (naturally or intentionally caused)

Global distribution of relative risk of an emerging infectious disease (EID) event

- **a**  zoonotic pathogens from wildlife
- **b**  zoonotic pathogens from non-wildlife
- **c**  drug-resistant pathogens
- **d**  vector-borne pathogens
Situational awareness in infectious disease surveillance

• Occurs through different means and at different levels (local, global)

• Tools needed to transform data into information
Situational awareness in infectious disease surveillance – LANL tools

- A suite of tools being developed to provide actionable information and knowledge for enhanced situational awareness during an unfolding event

A tool to validate/confirm disease surveillance information. Contains information on disease surveillance resources worldwide

A tool to rapidly select appropriate epidemiological models for infectious disease prediction, forecasting and monitoring

An app to provide context and a frame of reference for disease surveillance information through matching of user input to library of global historical disease outbreaks
The biosurveillance resource directory

- Relational database containing biosurveillance products and tools available worldwide (>350 records to date)
- Hosted through LANL research library (brd.lanl.gov)
- Based on framework that classifies and characterizes biosurveillance resources
- Searchable by multiple keywords (data streams, geographic location, disease, etc.)
- Provides access to resource website
- **Does not** house data per se, facilitates discovery and obtaining the right resources and data
- Anticipated users - analysts, public health officers, decision makers, national and local crisis planners and responders (military and civilian)
## BRD categories

<table>
<thead>
<tr>
<th>System Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supersystem</strong></td>
<td>GOARN</td>
</tr>
<tr>
<td></td>
<td>TESSy</td>
</tr>
<tr>
<td></td>
<td>SAGES</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>Biosentinel</td>
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<td></td>
<td>ASPREN</td>
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<td></td>
<td>ProMed</td>
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<td></td>
<td>Health Map</td>
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<tr>
<td><strong>Data Source</strong></td>
<td>Google News</td>
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<td></td>
<td>Gene Expression Omnibus</td>
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<tr>
<td></td>
<td>Crisis Mappers</td>
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<tr>
<td><strong>Tool / Software</strong></td>
<td>Essence</td>
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<tr>
<td></td>
<td>EARS</td>
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<td></td>
<td>First Watch</td>
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<tr>
<td><strong>Collective</strong></td>
<td>Mekong Basin Disease Surveillance</td>
</tr>
<tr>
<td></td>
<td>Wildlife Data Integration Network</td>
</tr>
</tbody>
</table>
Data stream categories used in active cataloged surveillance systems

1. Laboratory Records
2. Official Reports
3. Clinic/Health Care Provider
4. Personal Communication
5. ED/Hospital
6. Established Databases
7. News Aggregators
8. Help Lines
9. Social Media
10. Sales
11. Ambulance/EMT
12. Internet Search Queries
13. Employment/School
14. Prediction Markets
15. Police/Fire Dept
16. Financial Records

Number of Records

0 20 40 60 80 100 120
Results for: (disease:(cholera) AND resource:(system))

8 records sorted by relevance | year

Mark or Clear all on page
Mark records to export

1. Cholera and Other Vibrio Illness Surveillance System
   Centers for Disease Control and Prevention
   1988

2. Electronic Foodborne Outbreak Reporting System
   Centers for Disease Control and Prevention
   1998

3. National Outbreak Reporting System
   Environmental Protection Agency; Council of State and Territorial Epidemiologists;
   Centers for Disease Control and Prevention
   2009

4. State Electronic Notifiable Disease Surveillance System
   Georgia Department of Public Health
   2009

5. Quarantine Activity Reporting System
   Centers for Disease Control and Prevention
   2005

6. Syndrome Tracking and Encounter Management System
   New Hampshire Department of Health and Human Services
   20uu

7. Wisconsin Electronic Disease Surveillance System
   Wisconsin Department of Health Services
   20uu
Cholera and Other Vibrio Illness Surveillance System

**Acronym:** COVIS  
**Category:** System  
**Status:** Active  
**Scope:** The COVIS system is a national database of reported human illnesses caused by all Vibrio species. COVIS was initiated by CDC, FDA, and the Gulf Coast states (Alabama, Florida, Louisiana, Mississippi, and Texas) in 1988. CDC has maintained a database of Vibrio infections from humans in order to obtain reliable information on illnesses associated with Vibrio species.

