

SANDIA REPORT

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Final Documentation: Incident Management And Probabilities Courses of action Tool (IMPACT)

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Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Abstract

This report pulls together the documentation produced for the IMPACT tool, a software-based decision support tool that provides situational awareness, incident characterization, and guidance on public health and environmental response strategies for an unfolding bio-terrorism incident.

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1. INTRODUCTION

This report pulls together the final documentation produced on the Incident Management Probabilities And Courses of action Tool (IMPACT) developed for the Department of Defense/ Defense Threat Reduction Agency's Integrated Early Warning-Homeland Integrated Biological Response and Information Demonstration, building on the work done under the Transatlantic Collaborative Biological Resiliency Demonstration (TaCBRD). The contents include:

- IMPACT Brochure
- IMPACT White Paper
- IMPACT Concept
- Threat Probability to Action Tool (TPAT): Quick Reference Cards
- Threat Probability to Action Tool (TPAT): User Manual and Report
- Temporal Inverse Model (TIM)
- Cluster Model
- Products
- Tuning of Anomaly Detectors

2. IMPACT BROCHURE

Incident Management Probabilities And Courses of action Tool (IMPACT)

A software-based decision support tool that provides situational awareness, incident characterization, and guidance on public health and environmental response strategies for an unfolding bio-terrorism incident.

SCENARIO:

- Wide-area aerosol release of weaponized *Bacillus anthracis* spores in an urban area (civilian and military targets)
- Covert attack presents as influenza-like illness amid much uncertainty
- Decision-makers want to detect the incident early, project the evolution, and implement early, effective response options



TOOL OBJECTIVE:
IMPACT provides earlier warning, situational awareness, incident characterization, and response options guidance, allowing earlier intervention that prevents exposures and saves lives.

APPROACH: IMPACT applies decision-theoretic & epidemic models to integrate disparate datastreams, infer incident characteristics, and generate interim response and intervention guidance for an unfolding biological incident.

Incident Guidance Intervention Mission

Incident Characterization Evaluator

Incident Information

Id: Anthrax Related Activity Location: US
 Created: 4/1/2006 Starts: 4/1/2006 Ends: 9/8/2006
 Current: 09/02/2006 View Length (days): 129 Status: Active

Incident Meter Tracker Summary CDR

Attack Likelihood View
 Projected Consequences View
 Influenza-like illness View
 Disease 1 View
 Disease 2 View
 Disease 3 View
 Disease 4 View
 Disease 5 View

Incident Data Streams and Characterization

Stream	View	Characterization
911 Calls	☐	☐
Social Media	☐	☐
OTC Drug Sales	☐	☐
Medical Prescriptions	☐	☐
Fire, Smoke & Dust Data	☐	☐
Particle Detectors	☐	☒
Biowatch Collector	☐	☐

Incident Guidance Intervention Mission

Guidance Generator

Threat Data Gathering

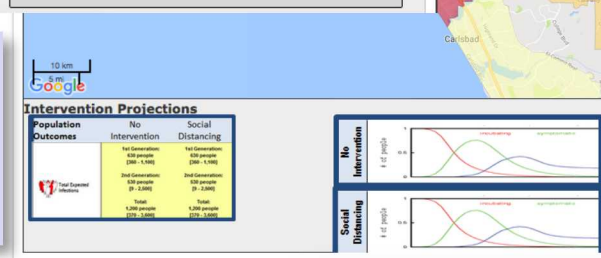
Measure	View	Map
Increase Collector Sampling Frequency	☐	☐
Add Collectors	☐	☐
Request Confirmatory Analysis	☐	☐
Conduct Environmental Sampling	☐	☒
Conduct Vector Surveillance	☐	☐
Run Cluster Model	☐	☐
Run Temporal Inverse Model	☐	☐

Interim Response Measures

Status	Response Measure	Actions	Map
☒	Alert Public Information Office	☐	☐
☒	Evaluate Base Security Level	☐	☐
☒	Notify Biowatch Action Committee	☐	☐
☒	Notify Command	☐	☐
☒	Engage Military Planning Cell	☐	☐
☒	Initiate Interagency Communication	☐	☐
☒	Restrict Area	☐	☐

Outputs include estimates and confidence bounds for incident characteristics, interim guidance & response measures, maps of projected affected areas, epidemic projection & response recommendations.

Input data sources may include intelligence/law enforcement, bio-surveillance data, over-the-counter drug sales, social media, environmental detection, etc.



Incident Guidance Intervention Mission

Intervention Calculator

Model Information and Settings

Model Run: Anthrax Related Activity #1
 Incident: Anthrax Related Activity
 Date: 09/03/2006 Status: Run
 Data Source: Particle Sensor - Env Samples
 Infectivity (%): 50
 Median Incubation Period (days): 7
 Sigma (variability in incubation period): 2
 Vaccination Day (from attack): 4
 Reproductive Rate: 5
 Intervention Measures:

Intervention Measures Display

Intervention Measure	Display	Clear
Shelter in Place	☐	☐
Administer Prophylaxis	☐	☐
Vaccination	☐	☐
Social Distancing	☒	☐
Quarantine	☐	☐
Evacuation	☐	☐

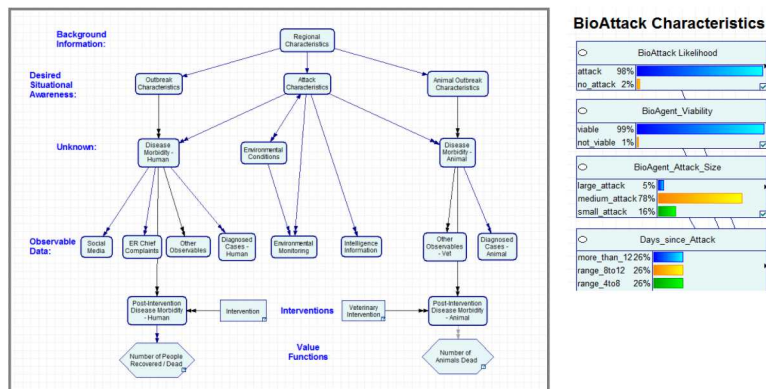
Point of Contact: Donna Edwards, (925) 294-2253, edwards@sandia.gov
 Project Sponsor: U. S. Department of Defense Threat Reduction Agency & The Department of Homeland Security

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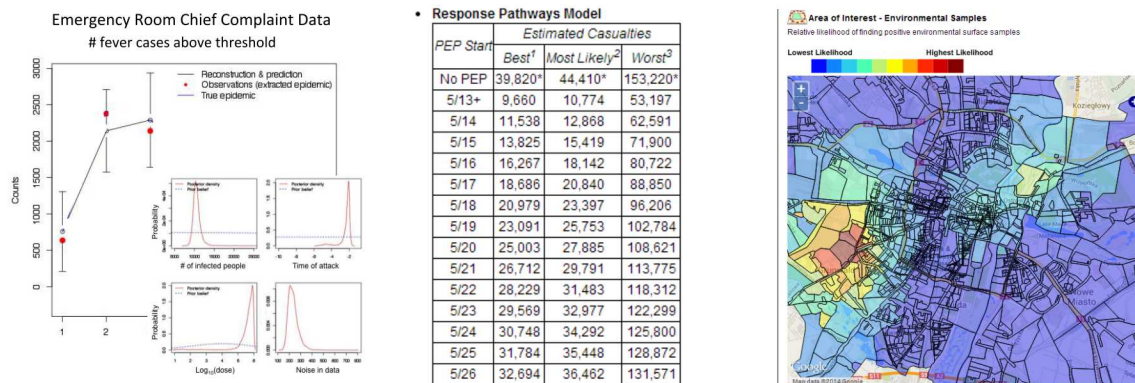
IMPACT applies decision-theoretic & epidemic models to integrate disparate datastreams, infer incident characteristics, and generate interim response and intervention guidance for an unfolding biological incident,

Three components of the tool are under development:

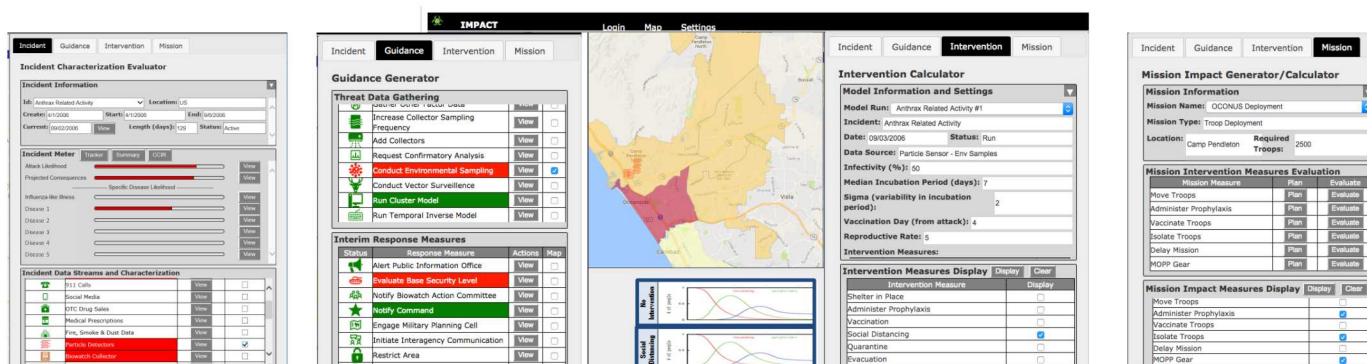
The **Bayesian Belief Network** monitors disparate observable datastreams to provide situational awareness around attack and/or outbreak characteristics and to recommend additional data gathering:



The **Disease Models** project the evolution of the epidemic in the population, calculate the impacts of various interventions, and provide geospatial correlation.



The **User Interface** organizes the information into Incident, Guidance, Intervention, and (military) Mission panels.



3. IMPACT WHITE PAPER

Incident Management Probabilities and Courses of Action Tool (IMPACT)

In an unfolding bio-incident, IMPACT will organize and present bioterrorism and public health knowledge to provide situational awareness, event characterization, response options, and response guidance to civilian and military responders. The objective of this tool is to support better response decisions that reduce downstream consequences of a bio-incident for public health, wide-area restoration, and military operations. IMPACT will use decision science approaches and mathematical models to help responders select appropriate public health interventions, environmental response strategies, and military courses of action (COAs), based on a set of indicators that have been pre-characterized in terms of their uncertainty and the value of information that they provide. IMPACT will also help responders determine additional indicators that should be sought in order to improve confidence levels. IMPACT includes Temporal Anomaly Detection on the incoming data feeds and presents four modules/views of an unfolding bio-incident: Incident Characterization Evaluator, Guidance Generator, Interventions Calculator, and Mission Impact Calculator. These components are described below.

IMPACT Data Feeds and Temporal Anomaly Detection

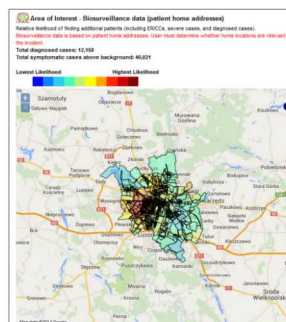
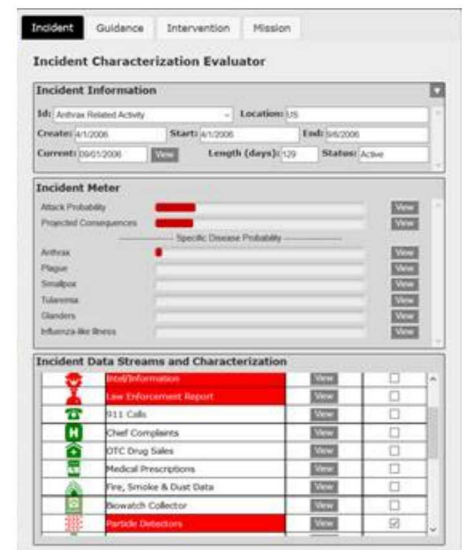
IMPACT ingests and tracks data streams that could provide early indication of an unfolding bio-incident, issuing an alarm upon detection of a statistically significant anomaly. Data streams include:

- Emergency room chief complaints (Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE))
- Diagnosed Cases of Bioterror Diseases (HL-7 Message alerts) (ESSENCE)
- Environmental sensor data, including BioWatch and TACBIO detectors
- Environmental sampling results (Tactical Dynamic Operational Guided Sampling (TacDOGS) tool)
- Intelligence data streams
- Syndromic surveillance data, including over-the-counter drug sales, absenteeism and veterinary data

Chief complaints data are processed through two time-series anomaly detectors (Cumulative SUM and Exponentially Weighted Moving Average) that detect the existence of a sudden rise in people showing symptoms of a bioattack. The detectors are configured for low false alarm rates rather than early detection. An alarm generated by an anomaly detector prompts an incident characterization.

Incident Characterization Evaluator

The Incident Characterization Evaluator provides an Incident Meter, which indicates the relative likelihood that a bio-incident is underway, the relative likelihood of different bio-agents (anthrax, smallpox, etc.) or natural diseases (influenza-like illness), and the relative severity level of the incident (i.e., level of concern warranted). These meter results are generated using a Bayesian Belief Network, which encodes subject matter expertise on

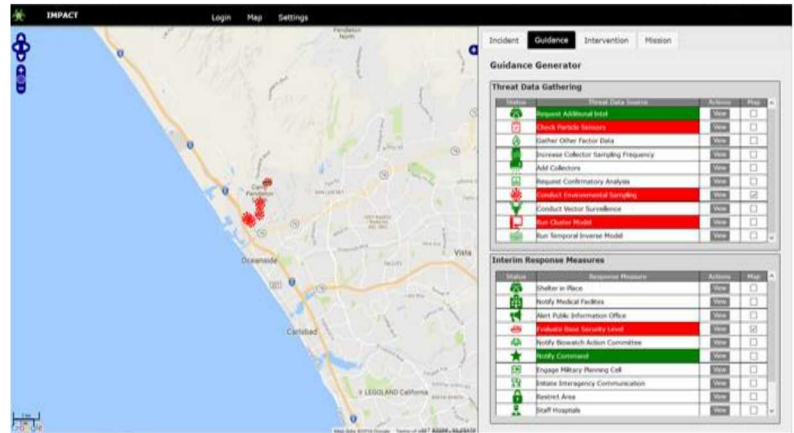



the relative weightings of the different early warning data feeds. The Evaluator includes:

- Geo-spatial cluster model: provides map layers, one for each chief complaint data stream and each environmental data stream, with statistically likely locations for additional positive results
- Epidemic Inference and Prediction Model: infers the date, average dose, and expected number of infections over time (after 3-4 days of chief complaint data is available).

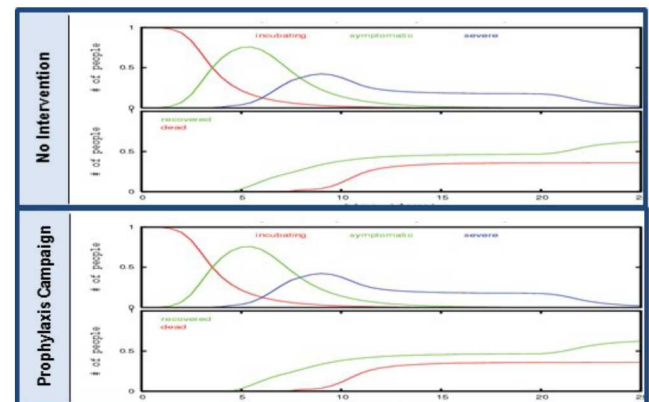
Guidance Generator

The Guidance Generator receives characterization data from the Incident Characterization Evaluator, and produces guidance including: where to gather additional data, alerts of upcoming decisions, interim response actions and required follow-on steps. This module uses encoded subject matter expert data that correlates data indicators with lower impact actions.



Interventions Calculator

The Interventions Calculator uses the inference results of the Epidemic Inference and Prediction Model (attack date and average dose) and the Response Pathways Model to predict the effects of different public health interventions (prophylaxis campaign, social distancing, vaccination status) on population outcomes.



Mission Impact Calculator

The Mission Impact Calculator takes in the projected population impacts and military mission data (e.g., # mission-critical personnel for different missions), in order to calculate mission impacts from both the bio-incident effects on population and the interventions under consideration. This allows the military planner or analyst to evaluate trade-offs between different courses of action. These calculations are made using military planning data and military planner subject matter expertise.

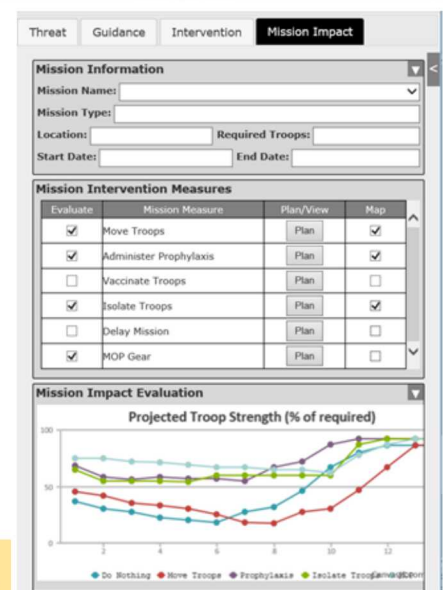
Point of contact For IMPACT:

Donna Edwards, Sandia National Laboratories, edwards@sandia.gov

Point of Contact for IEW Program Technology:

Don Macfarlane, ECBC, donald.w.macfarlane.civ@mail.mil

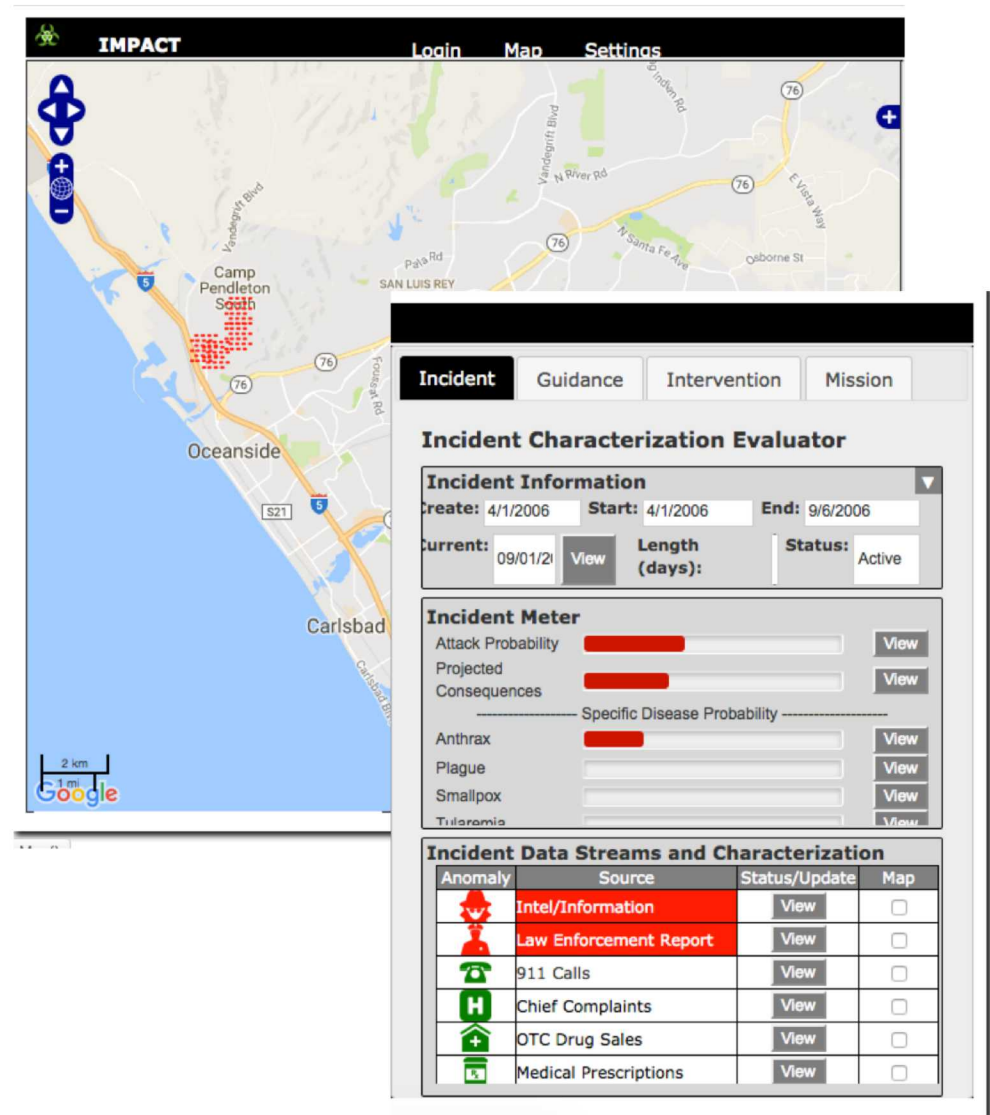
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4. IMPACT CONCEPT

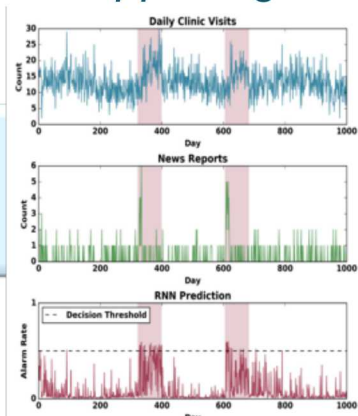
Incident Management Probabilities and COAs Tool (IMPACT)

- Integration of disparate information streams
 - Intel
 - Force Protection
 - Emergency Management
 - Public Health Data
- To provide
 - earlier warning
 - situational awareness
 - event characterization
 - response options
 - response guidance



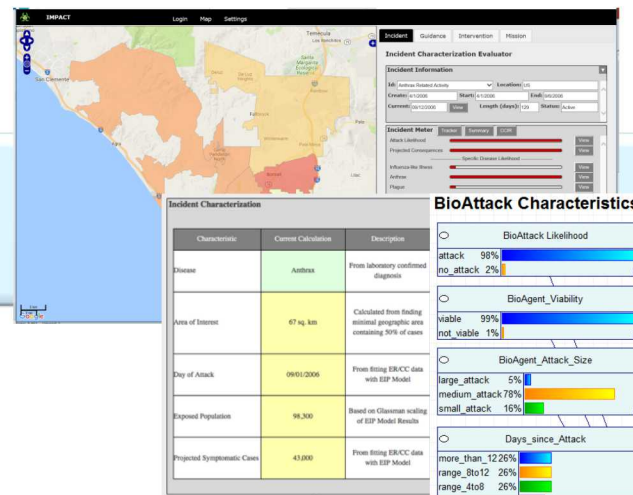
- ## Data Monitoring

Is something happening?



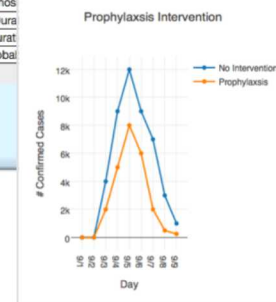
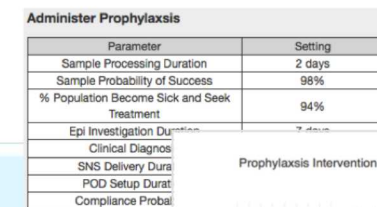
Incident Characterization

What is the incident?



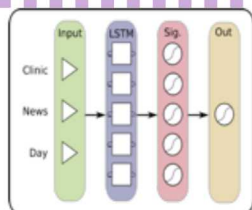
Interventions

What should we do?



