Department of Homeland Security
Federal Emergency Management Agency

Modeling and Data Working Group Biological Scenario Analysis

DRAFT

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Contents

Introduction

A large scale biological event is predicted to rapidly overwhelm resources at the state and local, rapidly requiring federal support; a biological emergency could easily be on par with the most catastrophic of other natural and man-made disasters. Events such as the on-going Zika outbreak, the 2014 Ebola outbreak in West Africa, and 2001 anthrax attacks (Amerithrax) highlight the need to plan for response to biological incidents. This report describes analysis of the current modeling and data capabilities employed across the Federal interagency to support the operational decision-making requirements for biological emergencies, whether naturally-occurring or intentional in origin.

The Modeling and Data Working Group (MDWG) commissioned an effort to identify and analyze the availability of models and datasets used to support emergency management for biological scenarios and the findings are presented in this report. The MDWG, chaired by the Director of FEMA's Planning Division, Response Directorate, was formed by the Emergency Support Function Leadership Group (ESFLG) to identify and characterize the models and datasets that are used across the federal interagency in support of operational decision making for emergency management. MDWG membership includes ESFLG-appointed representatives for each of the Federal Emergency Support Functions (ESFs) comprising subject matter experts, program managers, and program directors. The MDWG has produced the ESFLG Model and Data Inventory (MoDI),[1] an interactive, web-based resource that collates information about models and datasets and how they are used in support of emergency management. The MoDI now contains datasets and models for earthquakes, hurricanes, improvised nuclear device (IND), flood, and biological outbreak scenarios. will be added to the MoDI at the conclusion of the current expansion effort.

Report overview

This report includes a background introduction to biological incidents, results of the quantitative data and network analysis of the models and datasets identified through interagency interviews and the information flow between them, and recommendations highlighting opportunities to fill gaps identified by the network analysis. The background section focuses on identifying the unique characteristics that distinguish biological scenarios from other emergencies, the divergence between natural biological outbreaks and intentional attacks, and the response-relevant characteristics that determine data requirements for biological incidents. The current status of models and datasets available to support operational decision-making for biological scenarios is presented through the results of network and other quantitative analysis. In addition, these approaches are used to identify gaps in information availability. Finally, the network analysis results, information garnered from interviews, and lessons learned from analysis of non-biological scenarios are all incorporated to develop recommended solutions to fill identified gaps in information availability for biological scenarios.

Background: Understanding Biological Hazards for Emergency Management

To understand Federal response to biological hazards, it is important to understand types of emergency activations that apply to biological scenarios and the characteristics of the incidents that shape

[1] As of the publication date of this report, the MoDI is accessible at: http://gis.fema.gov/Model-and-Data-Inventory/

operational decision-making. The following background section addresses these two key points in detail. First, Federal agency response roles are described in terms of the type of Federal responses and emergency declarations that apply to biological incidents. Second, a framework is described that categorizes biological scenarios based on the characteristics most significant to influencing the decisions that must be made during a biological emergency response.

Agency Response Roles

The framework for agency response roles to biological scenarios is outlined in the National Response Framework (NRF) in the Biological Incident Annex (BIA) and ESF #8 – Public Health and Medical Services Annex. The Department of Health and Human Services "serves as the Federal Government's primary agency for the public health and medical preparation and planning for and response to a biological terrorism attack or naturally occurring outbreak that results from either a known or novel pathogen, including an emerging infectious disease" as defined in the BIA. The BIA also specifies, with respect to the Department of Homeland Security (DHS) that "The Secretary of Homeland Security is the principal Federal official for domestic incident management. Pursuant to the Homeland Security Act of 2002, the Secretary is responsible for coordinating Federal operations within the United States to prepare for, respond to, and recover from terrorist attacks, major disasters, and other emergencies, including biological incidents." In this way, DHS acts as incident coordinator for non-medial aspects of Federal interagency emergency response and HHS oversees coordination of all public health and medical response operations.

The Federal response to a public health emergency could include agency-level actions in the absence of formal emergency activation (e.g., public health response activities), activation of ESF # 8, Public Health Emergency declarations made by the Secretary of HHS, and Presidential disaster declarations under the Stafford act. Multiple Federal response levels may apply over the course of a single biological incident as it develops. For example, HHS expert scientific agencies, such as the Centers for Disease Control and Prevention (CDC), perform public health surveillance and response efforts as part of their day-to-day-mission, and are often the first to initiate activities in the early stages of an incident. Subsequently, activation of ESF #8 would initiate response by the HHS Office of the Assistant Secretary for Preparedness and Response (ASPR) that is tasked as the primary lead for emergency preparedness and response for HHS. Thus, the Secretary of HHS, primarily acts through HHS ASPR to lead domestic emergency response to biological incidents. HHS, including its actions through FEMA, supports interagency coordination and additional response elements not related to public health and medicine. This activation of ESF #8 through the National Response Framework is specific to domestic outbreaks and requires a coordinated hand-off from the day-to-day role of CDC in managing public health to the ASPR emergency response efforts for a large scale outbreak.

In addition to HHS and DHS, interagency response to biological incidents also includes many cooperating agencies with roles unique to their specialties, authorities, and the response-relevant characteristics of the biological incident, demonstrated in the following examples. For a natural biological outbreak of international origin or with international impacts, Department of State will be key to international communications and coordinating international response efforts, in collaboration with CDC and international health organizations such as the World Health Organization (WHO). In the case of an intentional biological release, the attack is a criminal act in addition to a public health emergency, and the Federal Bureau of Investigation would coordinate law enforcement efforts with the Environmental Protection Agency leading decontamination and cleanup of an environmentally persistent agent.

Once it is clear that an outbreak or attack has occurred, agencies with authority for biological incident emergency response must decide if cases are numerous enough to activate a federal emergency response and, if so, what type of response is appropriate (Stafford Act emergency declaration, public health emergency determination, or other Federal response). The delayed onset nature of biological events means that, even with rapid decision-making, the response has a strong chance of arriving late in the event.

Response-relevant characteristics

Biological outbreaks and public health emergencies can be caused by a wide range of agents and necessitate a framework to define the incident-specific data that define response requirements. To support a framework applicable to biological emergencies broadly, specific response-relevant characteristics were identified for biological scenarios. This approach to cataloging information departs from a strictly agent-based method, such as planning selectively for anthrax attacks or avian influenza outbreaks. A focus on response-relevant characteristics extends rather than precludes the development of agent-specific data requirements or plans by defining the essential attributes of the biological agent and event that influence the operational decisions that must be made to support the emergency response.

Biological scenarios exhibit six response-relevant characteristics that shape event-specific data requirements:

- Is there a natural outbreak or intentional release of a biological agent?
- Is the event international or domestic?
- Is the agent contagious?
- Is it known and detectable?
- Are medical countermeasures available?
- Is the agent environmentally persistent?

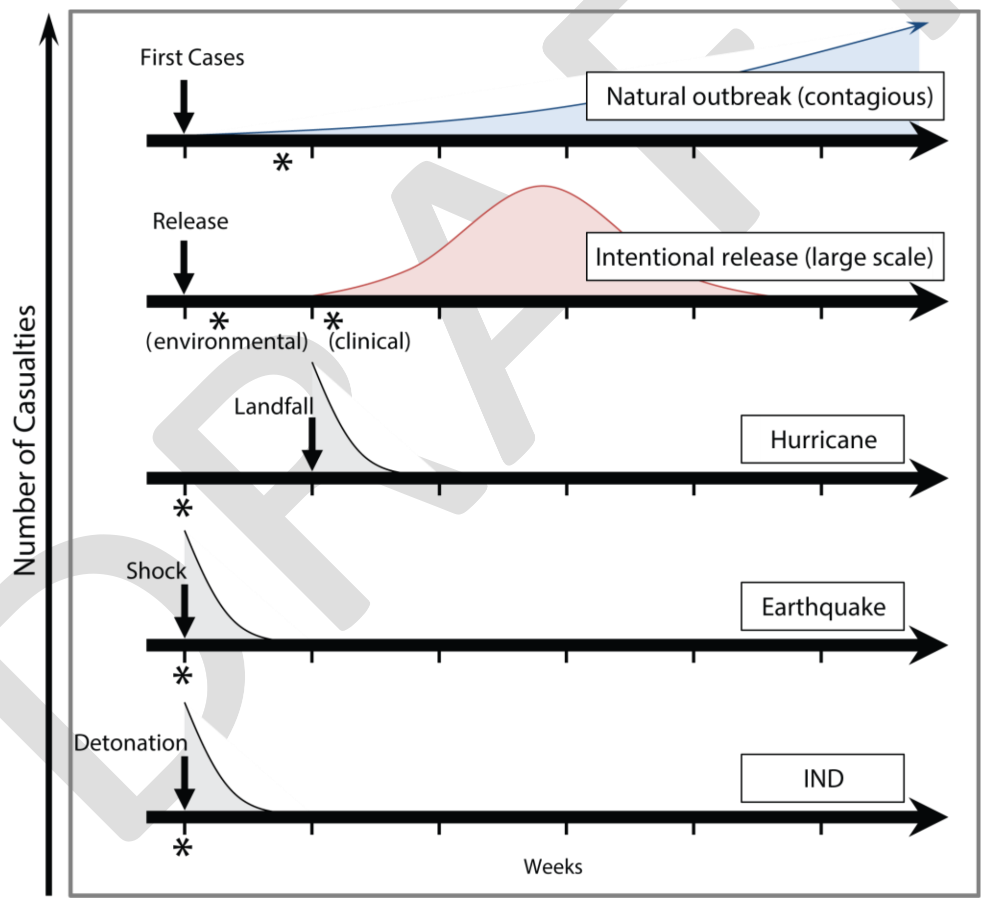
The response-relevant approach simplifies the response to biological hazards, despite the diversity and complexity of causative agents, and focuses effort on those characteristics that are immediately relevant to emergency management efforts. Response-relevant characteristics provide a framework to understand the key incident features in developing emergency operations for such events.

Natural and Intentional Events

Natural biological outbreaks and intentional biological releases differ in several key ways that distinguish them as functionally separate scenarios under the biological hazard. First, natural outbreaks are likely to differ significantly from intentional attacks with respect to the Federal agencies involved in and responsible for the response, including the likelihood of a Stafford Act declaration and law enforcement engagement. In addition, models and datasets that support natural biological outbreaks are different from those applicable to an intentional biological release given both the mechanisms of spread and the types of causative agents. Finally, intentional attacks and natural outbreaks follow unique event timelines, as described in more detail below. As a result, the analysis presented in this report separate naturally-occurring disease outbreaks and the relevant datasets and models from those applicable to intentional biological release events.

Biological Event Timelines

Biological hazards unfold with distinct timelines for intentional attacks and naturally occurring outbreaks. Intentional biological scenarios included in the current analysis are assumed to involve a large-scale release of a biological agent. Figure 1 diagrams the notional time-course of casualties resulting from an intentional biological release event with a non-contagious biological agent (shaded red). The incident begins when individuals become exposed at the time of the attack (marked "Release" in the inset). However, illnesses emerge with a lag due to the incubation period of the biological agent, and then present as a clustered, mass onset of cases. Infected individuals do not develop symptoms for days or weeks, and casualties increase with a pronounced delay from the start of the incident. As a result, an emergency declaration cannot occur until the unfolding incident is detected by environmental sampling[2] or clinical cases (marked with asterisks).



2 The delay between release, when an environmental sample collects evidence of the biological agent, and environmental detection represents the time required for sample collection, laboratory testing, and confirmation of a biological attack.

Figure 1. Biological Incident Event Timeline Compared to other Scenarios. Plot of the casualty timeline for different emergency scenarios. Biological scenarios have a much slower onset of casualties compared to hurricanes, earthquakes, and INDs where casualties peak early in the event and rapidly trail off.

Biological agents that cause natural outbreaks, as included in this analysis, are contagious and build from isolated cases to a full-blown outbreak – making the onset of natural outbreaks even more gradual than intentional release events. The slow "ramp up" of cases during a contagious natural outbreak reflects both the incubation period of the infectious biological agent and how likely each infected person is to transmit the disease to others. Detection of a highly contagious or deadly outbreak could trigger a near-immediate response, but for an emerging infectious disease, it is difficult to determine how many cases represent cause for concern and meet the threshold for a Federal response, particularly when the agent is poorly-characterized.

The delayed, progressive increase in casualties characteristic of biological events is fundamentally different from the timeline of other natural disasters or man-made events. By analogy to advanced notice and no-notice events, biological events are "delayed onset" events (Figure 1). No notice events include earthquake and IND scenarios where the incident occurs without warning and causalities immediately result. Advanced notice events, such as hurricanes, also cause casualties immediately after they occur; but these events are forecast in advance, affording time for evacuations and other interventions to reduce casualties. Delayed onset events, including naturally-occurring biological outbreaks and intentional biological releases, are unlike other events: biological incidents may go undetected even as they are occurring. Delayed onset events still have the potential for intervention before maximal casualties occur, but the incident must be positively identified and rapid response mounted.

One of the major challenges in managing or mitigating a disease outbreak is that the major decisions that can be mediated by the federal government must be made very early in the event to have an effect. For example, development of a new medical countermeasure requires a minimum of six months and is more likely to take 12-18 months and must therefore be initiated very early if it is to have any effect. Similarly, large-scale vaccination or social distancing campaigns (including school closures) need to be implemented before the majority of the population has been exposed. Therefore, these decisions must often be made long before an outbreak has been confirmed, which is often politically untenable.

International or domestic origin?

Whether a biological incident has an international or domestic origin is a key determinant of the nature of the emergency response. Only a subset federal agencies have an international response mission; therefore, some agencies lack the authority or funding to monitor or respond to international events with the potential for a domestic impact. In addition, during a natural outbreak, information must be obtained from foreign governments and international non-governmental organizations (NGOs). The availability of this information and rules governing information sharing are different than for domestic incidents and vary widely between countries. For example, data as seemingly simple as the case count and fatality rate were available only from some of the countries affected by the 2014 Ebola outbreak in Western Africa, which significantly impacted the ability of the U.S. to respond effectively or plan for mitigating efforts domestically.

Is the agent contagious? If so, how?

Contagiousness influences both the event timeline and the decisions faced by state, local, tribal, territorial and Federal government officials. Contagious agents are defined as those transmitted from person to person through casual contact. Natural biological outbreaks, as shown in Figure 1, will drive waves of infection and will continue to spread until transmission is brought under control. Waves of transmission would also occur if a contagious biological agent was intentionally released (not shown in Figure 1). To stop transmission and bring a contagious outbreak under control, government officials may recommend social distancing (reducing person to person contact by cancelling events or closing school), instituting travel bans, and, potentially, mandating quarantine. Vector borne disease are those transmitted from person to person by insects, such as the transmission of Zika virus by mosquitos. Since vector-borne diseases spread across the human population, though indirectly, the event timeline follows a similar time course as contagious agents. Given their mode of transmission, vector-borne diseases call for vector control (e.g., insecticides) and other measures to prevent individuals from coming into contact with the insect vectors that transmit the disease.

Known and detectable?

The range of knowledge about biological agents spans from well-characterized for some extensively studied agents of concern for intentional release by terrorists to completely unknown and undetectable for a novel infectious disease. For those agents that are well-characterized, historical data or modeling may be available to help support response decisions. Medical countermeasures (e.g. vaccines to prevent infections or antibiotics to provide treatment) and diagnostic tests to distinguish the sick from the well may be available to support the response for such agents. Finally, known agents may be detected upon intentional release by a detection system, such as the BioWatch program, providing the ability to mobilize resources even before the exposed population develops symptoms.