**Sponsor(s):** Centers for Disease Control and Prevention (CDC)  
**Primary Sponsor Type:** Government  
**Population Domain:** Human  
**Disease Category:** Transmission ; Syndrome ; Transmission ; Diseases of Organizational Importance  
**Disease (Human):** Cholera ; Vibrio, non cholera  
**Geographical Domain:** United States  
**Geocoverage (States):** All States and Territories  
**Contact:** CDC ; Atlanta ; Georgia ; United States of America ; 30329-4018 ; 404.718.4560 ; bwk9@cdc.gov ; Contact: ; Ezra Barzilay ; MEDICAL EPIDEMIOLOGIST ; Contact Website : www.cdc.gov  
**Contact:** CDC ; Atlanta ; Georgia ; United States of America ; 30329-4018 ; 404.639.2839 ; ivz9@cdc.gov ; Contact: ; Anna Newton ; GUEST RESEARCHER/AREF ; Contact Website : www.cdc.gov  
**System Domain:** Human  
**Date First in Service:** 1988  
**Update Frequency:** Yearly  
**Accessibility:** Limited

**Datastream**

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub Category</th>
<th>Population</th>
<th>Type</th>
<th>Collection Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Records</td>
<td>Laboratory Results</td>
<td>Human</td>
<td>Diagnostic</td>
<td>Email</td>
<td></td>
</tr>
<tr>
<td>Official Records</td>
<td>Government</td>
<td>Human</td>
<td>Syndromic</td>
<td>Email</td>
<td></td>
</tr>
</tbody>
</table>

**Database:** BRD
Motivation for BARD development

Epidemiological models have utility in disease surveillance, however, choice of an appropriate model is difficult without information about:

- Scope of their use (e.g. operational status of such models, their purpose, input data needs, time to results, etc.)
- Features - the diversity of model types and the manner in which they are described (risk mapping, disease dynamics, statistical, anomaly detection, network, etc.)
The biosurveillance analytics resource directory

- Prototype - 75 models covering Malaria, Cholera, Influenza, Foot and Mouth disease, Dengue

- Provides specific information about an operational model that has been systematically categorized and highlighted

- Allows “apples to apples” comparison of multiple models if available for a single disease

- Provides links to specific models and updated and accurate contact information for a model facilitating its immediate use

- Is a model characterization tool - The framework could be applicable to any new models that may be included in the future and common characteristics and attributes of models would be cataloged
FRED (Framework for Reconstructing Epidemiological Dynamics) is an open source modeling system developed by the University of Pittsburgh Public Health Dynamics Laboratory. The system uses agent-based modeling based on census-based synthetic populations that capture the demographic and geographic distributions of the population, as well as detailed household, school, and workplace social networks. FRED supports research on the dynamics of infectious disease epidemics and the interaction effects of mitigation strategies, viral evolution, and.

FRED is available through open source in the hopes of making large-scale agent-based epidemic models more useful to the policy-making community, the research community, and as a teaching tool for students in public health.
The surveillance window concept

The duration of time within which information obtained can be used for early warning or early detection of a disease outbreak.
The surveillance window app

• Cross platform app based on the surveillance window concept

• Contextualizes incoming information during an infectious disease outbreak, supports decision making

• Places a frame of reference for where a case count is during an outbreak

• Determines whether the unfolding events are still within a surveillance window, and therefore feasible to control

• Suggests additional information sources that could support effective consequence management of an outbreak

• Increases the granularity of situational awareness
The surveillance window app - SWAP

Select a disease.

- Disease: Foot And Mouth Disease
- Location: 
- Animal identifier:
- Number of infected premises:
- Case count interval:
  - Weekly
  - Total
- Cattle density:
- Swine density:
- Date of first case report:
- Date of last case report:

Map

Surveillance Window App  Terminology  Data Streams  About

Surveillance Window App  Terminology  Data Streams  About

Surveillance Window App  Terminology  Data Streams  About

World Map

Disease
Location
Animal identifier
Number of infected premises
Case count interval
Cattle density
Swine density
Date of first case report
Date of last case report

Map by emCharts

3D map by emCharts

Back to continents map by emCharts

Angola
User input: Cholera

96% Cholera in Angola (2006)

Outbreak factors:
- The outbreak affected the entire country
- Many cases occurred in Luanda, where the population was concentrated in the capital
- The area was without sufficient quantities of water, proper drainage and rubbish collection
- This was the first outbreak in Angola in 9 years

SWAP output – display of closest matching historical outbreak with point estimate for user input