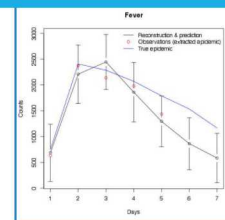
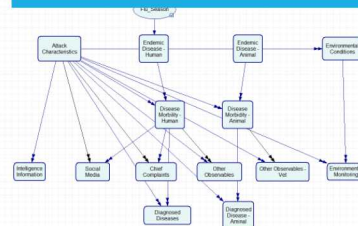
Anomaly Detectors

- Statistical
- Deep Learning
Neural Net



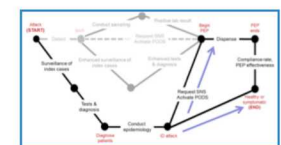
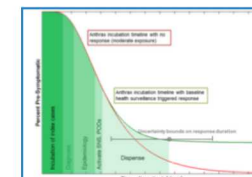
Mathematical Models

- Bayesian Belief Network
- Data fusion & assimilation
- Disease projection



Response Evaluation

- Interim response measures & data gathering
- Interventions
- Impact on military mission

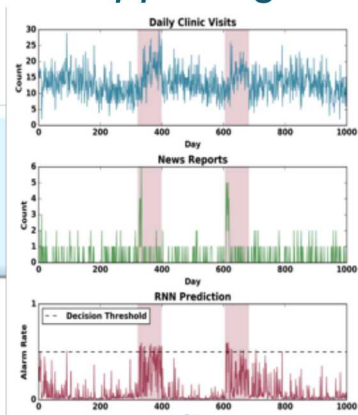


IMPACT Status

- User Interface – built in IEW

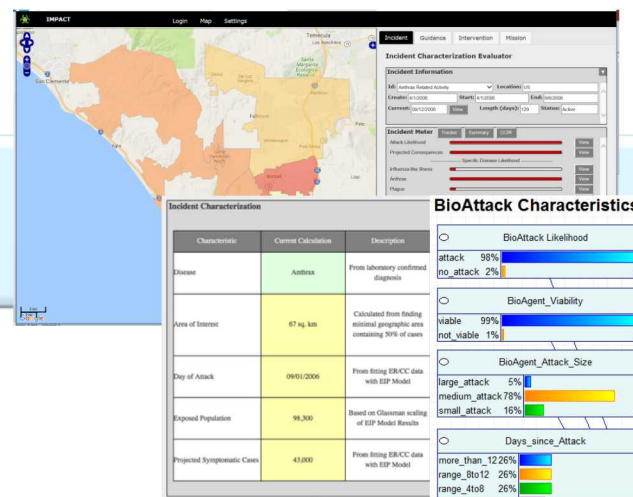
Data Monitoring

Is something happening?



Incident Characterization

What is the incident?

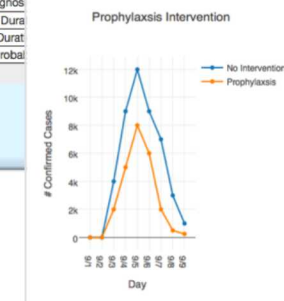


Interventions

What should we do?

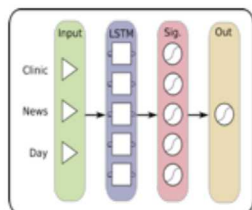
Administer Prophylaxis

Parameter	Setting
Sample Processing Duration	2 days
Sample Probability of Success	98%
% Population Become Sick and Seek Treatment	94%
Epi Investigation Duration	7 days
Clinical Diagnosis	
SNS Delivery Duration	
POD Setup Duration	
Compliance Probability	



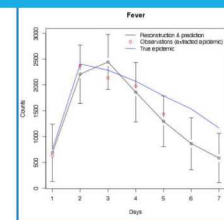
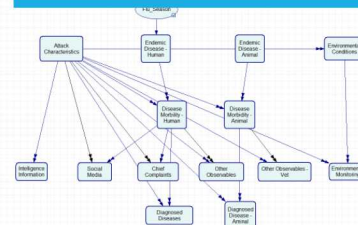
Anomaly Detectors

- Statistical
- Deep Learning Neural Net



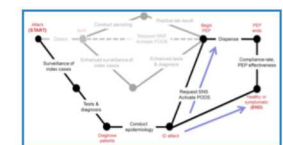
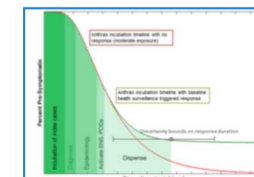
Mathematical Models

- Bayesian Belief Network
- Data fusion & assimilation
- Disease projection



Response Evaluation

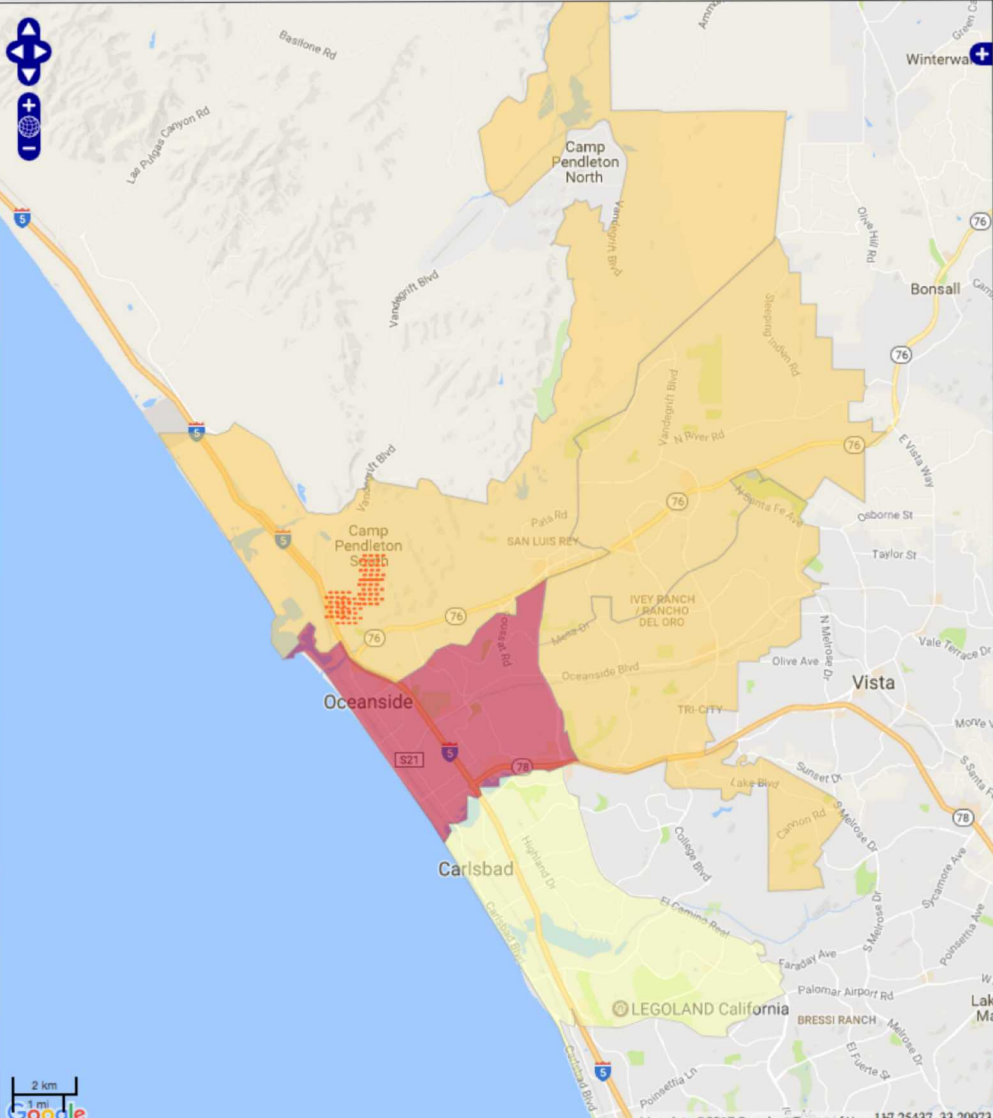
- Interim response measures & data gathering
- Interventions
- Impact on military mission



IMPACT:

Incident Characterization Generator/Calculator

IMPACT Login Map Settings



Incident Guidance Intervention Mission

Incident Characterization Evaluator

Incident Information

Id: Anthrax Related Activity Location: US

Create: 4/1/2006 Start: 4/1/2006 End: 9/6/2006

Current: 09/02/2006 View Length (days): 129 Status: Active

Incident Meter Tracker Summary CCIR

Attack Likelihood View

Projected Consequences View

----- Specific Disease Likelihood -----

Influenza-like Illness View

Anthrax View

Plague View

Smallpox View

Tularemia View

Glanders View

Incident Data Streams and Characterization

	Chief Complaints	View	☐
	Military Sick Call	View	☐
	Absenteeism	View	☐
	Animal Vectors	View	☐
	Clinical Diagnosis	View	☐
	Fatalities	View	☐
	Hospital/Medical Facilities	View	☐
	Cluster Model	View/Map	Remove
	EIP Model	View	☐
	Agent Characteristics	View	☐

Map data ©2017 Google Terms of Use 187 25437 33 20023

IMPACT:

Interim Guidance Generator

IMPACT Login Map Settings

Guidance Generator

Incident Data Gathering

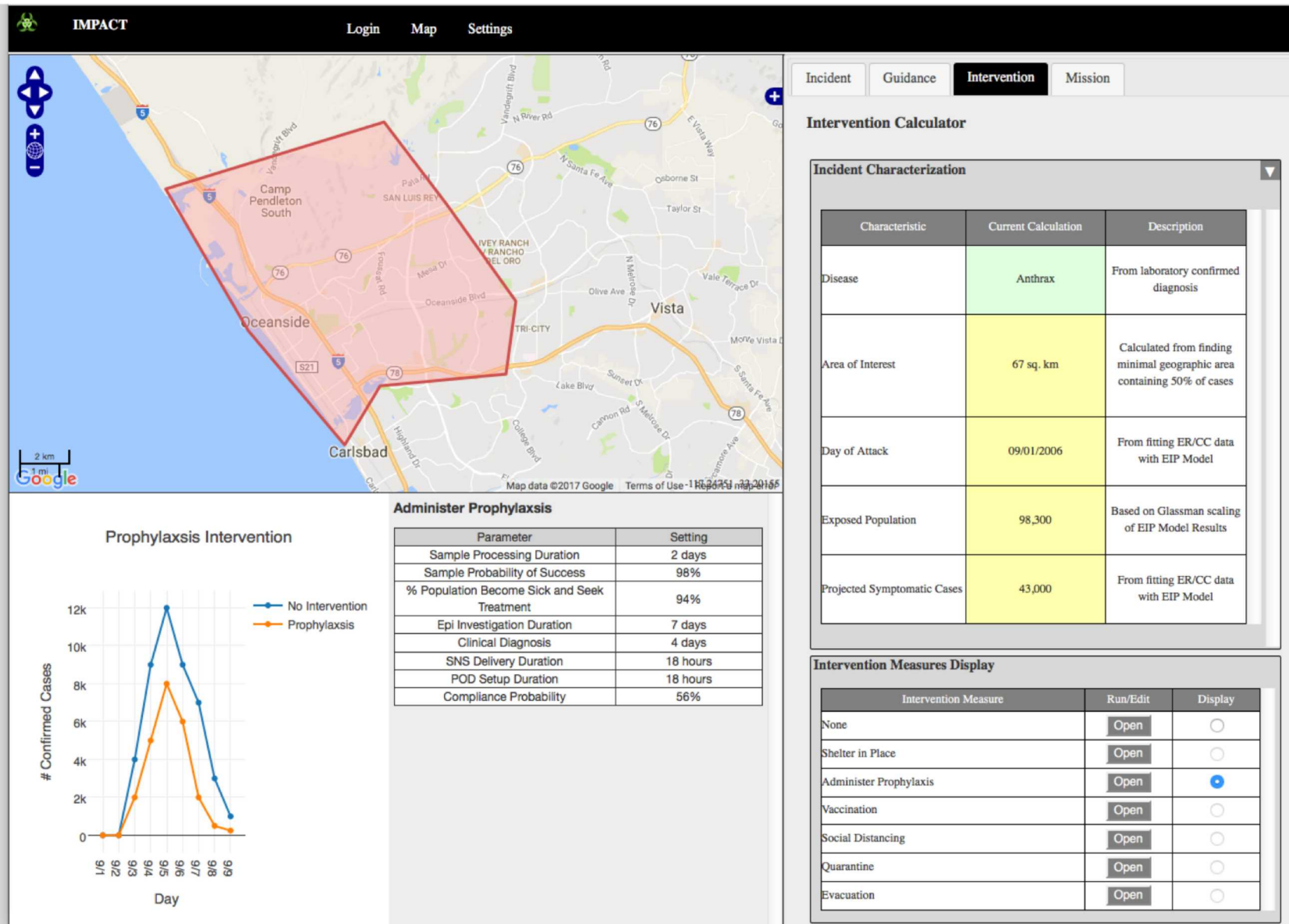
Status	Incident Data Source	Actions	Map
	Request Additional Intel	View	☐
	Check Particle Sensors	View	☐
	Gather Other Factor Data	View	☐
	Increase Collector Sampling Frequency	View	☐
	Add Collectors	View	☐
	Request Confirmatory Analysis	View	☐
	Conduct Environmental Sampling	View	☒
	Conduct Vector Surveillance	View	☐
	Run Cluster Model	View	☐
	Run EIP Model	View	☐

Interim Response Measures (low regret)

Status	Response Measure	Actions	Map
	Alert Public Information Office	View	☐
	Evaluate Base Security Level	View	☐
	Notify Biowatch Action Committee	View	☐
	Notify Command	View	☐
	Engage Military Planning Cell	View	☐
	Initiate Interagency Communication	View	☐
	Restrict Area	View	☐
	Staff Hospitals	View	☐
	Review Prophylaxis Readiness	View	☐
	Review Force Immunization Status	View	☐
	Activate Civilian EOC	View	☐
	Activate Military EOC	View	☐

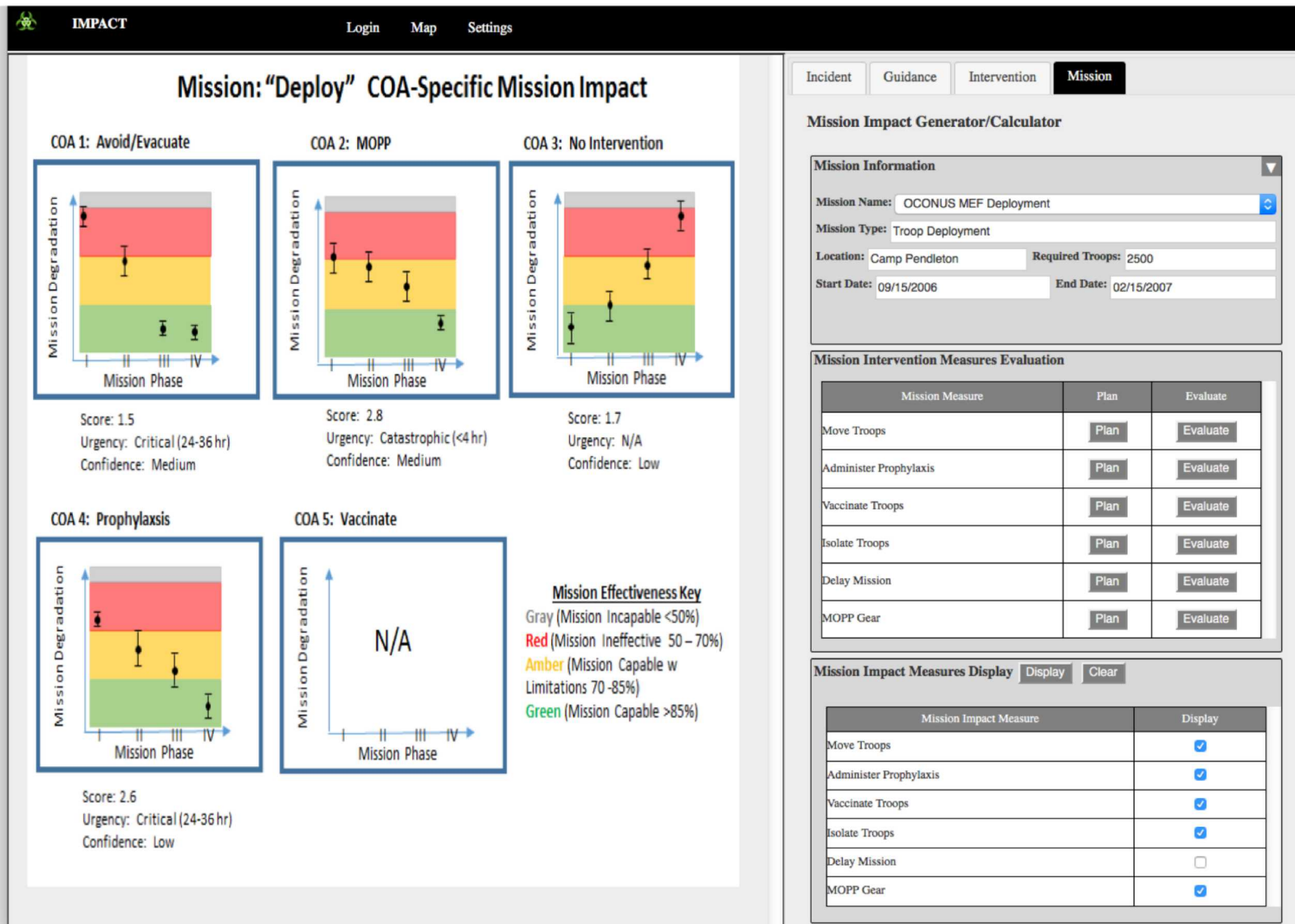
IMPACT:

Intervention Calculator



IMPACT:

Mission Impact Calculator

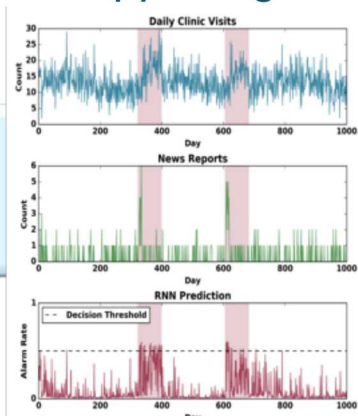


IMPACT Status

- User Interface – built in IEW
- Underlying math & modeling tools – built in TacBRD + IEW

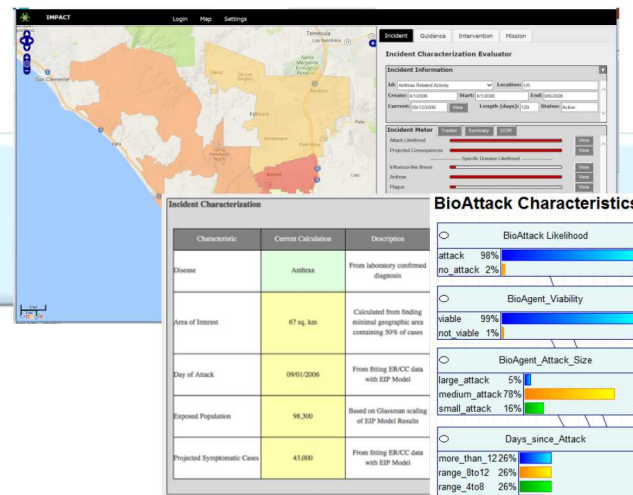
Data Monitoring

Is something happening?



Incident Characterization

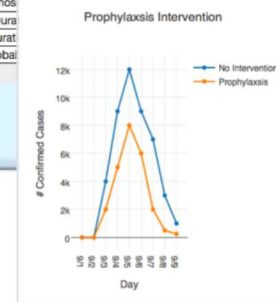
What is the incident?



Interventions

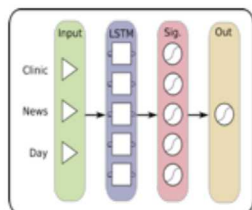
What should we do?

Administer Prophylaxis	
Parameter	Setting
Sample Processing Duration	2 days
Sample Probability of Success	98%
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Compliance Probability	



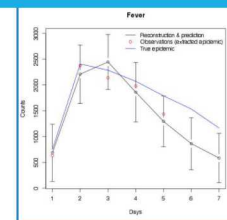
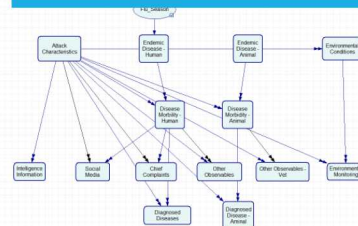
Anomaly Detectors

- Statistical
- Deep Learning Neural Net



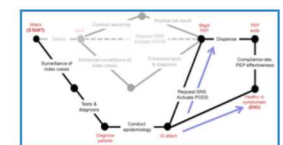
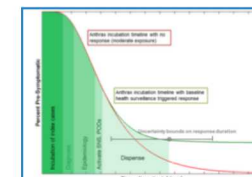
Mathematical Models

- Bayesian Belief Network
- Data fusion & assimilation
- Disease projection



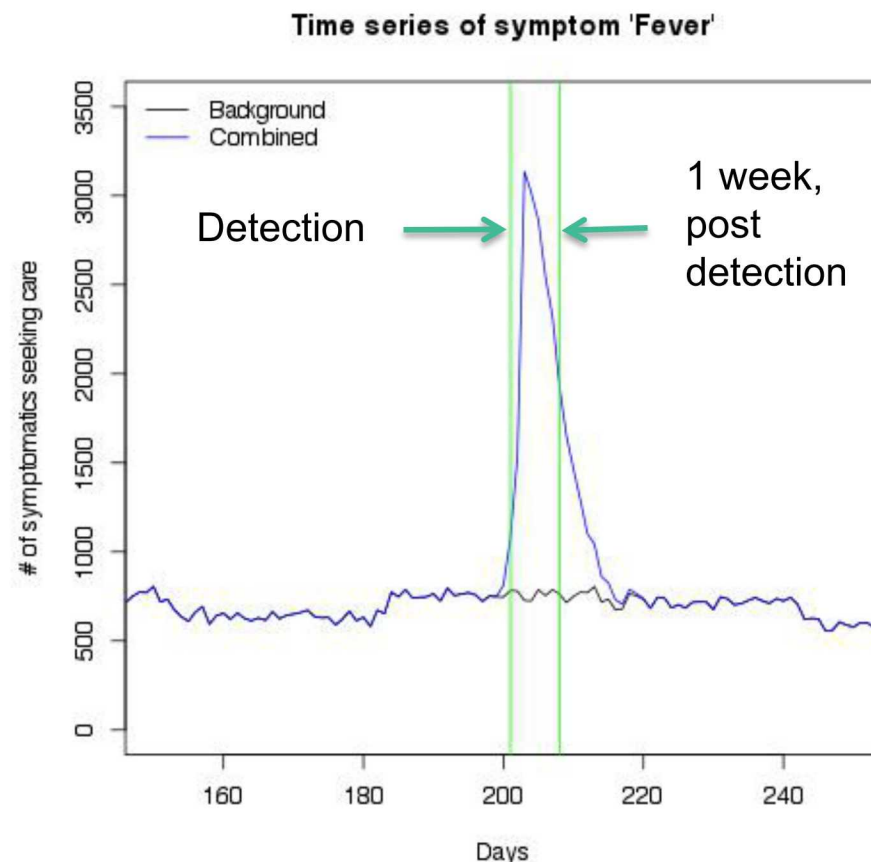
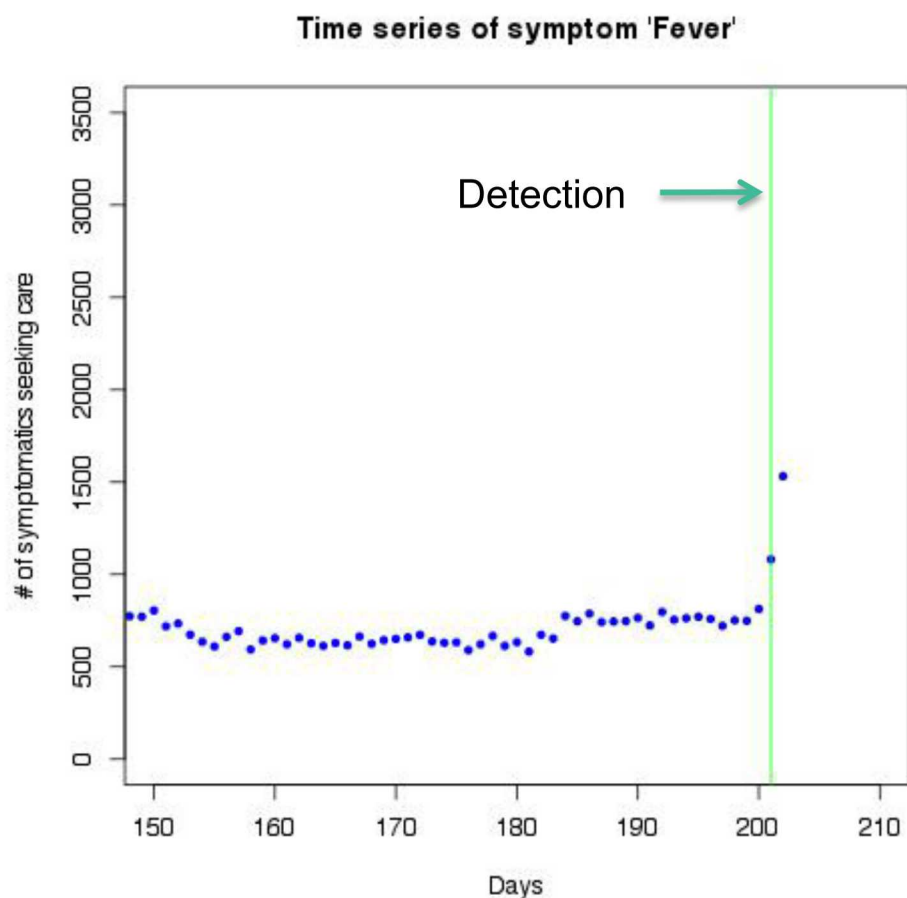
Response Evaluation