Without vaccines, treatments, diagnostic tests, or environmental detection, unknown agent, emerging infectious diseases, or modified agents present many additional challenges. Significant work is required simply to define the characteristics of the agent itself and determine expected consequences of the outbreak or attack. In addition, since unknown agents have not been previously characterized, no specific predictive models or historical datasets will be available and information will be limited to case reports and the situational awareness that develops during the incident.

Available medical countermeasures?

Vaccines, treatments, or tests may be available for known agents and can be mobilized if they are stockpiled. For some agents, countermeasures are general, such as a broad spectrum antibiotic that can treat many types of infections or ventilators to support the surge requirements of hospitals with large number of patients experiencing respiratory distress. Even the most basic personal protective equipment (PPE), such as respirators, facemasks, goggles, and other protective coverings are important for supporting response operations. In other cases, only highly specific medicines or tests are useful. A large-scale natural outbreak or intentional biological release event may trigger development of new countermeasures or Emergency Use Authorization (EUA) for the use of a previously developed, but not approved, medicine or test by the Food and Drug Administration. For example, recent EUAs permitted use of tests for H7N9 (avian influenza A), Zika, and Ebola viruses.[3]

Environmentally persistent?

The final response-relevant characteristic is environmental persistence: the more persistent and agent, the longer it survives in the environment with the ability to infect people. Environmental persistence is of greatest concern for large-scale intentional release events with highly stable biological agents, such as anthrax spores, where a large-scale clean-up and decontamination effort would be required to protect the public from additional infections. Nevertheless, environmental persistence will also be a concern for natural events as the public will expect information about the safety of areas where infected patients lived, worked, or were treated. If an agent is persistent in the environment, the EPA is likely to have a much more active role in the response and recovery to the event.

Flow of Information Overview: Data and modeling to support biological incident data requirements

The information required to support operational decision-making for an emergency is produced through an iterative process of data collection, data analysis, and modeling. Figure 2 outlines this flow of information with examples specific to a natural biological outbreak. Raw data, including individual case reports describing ill individuals, are processed by biosurveillance and epidemiological analysis that provide event characterization and determine if a cluster of case reports constitute an outbreak. Event characterization tools for other hazards are typically computational models (e.g. weather forecasting models for hurricanes or ground shaking models for earthquakes); in contrast, biosurveillance and epidemiology used for biological incidents are primarily observational and based on trend analysis, rather than predictive.

Epidemiological analysis provides situational awareness data in the form of specific disease parameters such as basic reproduction number R_0 (how many others a sick person can infect) and the case fatality ratio (likelihood of death in individual cases). Consequence models or analysis process situational awareness data into impact estimates. Epidemiological models predict how many will become sick or die, thus generating impact estimates for the incident. Finally, decision support tools analyze impact estimates to guide decision-making (e.g., determine if schools should close) and calculate mission-specific requirements for personnel and materials. For a natural biological outbreak, mission-specific requirements include the number of medical personnel with specific skills and requirements for medications, ventilators, and other medical supplies.

3 U.S. Food and Drug Administration. *Emergency Use Authorizations.* Retrieved from http://www.fda.gov/MedicalDevices/Safety/EmergencySituations/ucm161496.htm. Accessed 24 Aug. 2016.

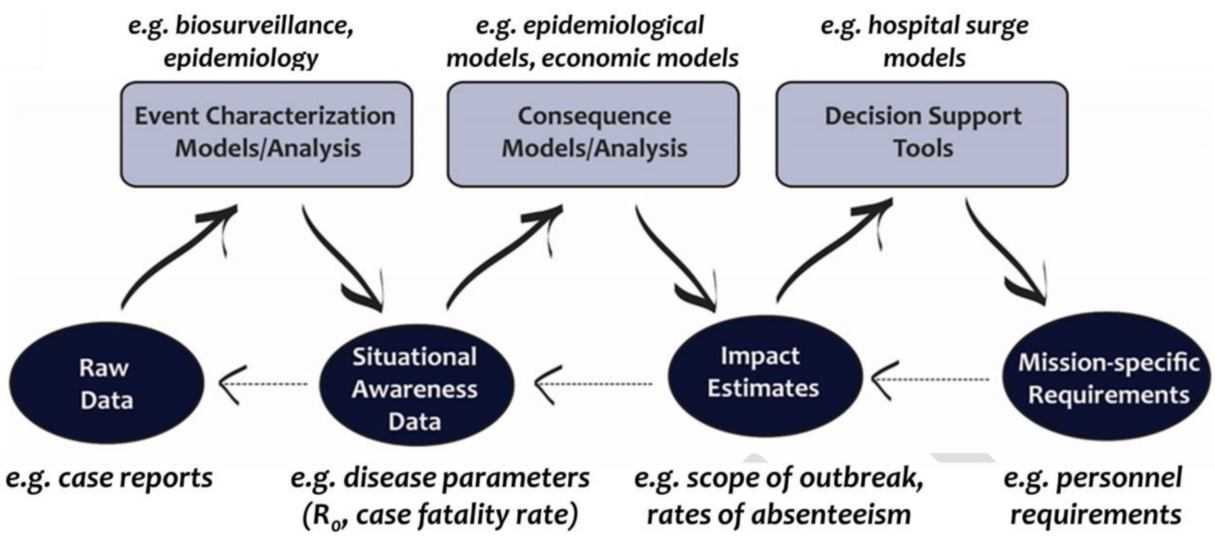


Figure 2. Flow of Information Framework. Iterative process of data collection and analysis through the different types of datasets and models used by the federal emergency management community. Biological scenario-related examples are described above or below each category for the purposes of illustration.

Results

To identify models and datasets in use across the Federal interagency for response to both natural biological outbreaks and intentional biological releases, 86 interviews were conducted with 134 individuals representing 22 federal agencies, division, and groups representing a cross-section of the interagency. The majority of interviews were conducted with HHS, the coordinating agency for biological incidents, including HHS CDC and HHS ASPR, followed by DHS and Department of Defense (DoD). Interviewees included senior leadership, program leads, and subject matter experts. Models and datasets identified through the interview process were cataloged and information from interviews was combined with background research to describe the tools themselves and their use to support operational decision-making. Finally, quantitative and network analysis were performed to characterize information resources for biological scenarios and the results are presented below.

Naturally-occurring infectious disease outbreaks

Results Overview for Natural Biological Outbreaks

- Subject matter experts are primary information sources and coordinators and provide models/datasets across the flow of information
    - HHS-CDC, HHS-ASPR, and Academia/NGOs
- HHS-CDC is central to information coordination for biological-natural scenarios due to the centrality of models/datasets owned by CDC and because of the agency's perceived role as coordinator, as identified from interagency interviews

Naturally-occurring infectious disease outbreaks happen every year in the U.S. Such outbreaks include both contagious and non-contagious disease, those that are preventable (e.g. by vaccination), those for which there are medical countermeasures, and largely unknown diseases for which there is little recourse. The federal emergency management community engages in a subset of these outbreaks when there is sufficient concern that limiting the scope or impact of the outbreak will require federal action: funding the development of a new vaccine or supporting a large-scale vaccination campaign, advising states on monitoring and managing school closures or quarantine measures, supporting strained state and local healthcare capabilities, or managing cross-border travel with other countries experiencing outbreaks of significant concern. In previous years, such events have included outbreaks of novel influenzas (e.g., H1N1, H7N9, H5N1), measles outbreaks in the U.S., Ebola in West Africa and then the U.S., and the Zika virus. Food-borne and animal disease are of significant concern, but tend to be managed by a different subset of agencies and encompass a wide community outside the scope of this effort.

Flow of Information within the Network

Each dataset and model identified in interviews as used to support federal emergency management efforts for naturally-occurring biological outbreaks is mapped in the network in Figure 3. Tools are colored by their type, as outlined in the flow of information framework above, with the lightest color representing raw data and the darkest color representing mission-specific requirement datasets. Linkages between the datasets and models represent the transfer of information between tools. This network provides a systems-level overview of the information network used by the federal emergency management community.

This type of analysis has been performed previously for a range of hazards, including hurricanes, earthquakes, flooding, and nuclear detonation scenarios. Notably, there are significantly fewer total datasets and models available to and used by the federal emergency management community for naturally-occurring biological outbreaks than any other scenario (73 datasets and models, as compared to 189 for hurricanes).[4] Of these, there is an overrepresentation of lightly-colored, or minimally processed, datasets and analysis. The combination of these results suggests that there are relatively few datasets and models available to support operational decision making. Among those that are available, most are not tailored support operational decisions because most data do not flow into decision support tools, and data are not processed into the mission-specific requirements that directly support specific emergency management missions.

In addition, the relatively small number of datasets and models (compared to other hazards), and fewer connections between them, means that the network is prone to destabilization. Addition or removal of tools or connections may have far-reaching impacts on the network, much more than would be predicted for a larger and more interconnected network. Though this could represent vulnerability in network stability network, it also means that investments in the available tools or connections can rapidly result in tangible improvements.

Orphan models/datasets by hazard

In the upper right hand corner of the network map is a cluster of datasets and models that are entirely unconnected to the rest of the network – datasets and models, termed “orphans”, that exchange no data with other tools in the network. As with nearly every other hazard analyzed, this cluster of orphans

4 Emergency Support Function Leadership Group. *ESFLG Model and Data Inventory.* Retrieved from http://gis.fema.gov/Model-and-Data-Inventory/index.html. Accessed 24 Aug. 2016.

is significantly darker in color than the rest of the network, suggesting a disconnect in the incorporation of event-specific data and analysis into the most operationally-focused tools. As shown in Table 1, when compared to other hazards, there is a much larger percentage of orphan tools in the naturally-occurring biological hazard network map than for other hazards. This result highlights a lack of robust data and information sharing between analysis tools for these events.

Table 1. Orphan Datasets and Models

Hazard	Orphan Datasets and Models
Natural Biological Outbreaks	37% (27 / 73)
Intentional Biological Release	34% (25 / 74)
Improvised Nuclear Device (IND)	30% (50 / 169)
Hurricane	21% (40 / 189)
Flood	20% (38 / 189)

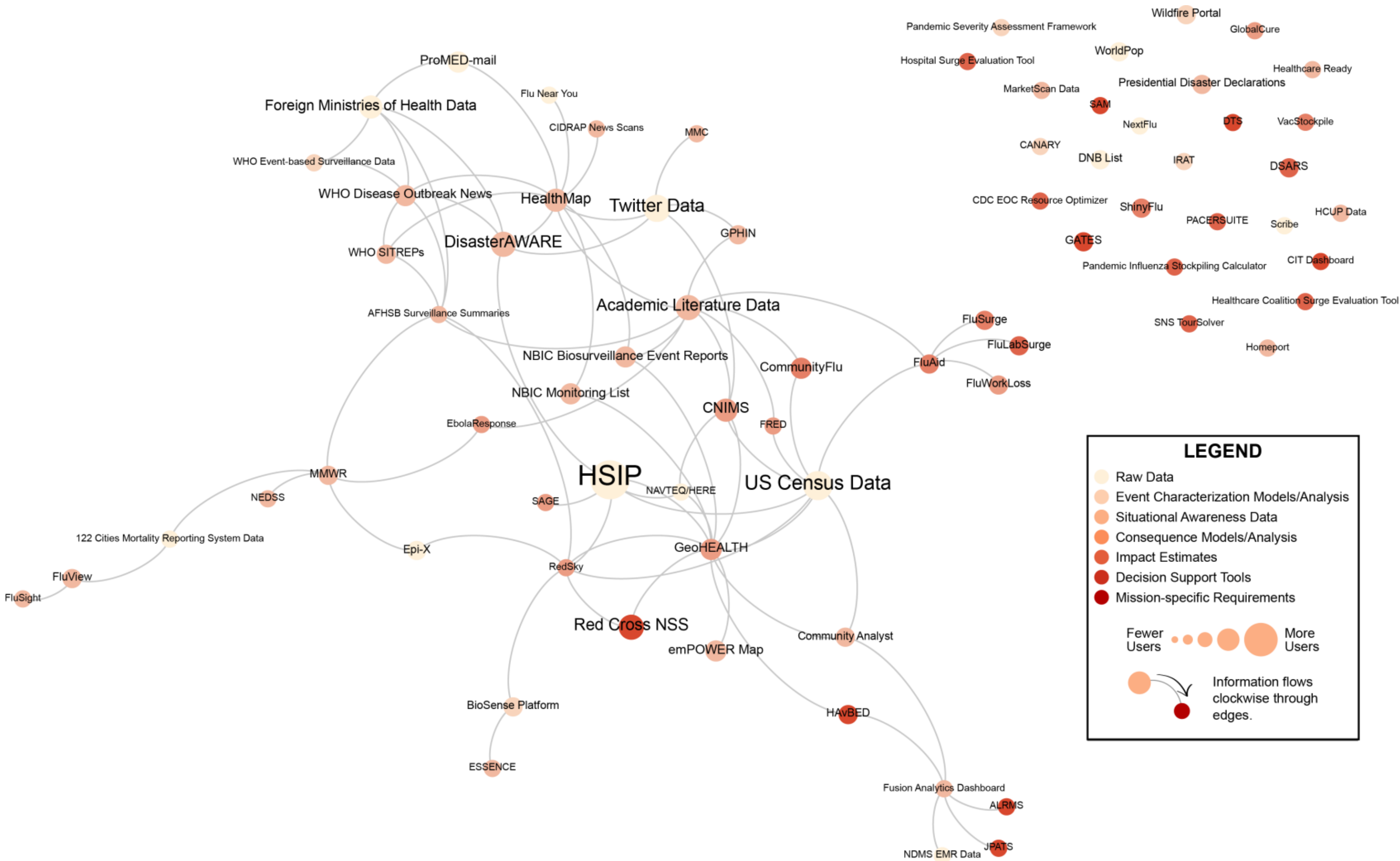


Figure 3. Network Map for Natural Biological Outbreaks. Nodes (circles) are sized by the number of federal agencies using the tool. Information flows clockwise along edges (lines) between the datasets and models and indicate data transfer between information resources. Each node is colored by its position in the flow of information framework with raw data and event characterization models colored most lightly and decision support tools and mission specific requirement datasets colored most darkly.

Centrality in the network

In Figure 4, the network map shown shows the centrality of each dataset or model in the network - a measure of the degree to which a specific dataset or model functions as a bridge between other datasets and models.[5] Overall, the network of datasets and models used for naturally-occurring biological outbreaks lacks central tools, especially those that are widely used. Indeed, RedSky, the situational awareness tool owned by HHS CDC, is most central, but is only used by HHS CDC. GeoHealth, also a situational awareness viewer, and Health Map, a private sector data integration and biosurveillance platform, are also among the most central tools in this network and both are somewhat more widely-used than RedSky. However, by contrast to all other networks analyzed, this network has no central, widely-used consequence model. This finding suggests both a lack of coordination and information exchange across the information network supporting natural biological outbreaks, but also suggests that there is no widely-accessible or shared source of consequence modeling (i.e., epidemiological modeling) for the interagency.

In parallel with previous analyses, it was expected that the most central dataset or model would be a consequence model or the outputs of that models. In the case of natural biological outbreaks, this consequence model(s) would be an epidemiological model or a platform that widely disseminates the modeling outputs to the broader emergency management and response community as an outbreak unfolds. However, while RedSky indeed provides the results of epidemiological analysis and modeling, it does not serve as an information dissemination platform beyond CDC. The predictive analysis provided through the tool is also limited. As a comparison to other hazards, the National Oceanic and Atmospheric Administration (NOAA), through the National Hurricane Center, currently implements this type of dissemination of complex scientific modeling results for hurricanes by reviewing and analyzing the available models as soon as they become available and publishing those results in a response-relevant format to the broader emergency management community. These hurricane forecasting products also include clearly defined recommendations for action – a standardized event characterization modeling output released not only to the emergency management community, but to the public. Similarly, HHS CDC or HHS ASPR could review and analyze the available epidemiological models produced by the academic and expert communities as an event is unfolding and make those results available in a response-relevant format to the broader emergency management community with clearly defined recommendations for action.