SWAP output - Similarity scores for outbreaks in SWAP library:
- 96% | Angola - 2006
- 73% | South Africa - 2000
- 69% | Democratic Republic of the Congo - 2011
- 68% | Republic of Congo - 2006
- 65% | Laos - 2007
- 64% | Cameroon - 2011
- 62% | Zambia - 2003
- 61% | Nigeria - 2010
- 59% | India - 2007
- 57% | Niger - 2012
- 57% | Cameroon - 2010
- 54% | Zambia - 2008
## References

## Suggested data streams

<table>
<thead>
<tr>
<th>Inside surveillance window</th>
<th>Outside surveillance window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory records</td>
<td>News aggregators</td>
</tr>
<tr>
<td>ED/Hospital records</td>
<td>Official reports</td>
</tr>
<tr>
<td>Clinic/health care provider records</td>
<td>Social media</td>
</tr>
</tbody>
</table>

## Scores

<table>
<thead>
<tr>
<th>Factor</th>
<th>Score</th>
<th>Weight</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case count</td>
<td>100</td>
<td>0.300</td>
<td>30</td>
</tr>
<tr>
<td>Time</td>
<td>100</td>
<td>0.300</td>
<td>30</td>
</tr>
<tr>
<td>Population at risk</td>
<td>80.5</td>
<td>0.200</td>
<td>16.1</td>
</tr>
<tr>
<td>Disease status</td>
<td>100</td>
<td>0.130</td>
<td>13</td>
</tr>
<tr>
<td>Location</td>
<td>100</td>
<td>0.070</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>96.1</strong></td>
</tr>
</tbody>
</table>
LANL decision support tools - the challenges

- Sustainability of tools and resources
  - Updated and expanded content – automated data mining tools
  - Curated content – interactive content management, engaging all stakeholders
- Maintaining utility - outreach and tool refinement
Decision support tools will be offered through LANL’s Biosurveillance (BSV) gateway (bsv.lanl.gov) coming soon
- Knowing the resources available
- Matching resources to need
- Identifying gaps in resources
- Developing support tools
- Building collaborations
- Fostering innovation

Surveillance Window App (SWAP) An app to provide context and a frame of reference for disease surveillance information.

Biosurveillance Resource Directory (BRD) A tool to validate/confirm disease surveillance information.

Biosurveillance Analytics Resource Directory (BARD) A tool to rapidly select appropriate epidemiological models.
Take home message

- LANL is developing new decision support tools for infectious disease surveillance - focus on information analysis and integration

- Tools will be accessible to global disease surveillance community through the LANL BSV gateway
LANL team

- Mr. Esteban Abeyta
- Ms. Lauren Castro
- Ms. Ashlynn Daughton
- Mr. Eric Generous
- Mr. Geoffrey Fairchild
- Dr. Kristen Margevicius
- Dr. Reid Priedhorsky
- Dr. Kirsten Taylor-McCabe
- Dr. Alina Deshpande
Thank you!

“Be the best you can be every day, for cholera beckons always.”

-James Madison
Extra Slides
**Biosurveillance**

**Process:** The process of gathering, integrating, interpreting, and communicating.

**Knowledge:** Essential information related to all-hazards threats or disease activity affecting human, animal, or plant health.

**Purpose:** To achieve early detection and warning, contribute to overall situational awareness of the health aspects of an incident, and to enable better decision making at all levels.

**National Strategy for Biosurveillance, 2012**

### GOALS

- **Early Warning of Health Threats**
  Surveillance that enables the identification of potential threats, including emerging and re-emerging diseases, that may be undefined or unexpected.

- **Early Detection of Health Events**
  Surveillance that enables identification of disease outbreaks (either natural or intentional in origin), or events that have occurred, before they become significant.

- **Situational Awareness**
  Surveillance that monitors the location, magnitude and spread of an outbreak or event once it has occurred.

- **Consequence Management**
  Surveillance that assesses impacts and informs response to an outbreak or an event.

### Baseline Awareness

Information that can inform and facilitate the achievement of the above surveillance goals and can be related to population demographics and health, the natural, social, and built environment and underlying disease patterns and characteristics.