- Interim response measures & data gathering
- Interventions
- Impact on military mission



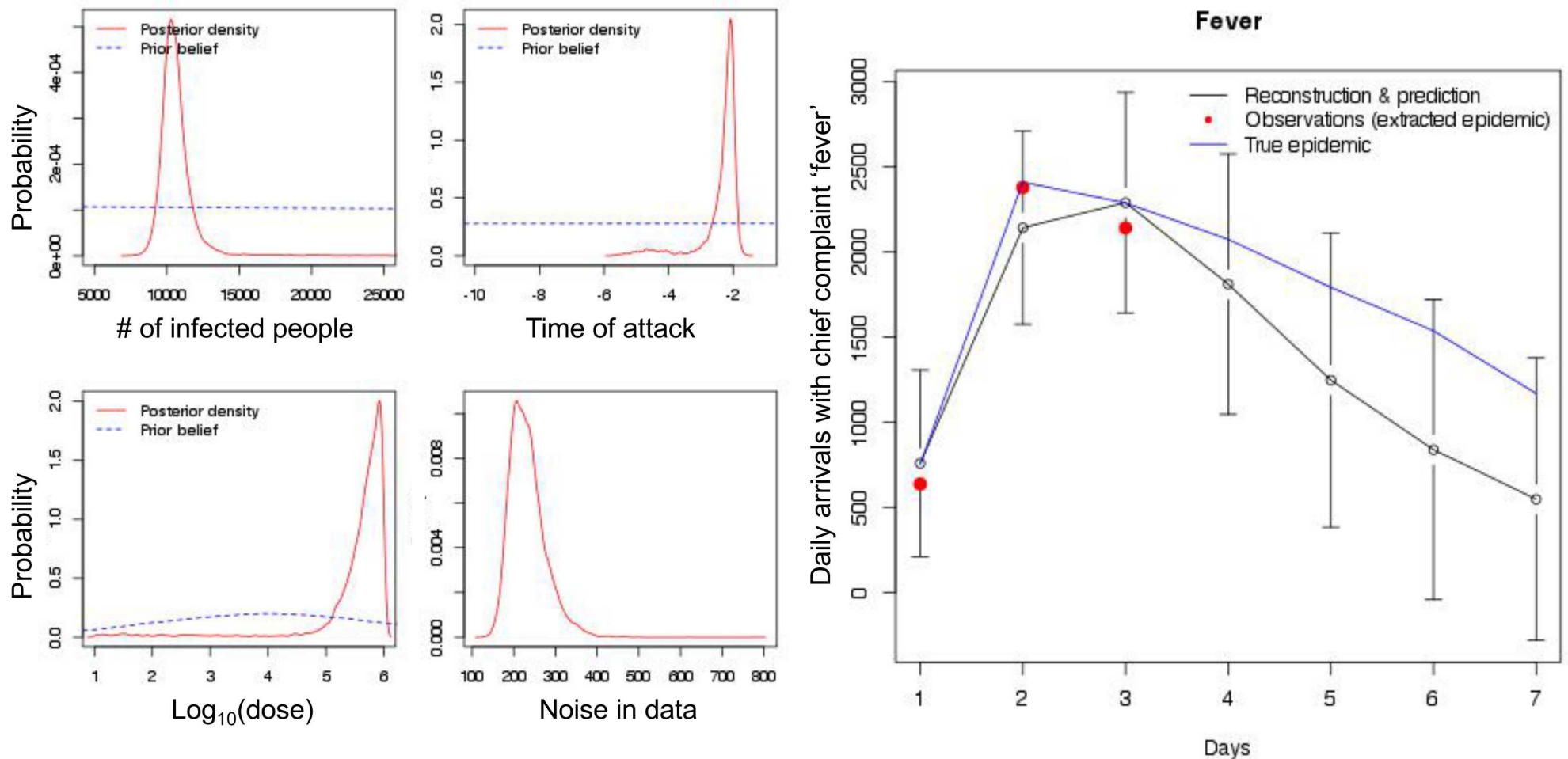
Early data and its statistical analysis

- Syndromic detection of an attack occurs 1-3 days, post-attack / post-release
 - Anomaly detection in the time-series of Emergency Room (ER) chief complaints



- Post-detection, relevant questions are:
 - How big an attack? Which areas affected? How will it evolve?
- Bayesian inference can answer these question with 2-4 days of data

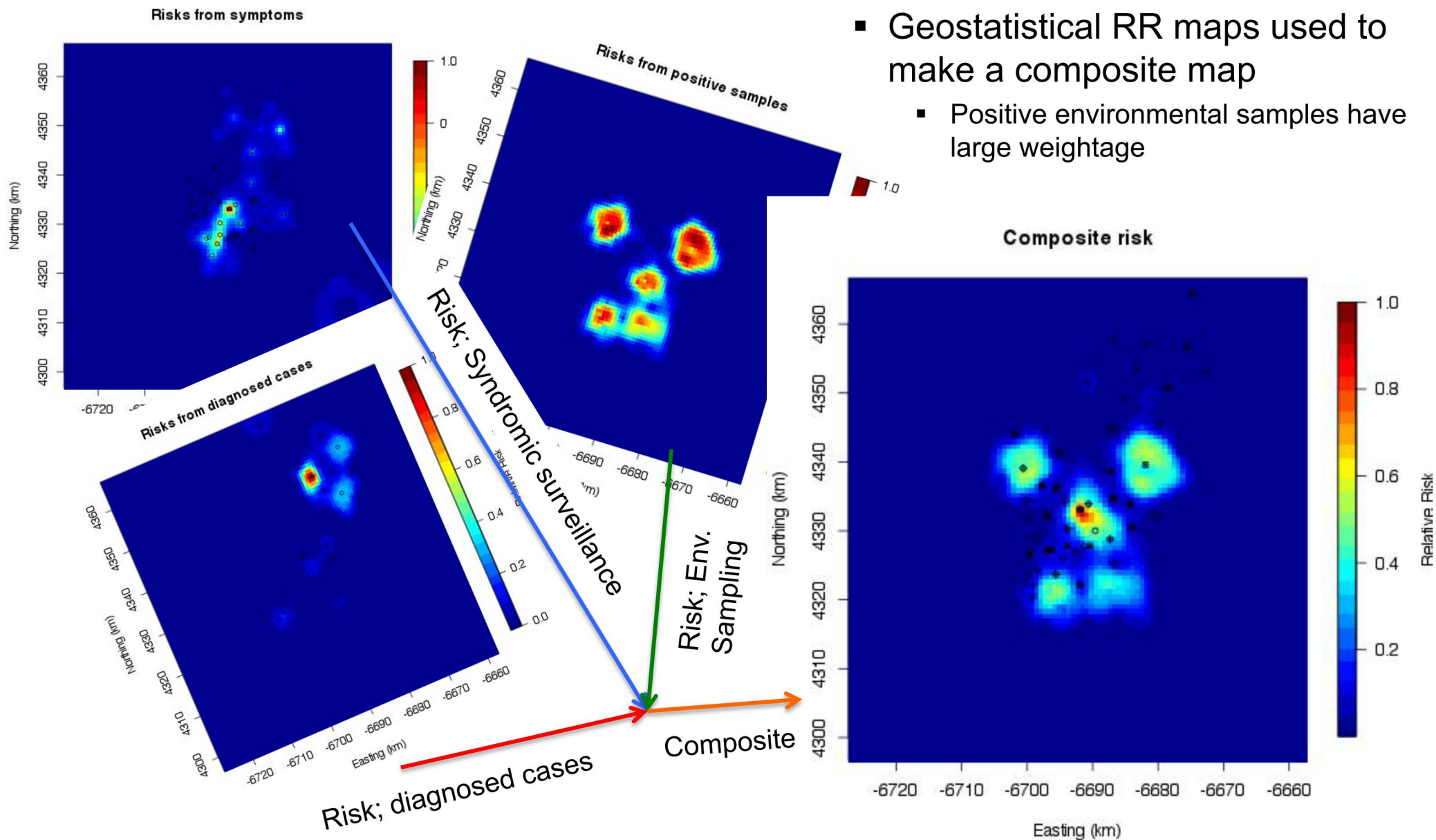
Inference & forecasting with 3 days of data



- Extracted epidemic not too bad; under-estimating the attack (~12,000 v/s 15,000); day of attack = -2 is OK
- Prediction is not too good – but within $\pm 2\sigma$ bounds

Compositing relative risk maps

- Geostatistical RR maps used to make a composite map
 - Positive environmental samples have large weightage

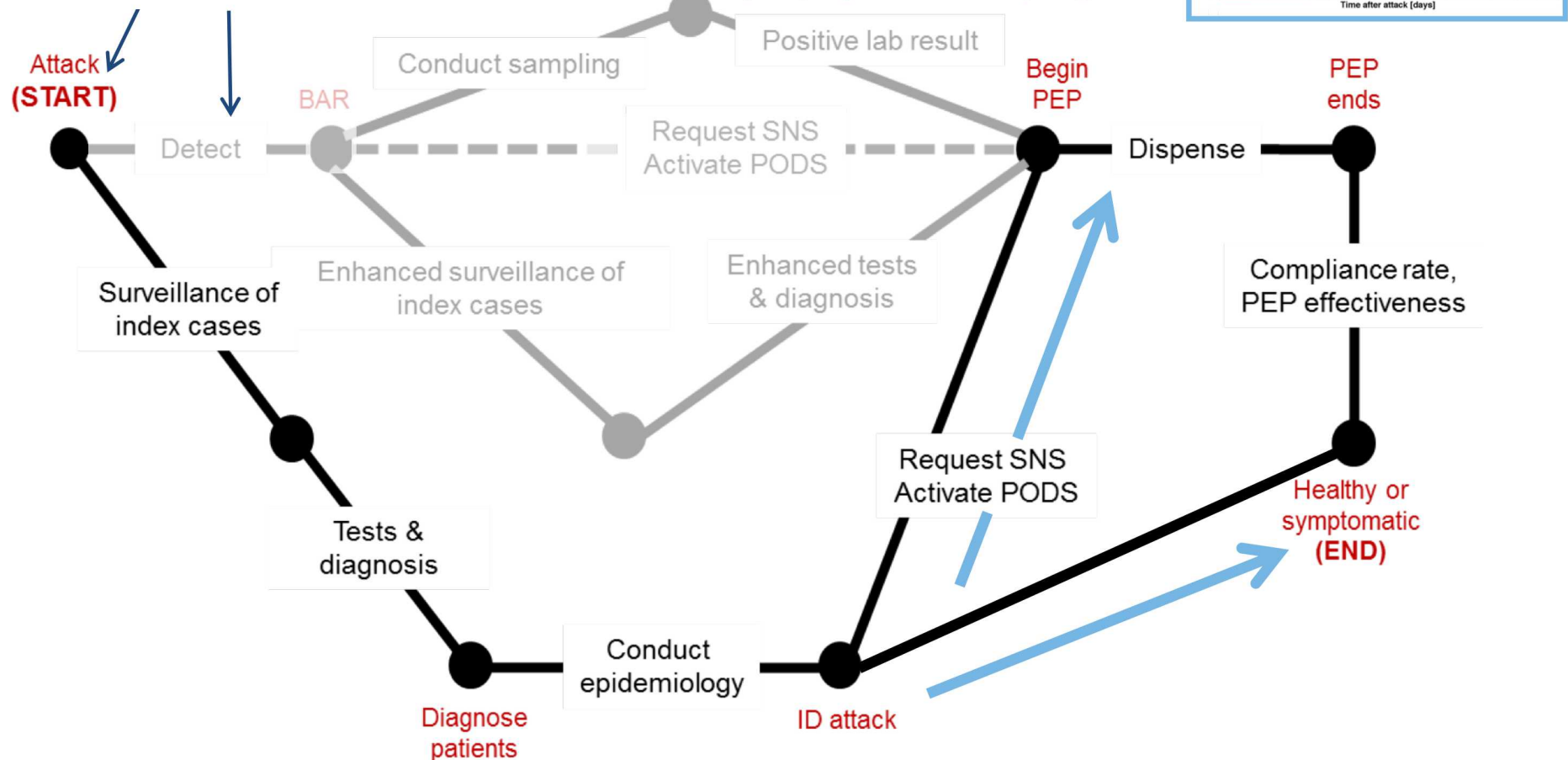


Threat Probability to Action Tool (TPAT)

Response Evaluation – Cost/Benefit Evaluation

Sandia's Response Pathways Model evaluates the cost, duration, and benefit of various response decisions.

- Each point is a decision
- Each line is an activity of uncertain duration, cost & benefit
- Comparison of branches determines value of prophylaxis campaign

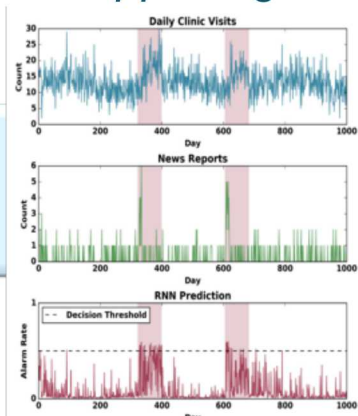


IMPACT Status

- User Interface – built in IEW
- Underlying math & modeling tools – built in TacBRD + IEW
- Bayesian Belief Network – v 1.0 built in IEW

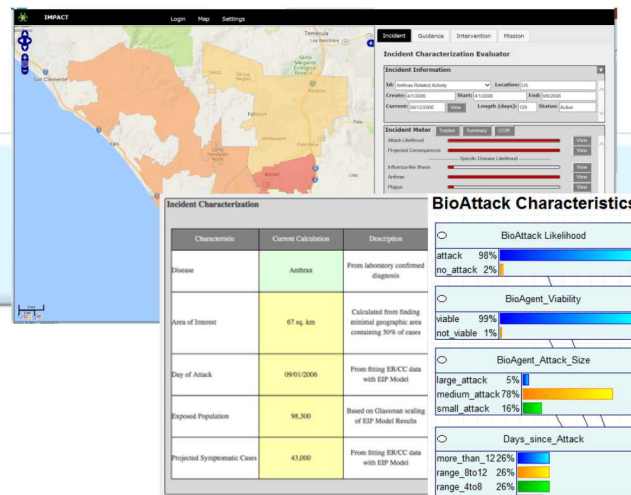
Data Monitoring

Is something happening?



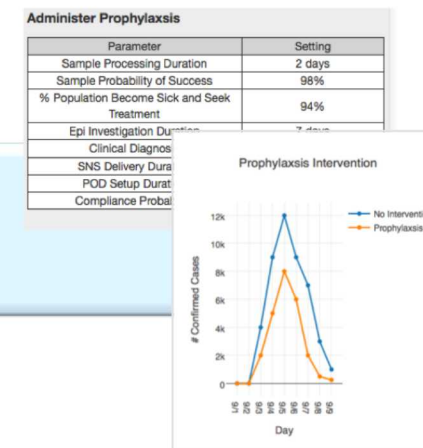
Incident Characterization

What is the incident?



Interventions

What should we do?



Anomaly Detectors

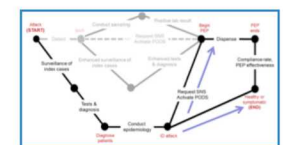
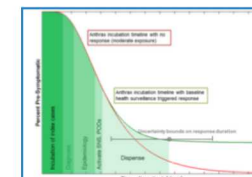
- Statistical
- Deep Learning Neural Net

Mathematical Models

- Bayesian Belief Network
- Data fusion & assimilation
- Disease projection

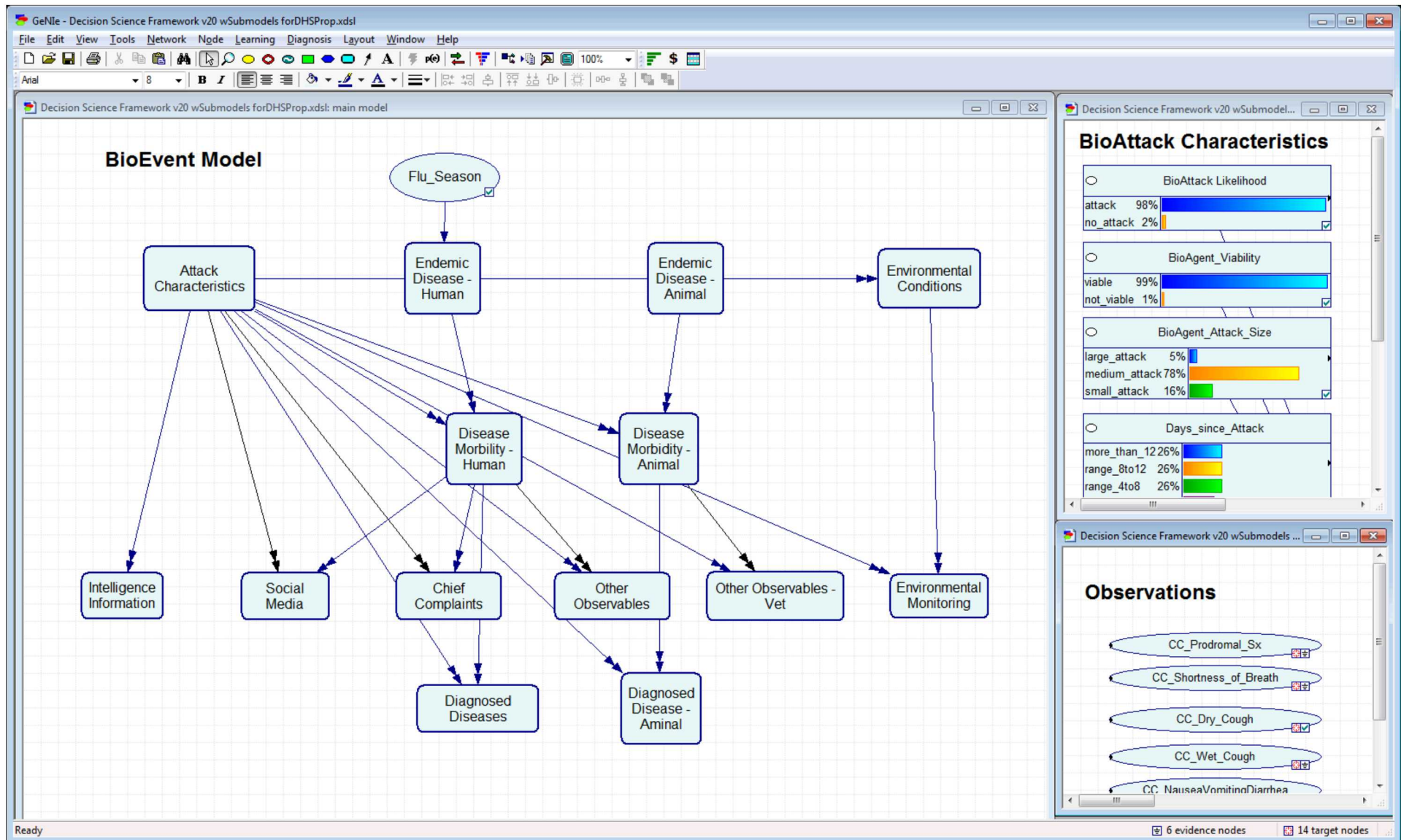
Response Evaluation

- Interim response measures & data gathering
- Interventions
- Impact on military mission



IMPACT:

Incident Characterization Generator/Calculator

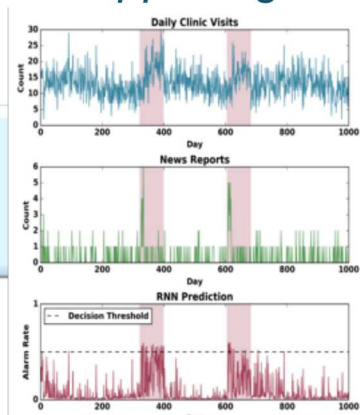


IMPACT Status

- User Interface – built in IEW
- Underlying math & modeling tools – built in TacBRD + IEW
- Bayesian Belief Network – v 1.0 built in IEW
- Deep Learning Neural Net – proposed to DHS S&T

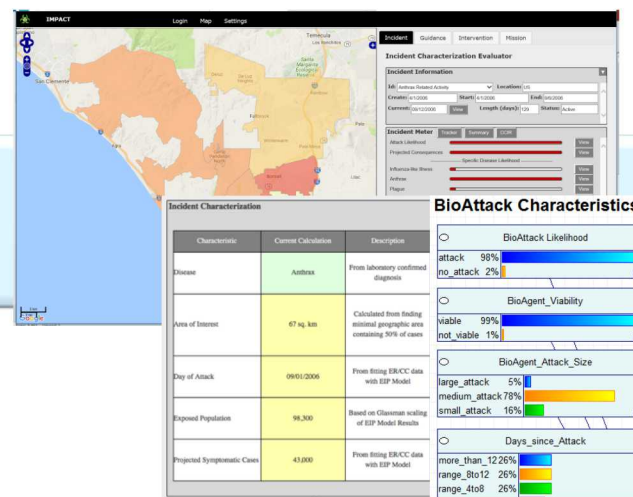
Data Monitoring

Is something happening?



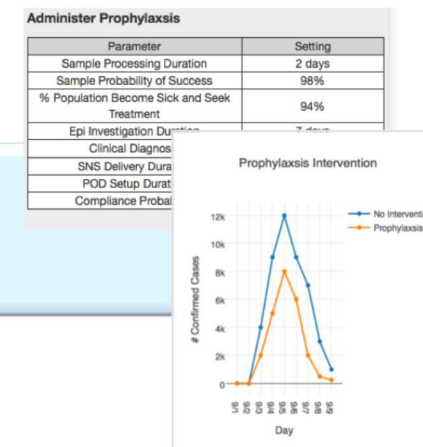
Incident Characterization

What is the incident?



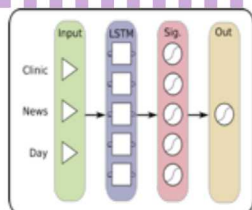
Interventions

What should we do?