[5] The integration of a model or dataset into the network can be quantified by betweenness centrality, a centrality measure that characterizes how often a node is found between other nodes in the network. Additional details on network analysis methods are described in Appendix B.

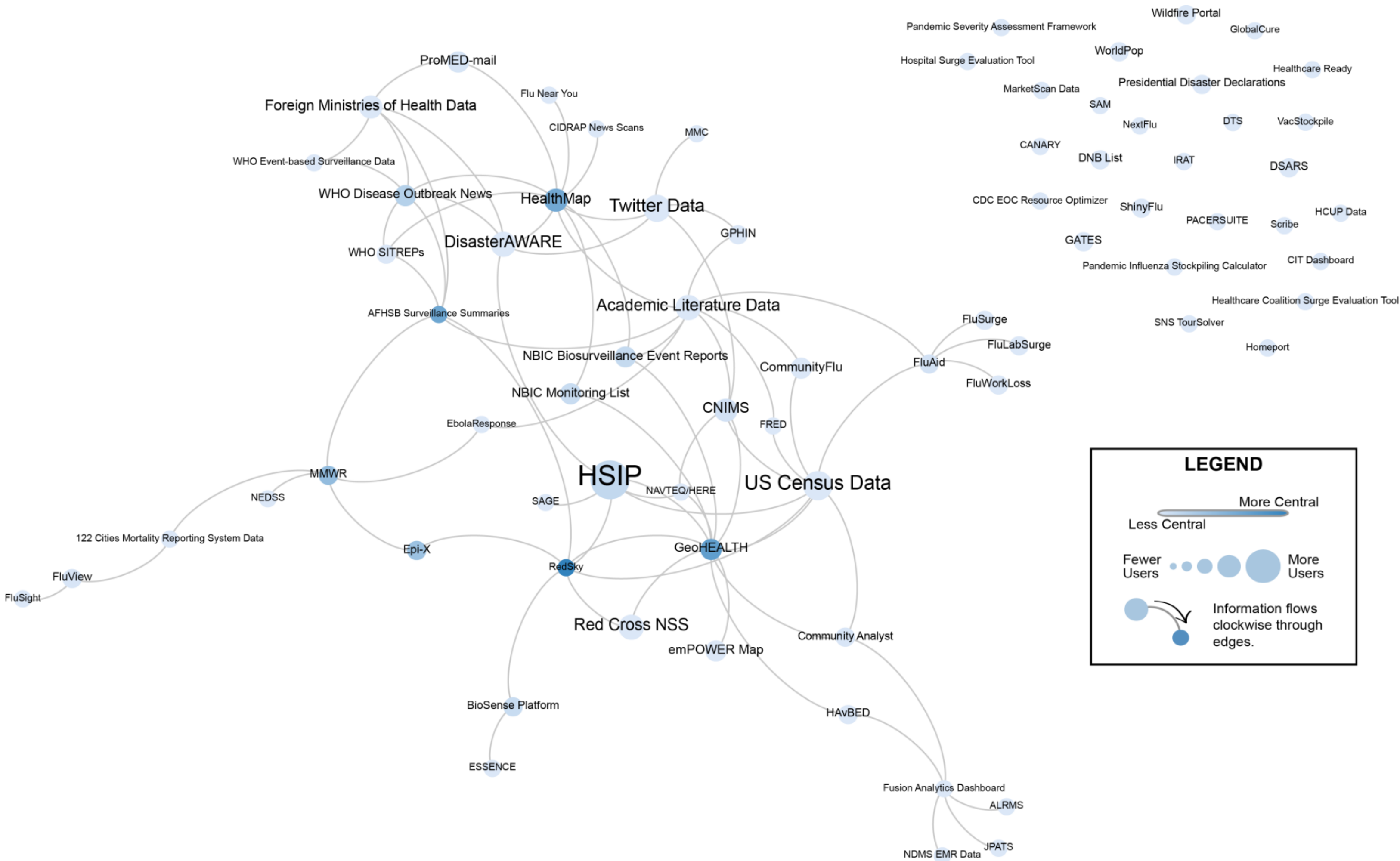


Figure 4. Centrality Network Map for Natural Biological Outbreaks. Nodes (circles) are sized by the number of federal agencies using the tool. Information flows clockwise along edges (lines) between the datasets and models and indicate data transfer between information resources. Each node is colored from less central (lighter blues) to more central (darker blues) using the betweenness centrality metric. Darker, more central models/datasets serve as primary information bridges between other models/datasets.

Agency owner centrality

Centrality analysis can also be applied to a network of the agencies involved in biological hazard emergency management, as shown in Figure 5. Analysis of the agencies that serve as information coordinators for public health emergencies suggests that HHS CDC is the lead for interagency information coordination and data sharing with the most tools overall and many of the most central tools. DoD also owns highly central tools, but they own fewer of them. A central coordination role for HHS CDC is consistent with the results from interviews, during which HHS CDC was typically identified as the primary source of subject matter expertise and analysis for naturally-occurring biological outbreaks. However, the primary subject matter expert agencies for other hazards (e.g., NOAA for hurricanes and USGS for earthquakes) are typically the source of raw data, event characterization models, and situational awareness data, but share the role as primary information coordinator with the agencies responsible for response coordination (e.g., FEMA). Interviewees at the CDC indicated that the agency does not consider itself to hold the lead coordinator role for the interagency response for naturally occurring biological incidents. Instead, HHS ASPR, which owns more, but less central, tools in the network, is identified under ESF #8 as the lead agency for HHS emergency response.[6]

Also of note, academia has prominent role in the network. While the academic literature can provide important fundamental modeling parameters, academic research is not well-suited to the time-sensitive requirements of providing event-specific emergency response information, particularly given the delays required to publish in peer-reviewed academic journals. These delays persist despite efforts to reduce publication delays during outbreaks. Moreover, research outputs prioritize information that supports the research questions rather than the operational requirements of emergency management.

[6] ESF #8 Public Health Emergency Preparedness. http://www.phe.gov/Preparedness/support/esf8/Pages/default.aspx#8 accessed August, 2016.

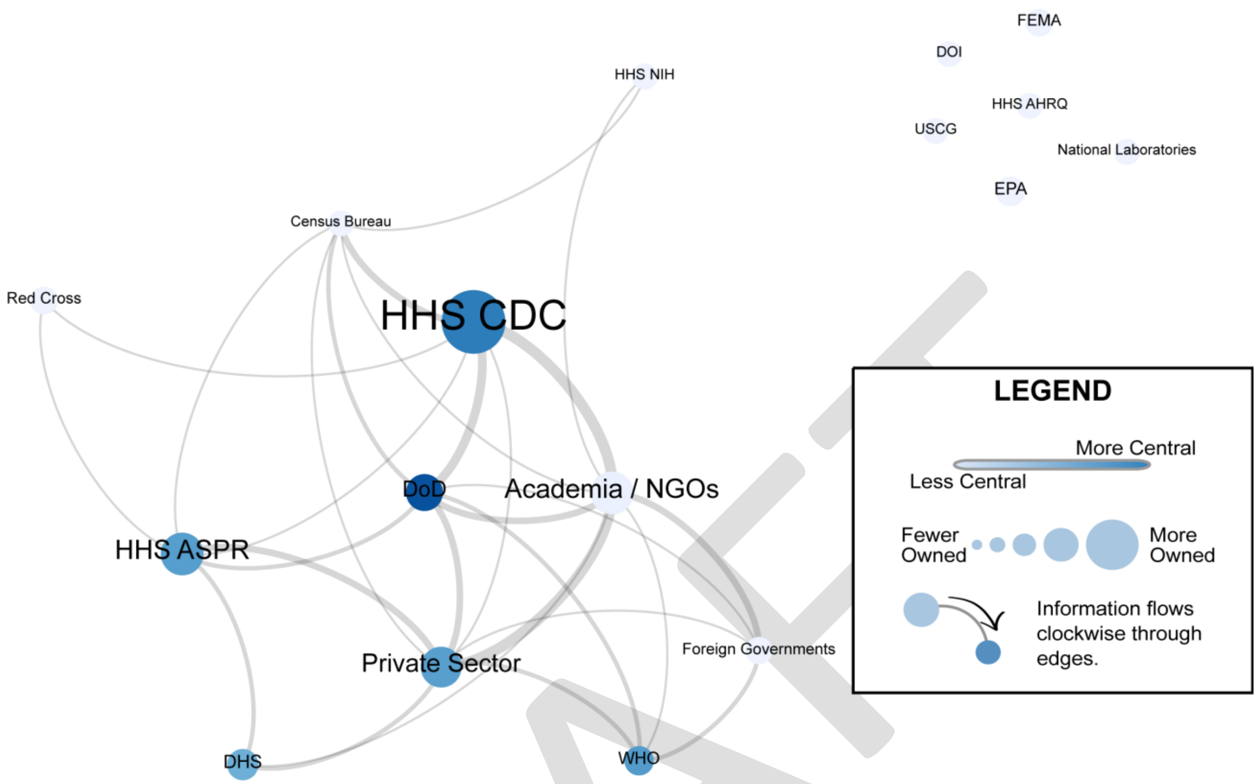


Figure 5. Owner Centrality Network for Natural Biological Outbreaks. Nodes (circles) represent federal agencies that own models/datasets used to support response to natural biological outbreaks and are sized by the number of models/datasets owned. Information flows clockwise along edges (lines) between the datasets and models and indicate data transfer between information resources. Each node is colored from less central (lighter blues) to more central (darker blues) using the betweenness centrality metric. Centrality and information flow in this network represent the average across all models and datasets owned by a given agency for naturally occurring biological scenarios.

Agency roles in information coordination

Based on the results of analyses of other hazards, expert scientific agencies typically own tools early in the flow of information framework – raw data, event characterization, and situational awareness data – for which they provide and subject matter expertise and act as an early information hub. Agencies responsible for coordinating and executing the response own datasets and models late in the flow of information – consequence and decision support analysis – for which they play a complementary role as information coordinators. This result is highlighted in Figure 6, a Sankey diagram in which information types are organized according to flow of information framework on the left with connections to agencies, on the right, based on the distribution of information types they own. For hurricanes, NOAA, provides the majority of datasets and models early in the flow of information, and FEMA provides the largest number of tools late in the flow of information framework. Each agency owns a significant subset of models and datasets corresponding to their respective specialized roles, and the agency serving as the primary coordinator of the response is highly central – receiving data and modeling results from the expert agencies doing the initial data collection and analysis. FEMA the coordinates the information processing and exchange required to inform response and recovery activities that require consequence analysis and decision support.

Figure 7 presents the same analysis for naturally-occurring biological outbreaks. By contrast to hurricanes, there are significantly fewer agencies contributing tools for response to natural biological outbreaks. As for hurricanes, a scientific subject matter expert agency, HHS CDC, is both the primary agency providing subject matter expertise for the hazard and is the largest provider of datasets and models early in the flow of information. HHS ASPR owns the largest number of models toward the end of the flow of information, including decision support tools, which corresponds to its role as the lead for coordinating the response. However, by contrast to the situation for the other hazards analyzed[7], HHS ASPR does not own the most central tools (as described in Figure 5) nor was it described by interviewees as a primary source of information for response and recovery efforts. Taken together, these results suggest that HHS ASPR has the datasets and models and the technical expertise to coordinate the response, but the information is not shared or coordinated within the interagency during an event.

Finally, academia/NGOs and the private sector provide much greater proportion of the information for naturally-occurring biological hazards than for hurricanes. Because these organizations are not organized around a federal emergency management mission, the information they produce is not likely to be tailored to the data requirements or produced in the formats and timeline required to support operational decision-making during a natural biological outbreak.

[7] The other hazards analyzed to date include hurricanes, earthquakes, floods, and INDs.

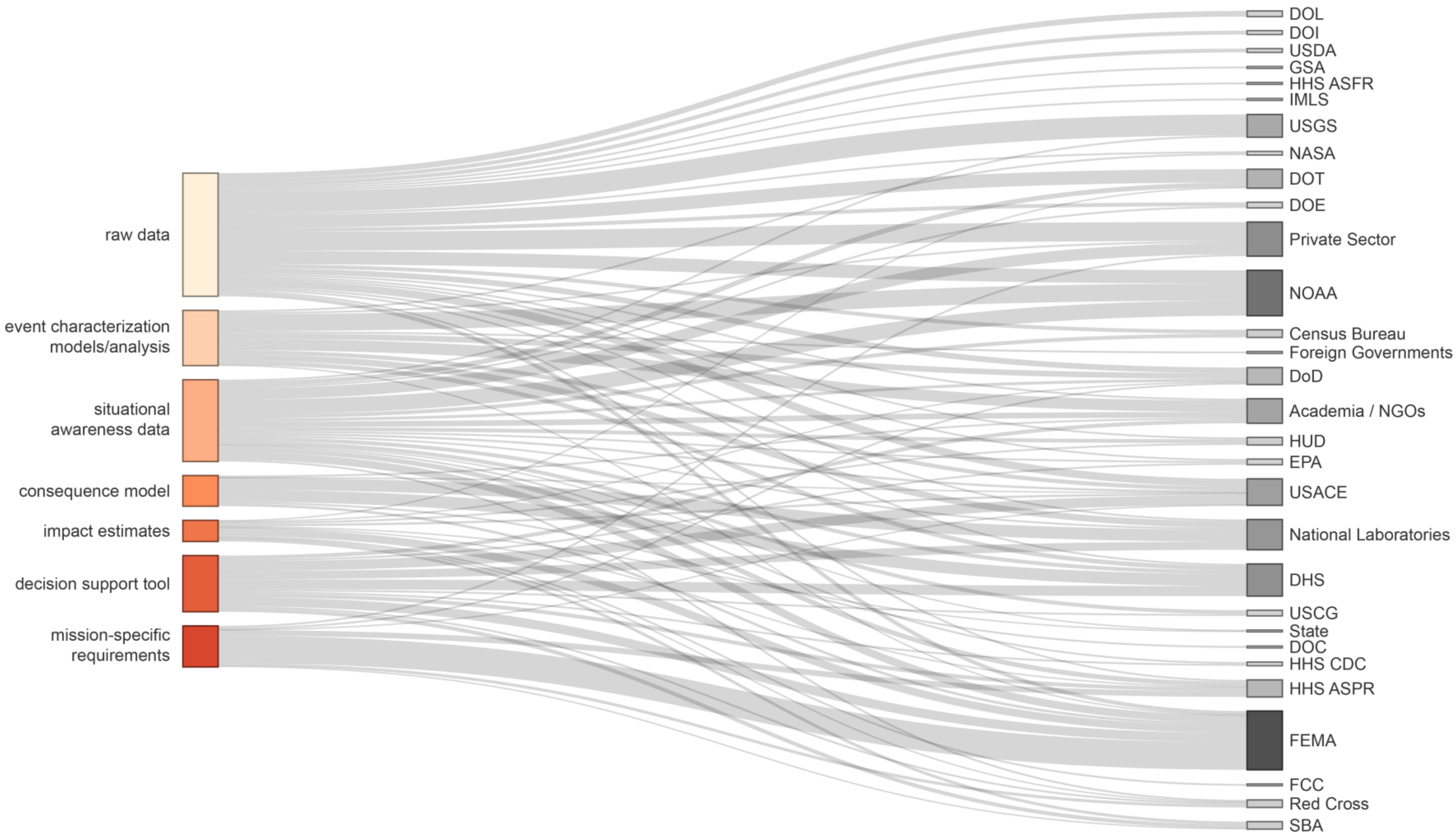


Figure 6. Hurricane Owner Sankey Diagram. Agency model/dataset owners (right) are connected in proportion to their tool ownerhsip to each type of information (left). Dataset and model types are oragnized by the flow of information framework down the left side and sizes are proportional to total number of tools of each type. Agencies are sized and shaded according to the number of tools they own. For tools tagged as multiple types, multiple connecitons are included: for example, a tool tagged as raw data and situational awareness data would connect its agency owner to each of those information types.