### DATA STREAM FRAMEWORK

#### DATA STREAM CONTEXT

- **Disease, Population, Type**
  - Infectious Disease(s) of Interest
  - Human Animal Plant Pathogen Pest

- **Diagnostic**
  Data that leads to identification of a pathogen, or confirmed diagnosis of disease

- **Syndromic**
  Health-related data that may precede or substitute for formal diagnosis

- **Environmental**
  Non-health related data associated with the social, natural, and/or built environment

#### DATA STREAM CATEGORIES

- **Ambulance / EMT Records**
  - Clinic/Health Care Provider Records
  - ED/Hospital Records
  - Employment/School Records
  - Established Databases
  - Financial Records
  - Help Lines
  - Internet Search Queries
  - Laboratory Records
  - News Aggregators
  - Official Reports
  - Police/Fire Department Records
  - Personal Communication
  - Prediction Markets
  - Sales
  - Social Media

#### DATA STREAM DETAILS

- **Algorithms**
  - Collection Method
  - Data Accuracy
  - Data Processing Before Analysis
  - Data Quality
  - Data Reporting
  - Data Security
  - Data Structure
  - Data Transmission
  - Geospatial Characteristics
  - Metadata Collected
  - Population Characteristics
  - Stakeholders
  - ...
### Model Objective

- **Early Warning of Health Threats**
- **Early Detection of Health Events**
- **Situational Awareness**
- **Consequence Management**

### Model Scope

- **Baseline Awareness**
- **Risk Mapping**
  - Risk factor analysis displayed spatially or spatio-temporally
- **Anomaly Detection**
  - Alerts over thresholds: “Finding patterns in data that do not conform to expected behavior”

### Disease Dynamics

- Disease Transmission Model (States/Compartment)
  - Equation-Based
  - Simulation
  - Network Structure

### Auxiliary Models

- Economic, Financial, Risk Analysis, CBA, Airborne transmission, ...

### Conceptual Model

- **Model Tools**
  - Computational, Machine learning, Regression, Statistical ...
- **Tool Purpose**
  - Model Fit, Model Validation, Parameter Estimation, Time series Analysis, Threshold Detection...

### Model Inputs

- Host Population, Disease, Vector/Reservoir
- Environment (natural, social, built), Control Efforts

### Model Outputs

- Model Assembly: single, multiple, complex, modular, hybrid, ...

### Assumptions and Limitations

### Model Utility

- Data
  - Data sources required
  - Availability of data sets
  - Data is spatially referenced
  - Accuracy and completeness of data
  - Documentation

- Verification Validation
  - Model verified for purpose built
  - Sensitivity analysis of parameters
  - Uncertainty (input, output)
  - Comparison with other models
  - Comparison with real system
  - Model independently tested
  - Documentation

- Operations
  - Model and developer team accessibility
  - Funding support
  - Model used for decision support
  - Extensibility, model adaptation time
  - Source code / software availability
  - Hardware platform, OS
  - Computational time
  - Cost to implement, documentation
Situational awareness in infectious disease surveillance – pandemic potential

OUTBREAK
Deadliest Pandemics in History

What is a Pandemic?
Derived from the Greek word "pandemos" meaning "pertaining to all people," a pandemic is a widespread disease that affects humans over a wide geographic area.

Key:
- PANDEMIC YEAR
- DEATH TOLL

HIV / AIDS
1981 - TODAY
25+ million

PLAGUE of JUSTINIAN
543 - 560

25 million

MEASLES
7th Century BC - 1963
200 million

SMALLPOX
3,000 BC - 1979
300+ million

BLACK DEATH
1348 - 1351
75 million

SPANISH FLU
1918 - 1920
50-100 million

TYPHUS
14th Century - TODAY
4 million

CHOLERA
1852 - TODAY
3 million

HONG KONG FLU
1968 - 1969
1 million

HONORABLE MENTIONS

MALARIA
1500 - Today
Common Symptoms:
Chills, Nightmares, Fever, Jaundice, Muscle Pain, Nausea, Vomiting, Seizures

Death Toll:
According to the World Health Organization's 2020 report, an estimated 750,000 people are killed by the disease every year.

TUBERCULOSIS
700 BC - Today
Common Symptoms:
Chest Pain, Cough, Fever, Chills, Fatigue

Death Toll:
There are almost 2 million tuberculosis-related deaths worldwide every year.

YELLOW FEVER
19th Century - Today
Common Symptoms:
Bleeding, Fever, Nausea, Vomiting, Delirium, Seizures, Jaundice

Death Toll:
Worldwide, 30,000 deaths are caused by the infection every year.

Legend:
The Black Death plague inspired the children's rhyme "Ring Around the Rosie," which alluded to the rash-like rings and ashes of the deceased victim.

Sources:

A COLLABORATION BETWEEN GOOD AND COLUMN FIVE
The surveillance window concept

Influenza: La Gloria, Mexico, 2009 Data available vs utilized