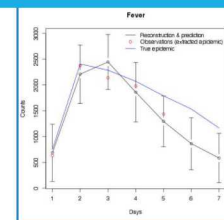
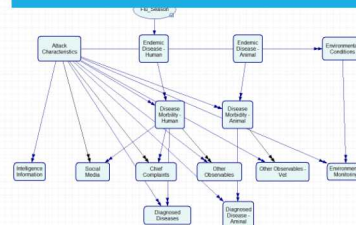
Anomaly Detectors

- Statistical
- Deep Learning Neural Net



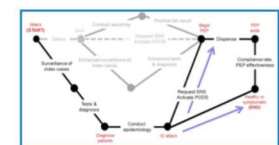
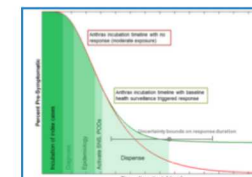
Mathematical Models

- Bayesian Belief Network
- Data fusion & assimilation
- Disease projection



Response Evaluation

- Interim response measures & data gathering
- Interventions
- Impact on military mission



**5. THREAT PROBABILITY TO ACTION TOOL (TPAT) QUICK
REFERENCE CARDS**

Quick Reference Card

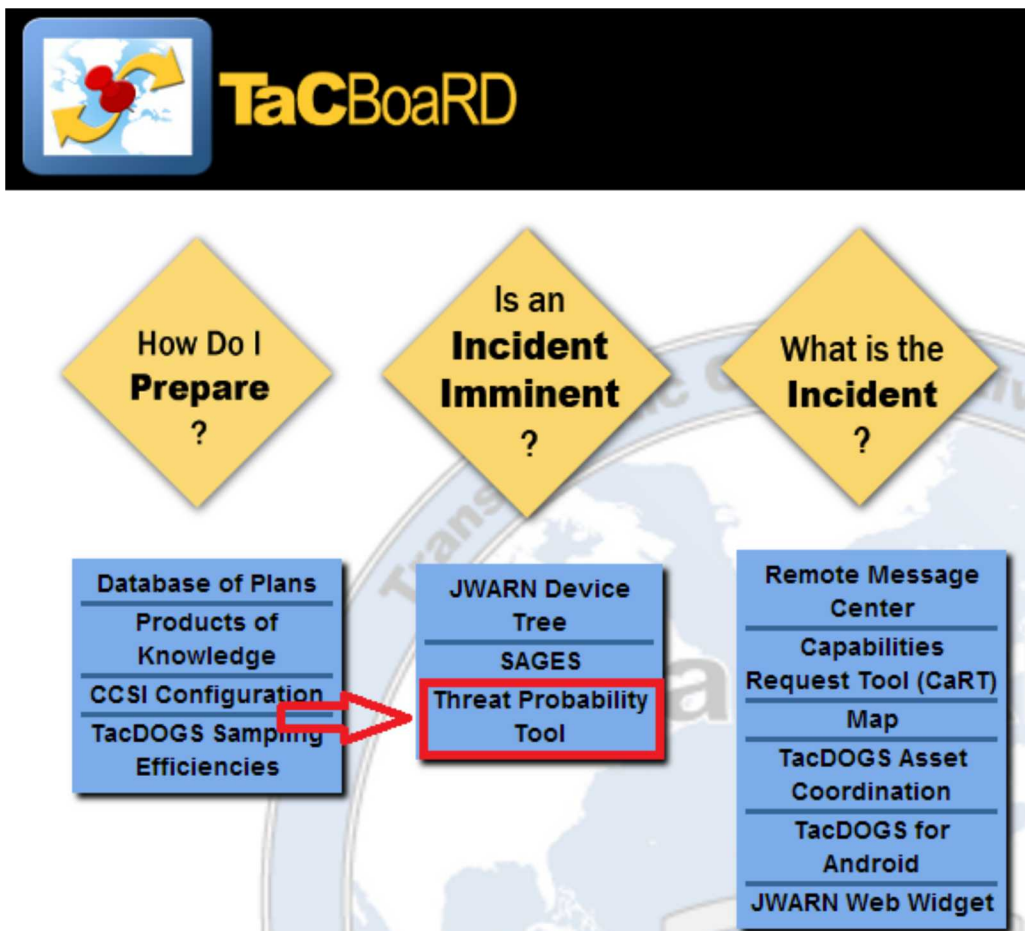
Threat Probability to Action Tool (TPAT) is a decision support tool that organizes and presents bioterrorism and public health knowledge to provide situational awareness, incident characterization, response options, and response guidance in order to help responders select the most appropriate public health and environmental response strategies for the unfolding bioterrorism incident.

TPAT consists of four tabs of information:

- Data Streams
- Incident Characterization
- Response
- Analysis-Characterization

TPAT also outputs layers on the TaCBoaRD Map

Launching TPAT



After logging into the TaCBoaRD, TPAT can be launched from the “Is an Incident Imminent?” section.

Data Feeds Tab

Data Feeds	Characterization	Response	Analysis - Characterization
Date/Time	Enabled	Source	Value
☐ Environmental Sampling	☒ *		
☐ 1/8/2014	☒ *	TacDOGS	(0/10) samples positive for Anthrax
☐ 1/6/2014	☒ *	TacDOGS	(300/305) samples positive for Anthrax
☐ ER/CC ●	☒ *		
☐ 3/5/2014 ●	☒ *	SAGES	Fever over threshold in 20008
☐ 3/4/2014	☒ *	SAGES	Fever over threshold in 20008
21:00	☒ *	SAGES	3/4/2014, +50 Fever Zip Codes: 20008
☐ 1/7/2014	☐	SAGES	Symptoms over threshold in multiple locations
☐ HL7	☐		
☐ OTC	☐		
☐ Other	☐		

Enable Selected Data

Disable Selected Data

● Newly received data

* Enabled/disabled data is not yet included in current TPAT results

Times are in GMT-0500 (Eastern Standard Time)

The Data Feeds tab shows every data feed that enters TPAT. The table displays the received data feeds in a tree. At the root of the tree are the data feed types:

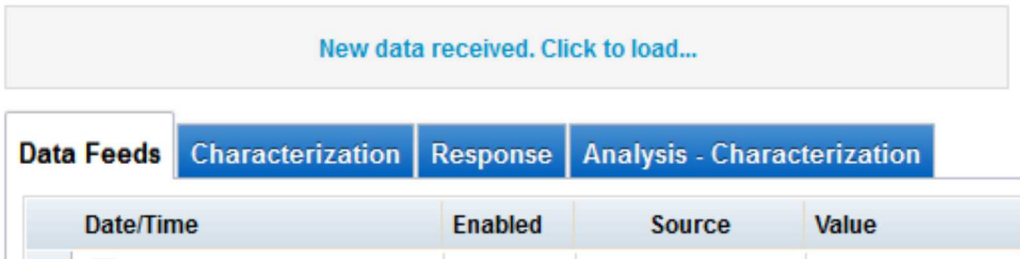
- **Environmental Sampling:** environmental surface samples received from TacDOGS
- **ER/CC:** emergency room/chief complaint alerts received from SAGES
- **HL7:** HL7 positive diagnosed cases received from SAGES
- **OTC:** over-the-counter drug sale alerts received from SAGES
- **Twitter:** Twitter alerts received from SAGES
- **Other:** manual alerts received from SAGES

To view alerts of a certain type, expand the corresponding row by pressing the ☐ button. Rows can be collapsed by pressing the ☐ button. At the 2nd level, each data feed is rolled up by day. To see all data feeds from a certain day, expand the row for that day. The Value column provides a summary of the data.

Quick Reference Card

Data Feeds Tab
Receiving New Data

When TPAT receives new data, the following status message will appear to the user:



Clicking on the message will cause the Data Feeds tab to refresh, and the new latest data will appear in the table. Newly received data is indicated by a blue dot.

Data Feeds	Characterization	Response	Analysis - Characterization
Date/Time	Enabled	Source	Value
☐ Environmental Sampling	☒ *		
☐ 1/8/2014	☒ *	TacDOGS	(0/10) samples positive for Anthrax
☐ 1/6/2014	☒ *	TacDOGS	(300/305) samples positive for Anthrax
☐ ER/CC	☒ *		
☐ 3/5/2014	☒ *	SAGES	Fever over threshold in 20008
☐ 3/4/2014	☒ *	SAGES	Fever over threshold in 20008
21:00	☒ *	SAGES	3/4/2014, +50 Fever Zip Codes: 20008
☐ 1/7/2014	☐	SAGES	Symptoms over threshold in multiple locations
☐ HL7	☐		
☐ OTC	☐		
☐ Other	☐		

Enable Selected Data Disable Selected Data

● Newly received data

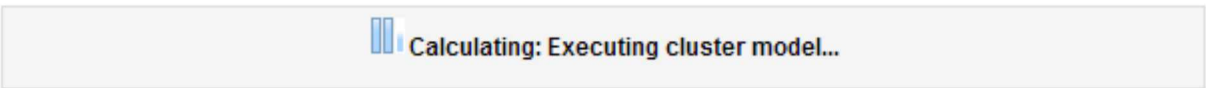
* Enabled/disabled data is not yet included in current TPAT results

Times are in GMT-0500 (Eastern Standard Time)

Quick Reference Card

TPAT Calculations

When TPAT is in the process of recalculating, a status message will appear indicating the current stage of calculation:

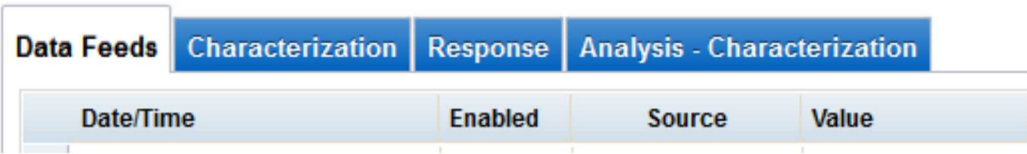
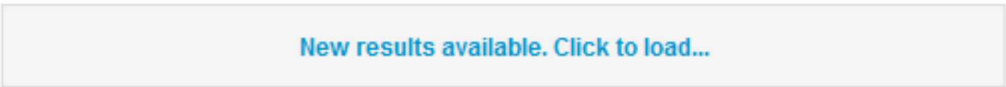


When TPAT receives new data, the user can trigger an immediate recalculation by clicking on the “recalculate” message that appears:



Otherwise TPAT will automatically recalculate results after the current calculation has finished.

When the calculations are complete, the following message will appear:



Clicking on the message will cause TPAT to refresh and latest results to be loaded which can be viewed in the Incident Characterization, Response, and Analysis-Characterization tabs.

Data Feeds Tab

Enabling/Disabling Data

Data Feeds
Characterization
Response
Analysis - Characterization

Date/Time	Enabled	Source	Value
☐ Environmental Sampling	☒ *		
☐ 1/8/2014	☒ *	TacDOGS	(0/10) samples positive for Anthrax
☐ 1/6/2014	☒ *	TacDOGS	(300/305) samples positive for Anthrax
☐ ER/CC	☒ *		
☐ 3/5/2014	☒ *	SAGES	Fever over threshold in 20008
☐ 3/4/2014	☒ *	SAGES	Fever over threshold in 20008
21:00	☒ *	SAGES	3/4/2014, +50 Fever Zip Codes: 20008
☐ 1/7/2014	☐	SAGES	Symptoms over threshold in multiple locations
☐ HL7	☐		
☐ OTC	☐		
☐ Other	☐		

Enable Selected Data
Disable Selected Data

● Newly received data

* Enabled/disabled data is not yet included in current TPAT results

Times are in GMT-0500 (Eastern Standard Time)

The Enabled column contains a checkbox which tells the user whether or not the data feed should be included in the TPAT result calculations. The user can determine whether or not to include data by toggling the checkbox for a certain row, or selecting the desired data and pressing Enable Selected Data or Disable Selected Data. All child alerts will be enabled/disabled as well. After toggling the checkbox, a * will appear besides the checkbox which indicates that the change has not yet been included in the current TPAT calculations. The user will also see the below “recalculate” message:

Current TPAT results are out-of-date. Click to recalculate...

Clicking on the message will cause TPAT to recalculate its results and include/exclude data depending on their enabled state.

Incident Characterization Tab

Incident Characteristic	Best Answer So Far	Notes
 Disease	Anthrax	From laboratory-confirmed diagnoses.
 Area of Interest	View area of interest based on: ☒ Environmental Samples ☐ Biosurveillance data (patient home addresses) ☐ Composite (use with caution)	Calculated by finding the minimal geographic area that contains 90% of cases and includes the zone with the highest number of cases.
 Day of Attack	5/10/2014 [5/9/2014 - 5/11/2014]	From fitting of observed ER/CC data with epidemic projection model. Number displayed is the most likely value, with 95% confidence that the value falls in the predicted range.
 Exposed Population	34,850 people [25,740 - 45,220] (estimated range for lower bound)	Total number of people who received any level of exposure to the agent in the environment, including levels of exposure too small to be infectious. For contagious disease, does not include secondary infections. Number based on Glassman scaling of epidemic projection model results. Number displayed is the most likely lower bound value, with 95% confidence that the lower bound falls in the predicted range.
 Projected # Symptomatic Cases	30,860 people [22,730 - 38,780] See graph	Total number of people who will become symptomatic over the course of the epidemic without intervention. From fitting of observed ER/CC data with epidemic projection model. Number displayed is the most likely value, with 95% confidence that the value falls in the predicted range.
Answer Quality Requires refinement with additional data or better model Depends on model result Answer is specific and certain enough to require little/no refinement		
* Values may change from run to run due to the stochastic nature of the underlying models.		

The Incident Characterization tab provides a comprehensive picture of the key incident characteristics, including:

[Disease type](#) – type of disease/agent suspected

[Area of interest](#) – the area that is most likely to have additional symptomatic people and contaminated areas.

[Day of attack](#) - estimated day when the attack occurred

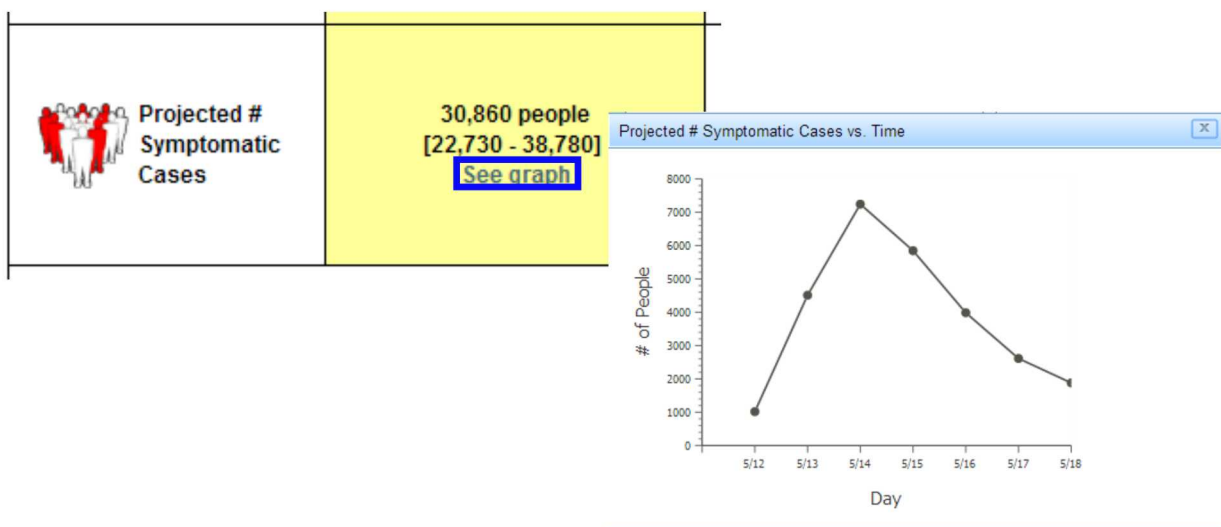
[Exposed population](#) - total number of people who received any level of exposure to the agent/disease. This includes levels of exposure too small to be infectious.

[Projected # symptomatic cases](#) - total number of people who will become symptomatic over the course of the epidemic without intervention.

The incident characteristics are calculated based on the incoming data feeds processed by the TPAT algorithms, as shown on the Analysis – Characterization tab. **When no diagnoses or positive environmental samples have been received, only the Disease and Area Of Interest characteristics are displayed.**

Incident Characterization Tab (cont.)

Clicking on [See Graph](#) in Projected # Symptomatic Cases displays a graph of the projected symptomatic cases over time, starting with the day of the first ER/CC alert from SAGES.



The Next Info To Seek Table displays further data gathering response options that are currently recommended by TPAT.

Next Info To Seek
- Initiate virologic testing and testing for bacterial infection - Environmental sampling - Epidemiological investigation - Syndromic/veterinary surveillance - Data combination

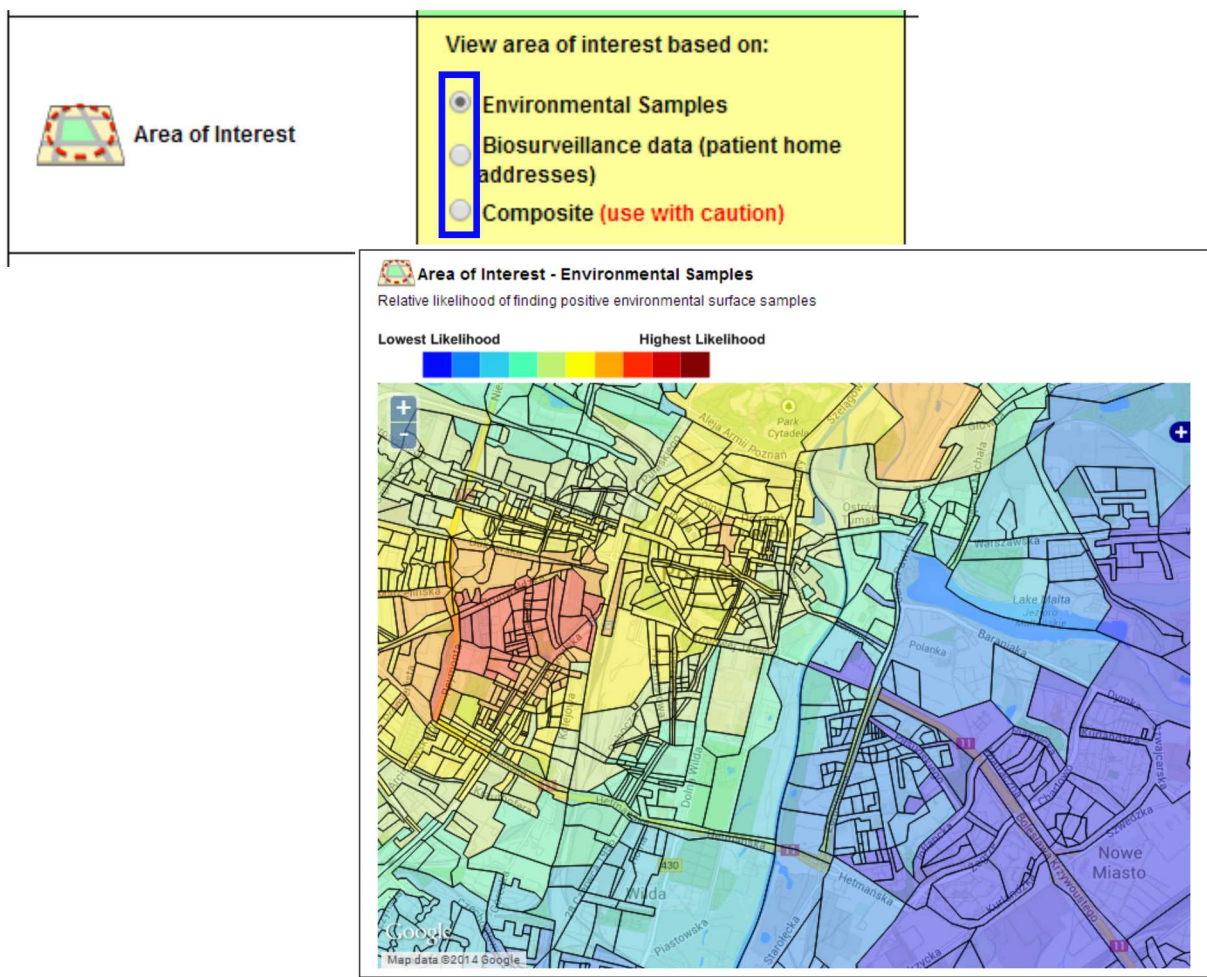
Incident Characterization Tab (cont.)

Area Of Interest

The Area of Interest map is displayed to the right of the Characterization table. The user can select which area of interest map to view by selecting the corresponding radio button in the Characterization table. TPAT generates area of interest maps based on the following:

- Environmental samples - Relative likelihood of finding positive environmental surface samples
- Biosurveillance data - Relative likelihood of finding additional patients (including ER/CCs, severe cases, and diagnosed cases). **Biosurveillance data is based on patient home addresses. User must determine whether home locations are relevant to the incident.**
- Composite - Relative likelihood of finding additional patients and/or positive environmental surface samples. **Composite of maps based on biosurveillance data using patient home locations and environmental samples together. User must determine whether this composite is relevant to the incident.**

The area of interest map provides zoom ability by clicking the (+/-) buttons on the top-left, or panning by clicking and dragging in the map.



Response Tab

Data Feeds

Characterization

Response

Analysis - Characterization

TPAT recommended responses highlighted in green

 Gather More Information	 Communicate	 People Movement	 Medical Countermeasures	 Agent Containment
• Syndromic/veterinary surveillance • Epidemiological investigation • Environmental sampling • Data combination • Initiate virologic testing and testing for bacterial infection	• Communication and coordination with national officials and agencies • Communications with public	• Consider shelter-in-place • Consider evacuation / temporary relocation • Evacuation and closure of potentially contaminated facility(ies)	• Post-exposure prophylaxis campaign • Social Distancing • National/government resources	• Contamination isolation • Decontamination and/or fixatives • Evacuation and closure of potentially contaminated facility(ies) • Restrictions on transportation

Show Cost/Benefits

The Response tab shows possible responses in five categories: additional data gathering, communications, people movement, medical countermeasures, and agent containment. The situation-dependent responses recommended by TPAT are highlighted in green, with the recommendation being based on the current incident characterization.

User Actions

The user may push the Show Cost/Benefits button to opens cost/benefit information on each of the potential response options.