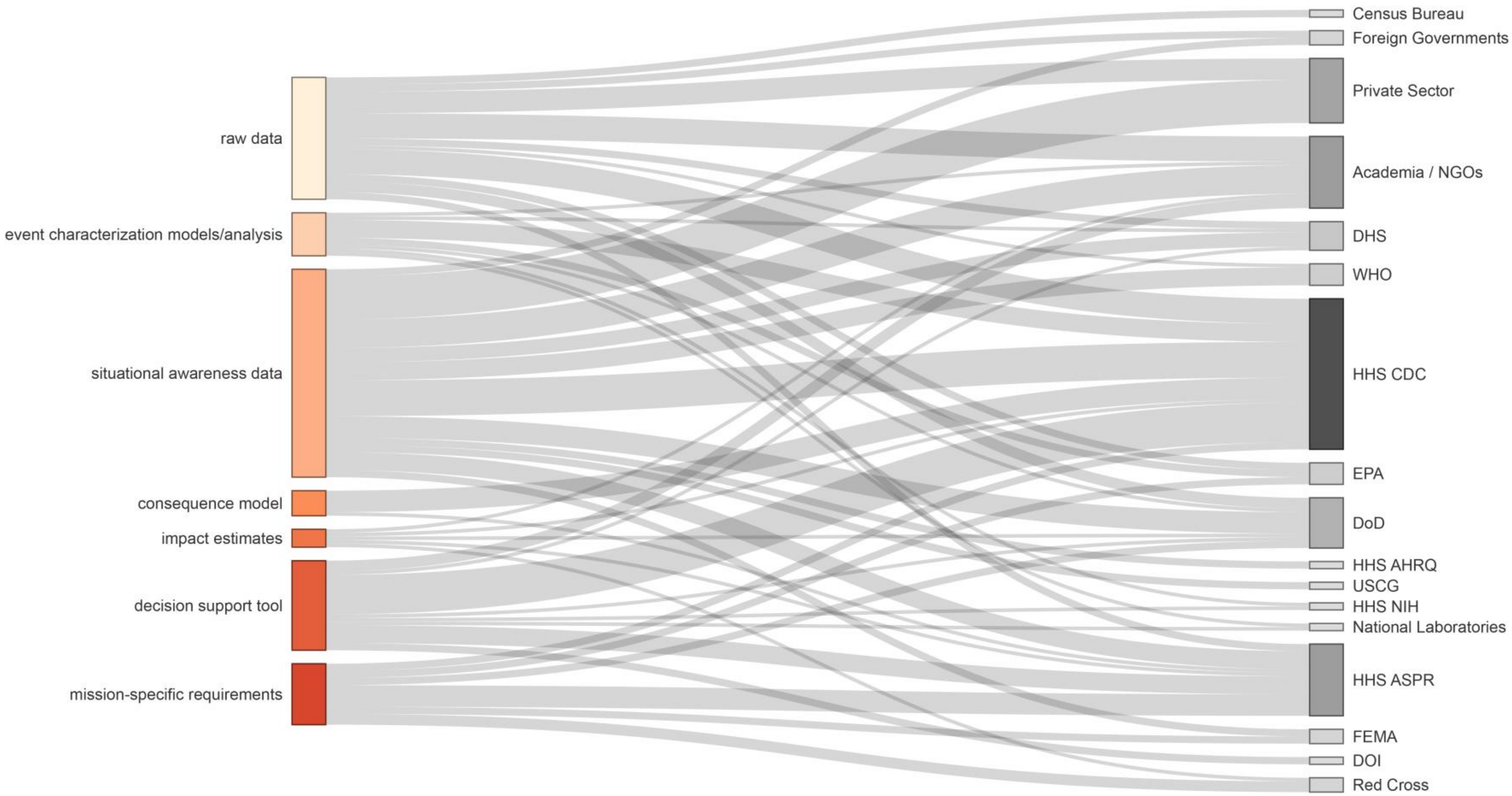


Figure 7. Biological-Natural Owner Sankey Diagram. Agency model/dataset owners (right) are connected in proportion to their tool ownerhsip to each type of information (left). Dataset and model types are oragnized by the flow of information framework down the left side and sizes are proportional to total number of tools of each type. Agencies are sized and shaded according to the number of tools they own. For tools tagged as multiple types, multiple connecitons are included: for example, a tool tagged as raw data and situational awareness data would connect its agency owner to each of those information types.

Intentional Biological Release Scenarios

Results Overview for Intentional Biological Releases

- Tools to support analysis of attacks with contagious agents are underrepresented in the inventory
- Most event characterization and consequence models are atmospheric dispersion models
- Well-established response tools are available, but decision support overall is disconnected from event-specific, real-time data information upstream in the flow of information

An intentional biological hazard could be either a bioterror or other intentional criminal release of biological weapons. For the purposes of this analysis, we assume a large-scale release such as the aerosolized dispersion of anthrax or the intentional spread of weaponized smallpox. Though the list of scenarios of concern has often focused on a specific list of high-risk agents or species, we address this hazard based on response-relevant characteristics, as outlined in the introduction. This method is a critical step toward better understanding and preparing for such an event, particularly in an age of genetic manipulation and Do-It-Yourself biology: the agent(s) used for release could be modified or fall outside the "expected" list of risk agents. In any such event, approaching diagnosis and the response based on the known characteristics of the event, as gathered in real time, will be critical in assuring that early assumptions about the agent do not slow or impede an effective response.

An intentional release event would be fundamentally different from naturally-occurring outbreaks. First, a naturally-occurring outbreak typically unfolds slowly with a gradual appearance of new cases and progressive spread. By contrast, a large-scale intentional release would be marked by a bolus of cases emerging together. Second, though it is possible that the agent released could be novel or modified, many of the agents of greatest concern for biological attacks are well-characterized. Indeed, there are specific response tools and medical countermeasures stockpiled to respond to releases of a subset of agents. Third, a large-scale release would immediately trigger a coordinated emergency management response, bypassing any ambiguity about whether an event has reached emergency status and what agency decides to declare the emergency, as is the case for naturally-occurring biological outbreaks. Finally, an intentional release would require a significant law enforcement effort alongside the public health and medical response. Information sharing may be limited by the ongoing investigation, including the potential classification of some of the information. Sample collection, testing, and clean-up efforts may be guided by evidence preservation requirements.

Modeling and information sharing during a large-scale biological release, at least one involving an aerosol release requiring plume modeling, would be expected to be managed by the Interagency Modeling Atmospheric Assessment Center (IMAAC) led by FEMA. IMAAC is the interagency coordinating body for atmospheric dispersion modeling responsible for disseminating predictive analysis results to support emergency response operations. IMAAC models plumes of hazardous materials including chemical, radiological, and biological release events. If an intentional biological release event is detected, IMAAC can provide analysis and predictions of an aerial dispersion attack. This involvement is governed by a clearly-stated set of policies that outline the reachback data collection and modeling capabilities upon which the government will rely and the adjudication process by which those data will be collated by IMAAC and disseminated to the interagency, including the emergency management and law enforcement communities.

Flow of Information within the Network

The result of network analysis of the datasets and models in the inventory specifically used for intentional biological releases is shown in Figure 8. As for naturally-occurring biological outbreaks, the network includes many fewer datasets and models than for previously-analyzed hazards (e.g., hurricanes are supported by 189 datasets and models compared to 74 for intentional biological release scenarios.) The most used tools in the network are the DHS-managed tools, BioWatch and QUIC, the core data collection tools and models that support IMAAC. A cluster of weather data and models toward the top of the network is specifically required to support atmospheric dispersion models (e.g., QUIC-IMAAC and HPAC). The analysis for these scenarios shares a fundamental reliance on population (US Census Data) and infrastructure datasets (HSIP) with other hazards analyzed previously.

The orphan tools in the upper right are not connected to other tools in the inventory. Notably, the main network is more lightly colored than the orphan cluster, indicating that decision support tools and mission specific requirements are disproportionally disconnected from the upstream event characterization, situational awareness, and consequence models, suggesting that these tools do not ingest or analyze real-time specific information. Many of the tools supporting operational decision making are established components of emergency response decision-making, notably those tools that support deployment and management of the Strategic National Stockpile. However, the fact that decision support tools predominate among orphans for this hazard indicates that tools to define response requirements are not well integrated with the other datasets and models in the network.

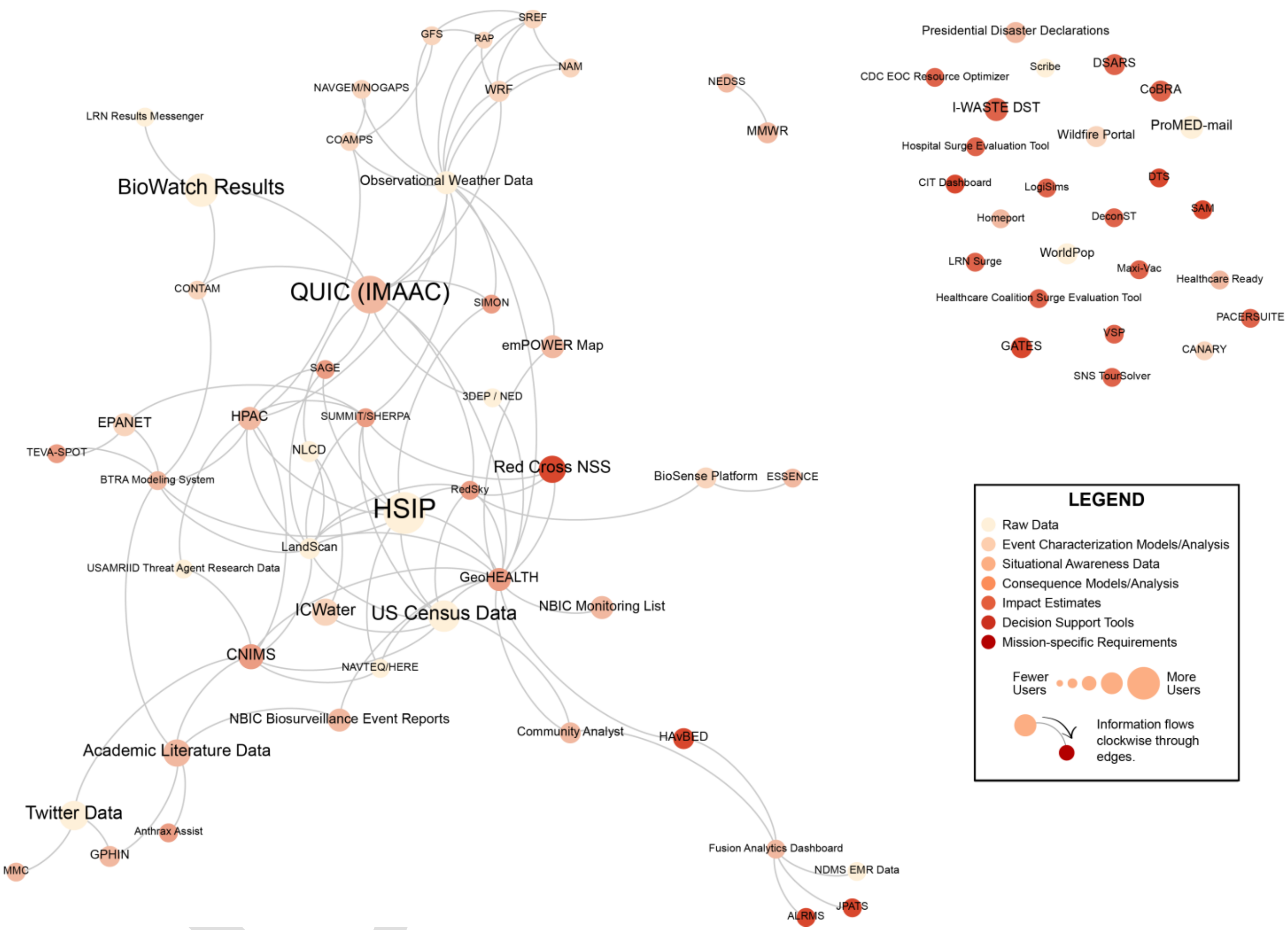


Figure 8. Network Map for Intentional Biological Releases. Nodes (circles) are sized by the number of federal agencies using the tool. Information flows clockwise along edges (lines) between the datasets and models and indicate data transfer between information resources. Each node is colored by its position in the flow of information framework with raw data and event characterization models colored most lightly and decision support tools and mission specific requirement datasets colored most darkly.

Centrality in the network

As shown in Figure 9 and in comparison to other hazard networks analyzed during previous efforts, the overall centrality is low for this network with only a few weakly central datasets and models. QUIC, the IMAAC-based event characterization and consequence model, is the most central, as it links the upstream event data collected by weather models and biosurveilance efforts such as BioWatch and feeds the majority of downstream tools for intentional biological release events. However, QUIC is only designed for modeling atmospheric release scenarios, and there are no corresponding widely-used sources for data collection and consequence modeling for other release types. Indeed, while the centrality of QUIC aligns with IMAAC's role in coordinating information for intentional biological attacks, interviews suggested a lack of clarity regarding the role of IMAAC in coordinating the response to biological release events that are not atmospheric. Though BioWatch sensors and the BioWatch systems have been activated and tested with relative frequency since its inception, no bioterror or intentional biological release has occurred in the U.S. since the inception of IMAAC; the system has not been tested outside of exercises.