Response Tab Cost/Benefits

 Gather More Information
  Communicate
  People Movement
  Medical Countermeasures
  Agent Containment

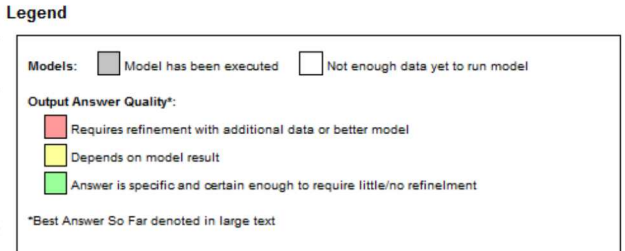
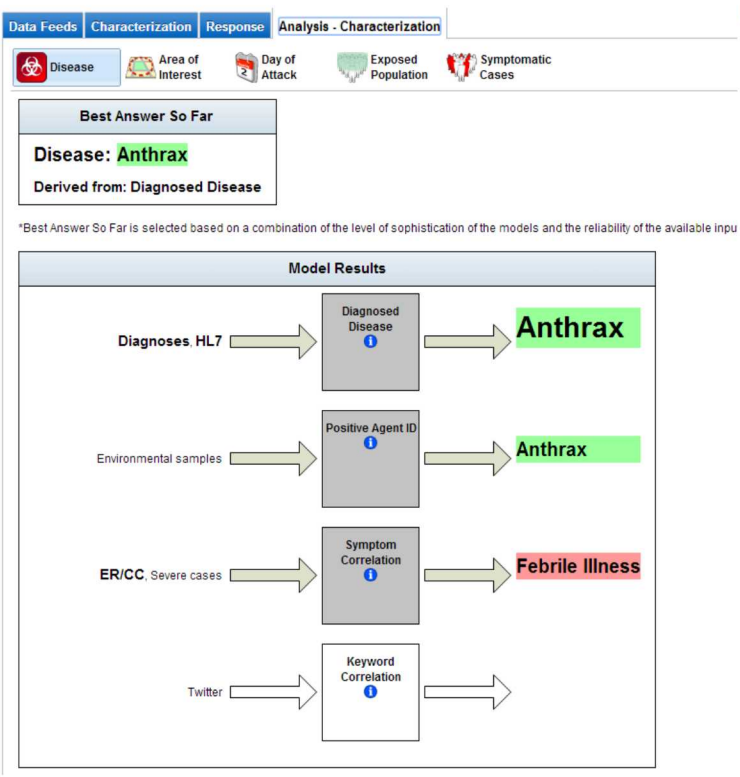
Response Option	Benefits	Costs/Considerations																																																																			
Post-exposure prophylaxis campaign	- One of the best approaches for reducing the impact of limited medical capacity, reducing public fears. (SMEs) Response Pathways Model<table><tr><th rowspan="2">PEP Start</th><th colspan="3">Estimated Casualties</th></tr><tr><th>Best¹</th><th>Most Likely²</th><th>Worst³</th></tr><tr><td>No PEP</td><td>17,205*</td><td>20,992*</td><td>24,893*</td></tr><tr><td>5/5+</td><td>5,973</td><td>7,288</td><td>10,169</td></tr><tr><td>5/6</td><td>7,028</td><td>8,575</td><td>11,681</td></tr><tr><td>5/7</td><td>8,074</td><td>9,851</td><td>13,115</td></tr><tr><td>5/8</td><td>9,064</td><td>11,059</td><td>14,435</td></tr><tr><td>5/9</td><td>9,977</td><td>12,173</td><td>15,630</td></tr><tr><td>5/10</td><td>10,803</td><td>13,181</td><td>16,699</td></tr><tr><td>5/11</td><td>11,542</td><td>14,082</td><td>17,647</td></tr><tr><td>5/12</td><td>12,197</td><td>14,882</td><td>18,485</td></tr><tr><td>5/13</td><td>12,776</td><td>15,588</td><td>19,222</td></tr><tr><td>5/14</td><td>13,285</td><td>16,209</td><td>19,869</td></tr><tr><td>5/15</td><td>13,733</td><td>16,756</td><td>20,438</td></tr><tr><td>5/16</td><td>14,126</td><td>17,235</td><td>20,937</td></tr><tr><td>5/17</td><td>14,471</td><td>17,656</td><td>21,376</td></tr><tr><td>5/18</td><td>14,774</td><td>18,026</td><td>21,761</td></tr></table> Assuming 2 days to prophylaxis exposed population + - Date of earliest diagnosis * - Total symptomatic population calculated by Temporal Inverse Model 1 - 'Best' using latest attack date 5/1 calculated by Temporal Inverse Model 2 - 'Most Likely' using most likely attack date 5/1 calculated by Temporal Inverse Model 3 - 'Worst' using earliest attack date 4/30 calculated by Temporal Inverse Model	PEP Start	Estimated Casualties			Best ¹	Most Likely ²	Worst ³	No PEP	17,205*	20,992*	24,893*	5/5+	5,973	7,288	10,169	5/6	7,028	8,575	11,681	5/7	8,074	9,851	13,115	5/8	9,064	11,059	14,435	5/9	9,977	12,173	15,630	5/10	10,803	13,181	16,699	5/11	11,542	14,082	17,647	5/12	12,197	14,882	18,485	5/13	12,776	15,588	19,222	5/14	13,285	16,209	19,869	5/15	13,733	16,756	20,438	5/16	14,126	17,235	20,937	5/17	14,471	17,656	21,376	5/18	14,774	18,026	21,761	- Difficult to target prophylaxis campaign (SMEs) - Monitoring required for adverse incidents, effectiveness of treatment and prophylaxis, and drug resistance. (HHS)
PEP Start	Estimated Casualties																																																																				
	Best ¹	Most Likely ²	Worst ³																																																																		
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5/17	14,471	17,656	21,376																																																																		
5/18	14,774	18,026	21,761																																																																		
Social Distancing	Reduces disease transmission																																																																				
National/government resources	Provides necessary national assistance (e.g., prophylaxis, supplies, personnel, lab and hospital surge coordination); (attack could overwhelm capacity of even a well-prepared city). (SMEs)																																																																				

The Cost/Benefits button on the Response tab shows benefits and costs/considerations for each of the possible responses. The buttons at the top allow the user to switch between the response categories. The cost/benefits shown are generic cost/benefits information for all of the possible responses except for the post-exposure prophylaxis campaign; in that case, the table shows incident-specific calculations of the estimated number of casualties based on the start date of the prophylaxis campaign and the disease model projections consistent with the observed data.

User Actions

The user may select from among the sub-tabs which response option sub-tab to show.

Analysis-Characterization Tab



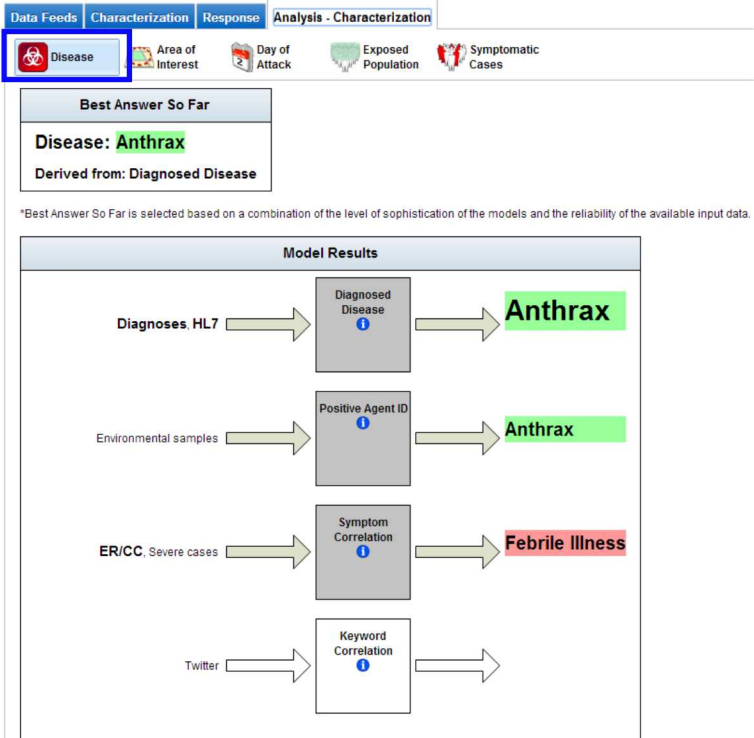
The Analysis – Characterization tab plus its sub-tabs, one for each incident characteristic, shows which models were used to produce each of the incident characteristics from the data streams. The model results box shows the different models that may be used to calculate the Best Answer So Far for the incident characteristic. The models are ordered from top to bottom by

quality level, with the top-most model being the highest quality, and the bottom-most model being the lowest quality. The required inputs are shown on the left side of the box with input arrows to each model. The data inputs that were used to produce the model output are shown in bold text. The models that have been executed are colored grey, while the models that are missing required input data and have not been run remain white. The model outputs and the output answer quality are shown on the right side of the box with output arrows from each model. The output that is selected by TPAT as the Best Answer So Far is shown in the largest text. This answer is repeated in the Best Answer So Far box at the top.

User Actions

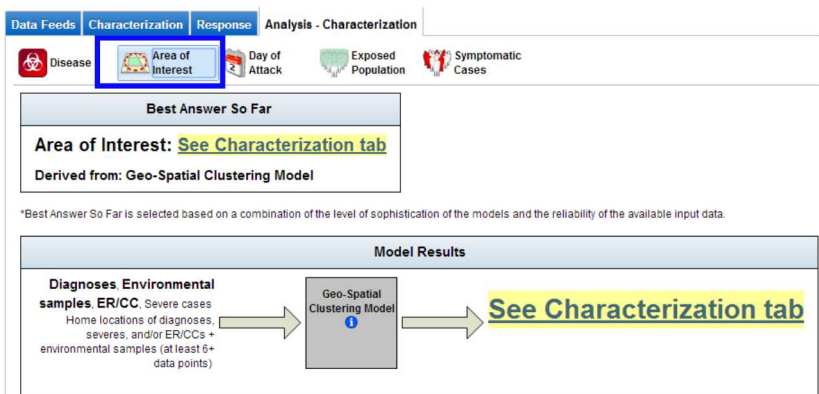
The user may select from among the sub-tabs which incident characteristic sub-tab to show. The user can click on the blue info button in the model box to read a description of the model.

Analysis-Characterization Tab Incident Characteristics Sub-tabs



The Disease tab shows the four models used to determine the disease:

- Diagnosed disease model – determines disease type based on received HL7 alerts
- Positive Agent ID – determines disease type based on received environmental samples
- Symptom Correlation – determines possible diseases based on symptoms of received ER/CC
- Keyword Correlation – determines possible disease type based on keywords contained in received Twitter data

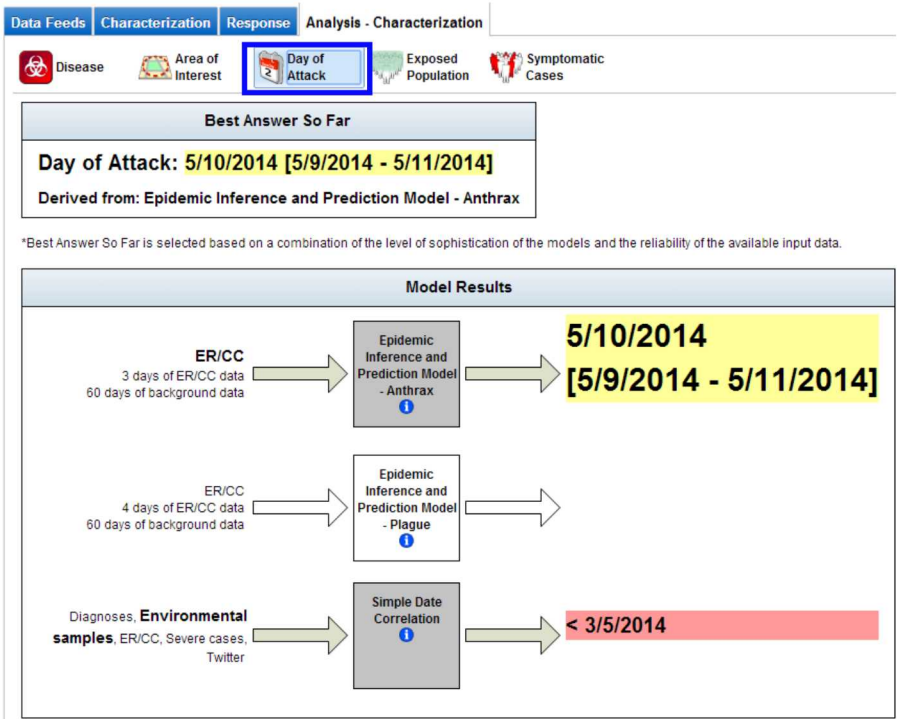


The Area of Interest tab shows the Geo-Spatial Clustering model, which calculates an area of interest by finding the minimal geographic area that contains 90% of cases and includes the zone with the highest number of cases. The clustering model generates 3 area of interest maps based on:

- (1) Environmental samples
- (2) Biosurveillance data (ER/CC, severe and diagnosed cases)
- (3) Composite – weighted average of environmental and biosurveillance data

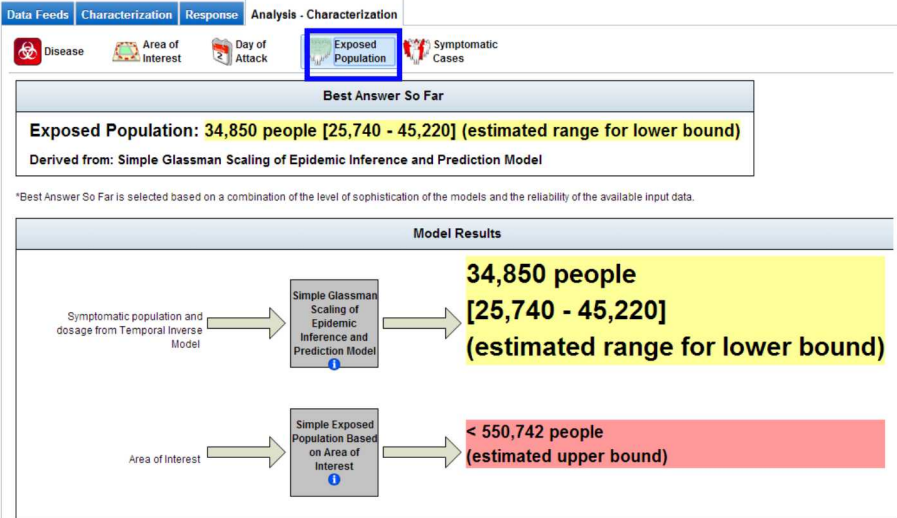
Quick Reference Card

Analysis-Characterization Tab Incident Characteristics Sub-tabs (continued)



The Day of Attack tab shows three models used for the estimate:

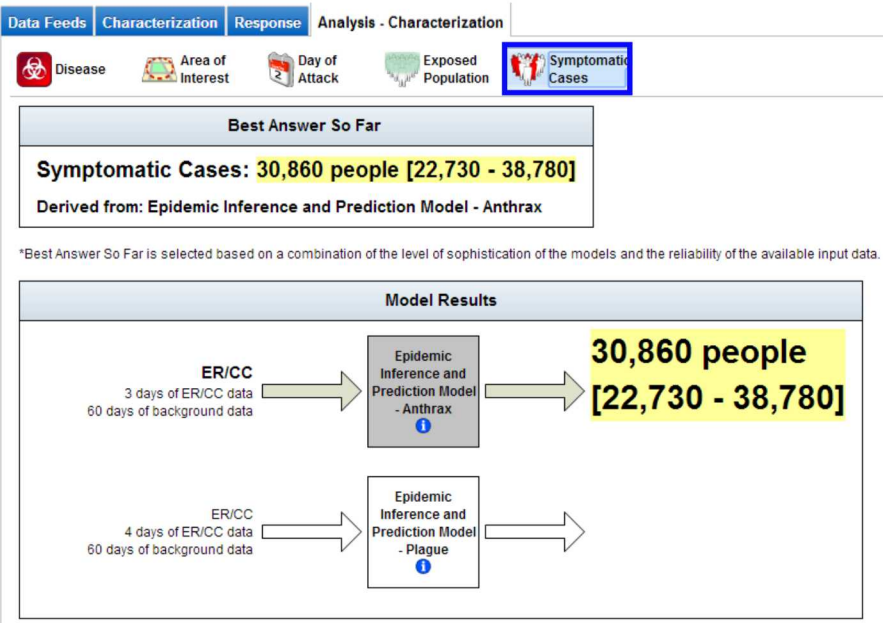
- Epidemic Inference and Prediction Model - Anthrax – after an anthrax diagnosis, estimates the anthrax epidemic curve (number of people who become symptomatic versus time) from the ER/CC data after
- Epidemic Inference and Prediction Model - Plague – after a plague diagnosis, estimates the plague epidemic curve (number of people who become symptomatic versus time) from the ER/CC data
- Simple Date Correlation – determines possible attack date based on dates of received ER/CC data together with disease incubation times.



The Exposed Population tab shows two models used for the estimate:

- Simple Based on Area of Interest– before enough data for Epidemic Prediction model available to run, estimated from population in the area of interest from the cluster model
- Simple Glassman Scaling of Epidemic Inference and Prediction Model– After Epidemic Prediction model run, a scaling factor is applied to the projected number of symptomatic cases.

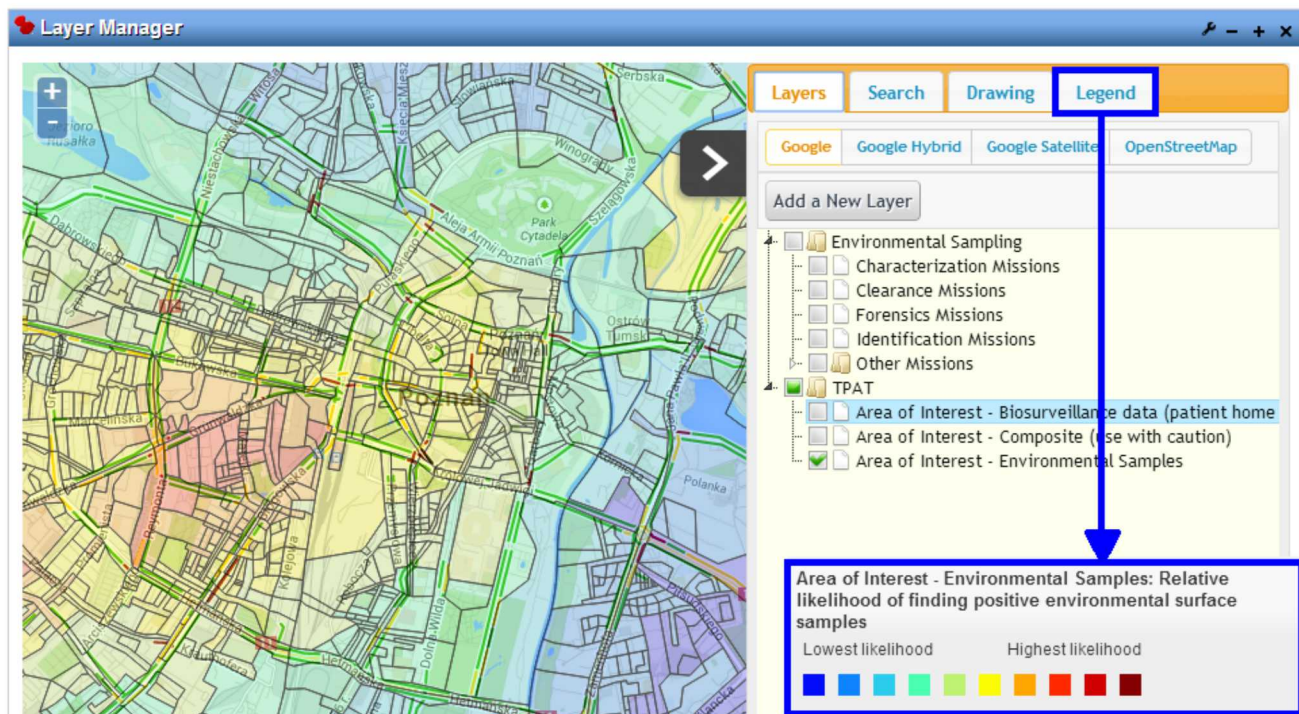
Analysis-Characterization Tab Incident Characteristics Sub-tabs (continued)



The Symptomatic Cases button shows two models used for the estimate:

- Epidemic Inference and Prediction Model - Anthrax – after an anthrax diagnosis, estimates the anthrax epidemic curve (number of people who become symptomatic versus time) from the ER/CC data
- Epidemic Inference and Prediction Model - Plague – after a plague diagnosis, estimates the plague epidemic curve (number of people who become symptomatic versus time) from the ER/CC data

TPAT Map Layers



The TaCBoaRD Map can be viewed by going to Incident->Map on the main TaCBoaRD menu bar. The TPAT Area of Interest map layers are located under the TPAT folder in the Layers tab. For a description of the area of interest layers generated by TPAT, see p. 8.

User Actions

The user uses the checkboxes on the right of the screen to select which map layers to display. Click on the Legend tab to view legends for the layers

**6. THREAT PROBABILITY TO ACTION TOOL (TPAT): USER MANUAL
AND REPORT**

Transatlantic Collaborative Biological Resiliency Demonstration (TaCBRD)

Threat Probability to Action Tool (TPAT): User Manual and Report

Draft October 2013



Foreword

The *Threat Probability to Action Tool: User Manual and Report* is a document developed by Sandia National Laboratories under contract to U.S. Department of Defense -- Defense Threat Reduction Agency (DoD-DTRA) as a stand-alone deliverable to the Transatlantic Collaborative Biological Resiliency Demonstration (TaCBRD) program. This document results from the *Threat Probability to Action Tool (TPAT); and Enhancements to PATH/AWARE Decision Support Tool Proposal 066121003*, revised 07/22/13 statement of work established between DoD-DTRA's Chemical and Biological Physical Science and Technology Division (CBT) and Sandia National Laboratories. It is designed to provide documentation on TPAT, a decision support tool that will organize and present bioterrorism and public health knowledge to provide situational awareness, event characterization, response options, and response guidance in order to help responders select the most appropriate public health and environmental response strategies for the unfolding incident.

DoD DTRA would like to thank the following individuals and groups for their support in development and review of this document. The content represents the best efforts of the participants based on the information available at the time of publication, but is not intended to convey formal guidance or policy of the federal government or other participating agencies. The views and opinions expressed herein do not necessarily state or reflect those of their respective organizations or the US Government.

The following individuals participated in the Technical Demonstration of an early version of TPAT in order to provide subject matter expert technical reviews, and their assistance is greatly appreciated:

- ...
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Additional thanks are due to

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Introduction and Purpose

The Threat Probability to Action Tool (TPAT) is a decision support tool that organizes and presents bioterrorism and public health knowledge to provide situational awareness, event characterization, response options, and response guidance in order to help responders select the most appropriate public health and environmental response strategies for the unfolding bioterrorism incident.

....

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Quick-Start Guide

This Quick-Start Guide enables the user to rapidly use TPAT to organize and present bioterrorism and public health knowledge to provide situational awareness, event characterization, response options, and response guidance in order to help responders select the most appropriate public health and environmental response strategies for the unfolding incident. For more comprehensive instructions, consult the User Manual.

Starting TPAT

TPAT is accessed from the Imminent Tab on the TaCBoaRD. TPAT operates in one of two modes: operational or testing. In operational mode, an alert from the Suite for Automated Global Electronic Surveillance (SAGES) system automatically triggers TPAT to run. In testing mode, the user sends simulated data streams to TPAT (see section on Testing Mode)

Overview

TPAT consists of five tabs of information—Data Streams, Event Characterization, Response, Analysis-Characterization, and Analysis-Response—plus the TPAT layers on the TaCBoaRD Map. The Data Streams tab shows every data stream that enters TPAT. These streams are combined by various algorithms in order to generate a comprehensive picture of the key event characteristics on the Event Characterization tab, including for example, the disease type, the day of attack, the projected number of symptomatic people, and the “area of interest” – the area that is most likely to have additional symptomatic people and contaminated areas. The TaCBoaRD Map shows information that can be displayed graphically, including both the health and environmental surveillance data streams and the TPAT-calculated results, such as the “area of interest.” The Response tab shows possible as well as TPAT-recommended responses in five categories, including additional data gathering, communications, people movement, medical countermeasures, and agent containment. The Analysis – Characterization tab shows which models were used to produce each of the event characteristics from the data streams. The Analysis – Response tab shows costs and benefits of the possible response measures.

Data Streams Tab

The Data Streams tab shows every data stream that enters TPAT; an example is shown in Figure 1. Each line on the table represents one type of data from one day, and includes the date and timestamp of the entry, the type of data (e.g., ER/CC), the source of that data (e.g., SAGES, hospital report, epidemiological investigation, TacDOGS), the data value, and contact information for a person that can provide additional information about that data. For public health data (ER/CC, severe cases, or diagnoses), the data value field includes the date of the data spike, the number of cases that exceeded the threshold (total across all zip codes), the type of symptom or diagnosis, and a list of the zip codes that reported this data spike. For environmental sampling data, the data value field includes the date the environmental samples were collected, the list of zip codes with positive environmental samples, and the list of zip codes with negative environmental samples.

User Actions

When new data arrives, it appears in the table on the Data Streams tab, and it appears in grey text, indicating that it is not yet incorporated into the TPAT calculations. In order to incorporate the new data, the user must accept it by pushing the “Update TPAT Results” button. While the TPAT models are running, the message box displays the following type of message: “Running TPAT models and computing results... -- 10/2/2013 13:57:18 -0700 (Pacific Standard Time).” When the TPAT models have finished running, the incorporated data appears in black text in the data streams table.