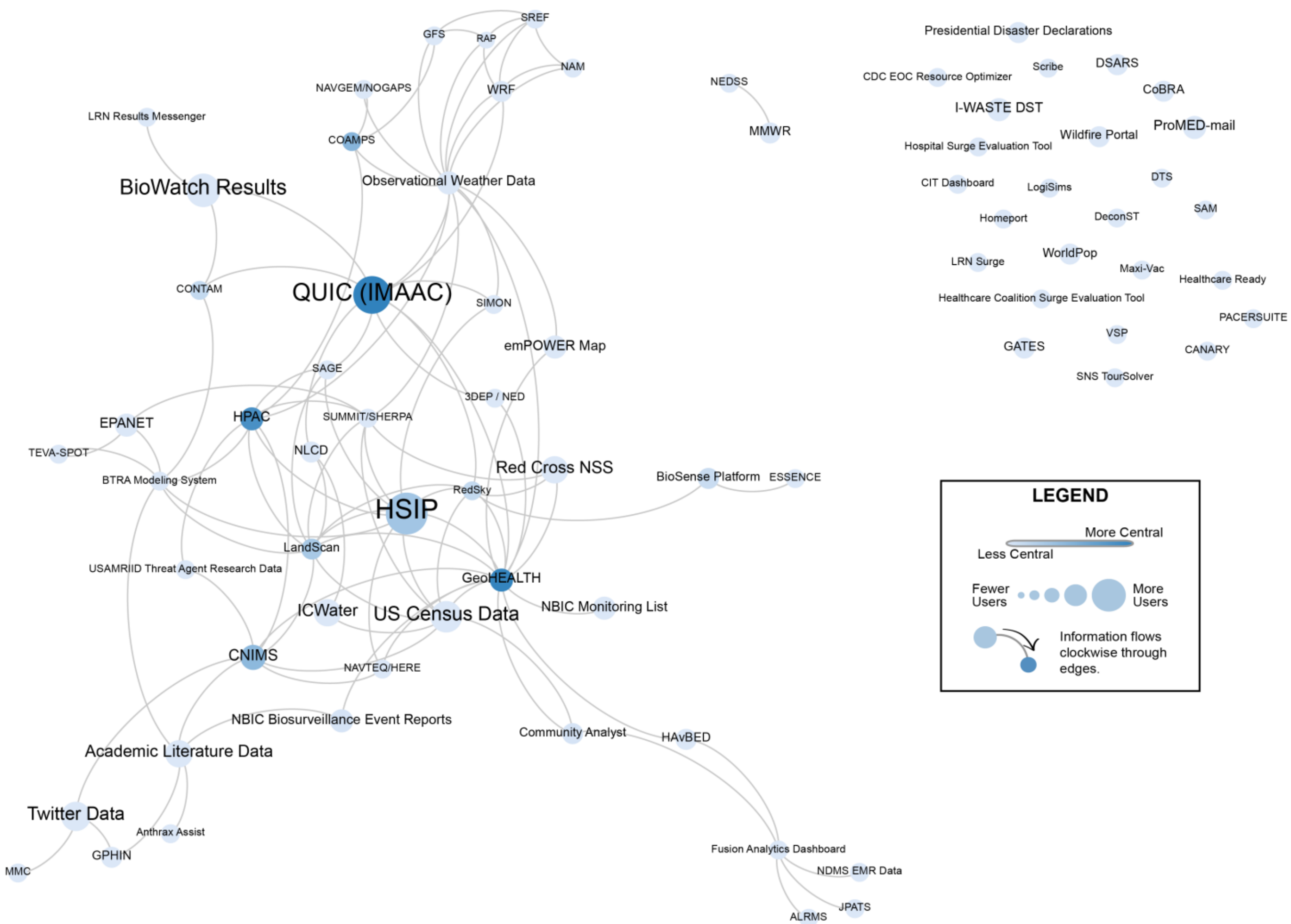


Figure 9. Centrality Network Map for Intentional Biological Release Scenarios. Nodes (circles) are sized by the number of federal agencies using the tool. Information flows clockwise along edges (lines) between the datasets and models and indicate data transfer between information resources. Each node is colored from less central (lighter blues) to more central (darker blues) using the betweenness centrality metric. Darker, more central datasets and models serve as primary information bridges between other datasets and models.

Agency owner centrality

By measuring which agencies own the most central tools in the biological-intentional network, National Laboratories and DoD were identified as the most central owners in the interagency emergency response network. This suggests National Laboratories and DoD currently play the role of central information coordinators for an intentional biological attack. In Figure 10, large sized agencies own more datasets and models while the average centrality of tools owned by an agency is scaled from less central (lighter blues) to more central (darker blues) and connections represent information flow from datasets and models owned by one agency to those owned by another. Since there is an overall lack of central, widely used tools in the intentional biological release network (Figure 9), the owner centrality is strongly driven by just a few datasets and models. Specifically, since the most central model, QUIC, is owned by Los Alamos National Laboratory and managed as part of the IMAAC modeling capabilities of the National Laboratories, this drives the finding of a central role for National Laboratories in the owner centrality network. The central information coordination role for DoD stems from its ownership of two key tools: the HSIP infrastructure dataset and the HPAC dispersion model.

The agency owner network also has orphans – agencies that own models that do share data with any other models in the network. The U.S. Coast Guard (USCG) is an agency orphan in the owner network of tools for intentional biological release events, likely due to its unique maritime law enforcement mission including the protection of ports. Incorporation of the USGS Homeport dataset with other datasets and models in the information network (Figure 8) represents an opportunity to better integrate the agency network.

As for naturally-occurring outbreaks, HHS ASPR is the lead agency for ESF #8 and public health emergencies. This role is complicated for intentional release scenarios by the lead role of DHS and FEMA in IMAAC. This lead role by DHS and FEMA is captured by the centrality of the IMAAC model, QUIC, and the National Laboratories that own and are the technical experts for the model. The lack of centrality for HHS ASPR and the fact that the agency owns many of the decision support tools and mission specific requirement data that would be required to inform an effective response suggests that the agency could take a more active information sharing and coordination role for these scenarios.

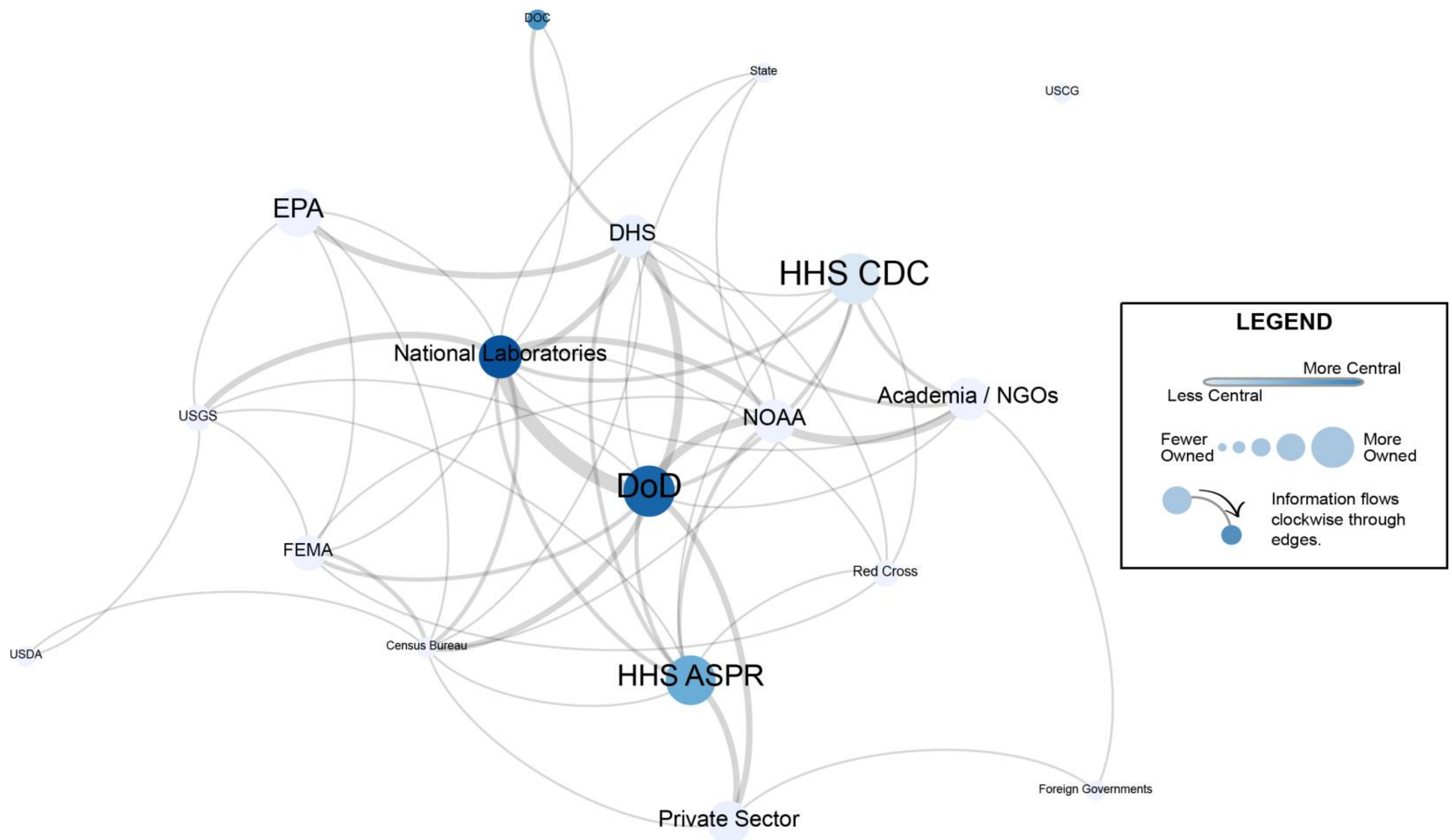


Figure 10. Owner Centrality Network for Intentional Biological Releases. Nodes (circles) represent federal agencies that own datasets and models used to support response to natural biological outbreaks and are sized by the number of datasets and models owned. Information flows clockwise along edges (lines) between the datasets and models and indicate data transfer between information resources. Each node is colored from less central (lighter blues) to more central (darker blues) using the betweenness centrality metric. Centrality and information flow in this network represent the average across all datasets and models owned by a given agency for intentional biological release scenarios.

Model ownership and use

DoD owns the most datasets and models for intentional biological release events, followed by EPA and HHS ASPR. However, the distribution of tool ownership is relatively even across the interagency with many additional agencies contributing a significant proportion of the available datasets and models (Figure 11). Importantly, the top owners for this hazard own tools that span the flow of information, unlike other hazards such as hurricanes described above, for which agencies owning the most models tend to own predominately datasets and models at either end of the flow of information.

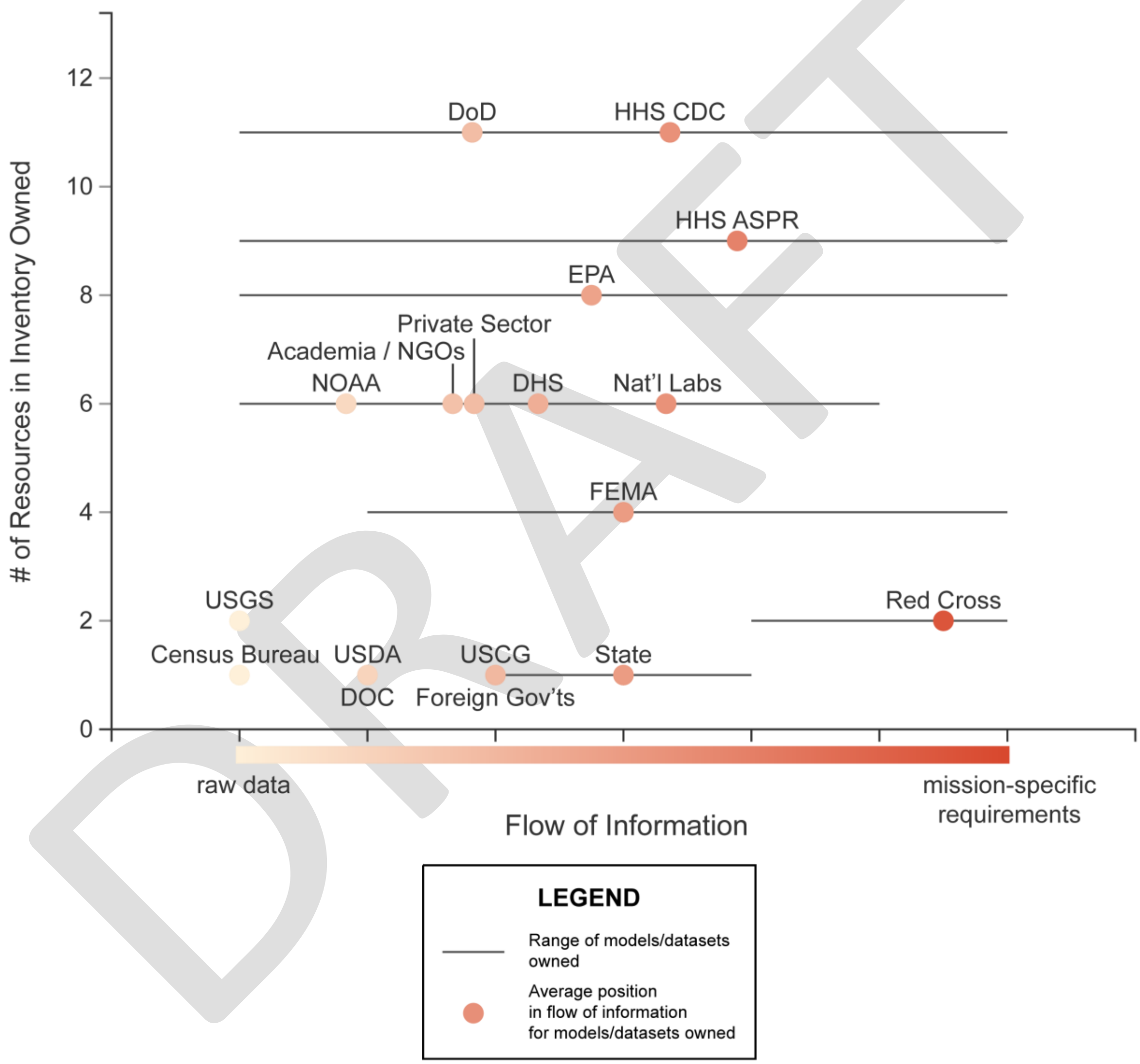


Figure 11. Dataset and Model Ownership for Intentional Biological Release Events. Agencies are plotted with respect to the number of models and datasets they own (y-axis). The color and position of each agency on the x-axis represents an average of the types of tools that agency owns. Agencies positioned more to the right or left tend to own tools toward those respective ends of the flow of information. The horizontal bars indicate the range of tool types each agency owns.

Bulk flow of information for biological-intentional scenarios

Bulk flow analysis, as shown in Figure 12 aggregates the datasets and models in each category of the flow of information framework and the data exchange between datasets and models of each category. This analysis has been performed for each of the hazards included in the inventory. As shown in the top bulk flow network, the hurricane inventory includes a large number of highly connected datasets and models early in the flow of information, including raw data, event characterization, and situational awareness data. As described in the previous section, these tools are largely owned by NOAA, the subject matter expert agency for the hazard. By contrast, both the naturally-occurring and intentional biological hazard inventories have many fewer datasets and models overall, with a specific lack of datasets and models early in the flow of information. This result further reinforces the previous results suggesting that robust event characterization and consequence analysis is not well-supported for biological hazards, including the early-event data collection upon which that analysis relies.

As observed for hurricanes, there is a paucity of datasets and models to support operational decisions: those datasets and models that serve as decision support tools and mission specific requirements. This lack of information sources is also true of both types of biological hazards, though there is a more even distribution of datasets and models over the flow of information. However, this even distribution is largely a reflection of the lack of event characterization and consequence models for biological hazards, not a large number of decision support tools and mission specific requirement datasets. The exception for biological hazards are the decision support tools and sources of data supporting deployment and management of the Strategic National Stockpile and the National Disaster Medical Service. HHS ASPR has developed a series of tools specifically focused on their deployment mission that, though not tested frequently, have the potential to provide significant practical decision support to medical countermeasure mobilization during an intentional biological attack.

In addition to the limited number of datasets and models used by the federal interagency, the decision support tools and mission specific requirement datasets in the network are almost completely disconnected from the rest of the datasets and models in the inventory. Indeed, the only connections to the mission specific requirement datasets is a feedback loop indicating that at least one situational awareness viewer incorporates these data. These results confirm and support the findings from the previous analyses described here: there are only limited datasets and models used to support federal emergency management efforts for biological hazards, and those that are available are not widely used nor well-connected with other datasets and models in the inventory.

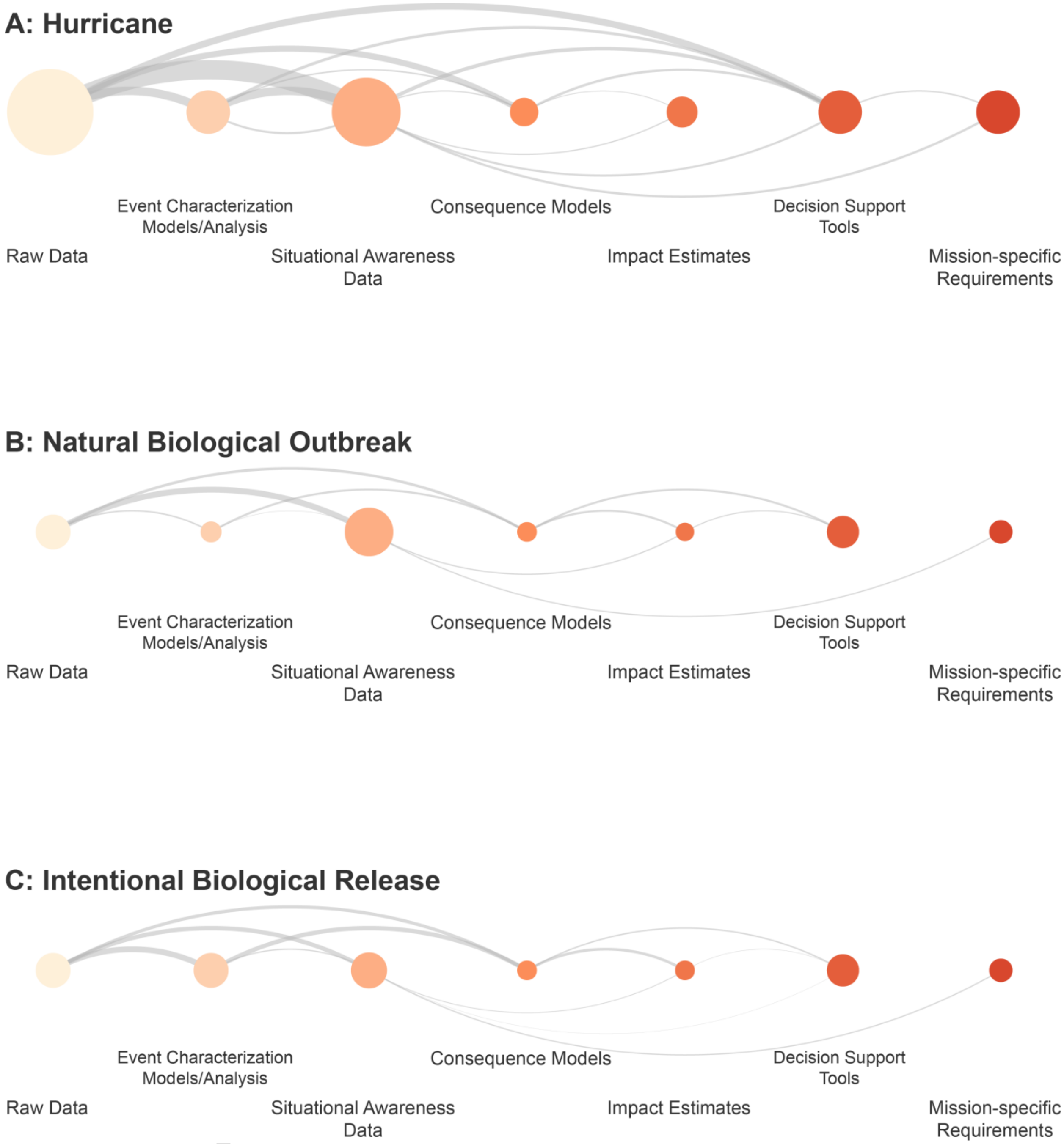


Figure 12. Bulk Flow of Information for All Tools for Biological and Hurricane Scenarios. Nodes represent each tool type in the flow of information and edges represent the flow of information from a dataset or model in one category to a dataset or model in another. Node size is proportional to aggregated number of datasets and models in each category for that hazard. Edge width is proportional to the total number of individual connections between the two resource types. Information flows clockwise and connections between two tools of the same type are omitted.

Information to Support Emergency Response to Biological Events

Planning for and responding to biological emergencies requires coordination of information between scientific expert and response-focused agencies across the Federal government and integration of datasets and models from academic researchers and the private sector. This section defines the datasets and models available to support data requirements for biological events and aligns specific tools with the phases and data requirements supported by each.

Incident overview

Natural biological outbreaks

Contagious outbreaks are the primary focus among naturally-occurring biological scenarios because contagious agents spread across the population and are most likely to trigger a large scale Federal emergency response. Outbreaks can result in large numbers of illnesses and deaths, causing mass hospital resource surges, high demand for vaccines and other medical countermeasures, and imposed cancellations of school, work, and public events.

Scientific research determines the characteristics of agents that cause natural biological outbreaks and provide the data needed to model the outbreak and interventions. These studies include growing the biological agents in the laboratory to conduct experiments, developing animal models of diseases – including studies of transmission and vaccine trials, and epidemiological studies of past human outbreaks. This research defines how dangerous the biological agent is, the modes of contagious spread, efficacy of vaccines or treatments. Most research and modeling is specific to a single biological agent or even a specific outbreak meaning models must be adapted or newly developed for each scenario and, consequently, modeling is unavailable for novel and emerging infectious diseases that have not been previously studied.

There is a marked reliance on subject matter expertise for real-time analysis and translation of the academic literature and raw biosurveillance data during all phases of a biological outbreak. Currently, the best sources of decision-making information for natural biological events at the Federal level are subject matter experts and the academic literature. Subject matter experts personally curate and interpret event data to determine what happened, how bad it was, and what should be done. Therefore, subject matter experts, rather than a suite of specific datasets and models, are typically responsible for providing event characterization, consequence analysis, and decision support.

Intentional biological release events

An intentional biological event is a deliberate attack on the U.S. with a bioweapon, using a contagious or non-contagious agent, and includes acts of bioterrorism. For the purposes of the current effort, intentional biological airborne release events are considered. Intentional biological releases into waterways or the water distribution system were also considered, but specific tools for this release type are limited. Food or agriculturally-based bioterror attacks were excluded and will be part of future efforts. Response to an intentional biological event would involve many federal agencies in a complex data sharing environment. It would likely create an extensive crime scene, involving multiple law enforcement agencies, and data sharing may be limited by the ongoing investigation.

As with natural biological outbreaks, academic research defines the characteristics of agents and subject matter experts play an important role in translating scientific information into information that can support response operations. For intentional biological release events into the air, the Interagency Modeling and Atmospheric Assessment Center (IMAAC) provides centralized analysis of the agent dispersion (plume) to guide evacuation, treatment, sampling, and decontamination activities. Plume modeling describes the dispersion of a released agent but, currently, no modeling is available for subsequent spread of a contagious agent from person to person. In addition, specific models are available for selected agents of significant concern for an intentional attack, such as anthrax or smallpox release.

Data requirements for biological incident response

Despite inherent differences, naturally-occurring outbreaks and intentional biological release events share a number of common data requirements. Biological events first require detection to discriminate emergencies from baseline illnesses in the population using biosurveillance systems, including environmental sampling and monitoring of hospitals. Specific diagnostic tests and detection systems may be available for known agents, but unknown agents (such as emerging infectious diseases) are only detected through the cases of illness they produce. Effective response for outbreaks, regardless of cause, requires information about the predicted number of illnesses and deaths, geographic spread of the disease over time, and impacts to the healthcare system. Models to predict such information may be available for natural outbreaks or intentional attacks caused by known agents. This type of information about unknown agents is only available through scientific research and epidemiological modeling conducted during the event. Mission-specific data needed to support an effective response include the number of medical personnel, number and type of medical countermeasures (e.g., vaccines or medications), and the number of available hospital beds; the optimal routes to deploy and distribute medical countermeasures; the methods needed to collect and analyze samples of the agent; and methods to decontaminate and remove contaminated waste from the impacted area.

In the following sections, specific datasets and models are identified and described with respect to how they support data requirements for natural biological outbreaks and intentional biological release events. Some of these models will be run by subject matter experts while others are designed for use by the end user. An explanation of who has access and is expected to run or analyze each type of dataset or model is provided.

Phase 1a: Normal Operations

The normal operations phase focuses on tools that can or are expected to be used during an event, and includes incorporating datasets and models into plans and exercises, medical countermeasure development and planning, and healthcare system planning. In addition, the use of biosurveillance systems is required during normal operations, as the tools are critical for detecting an event, so must be fully operational before an even is detected. Normal operations also provides users an opportunity to sign up for and become familiar with these systems.

Key questions that can be addressed during normal operations include:

- What are the known and predicted risks for biological incidents (e.g., naturally-occurring flu outbreaks and agents of greatest concern for bioterror)?
- What is known about the biological agents of greatest concern and what medical countermeasures are available?

- How can the healthcare system best plan for natural biological outbreaks and intentional biological release events?

The normal operations phase is focused on developing plans for known agents, especially those of historical risk for causing outbreaks and of greatest threat if used in a bioterror attack. Researchingthese agents, developing medical countermeasures, and planning for the mobilization of healthcare resources all occur during normal operations. In addition, users should sign up for accounts and distribution lists for biosurveillance systems and connect with subject matter experts who can interpret these data in the context of emergency management.

Develop plans and countermeasures for known threats

As introduced in the previous section, the academic scientific research community is the source of information about many of the specific agent characteristics that are required for modeling both natural biological outbreaks and intentional biological release events. On the basis of these characteristics, known threats can be modeled to plan for impacts and research performed to develop medical countermeasures. Naturally-occurring biological outbreaks include known threats from seasonal and pandemic influenza (flu) strains as well as international outbreaks with the potential for domestic impacts (e.g., Ebola in West Africa). For intentional release events, DHS defines bioterror threats to the U.S. through modeled, risk-based scenarios. DHS creates Material Threat Assessments (MTAs) based on these modeling results to determine which scenarios have the potential to produce the greatest consequences.

Intentional biological release

During normal operations, the Federal government invests in risk-based scenario planning to ensure preparedness efforts are targeted to the intentional biological scenarios with the greatest potential consequences and likelihood of occurrence. The key risk assessment for intentional biological events performed by the federal government is the Bioterrorism Risk Assessment (BTRA), developed by the DHS Science and Technology Directorate (S&T). The BTRA and other data are used to inform critical preparedness decisions, including countermeasure development and planning for the Strategic National Stockpile (SNS) – a reserve supply of medicines, antidotes, vaccines, and medical supplies.

BTRA Modeling System and Material Threat Assessments

The BTRA modeling system is developed and used by the DHS S&T to develop Material Threat Assessments (MTAs) and inform national bioterror event preparedness, including helping to determine the contents of the SNS. The BTRA modeling system considers combinations of adversaries, weapon designs, source materials, and attack pathways to understand overall risk of an attack given its likelihood of occurring and the consequences if it does. The BTRA modeling system is designed only for internal DHS use and results may be limited access or classified. Requests for information about the BTRA and its use for plan development should be made to the technical contact listed in the MoDI.

Beginning during normal operations and continuing through the response, scientific public health agencies are engaged in medical countermeasure development and planning, including identifying whether medical countermeasures are available for a specific threat, how they can be safely developed and produced at scale, and how they can be distributed and used most effectively during a response. This effort requires extensive collaboration between HHS ASPR Biomedical Advanced Research and Development Authority (BARDA), HHS CDC, and the academic community. Information from MTAs is used by HHS ASPR BARDA to model casualties and medical countermeasure interventions to plan for scenarios. These results determine which pathogens are assigned Material Threat Determinations, indicating they would affect national security, including anthrax and the Ebola virus. HHS ASPR BARDA uses its tools, expert analysis, and mission authority to assess and procure the contents of the SNS such that the Federal interagency can mount the most effective possible response to a biological event.

Natural biological outbreaks

The tools currently used to support detailed planning for natural biological outbreaks are all specific to influenza. These tools are owned and used by CDC at the Federal level, and used by others at the local level, to plan for flu outbreaks.

Additional tools to assess the impact and support planning for other agents are available within the academic literature, but these tools have not largely been operationalized, and no specific tools were identified as actively in use by the Federal emergency management community.

Influenza-specific planning tools

Both seasonal flu (influenza) outbreaks and novel influenza strains with the potential to cause pandemics (e.g., H1N1, H7N9, H5N1) are well-known biological hazards, and specific tools have been developed to support planning for these scenarios. These tools estimate the impacts of the outbreak (e.g., illnesses, deaths, and workplace absenteeism) as well as the predicted benefits from vaccinations and other medical and non-medical interventions.

Additionally, subject matter experts at the CDC use academic and expert data sources to support decision-making related to vaccine development. CDC experts analyze viral genetic data from the NextFlu database to help determine which influenza strains are high priority candidates for the current year's vaccination stockpile. They also use the Influenza Risk Assessment Tool (IRAT) to collate and analyze subject matter expertise indicating which influenza strains have the greatest potential to become pandemics, which also supports vaccine stockpile decisions. This information and analysis is exchanged between the CDC and HHS ASPR to support seasonal and pandemic influenza planning and response.

CDC public planning tools for pandemic influenza

CommunityFlu, FluAid, FluSurge, and FluWorkLoss are public planning tools developed by HHS CDC to estimate the impact of an influenza pandemic; each tool targeted to a unique planning requirement.

CommunityFlu simulates impacts of pandemic influenza on a community with and without a range of potential interventions (including vaccinations, school closures, use of face masks, and self-quarantine). CommunityFlu is used by the CDC and others at the federal, state, and local level to support pandemic planning and preparedness activities. The primary outputs of CommunityFlu are the tables and graphs estimating people who are ill with influenza at home, made outpatients, hospitalized, or dead, both with and without interventions. Additionally, CommunityFlu estimates the number of workdays lost due to personal illness or due to ill children. User inputs needed for CommunityFlu include the initial number of infections, the pandemic duration (days), and parameters describing the interventions used.

FluAid estimates the overall impacts to human health and healthcare systems in a local area, including the effects of vaccination campaigns. It is used by the CDC to assist state and local planners in preparing an influenza pandemic. Given the user's local data, FluAid estimates the minimum, most likely, and maximum deaths, hospitalizations, and outpatient visits due to pandemic influenza. The results inform plans by determining whether sufficient hospital beds and healthcare workers are available to support outbreak response and projecting what age and risk groups should be prioritized for vaccination.

FluSurge forecasts weekly hospital resources to aid public health and hospital administrators in planning for an influenza pandemic. Based on user inputs, FluSurge estimates the number of people hospitalized, percent hospital bed capacity needed, percent intensive care unit (ICU) capacity needed, and percent ventilator usage per week for the duration of the pandemic. Additionally, FluSurge estimates weekly and total hospital admissions and deaths for minimum, most likely, and maximum severity scenarios.

FluWorkLoss estimates the potential number of days lost from work due to a pandemic. It is developed and used by the CDC and intended to support state and local public health officials or businesses in developing continuity of operations plans with work loss from ill personal illness and from those caring for ill family members. Outputs include the total number of workdays lost and a plot of workdays lost over the pandemic. Minimum, most likely, and maximum severity estimates are provided as for other flu models described above.

All of the influenza-specific planning tools are open access and available online for download. Each requires custom data to be used most effectively and are best used during normal operations to support planning.

Planning for healthcare facility surge capacity

Several tools are available to predict the increased healthcare capacity requirements during a biological emergency to support planning for this surge capacity during either a natural biological outbreak or an intentional biological release event.