<<features to be removed...Until the SAGES tool provides the capability to send severe cases and diagnoses, the TPAT user may input these through the “Input Severe Cases” and “Input Diagnoses” buttons. The user may enter multiple cases with each button push.>>

<<features to be added...If new data arrives during TPAT model updates, the user has the option to stop and restart the model updating process in order to incorporate the new data; to accomplish this task, the user pushes the YYY button. The user also has the option to exclude certain data values from the TPAT model and accomplishes that task through the process of ZZZ.>>

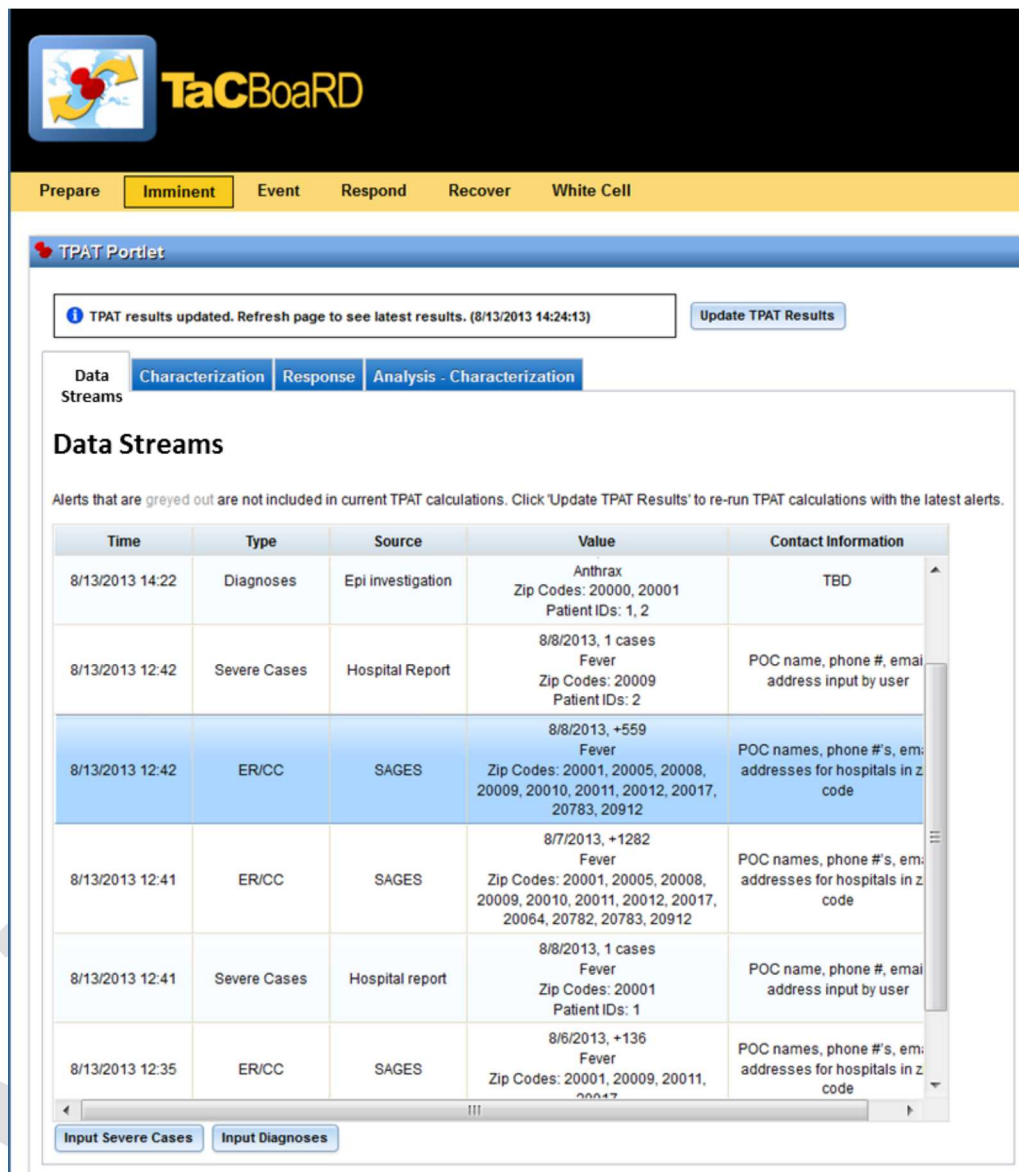


Figure 1. TPAT Data Streams Tab

Event Characterization Tab

The Event Characterization tab provides a comprehensive picture of the key event characteristics, including the disease type, the day of attack, the exposed population, the symptomatic population, and the “area of interest” – the area that is most likely to have additional symptomatic people and contaminated areas.¹ An example is shown in

¹ In the case that the data streams include sensors that detect biological agents in the environment (such as the U.S. Department of Homeland Security’s BioWatch system), then the event characterization tab could include the attack location and release quantity.

Figure 2. The event characteristics are based on the incoming data streams processed by the TPAT algorithms, as shown on the Analysis – Characterization tab.

While the TPAT models are running (because the user updated TPAT results on the Data Streams tab), the message box displays the following type of message: “Running TPAT models and computing results... -- 10/2/2013 13:57:18 -0700 (Pacific Standard Time).” When the TPAT models have finished running, the newly-computed Event Characteristics appear in the table.

<<features to be removed...The “Update TPAT Results” button will be removed from this tab.>>

User Actions

<<features to be added... The user will have the ability to override any of the event characteristics or the answer quality. To do this, the user must XXX.>>

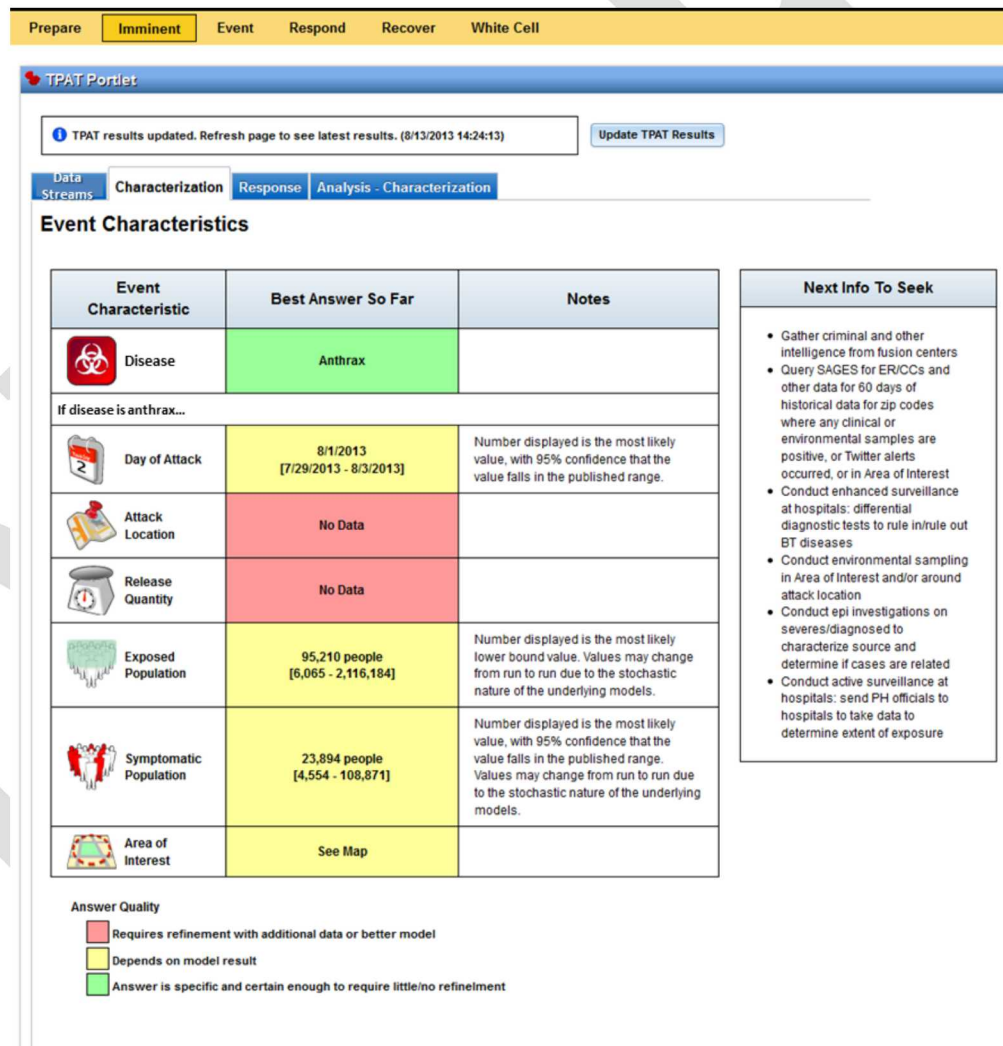


Figure 2. TPAT Event Characteristics Tab

TaCBoaRD Map

The TaCBoaRD Map (Figure 3) provides a geospatial view of the public health, environmental, and TPAT-calculated data and results in different layers, which can be turned on and off by the user. The Map can be viewed by going to Event->Map on the main TaCBoaRD menu bar. The SAGES ER/CC layer shows the zip-codes in which the numbers of emergency room chief complaints (ER/CCs) exceed threshold values. The SAGES Severe Cases and Diagnoses layers show the zip-code locations of residences of people who report as severe cases or diagnoses. The TacDOGS Sampling layer shows the locations (by latitude and longitude) and results (positive or negative) of each environmental sample. The TPAT Area of Interest layer shows the area that results from TPAT-calculated statistical correlation of the health and environmental data points. The Area of Interest represents the area most likely to have additional symptomatic people and contaminated areas.

User Actions

The user uses the checkboxes on the right of the screen to select which map layers to display.

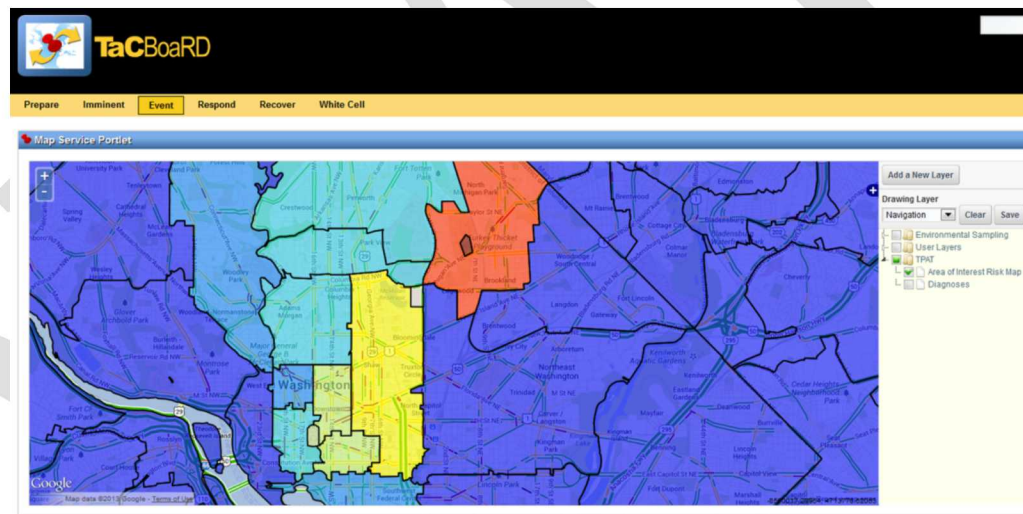


Figure 3. TaCBoaRD Map

Response Tab

Response tab (Figure 4) shows possible responses in five categories: additional data gathering, communications, people movement, medical countermeasures, and agent containment. The responses are grouped by level of impact from low through medium to high. The situation-dependent responses recommended by TPAT are highlighted in green, with the recommendation being based on the current event characterization.

User Actions

<<features to be added... The user will have the ability to select and deselect any response option and to submit response plans, some aspects of which may trigger downstream TaCBoaRD tools, notably TacDOGS.>>

TPAT Portal

TPAT results updated. Refresh page to see latest results. (8/13/2013 14:24:13) [Update TPAT Results](#)

[Data Streams](#) [Characterization](#) [Response](#) [Analysis - Characterization](#)

TPAT recommended responses highlighted in **green**

	Gather More Information	Communicate	People Movement	Medical Countermeasures	Agent Containment
H I G H	Conduct active surveillance at hospitals: send PH officials to hospitals to take data to determine extent of exposure	Press announcements that a bioattack has occurred to general public	- Wide-area Quarantine / Shelter-in-place - Targeted evacuation based on area of interest - Targeted Quarantine / Shelter in Place based on area of interest plus exposed/symptomatic population - Wide-area evacuation	"Harden" hospitals (restrict access, e.g. SARS response)(to limit spread of contagious agent) most likely to service exposed population - Wide-area mass prophylaxis - Wide-area mass vaccinations - Targeted mass prophylaxis based on most likely exposed population - Targeted mass vaccination based on most likely exposed population	- Seal and decontaminate buildings, prioritized according to contamination levels - Decontaminate people, prioritized by those most likely exposed "Harden" hospitals (restrict access, e.g. SARS response)(to contain agent particles) most likely to service exposed population
M E D I U M	- Conduct epi investigations on severe/diagnosed to characterize source and determine if cases are related - Conduct environmental sampling in Area of Interest and/or around attack location	Communicate that a bioattack is suspected to local, regional, and national response and government agencies	Transportation and/or Facility Shut-Downs based on known attack location and/or area of interest	- Alert hospitals and clinical labs to activate surge capacity for additional bioterrorism patients - Request Strategic National Stockpile - PH & Responder vaccinations and/or prophylaxis	
L O W	- Conduct enhanced surveillance at hospitals: differential diagnostic tests to rule in/rule out BT diseases - Gather criminal and other intelligence from fusion centers - Query SAGES for ERICCs and other data for 60 days of historical data for zip codes where any clinical or environmental samples are positive, or Twitter alerts occurred, or in Area of Interest	Communicate situation (e.g., BT agent has been found or bioattack is suspected, etc.) to local bioterrorism working groups			

Figure 4. TPAT Response Tab

Analysis – Characterization Tab

The Analysis – Characterization tab (Figure 5) plus its sub-tabs, one for each event characteristic, shows which models were used to produce each of the event characteristics from the data streams. The model results box shows the different models that may be used to calculate the Best Answer So Far for the event characteristic. The models are ordered from top-to-bottom by quality level, with the top-most model being the highest quality, and the lowest model being the lowest quality. The required inputs are shown on the left side of the box with input arrows to each model. The data inputs that were used to produce the model output are shown in bold text. The models that have been executed are colored grey, while the models that are missing required input data and have not been run remain white. The model outputs and the output answer quality are shown on the right side of the box with output arrows from each model. The output that is selected by TPAT as the Best Answer So Far is shown in the largest text. This answer is repeated in the Best Answer So Far box at the top.

User Actions

The user may select from among the sub-tabs which event characteristic sub-tab to show.

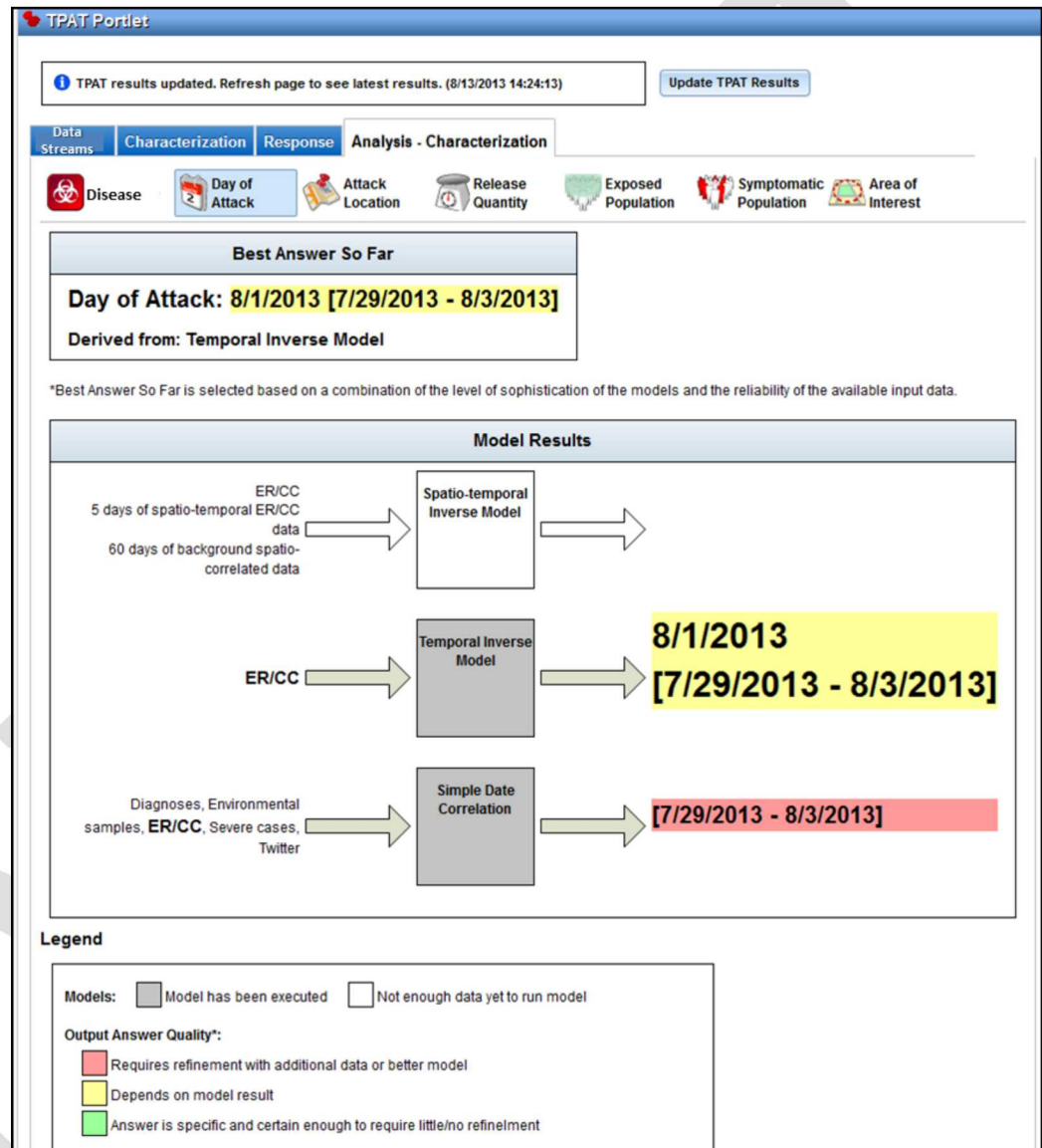


Figure 5. TPAT Analysis - Characterization Tab

Analysis – Response Tab (not implemented yet)

The Analysis – Response tab (not implemented yet) shows costs and benefits of the possible response measures.

Running in Test Mode

In order to facilitate testing of TPAT, the user can generate simulated SAGES data streams, can generate simulated TacDOGS environmental samples, and also can clear received data streams in TPAT.

Generating simulated SAGES data streams

To generate a SAGES alert in TPAT, use a browser to navigate to a URL of the following format:

`https://osgi.tacbrd.org/tpat/rest/triggerMockOeAlert?dateStr=userDefinedDateString&source=userDefinedSource&category=userDefinedCategory`

in which

- *userDefinedDateString* should be replaced with the desired date of the alert in the format `yyyymmdd`, e.g., 20130807.
 - *userDefinedSource* should be replaced with one of the following values:
 - ER – ER/CC alert
 - OTC – Over-the-counter drug sales
 - Twitter
 - MANUAL – user defined alert
 - *userDefinedCategory* should be replaced with a value that depends on the source type defined above:
 - For an ER/CC alert, *userDefinedCategory* defines the symptom the alert corresponds to. Symptom values that are currently supported in TPAT include FEVER, COLD, and HEADACHE
 - For an OTC alert, *userDefinedCategory* defines the type of OTC drug the alert corresponds to. TPAT does not currently use OTC alerts in its calculations so the category can be anything.
-

- For a Twitter alert, *userDefinedCategory* defines keyword the alert corresponds to. Keyword values that are currently supported in TPAT include FEVER, COLD, and HEADACHE
- For a MANUAL alert, *userDefinedCategory* is a free-form string that gives further information on the alert. TPAT does not use Manual alerts in its calculations.

After loading the URL, the alert should show up in the Data Streams table in TPAT. An example of the URL format for an ER/CC fever alert on August, 7th, 2013 is <https://osgi.tacbrd.org/tpat/rest/triggerMockOeAlert?dateStr=20130807&source=ER&category=FEVER>

Generating simulated TacDOGS data streams

To generate a positive TacDOGS environmental sample, navigate to White Cell->TacDOGS in the main TaCBoaRD menu bar. Figure 6 shows the panel for inputting sampling results.

The screenshot displays the TaCBoaRD web application. At the top, there's a navigation bar with links: Prepare, Imminent, Event, Respond, Recover, About, TaCBoaRD Team, WARRP, and White Cell. Below this, a modal window titled 'TacDOGS Test Results Injection' is open. It contains a form for 'Enter Sampling Data' with the following fields: Latitude (in decimal degrees) with a value of 0.0, Longitude (in decimal degrees) with a value of 0.0, Sampling Mission set to 'NONE' via a dropdown menu, and Date and Time. There is also a 'Duplicate?' checkbox. At the bottom of the form are four buttons: 'Presumptive (+)', 'Confirmatory (+)', 'Negative', and 'Inconclusive'. The background of the page features a large, faint watermark of a globe with the text 'Atlantic Collaborative Biological' and 'TaCBoaRD' over it, along with a biohazard symbol.

Figure 6. Panel for input of sampling data

Clear all received data streams

If you wish to “start over” and reset TPAT with no data streams, go to the following URL in a browser:

<https://osgi.tacbrd.org/tpat/rest/resetTpat>

- This should clear all entries in the Data Streams table in TPAT

Note: The text “<https://osgi.tacbrd.org>” should be replaced with the actual TaCBoaRD Virgo server URL, if applicable. If not known, retrieve from the TaCBoaRD administrator. The URL may also require a username/password, which can be retrieved from the TaCBoaRD administrator.

DRAFT

7. TEMPORAL INVERSE MODEL (TIM)

Temporal Inverse Model (TIM)

TIM estimates the number of people infected in a bioattack from 3-5 days of data collected by SAGES.

Background: During an outbreak caused by a bioattack, people will incubate a disease, show symptoms and seek care. One will observe a stream of people at hospitals, complaining of signs of morbidity. This data is collected by syndromic surveillance efforts, SAGES in particular. In its pristine form, the number of people seeking care, every day, forms a time-series. It is also called the epidemic curve and can be predicted by a disease model. The model prediction of the epidemic curve is defined by (1) N , the number of people infected by the initial release; (2) τ , the time of attack, (3) D , the dosage, in case of dose-dependent incubation and (4) a time-dependent spread rate, θ , which finally decays to zero. These are also disease-model inputs

Premise: These quantities are unknown during a bioattack. The premise is that if one can fit a model to the observed epidemic curve, one can (1) estimate N , τ , D and spread rate (called model calibration) and (2) use the calibrated model to predict future evolution of the disease.

Challenges: The time-series of people appearing in hospitals is corrupted by 2 other sources, which have to be filtered out

- *Background morbidity:* The observed data consists of chief complaints like fever, cough etc. The attack and many other endemic diseases cause these.
- *Worried-wells:* Once the word gets out that there has been an attack, the chief complaint stream will consist mainly of worried well and hypochondriacs. So the epidemic signal/curve is well and truly buried in these confounding data streams.

Solution: The solution proceeds in three steps: (1) filter out background morbidity; (2) filter out worried-wells and (3) use the residual, a noisy approximation of the epidemic curve, to do the calibration.

Filtering out background morbidity: Before the attack and the 'CNN moment', the observations available in SAGES reflect just the background morbidity. We use 8 weeks of this data, from SAGES, to create its time-series model. This time-series model is used to predict the background morbidity, for a week, after the detection of the attack / CNN moment. Any deviations from this prediction are attributed to the epidemic curve and the worried wells.

Filtering out the worried wells: We model the number of people with symptoms on day t , $n(t)$, as a combination of the truly sick people $s(t)$ and worried-wells modeled as a multiplier on the previous day's sick people $\beta s(t-1)$ i.e. $n(t) = s(t) + \beta s(t-1)$. Note that the observed data is $n(t)$. We use regression with $t = 1 \dots T$ days of observations,

to estimate the epidemic curve $s(t)$, $t = 0 \dots T$. After two bouts of filtering, the epidemic curve $s(t)$, $t = 1 \dots T$ is very noisy.