Healthcare Surge Evaluation Tools

The Hospital Surge Evaluation Tool is a planning and exercise tool designed to help individual hospitals evaluate their level of preparedness for mass casualty incidents through peer assessment. The tool models the number of patients expected over time, by triage category, and additional modules within the tool assist in managing the exercise itself. A companion tool called the Healthcare Coalition Surge Evaluation Tool supports similar planning functions at the level of healthcare coalitions involving multiple hospitals. Both Surge Evaluation Tools are open access and available online for download. They require custom data to be used most effectively, and are intended for use during normal operations to support planning and are not intended to characterize real-world incidents.

PACERSUITE

The Preparedness and Catastrophic Event Response Suite (PACERSUITE) is a set of online planning tools intended to help hospitals prepare for patient surges following mass casualty incidents. PACERSUITE applications allow users to view general planning reports of expected casualties based on National Planning Scenarios. Users can also enter their custom hospital operations data to view predicted healthcare surges. PACERSUITE is open access and available online. The tool requires custom data to be used most effectively, and is best used during normal operations to support planning.

Monitor biosurveillance for emerging events

This section describes biosurveillance tools that users should sign up for and become familiar with during normal operations in order to have ready access to data when a future biological event emerges. Familiarity with biosurveillance tools is key because natural biological events are delayed-onset events, meaning the event is already occurring before an emergency declaration; biosurveillance systems provide the situational awareness data required to monitor potential threats. Biosurveillance is the source of detection for naturally-occurring biological events and for any intentional biological release event that is not first detected by environmental sampling or announced by the attacker. Data provided by these systems can be used by subject matter experts to assess the potential impacts of an emerging domestic event or the likelihood that an event of international origin will lead to domestic impacts.

Biological events can be detected through national-level, federal surveillance systems in use at the CDC National Notifiable Diseases Surveillance System (NNDSS); reports from state public health agencies or hospitals; systems that monitor clinical case reports (syndromic surveillance), such as the CDC BioSense Platform; and tools that scan news reports and social media for signs of outbreaks. Suspected outbreaks are investigated by public health officials and epidemiologists to determine if an outbreak should be declared.

NBIC Monitoring List

Each day, the DHS National Biosurveillance Integration Center (NBIC) e-mails a monitoring list to federal, state, and local partners that summarizes high priority, newly detected, and ongoing events that the NBIC is currently tracking. The information reported for each event includes the reason the event is being reported; an assessment of whether the event is worsening, unchanging, or improving; weekly case count totals; and other event-specific data. NBIC monitors and analyzes over 250 targeted open source feeds from which it collects and aggregates data that feed its monitoring List. These data sources include aggregated data from Arkham at the National Center for Medical Intelligence (NCMI), media monitoring data from HealthMap, and manually curated open reports (typically RSS feeds) on the web. All data are aggregated and separated from any personally identifiable information.

In addition, to support planning for potential intentional biological release events, NBIC produces Biosurveillance Event Reports in PDF format in advance of National Security Special Events (NSSEs), such as political party conventions, Presidential inaugurations, and Super Bowls. NBIC distributes these situation reports to federal, state, and local partners. Users submit requests to DHS NBIC for addition to the distribution list. The NBIC technical contact listed in the MoDI responds these requests and event-specific information requests. Some NBIC data may be limited to federal use only.

GPHIN

The Global Public Health Intelligence Network (GPHIN) is used by federal agencies to receive early warning notifications for biological events worldwide. GPHIN continuously searches global media sources such as news wires and websites to identify information about outbreaks and other events of potential international public health concern. Relevant information is automatically filtered and curated by analysts; resulting biosurveillance alerts are categorized and sent to users. GPHIN monitors naturally-occurring and intentional biological release events. All data feeds for GPHIN are public domain and non-sensitive.

GPHIN is part of the World Health Organization's (WHO) Global Outbreak and Alert Response Network (GOARN). WHO provides verification for alerts reported through GPHIN and uses the information to develop plans of action to control outbreaks. The main source of news media data feeding GPHIN is Factiva, a news aggregator with about 9,000 sources in 22 languages, which also scans social media (including Twitter and academic sources).

GPHIN access requires paid subscription and is only available to organizations with an established public health mission. Alerts reported through GPHIN are automatically pushed to licensed users during events. Requests for information about subscriptions can be made to the technical contact listed in the MoDI.

HealthMap

HealthMap continuously monitors global disease outbreaks based on real-time surveillance of public domestic and international news, medical, and social media sources. Users can create customized alerts and summary reports provide alerts for potential events detected by the HealthMap. Data in HealthMap include the geo-tagged location of the article, the date published, a summary, and a link to the full article. Trend graphs showing the number of outbreak reports over time in a specific area can be created automatically. Outbreak reports and their media sources are mapped and can be viewed by symptom (e.g., respiratory) or specific disease (e.g., influenza, Zika, Ebolavirus).

All data feeds for HealthMap are public domain and non-sensitive. HealthMap processes about 3,000 alerts in 40,000 locations from over 200,000 sources daily. Frequently used data feeds include Twitter, Google News, ProMED-mail, World Health Organization notifications, and the CDC Emerging Infectious Disease Journal. Other data feeds include the Pacific Disaster Center (PDC), Wildlife Data Integration Network, the World Organisation for Animal Health, the Food and Agriculture Organization of the United Nations, GeoSeAntinel, EuroSurveillance, Moreover, Baidu News (China), and SOSO Info (China). HealthMap is open access and available online and a mobile application is also available ("Outbreaks Near Me").

WHO Disease Outbreak News

The WHO Disease Outbreak News bulletins are approximately daily updates on emerging and current global disease outbreaks and can be used to monitor international outbreaks of potential domestic concern. These bulletins are used by responding agencies to monitor case counts during outrbreaks, epidemiological characteristics embedded in case reports, and the geographic spread of an outbreak over time. Data are approved for public release and are non-sensitive; they may contain publicly-released foreign Ministries of Health data, if available.

Data include the following for each reporting country, when available: suspect, probable, and laboratory-confirmed case counts; fatality counts; sub-national origin of the case (e.g., state or municipality); age ranges and sexes of reported cases; and the dates the cases were reported. WHO Disease Outbreak News is open access and available online. Users can automatically receive news for updated and new events by subscribing to the RSS web feed at the website listed in the MoDI.

CDC MMWR and NEDSS

The MMWR published by the CDC provides public, non-sensitive total weekly morbidity and mortality counts for notifiable contagious and non-contagious diseases in the US. Additionally, MMWRs for ongoing international events to which the CDC is responding are also published. For events of international origin, these data may come from sources including CDC epidemiologists deployed in-country, the foreign Ministries of Health in the impacted countries, or data shared by other responding agencies. For some outbreaks, CDC produces supplements to the MMWR that include modeled predictions of future case counts and interpretation by subject matter experts. In addition to case count data, the MMWR also includes related public health articles and supplemental information. MMWRs are open access and available online in PDF format, and the underlying data may be downloaded in spreadsheet format.

The National Electronic Disease Surveillance System (NEDSS) is a standardized public health surveillance data reporting system developed and used by the CDC to monitor for abnormal numbers of disease cases that could signal an outbreak. State public health departments provide the data for notifiable diseases to CDC using NEDSS; the CDC does not own the data, which means CDC may not be authorized to share data submitted from the states through NEDSS. NEDSS supports internal CDC disease modeling and analysis that is distributed by CDC subject matter experts to subsequently inform emergency response operations, but the tools themselves are accessible only within CDC.

BioSense Platform

The BioSense platform is a component of the CDC National Syndromic Surveillance Program that supports expert US public health event surveillance by aggregating and facilitating analysis of non-sensitive datasets on hospital visits and other topics. The platform supports collation and analysis of data, such as reports of syndromes over time, to provide early event detection, quantification, and visualization of public health events and risks.

Data feeds for BioSense come from multiple sources and include structured hospital visit data from emergency department and urgent care records, raw doctor office visit data, and prescription data from RelayHealth. Additionally, each public health department participating in BioSense has the option to contribute data to BioSense through their relationships with local hospitals and treatment facilities. Data feeds for BioSense consist of Health Level-7 (HL7) messages, a standardized format for transmission of healthcare records, facilitating automated data ingestion by BioSense apps.

The BioSense Platform is limited access because a signed data use agreement, registration, and user training are necessary. It is primarily intended for use by public health experts, and several features require subject matter expertise to use effectively. Some BioSense features are for internal CDC use only. Account requests can be made at the website listed in the MoDI.

Phase 1b/c: Elevated / Credible Threat

An elevated or credible threat emerges through the monitoring of biosurveillance systems, including all of those described in Phase 1a: Normal Operations. In addition, a potential intentional biological release event may be detected by the BioWatch system and trigger subsequent laboratory testing to confirm or rule out an attack. Actions during the Elevated and Credible Threat phases depend on the scenario type, information available about the agent, and the tools available. For known threats, plans and information sources identified during normal operations are available immediately to raise awareness, initiate event characterization, and investigate modeled intervention strategies. For seasonal flu, tools are available to test whether there should be targeted or mass vaccination, whether there are benefits to limit movement of the impacted population, and whether schools should close. For previously uncharacterized agents, the scientific research has not been performed during normal operations and modeling tools are not available to characterize the event. Subject matter experts, drawing on what limited data are available, will be the only available source of information. Subsequent epidemiological and laboratory research must be performed as the event is unfolding to fill in missing information.

Detect the event

Natural biological outbreaks

Biosurveillance systems identify emerging potential threats, but subject matter expertise from government agencies, such as HHS CDC and academia, is required to determine when these data suggest an elevated or credible threat. Modeling from researchers in the Federal government and academia may then be available to predict and quantify the threat posed by an emerging event. For significant biological events, a major forum for the exchange of academic modeling information and ideas is the Modeling Coordination Group, an interagency group hosted and managed by the HHS ASPR BARDA. This group brings together modelers and a broad cross-section of the public health response community with academia, government, and the private sector to address the challenges of providing data-informed answers to questions regarding natural biological events.

Academia is a key source of event characterization, consequence analysis, and decision support during natural biological events. However, because these data are not typically intended to meet emergency management data requirements or to support decision-making on a rapid timeline. As a result, interagency working groups, including regular teleconference such as the Modeling Coordination Group, are a key platform for translating disease expertise into data that informs response operations.

Suspected outbreaks must usually be investigated by public health officials and epidemiologists before an outbreak can be declared. In some cases, an investigation would not be necessary to initiate the response even if only a single case were detected, such as for pathogens with Material Threat Determinations, like the Ebola virus. Otherwise, experts investigate the suspected outbreak and determine whether reported cases are linked. If they are, and an outbreak is underway, then situational awareness data describing the epidemiological characteristics of the outbreak are collected. These data, when available, can be used for consequence modeling to determine the geographic spread of the outbreak and predicted illnesses and deaths.

Influenza-specific detection

All of the influenza-specific tools described in the Phase 1a: Normal Operations section are available to help determine whether an influenza outbreak is likely to cause emergency-level impacts. In particular, FluView provides a database and weekly CDC report with information on influenza hospitalizations, deaths, and surveillance in the US. FluView merges influenza data from several CDC sources to provide a dashboard view of suspected and confirmed influenza cases by week. FluView is used by CDC to determine which US regions are experiencing relatively high or low reports of influenza cases and deaths relative to an epidemic threshold, which can help identify or track the progress of a pandemic influenza event. FluView also reports the percent of healthcare visits that are for influenza-like illness, which can provide a more rapid initial indication of an outbreak. Most data can be viewed at the national, HHS Region, or Census division level (Figure 13). FluView is open access and available online and trend data can be downloaded in both image and spreadsheet formats.

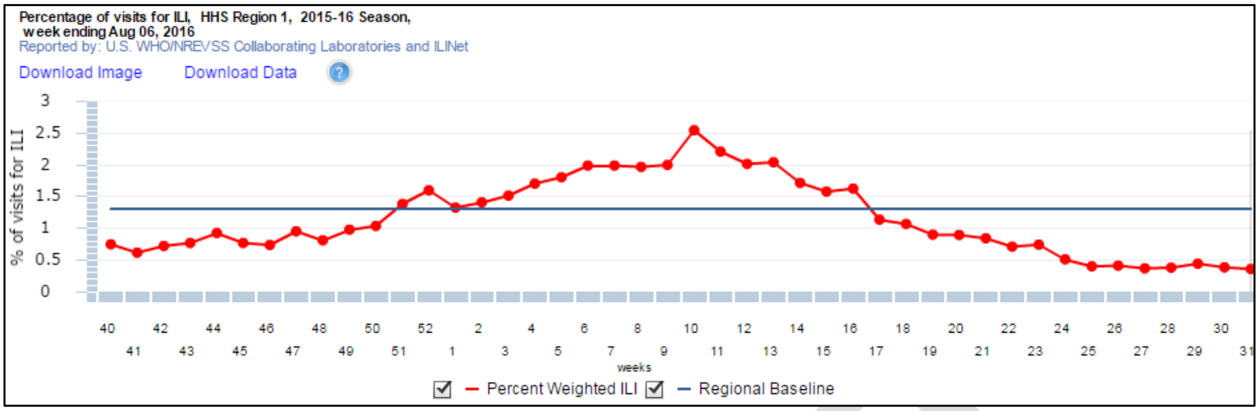


Figure 13. FluView data for HHS Region 1. Figure showing the percentage of healthcare visits for influenza-like illness each week, relative to the regional baseline.

Intentional biological releases

Detection of an intentional biological event can occur by detecting the agent itself, clinically identifying the cases generated by the attack, or by scanning media reports for signs of an attack. Events can be detected by observation if the attacker uses a visually obvious dissemination method or by airborne release detectors installed and managed by the BioWatch program. If the event is not detected by observation, it may be detected clinically by national-level, federal surveillance systems in use at the CDC NNDSS; reports from state public health agencies or hospitals; or national syndromic surveillance systems, such as the CDC BioSense Platform.

BioWatch Program

BioWatch is an early warning biosurveillance sensor network designed to detect the intentional release of specific aerosolized biological agents through airborne sampling in a select number of major metropolitan areas approximately 12 to 36 hours after release. The BioWatch system is integrated with local stakeholder groups and results are submitted to the CDC for confirmation through the Laboratory Response Network (LRN) Results Messenger.

If BioWatch results trigger an event response, the data collected from the sensors (the type of agent detected and the location of the detector) are shared by the BioWatch program with the DHS National Operations Center, who disseminates it to interagency partners. This information sharing allows downstream event characterization and consequence models to use the ground truth data from BioWatch results to reconstruct the event and support the response with plume modeling and consequence analysis products from the IMAAC (described in the Phase 2a: Immediate Response section).

BioWatch results are distributed to pre-authorized users automatically during events, including regional BioWatch program participants and with federal interagency partners. Inquiries about access to BioWatch results should be made during normal operations to the technical contact listed in the MoDI. Because detection by observation or the BioWatch program is not possible for all events, intentional biological event detection may be delayed until symptomatic cases emerge, which may be weeks after the release event.

Phase 2a: Immediate Response

The immediate response to a biological event is marked by declaration of a public health emergency or Presidential disaster declaration, and plans for vaccine or medicine distribution or for limiting spread within the population are implemented. These decisions are informed by tracking updated biosurveillance data and situation reports. For intentional release events, immediate response begins with the confirmation of BioWatch sampling results or with detection of a characteristic abrupt onset of disease cases. For unknown agents, including novel bioterror agents and emerging infectious diseases for which there is only limited data available, epidemiological and laboratory research are ongoing during this phase to help define the treatment. As the event unfolds, case data and reports of the extent of spread are distributed as the data become available and are analyzed and aggregated into situational awareness data, including situation reports.