Estimating model parameters N , τ , D , θ from noisy epidemic data, $s(t)$: We then fit a simple model of the epidemic to the noisy epidemic curve $s(t)$. For anthrax, we use a dose-dependent incubation period (Wilkening's Model D [1]). For plague, we use Gani & Leach's incubation period model [2]. In case of plague, the spread-rate is assumed to rise and then fall; it is parameterized by a Gamma function with an unknown scale factor θ .

These epidemic model parameters are estimated from the data using Bayesian inference. This particular method is used since it allows us to estimate them with error bounds (specifically, as probability densities). The error bounds are important because the data is noisy and there isn't much of it (3-5 days). The details are in [3].

Forecasting the epidemic: Once we know the model parameters, we can use the model to forecast the outbreak. Since the parameters are known in an uncertain manner, we draw 100 samples of the model parameters and make 100 predictions. This ensemble of forecasts allows us to predict the future – and put an error bar around it. It reflects our lack of precise knowledge due to the small and noisy data and shortcomings of the disease model.

Products: The TIM models (TIM-anthrax and TIM-plague) produce the following outputs; only a few are actually displayed

- Estimates of epidemic model parameters N , τ , D , θ These are estimated with error bars. The estimate of N , the number of index cases (or initial infected cases in the bioattack), along with confidence interval, is reported by TPAT. We need a minimum of 4 days of data to make the estimates.
- Epidemic forecasts with error bars: 100 samples of the model parameters are used to produce 100 forecasts. Median, 2.5th and 97.5th percentiles of the forecasts are reported for each day.

References

1. D. A. Wilkening, "Sverdlovsk revisited: modeling human inhalational anthrax", Proc. Natl. Acad. Sc., 103(20):7589—7594, 2006.
2. R. Gani and S. Leach, "Epidemiologic determinants for modeling pneumonic plague outbreaks", Emerging Infectious Diseases, 10(4):608—614, 2004.
3. C. Safta, J. Ray, K. Sargsyan, S. Lefantzi, K. Cheng and D. Crary, "Real-time characterization of partially observed epidemics using surrogate models" [Sandia Technical Report, SAND2011-6776](#). Printed October 2011. Sandia National Laboratories, Livermore, CA.

8. CLUSTER MODEL

Cluster Model Versions

We developed two versions of the cluster model:

- Early warning version – for use with early data (small numbers and lots of noise) to see area of interest
- Established epidemic version – for use in an established epidemic to see relative risk in different zip codes

Cluster Model Outputs

Early data

- No clustering looks like clusters that move around with each time step; user must discern this by examining spatio-temporal variation
- Can indicate an area of interest (calculated conservatively), with little difference in relative risk values across different zip codes

Established epidemic –

- No clustering looks like wide-area, homogenous coloring (i.e., an huge red area); users must discern this & interpret correctly
- Clusters that do not spread indicate that one set of people got a fairly homogenous dose, thus a spatially-localized attack.
- Clusters that spread indicate one of:
 - o a large attack – some people got a large dose, others got a smaller dose (and therefore show symptoms later in time), OR
 - o a second attack, OR
 - o the second generation of a contagious disease

TD2sw Scenario Outputs

Scenario 1 – fever symptoms should cluster & show relative risk; respiratory distress may cluster, but signal is low; rash should not cluster

Scenario 2 – attack is small; fever symptoms may cluster, but signal is low; respiratory distress has even lower signal so likely won't cluster; rash should not cluster

Scenario 3 – attack is very small and localized; fever and respiratory distress will likely not cluster; rash may cluster

9. PRODUCTS

Products

Product description:

- Estimates of the # of people infected with anthrax, the time of release of anthrax spores and the average dosage (# spores / person), along with error bars (errors in the estimate)
- A prediction of the evolution of the anthrax epidemic beyond the days of data that is already known. This prediction consists of the # of people with anthrax who will report to ER daily, for the next 7 days. These predictions come with error bars.

Which application produces it? : Temporal Inverse Model

What is the product and how is it created?

The products are created from a time-series containing the # of people with Chief Complaint 'Fever' who report to ER every day. We need at least 3 days of data after the outbreak is deemed to have started to create these products. We also need 60 days of 'Fever' data before the outbreak to "get a feel" of the background levels of 'Fever'.

What triggers its creation?

The TIM is run after the outbreak is deemed to have started. Receiving an alarm from SAGES is a necessary, but not sufficient, condition to start counting the 3 days one needs to wait before running TIM.

A human in the loop runs time i.e., he decides whether the SAGES alarm was also sufficient to run TIM. Of course, one has to collect 3 days of data, post-alarm, before invoking TIM.

What info is needed to create this product? Who supplies it?

We need:

- At least 3 days of data from SAGES. The data consists of # of people with Chief Complaint 'Fever', summed over all zip codes, that report to ER every day. This data is therefore a "daily time-series".
- We need 60 days of "daily time-series" data, of Chief Complaint "Fever", before the start of outbreak. We need this to obtain background levels of "Fever", before the anthrax outbreak starts. SAGES supplies this data

Who uses the product?

Public health official monitoring the outbreak.

Product description:

Relative risk maps of (1) the population with Chief Complaint “Fever”, (2) People with Severe Symptoms, (3) People with diagnosed cases of anthrax or plague, (4) Positive TacDOGS samples and (5) Composite risk map.

A relative risk map plots the probability of finding a person with Chief Complaint Fever (or severe symptoms or diagnosed anthrax/plague cases or positive TacDOGS samples) at a function of latitude and longitude

Which application produces it? Cluster model

What is the product and how is it created?

A relative risk map of Chief Complaint Fever plots, as a function of space, the relative chance of finding a person with Chief Complaint “Fever”. It does so by (1) dividing the # of people with Chief Complaint “Fever” in each zipcode by the population (to get the risk) and (2) dividing all zipcodes’ risks by the maximum risk, to get the relative risk. The data is calculated at zip-code centroids and interpolated to a grid covering the region of interest. The same is done for cases with severe symptoms, diagnosed cases and positive TacDOGS samples.

The interpolation can go wrong if too few zipcodes have data (happens when creating risk maps for severe and diagnosed cases, and positive tacDOGS samples). Also, the data used in the relative risk maps are cumulative e.g., the number of diagnosed cases 10 days after a SAGES alert is calculated with the total # of diagnosed cases over 10 days, and not with the cases diagnosed *on* Day 10.

The composite relative risk map is a weighted average of the 4 relative risk maps described above.

What triggers its creation?

The relative risk maps can be created any time after a SAGES alarm.

What info is needed to create it? Who supplies it?

- Number of people with Chief Complaint Fever, by zip code, summed up over the duration of the outbreak. SAGES supplies this.
- Number of people with Severe Symptoms, by zip code, summed up over the duration of the outbreak. **This is entered manually.**
- Number of (positive) diagnosed cases, by zip code, summed up over the duration of the outbreak. **This is entered manually.**
-

- Latitude and longitude of positive TacDOGS samples over the duration of outbreak. **Obtained from TacDOGS and entered manually.**
- The latitude and longitude of the region of interest, locations (lat./long.) of zip-code centroids and zip-code populations. SAGES supplies this.

Who uses the product?

- The individual relative risk maps are plotted on the map, as is the composite relative risk map. These are individual layers in the map

Product description:

- Estimates of the # of people infected with plague, the time of release of anthrax spores, a parameter in the spread rate model that controls its attenuation over time and the total number of secondary infections, along with error bars (errors in the estimate)
- A prediction of the evolution of the plague epidemic beyond the days of data that is already known. This prediction consists of the # of people with plague who will report to ER daily, for the next 7 days. These predictions come with error bars.

Which application produces it? : Temporal Inverse Model**What is the product and how is it created?**

The products are created from a time-series containing the # of people with Chief Complaint 'Fever' who report to ER every day. We need at least 4 days of data after the outbreak is deemed to have started to create these products. We also need 60 days of 'Fever' data before the outbreak to "get a feel" of the background levels of 'Fever'.

What triggers its creation?

The TIM is run after the outbreak is deemed to have started. Receiving an alarm from SAGES is a necessary, but not sufficient, condition to start counting the 4 days one needs to wait before running TIM.

A human in the loop runs time i.e., he decides whether the SAGES alarm was also sufficient to run TIM. Of course, one has to collect 4 days of data, post-alarm, before invoking TIM.

What info is needed to create this product? Who supplies it?

We need:

- At least 4 days of data from SAGES. The data consists of # of people with Chief Complaint 'Fever', summed over all zip codes, that report to ER every day. This data is therefore a "daily time-series".
- We need 60 days of "daily time-series" data, of Chief Complaint "Fever", before the start of outbreak. We need this to obtain background levels of "Fever", before the plague outbreak starts. SAGES supplies this data

Who uses the product?

Public health official monitoring the outbreak.

- Latitude and longitude of positive TacDOGS samples over the duration of outbreak. **Obtained from TacDOGS and entered manually.**
- The latitude and longitude of the region of interest, locations (lat./long.) of zip-code centroids and zip-code populations. SAGES supplies this.

Who uses the product?

- The individual relative risk maps are plotted on the map, as is the composite relative risk map. These are individual layers in the map

10. TUNING OF ANOMALY DETECTORS

Anomaly Detectors

Tuning after TD2

1/9/17

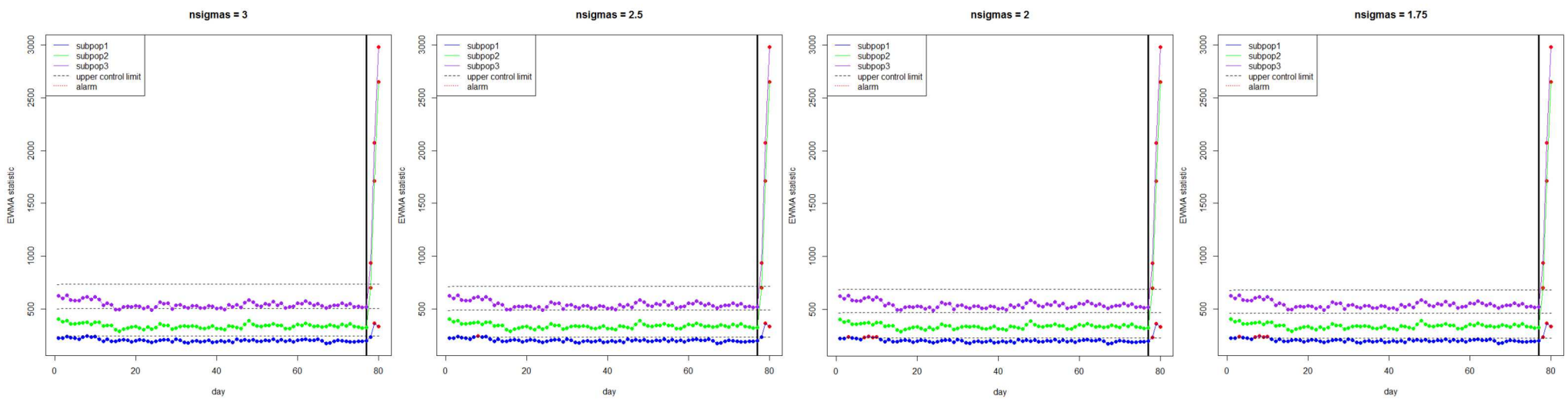
Description

- Data from TD 2 are comprised of multiple data streams from ESSENCE; used these timestamps:
 - Anthrax (scenario 1): Sep 4
 - Plague (scenario 2): Sep 5
 - Smallpox (scenario 3): Sep 17
- Each syndrome for each scenario includes 2+ ESSENCE data streams from different subpopulations
- Release dates are known; they are marked by a vertical black line in each graph
- In TD 2 we saw EWMA alarming too infrequently and CUSUM alarming too frequently

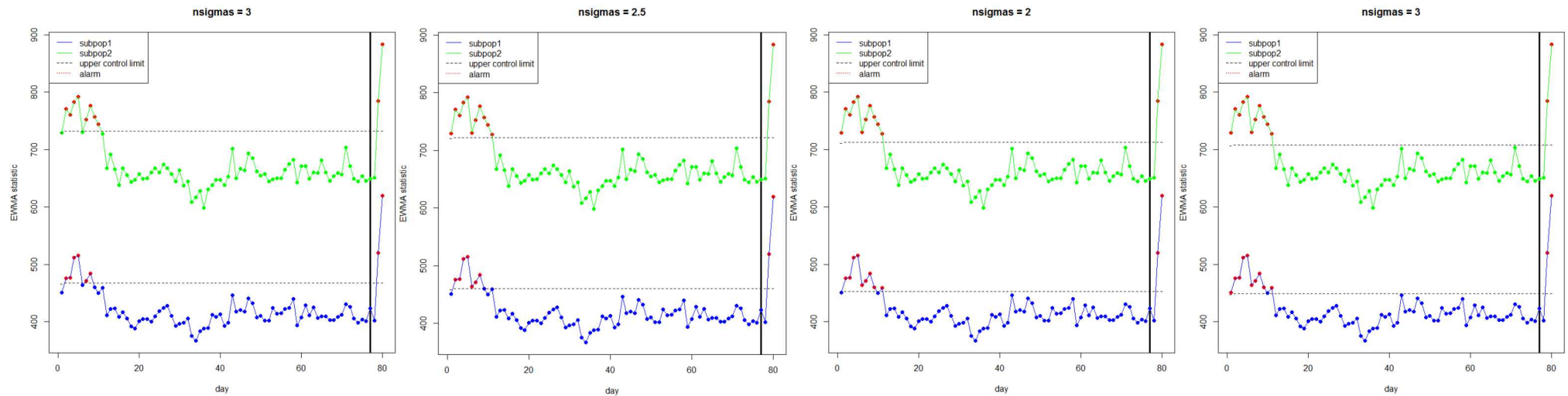
EWMA

$\lambda = 0.7$

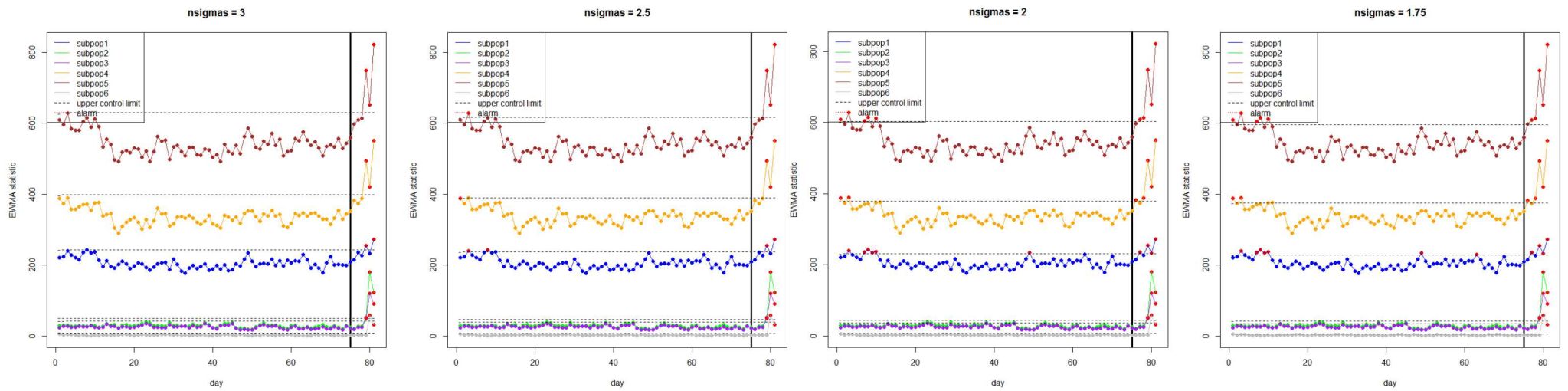
Scenario 1: Anthrax - fever



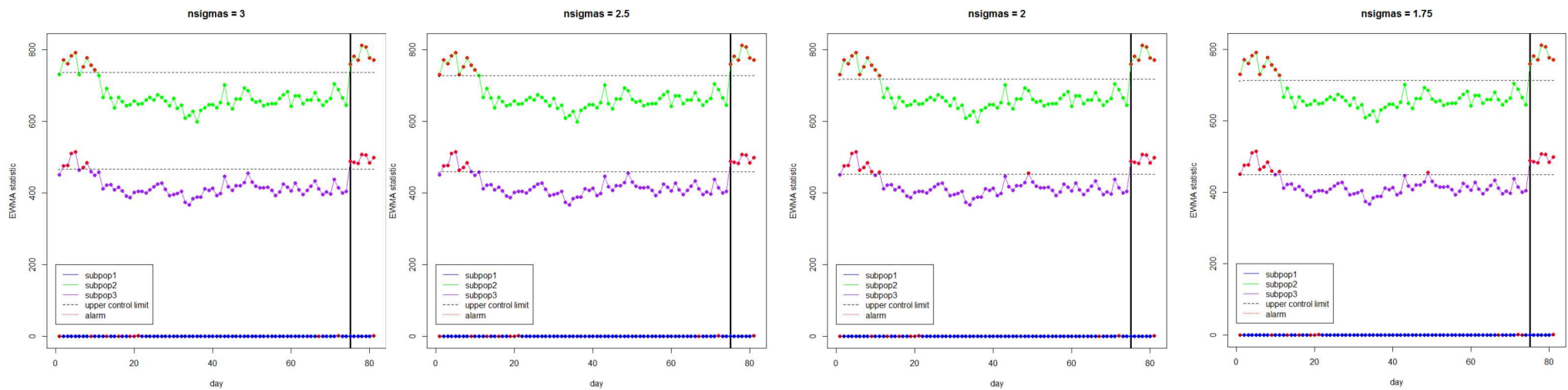
Scenario 1: Anthrax - respiratory



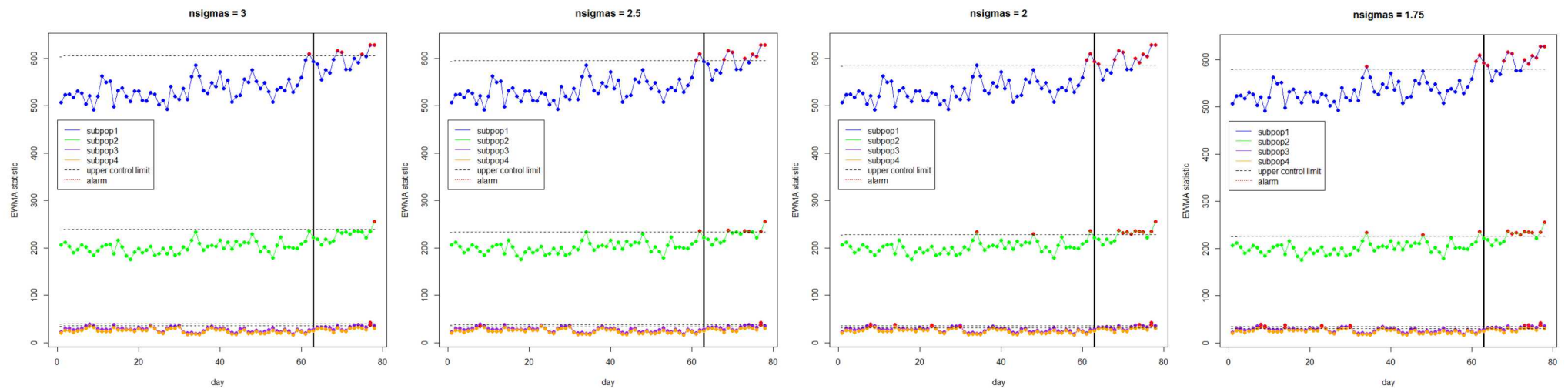
Scenario 2: Plague - fever



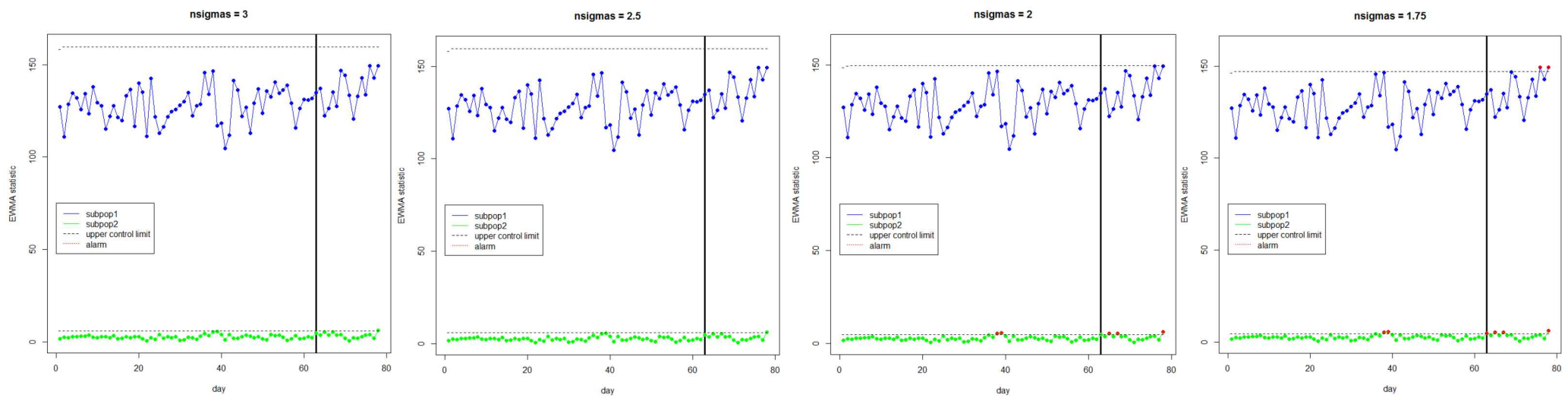
Scenario 2: Plague - respiratory



Scenario 3: Smallpox - fever



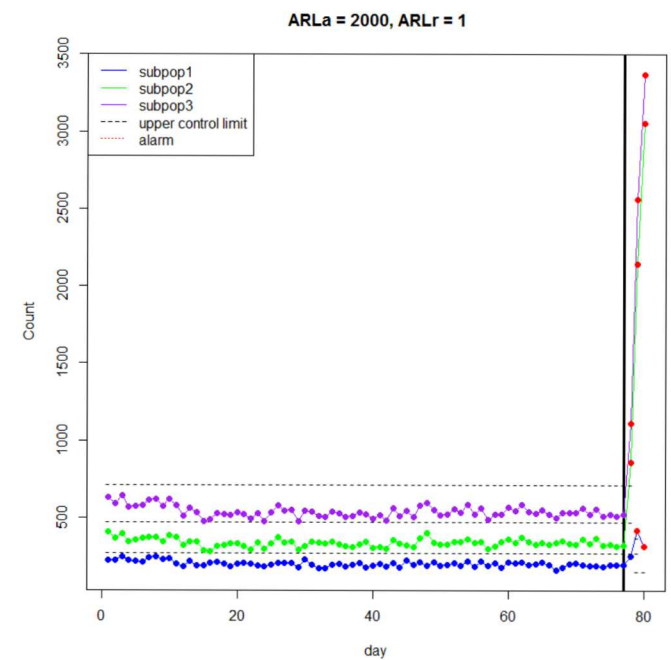
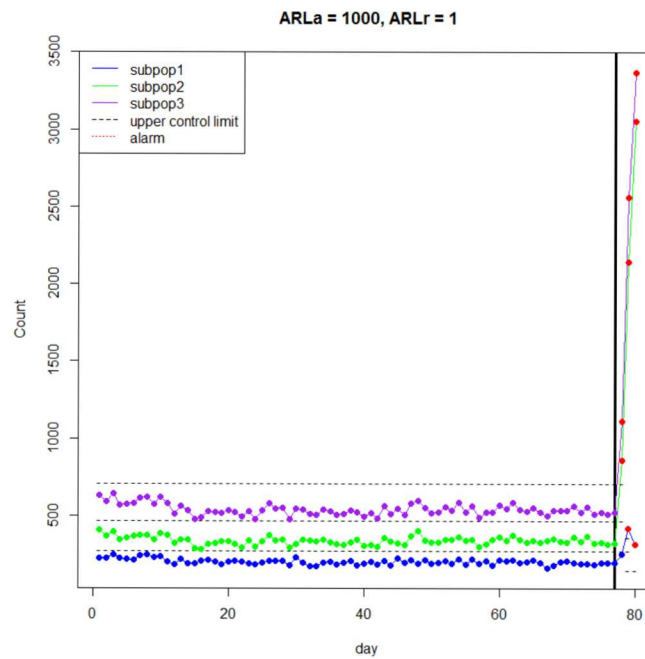
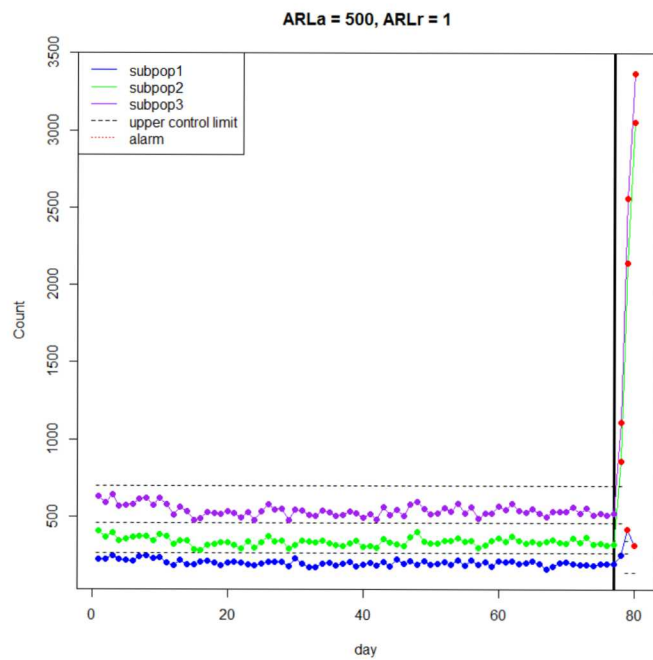
Scenario 3: Smallpox - respiratory



CUSUM

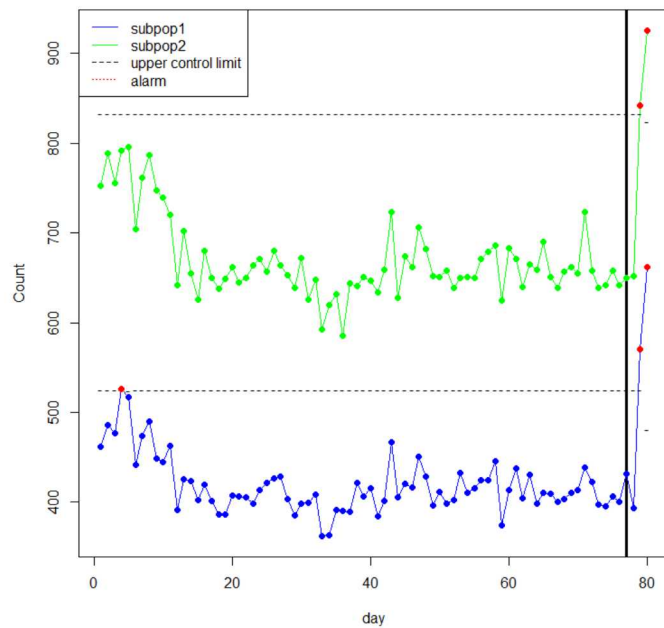
$ARL_r = 1$

Scenario 1: Anthrax - fever

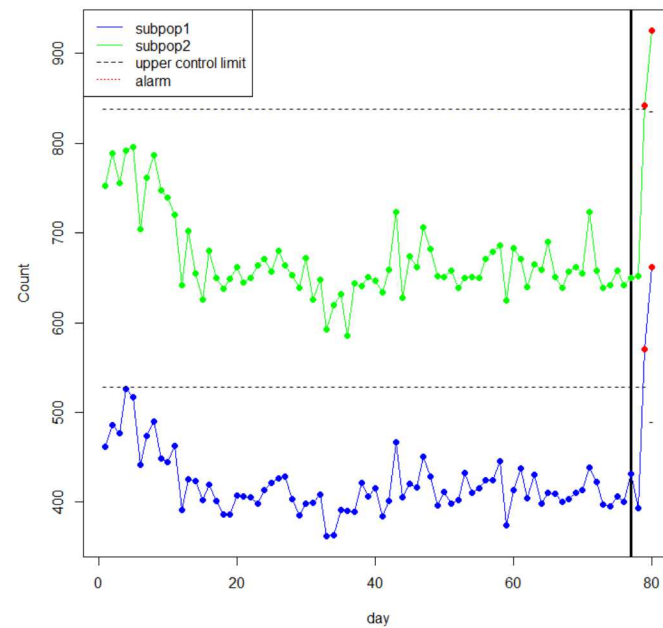


Scenario 1: Anthrax - respiratory

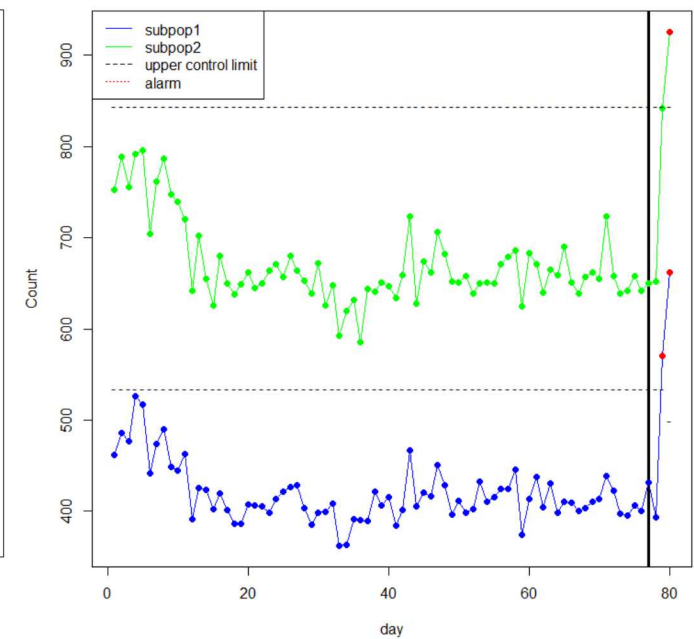
ARLa = 500, ARLr = 1



ARLa = 1000, ARLr = 1

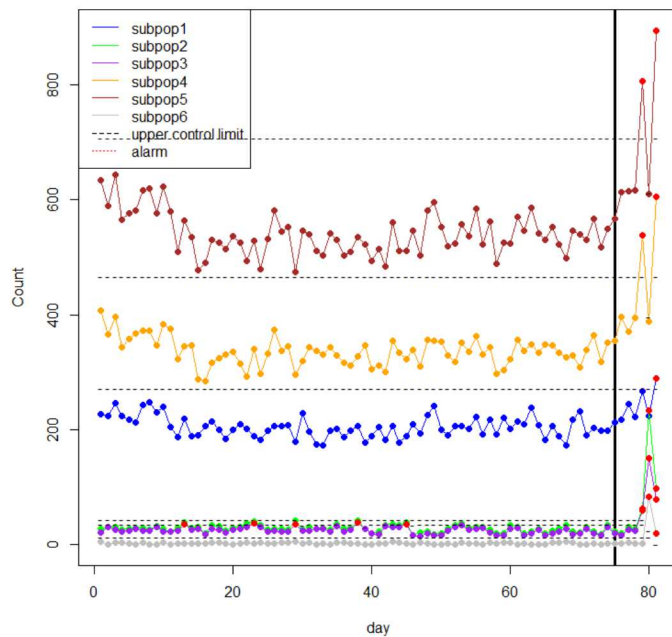


ARLa = 2000, ARLr = 1

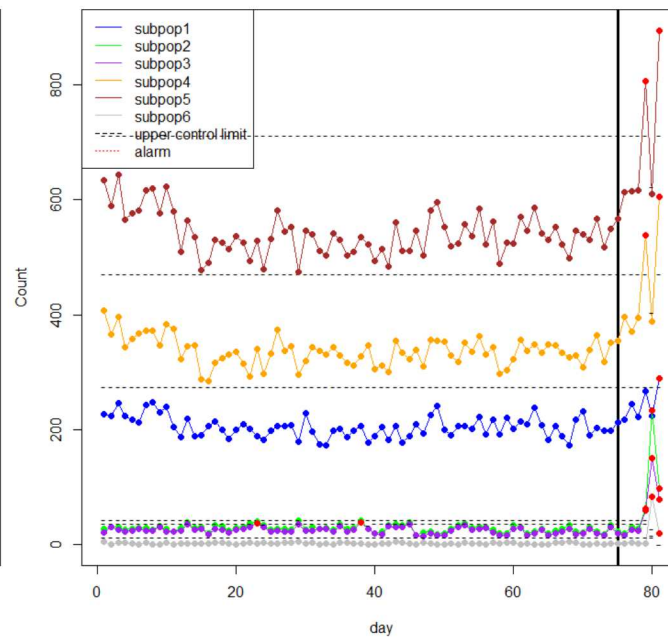


Scenario 2: Plague - fever

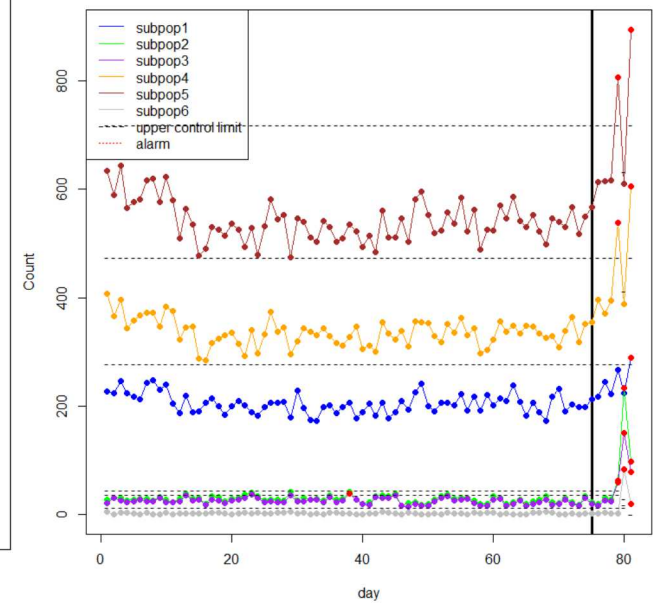
ARLa = 500, ARLr = 1



ARLa = 1000, ARLr = 1

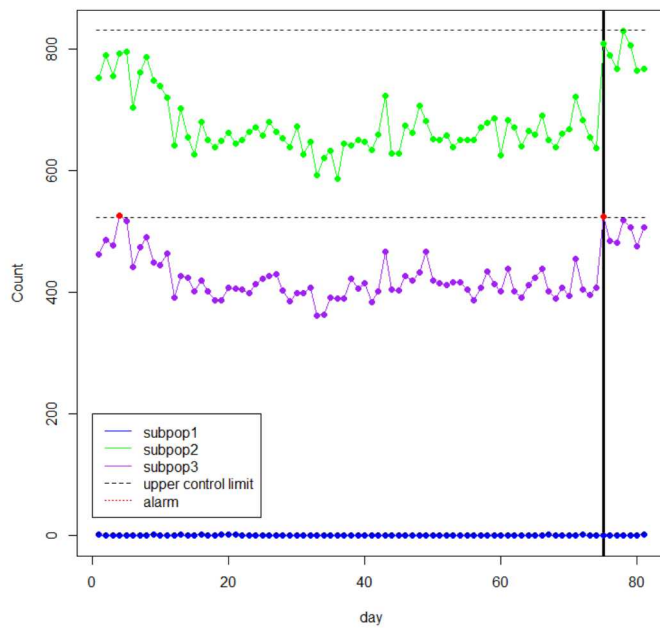


ARLa = 2000, ARLr = 1

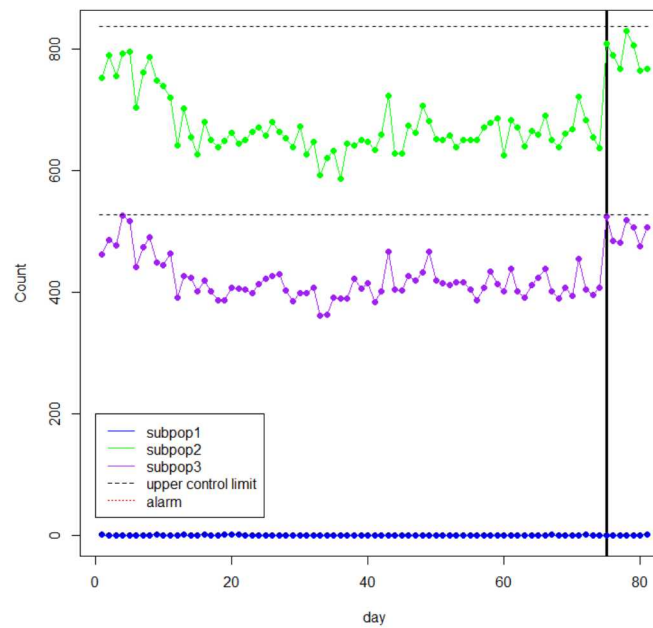


Scenario 2: Plague - respiratory

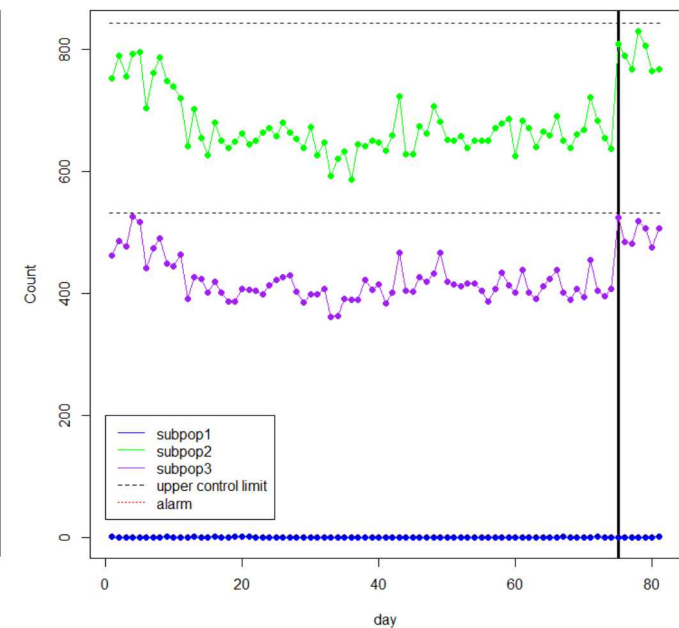
ARLa = 500, ARLr = 1



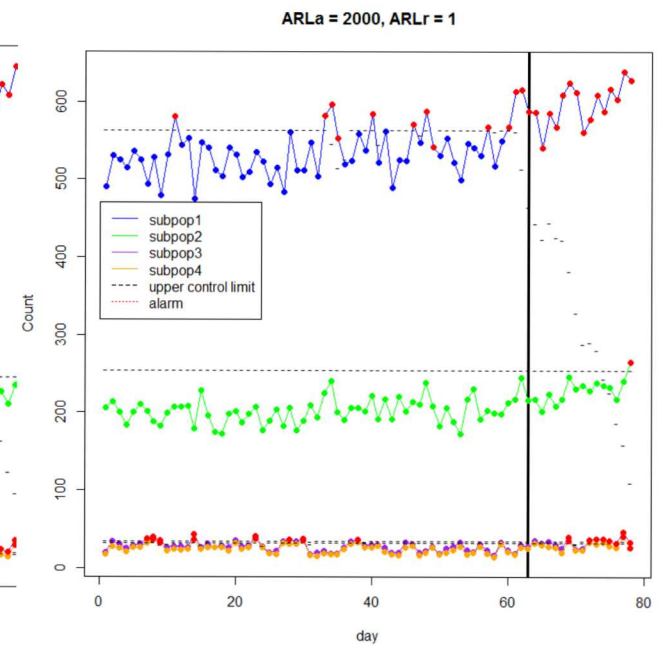
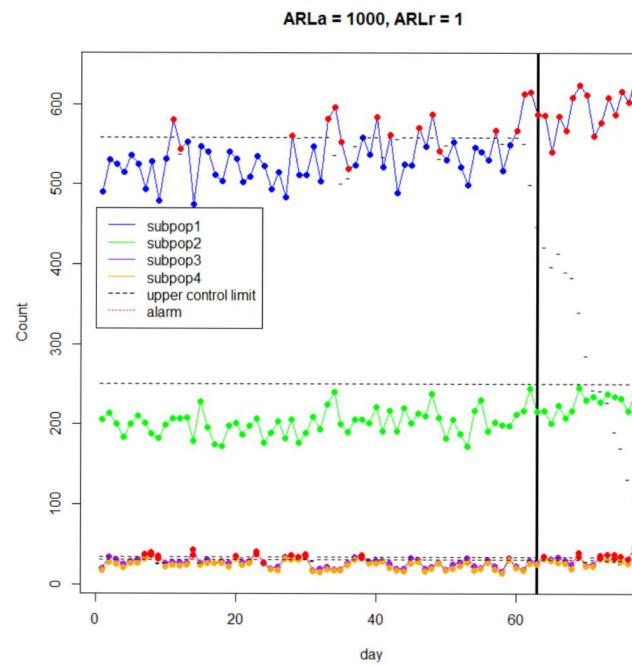
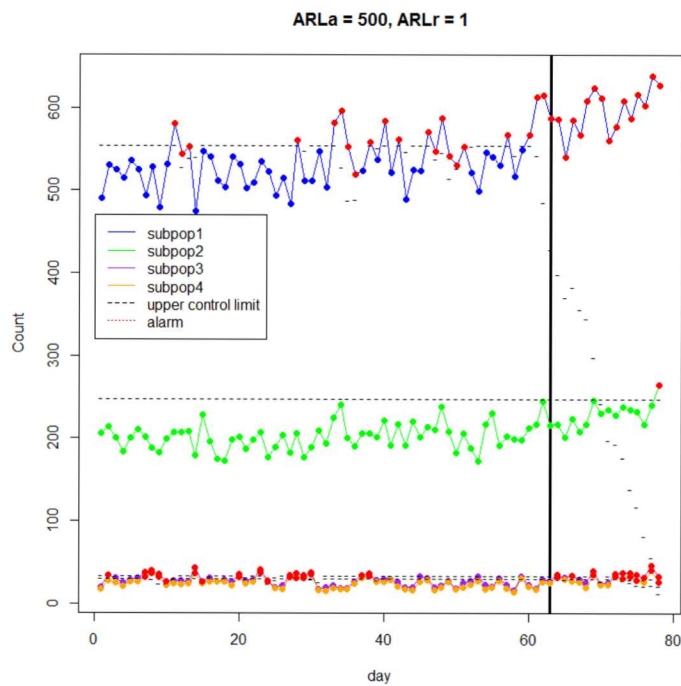
ARLa = 1000, ARLr = 1



ARLa = 2000, ARLr = 1

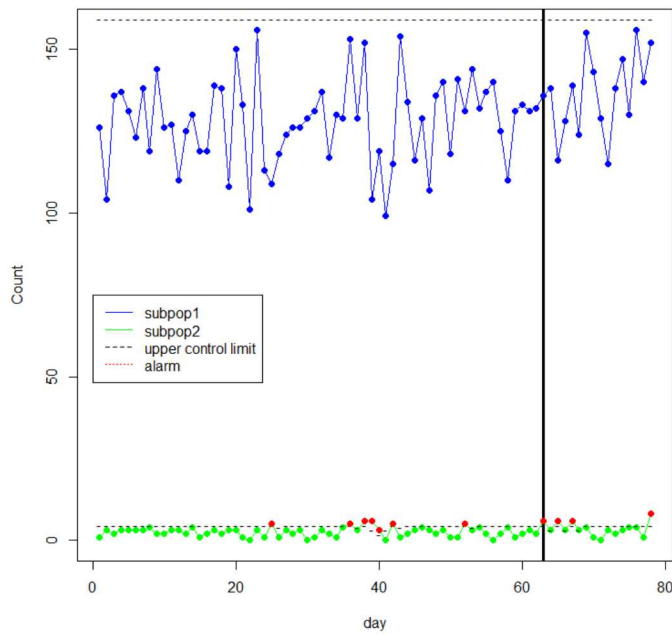


Scenario 3: Smallpox - fever

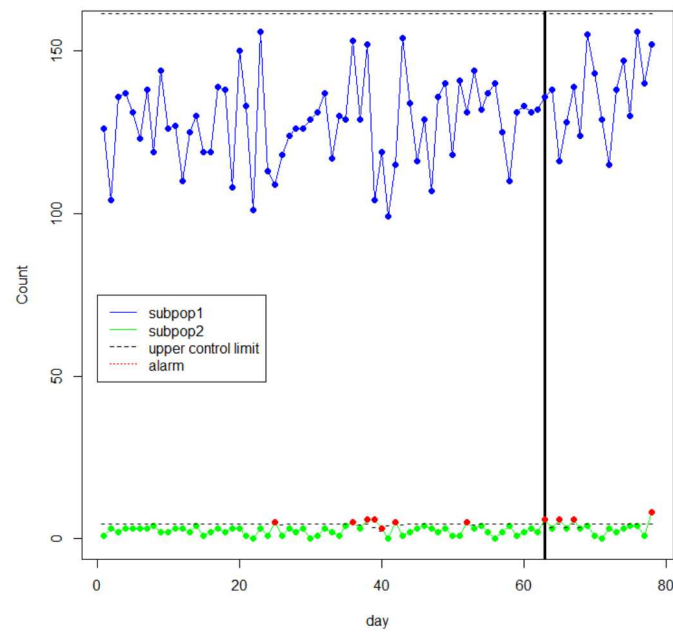


Scenario 3: Smallpox - respiratory

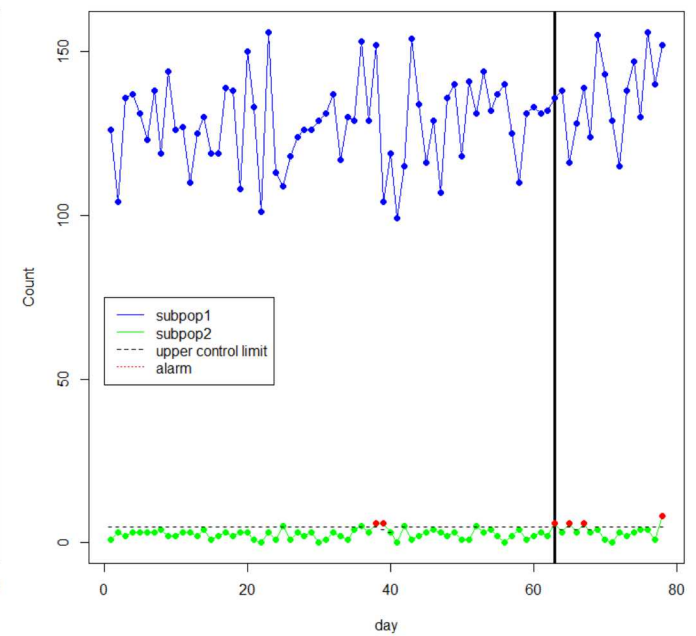
ARLa = 500, ARLr = 1



ARLa = 1000, ARLr = 1



ARLa = 2000, ARLr = 1



Conclusions

- EWMA - change default *nsigmas* from 3 to 1.75
 - Results in some new false alarms, but not an excessive amount
 - Results in earlier detection on many data streams (1 Anthrax-fever, 3 Plague-fever, 4 Smallpox-fever, and 2 Smallpox-respiratory data streams)
- CUSUM – change default *ARL α* from 500 to 2000
 - Results in fewer false alarms on many data streams (1 Anthrax-respiratory, 1 Plague-fever, 1 Plague-respiratory, 3 Smallpox-fever, 1 Smallpox-respiratory data streams)
 - Results in slightly later detection on a few data streams (1 Anthrax-respiratory by 1 day, 1 Plague respiratory goes undetected, 2 Smallpox-fever by 5 days)
 - Of these, other than Smallpox-fever, these are all mitigated by the sensitivity of EWMA

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