Key questions that can be addressed during immediate response include:

- How large is the event: what area and who is impacted?
- What is the available medical response and medical countermeasure capacity?
- How is the event unfolding (is it getting better or worse)?

Characterize event spread and impacts

Event characterization focuses response efforts on the impacted area and supports operational response decisions. During the immediate response phase, interagency conference calls, collaboration with academic researchers, and open data sources – such as Twitter – remain important sources of event data.

Natural biological outbreaks and intentional biological releases

CNIMS

The Comprehensive National Incident Management System (CNIMS) models the regional spread of infectious disease by interpersonal contact at the individual level and supports analysis of natural biological outbreaks and intentional biological release events. Notably, it is intended to simulate spread through interpersonal contact and cannot be used for vector-borne disease scenarios (e.g. Zika virus). CNIMS predicts the number of infections over the course of an event and the effects of interventions on reducing total infections (e.g., vaccination, medical countermeasures, and isolation). These outputs can be analyzed by specific geographic regions (e.g., by county) or by demographics such as age groups. Analyses for large-scale events (millions of people) can be completed in about 12 hours. Smaller scale analyses can be completed more quickly. These outputs are available in spreadsheet and video formats.

CNIMS is limited access, must be run by submitting a request for information to subject matter experts at the Defense Threat Reduction Agency (DTRA), and may not be available for all events. CNIMS data requests for real-world events can be made to the DTRA Joint Operations Center or Reachback Analysis Branch, whose contact information is listed in the MoDI. These analyses are not automatically pushed to users by default and must initially be requested on demand for each event.

Intentional biological releases

Tools to estimate the spread and impacts of an intentional biological attack are primarily limited to the atmospheric release modeling provided by the IMAAC and Anthrax Assist, an anthrax release-specific tool owned and operated by HHS CDC. In addition, ICWater, a general purpose water contamination model, may be used to support response to a water-borne intentional biological release event.

Interagency Modeling and Atmospheric Assessment Center

The Interagency Modeling and Atmospheric Assessment Center (IMAAC), owned and managed by FEMA, is responsible for coordinating the development and dissemination of federal atmospheric dispersion event characterization and consequence analysis products. These products represent the common federal operating picture during an atmospheric release event. They are available to support both planning exercises and real-world event operations. IMAAC products are designed to be created and disseminated within 30 minutes to 2 hours following activation. During an event, the IMAAC automatically distributes event characterization and consequence analysis products to the requestor and the agencies that participate in the IMAAC, along with interpretations, explanations, and non-technical summaries.

Los Alamos National Laboratory (LANL) currently has primary responsibility for running intentional biological airborne release scenarios for the IMAAC through a 24/7 reachback agreement using the Quick Urban and Industrial Complex (QUIC) dispersion modeling system for outdoor releases. QUIC is coupled with the CONTAM model, also supported by LANL, to simulate indoor release scenarios. IMAAC products account for weather at the time of the release and effects of the urban built environment on agent dispersion: but, QUIC does not support simulation of subsequent spread of contagious agents from person to person.

The data in IMAAC intentional biological event products can be used to guide evacuation, treatment, sampling, and decontamination activities. Data provided include the estimated source release location and time, a map of the dispersion plume over time, a map of surface deposition of the agent over time, the population under the dispersion plume, the amount of agent deposited in the respiratory tract, the number of illnesses, and the number of deaths. Additionally, the plume contours show acute exposure guideline levels (AEGLs) developed by the Environmental Protection Agency (EPA) to help protect emergency responders conducting life-saving operations in the impacted area.

If BioWatch system sensors detect an airborne biological release, the estimated time and location of the release can be used as inputs to the IMAAC modeling products. BioWatch data are shared with the IMAAC through the DHS National Operations Center (NOC), which disseminates BioWatch results to interagency partners. During an emergency, modeling support may be requested by contacting the IMAAC, as listed in the MoDI entry for the QUIC model. Additionally, IMAAC products are automatically distributed to pre-authorized users during events by making a request to the IMAAC contact during normal operations.

Anthrax Assist

Anthrax Assist projects hospitalizations and casualties for an airborne anthrax release event and compares potential interventions. It is developed and used by the CDC to assist in public health planning and response for anthrax inhalation events. Anthrax Assist is designed to work even when data are limited and only requires the number of patients by date of illness onset and parameters describing the public health response. Outputs include the predicted epidemic curve (total cases over time), the number of casualties and hospitalizations by day (measuring burden to the healthcare system), and the benefits of post-exposure prophylaxis (PEP).

Anthrax Assist currently only available for internal CDC, but will be made more widely available, including for download, once published. It is a standalone model that users download and run themselves. However, technical support may be available during normal operations on request from the technical contact listed in the MoDI.

Waterborne release: ICWater

The Incident Command Tool for Protecting Drinking Water (ICWater) is an operational emergency response system for modeling chemical, biological, or radiological material spills in surface waters. It may be used to provide time-of-travel and concentration values for an intentional biological release event into water. Data in ICWater outputs include the time required for a contaminant to reach specific locations, and the concentration of the contaminant over time.

ICWater is available by request from DTRA and may not be available for all events. ICWater data requests for real-world events can be made to the DTRA Joint Operations Center or Reachback Analysis Branch. These analyses are not automatically distributed to users, and must be requested for each event.

Define and communicate movement control strategies

Movement control strategies, such as evacuation, school closures, or isolation of the impacted area are considered during the immediate response phase to avoid further disease spread. These interventions apply to natural biological outbreaks and intentional biological releases. Data sources, including the event surveillance reports or event characterization models described above, can be used to determine the geographic spread of the outbreak and inform movement control decisions for subsequent communication to the public. For flu outbreaks, influenza-specific tools described in the Phase 1a: Normal Operations section can be used to model the potential benefits of movement control strategies.

During events for which IMAAC plume modeling products are available, controlled evacuation or isolation of the dispersion-impacted area can be planned using the plume footprint. If the event is not an airborne release, then other data sources, such as the event surveillance reports or event characterization models described above, will be the only available sources to determine the geographic spread of the contamination and inform movement control decisions.

Initiate medical response

The medical response to a large scale event is driven by situational awareness data translated into decisions about the requirements and deployment strategy for medical countermeasures. Medical countermeasures can include specific medications and vaccines, for known agents where they are available, or general medical supplies (e.g. ventilators and personal protective equipment). In addition, analysis tools or models can be used to anticipate shortages in hospital bed capacity in order to support medical surge deployments. Medical response to known agents can be supported by plans developed during Normal Operations. With the exception of two agent-specific tools for intentional biological release events (Anthrax Assist and Maxi-Vac) the tools to support medical response planning apply to both naturally-occurring and intentional release events.

CIT Dashboard

The Countermeasure Inventory Tracking (CIT) Dashboard is a national CDC database of current medical and non-medical resources available from the commercial drug sector and state public health agencies.

This dashboard gives responding public health agencies visibility on resources available in the U.S. that could complement the current contents of the SNS. During an event, the CIT Dashboard is used in addition to the SNS to develop sourcing strategies for medical and non-medical resources. A key decision supported by CIT Dashboard is whether it is necessary to release SNS resources, or if needs can be met by other sources.

The CIT Dashboard tracks medical countermeasures, interventions, and supportive care items useful for responses to biological events including: vaccines, antivirals, respirators, ventilators, personal protective equipment (PPE), and surgical masks. Access to the CIT Dashboard is limited to CDC personnel and the CDC's public health partners. Requests for access should be made in advance of an event to the technical contact listed in the MoDI. The data are then made accessible to authorized users online.

SNS TourSolver

The SNS TourSolver optimizes routes to distribute medical countermeasure supplies from Receive, Stage, and Store facilities to the Points of Dispensing locations. It is used by the CDC and SNS managers during planning and operations to ensure SNS resources are distributed as efficiently as possible. TourSolver supports route optimization based on basic information about the fleet and Stops and also provides the ability to simulate multiple scenarios and quickly see the impact on the overall distribution operation, allowing the optimal route to be chosen based on current conditions at the time of the event.

Only participants of the SNS are allowed access to TourSolver. An account is required for use and must be requested in advance. Account requests can be made at the website listed in the MoDI. The data are then made accessible to authorized users online.

HAvBED

Hospital Available Beds for Emergencies and Disasters (HAvBED) is an online database of hospital bed availability counts. HAvBED is used by federal agencies during events to determine how many beds of a particular type are available, determine potential shortfalls, and inform decisions to request additional medical resources. HAvBED is designed to be activated and updated primarily during real-world events, and its bed count data is typically most up-to-date during activation. Information available in HAvBED includes hospital bed availability counts by region or by facility, including specialty bed capacity, notably airborne infection isolation and operating rooms. During events, this information is automatically ingested by situational awareness viewers and analysis applications used by HHS ASPR.

HAvBED access requires pre-registration. Account requests can be made to the technical contact listed in the MoDI. The data are then made accessible to authorized users online.

Intentional biological releases

Anthrax Assist and Maxi-Vac

As described above, Anthrax Assist can be used to evaluate post-exposure prophylaxis, specifically following anthrax release events. Thus, the results of Anthrax Assist are directly useful to inform the medical response.

Maxi-Vac is a planning tool for intentional smallpox release scenarios that determines the optimal staff placement per shift for each of 9 possible stations in a smallpox vaccination clinic. It is developed and used by the CDC and primarily intended for use by state and local public health officials to develop smallpox emergency response plans. Maxi-Vac is open access and available online. It requires custom data to be used most effectively and is best used during normal operations to support plans for vaccination that can be executed during the immediate response phase.

Collect ground truth data samples

For intentional biological release events, in addition to dispersion modeling, two tools exist to support sample collection strategies and analysis to support refinement of the known impacted area and inform later decontamination efforts.

SAM

The Selected Analytical Methods for Remediation and Recovery (SAM) database guides users in determining the proper sampling and analysis techniques for a specific chemical, radiochemical, pathogen, or biotoxin contaminant. It would be used by the EPA following an intentional biological event to ensure samples are collection and analysis are consistent with best practices. The output data include sample preparation methods, analytic techniques, and special considerations specific to the contaminant and analysis techniques. SAM is open access and available online, but data are most useful to experts in environmental sampling and analysis. A PDF manual version of SAM can also be downloaded for use when the web application cannot be accessed.

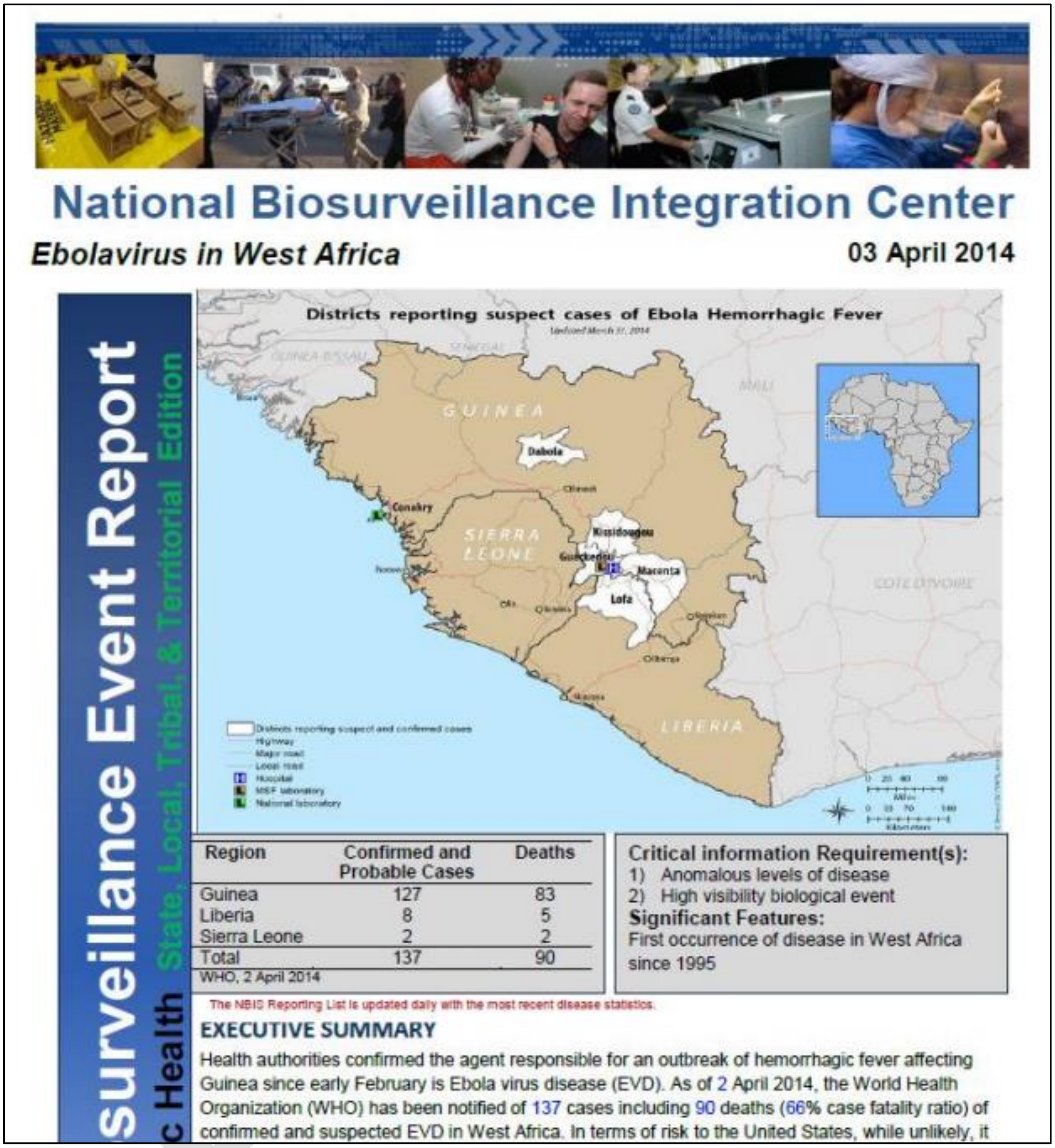
VSP

Visual Sample Plan (VSP) supports development of an environmental or building interior sampling plan. VSP is intended to help non-statisticians determine how many samples are needed, where samples should be taken, and what decisions the sample data support. The EPA uses VSP to plan cost-effective sampling to support responses to intentional biological release. Given user-input sampling areas, interior models, budget constraints, and specific goals, VSP outputs a report describing the details and cost of the optimal sampling plan given budget constraints and specific goals. The geospatial locations of samples can be downloaded in geospatial or text formats.

VSP is open access and available online for download. However, it requires subject matter expertise to use effectively and is most applicable to the EPA's specific mission space. Requests for information can be made to the technical contact listed in the MoDI.

Track reported event spread and impacts

During immediate response, biosurveillance systems described in the normal operations section continue to provide situational awareness information. Some biosurveillance systems shift to producing situation reports during events, such as the NBIC Biosurveillance Event Reports and HealthMap Event-specific Pages shown in Figure 14 and Figure 15. In addition, situational awareness viewers are a key tool to integrate information about the ongoing event. Situational awareness viewers may be specifically used by a single agency, such as CDC RedSky, a few agencies (HHS GeoHealth), or available to a broader usership with prior enrollment as is the case with DisasterAWARE (described below).



National Biosurveillance Integration Center

Ebolavirus in West Africa 03 April 2014

Biosurveillance Event Report
Public Health State, Local, Tribal, & Territorial Edition

Region	Confirmed and Probable Cases	Deaths
Guinea	127	83
Liberia	8	5
Sierra Leone	2	2
Total	137	90

WHO, 2 April 2014

Critical information Requirement(s):
1) Anomalous levels of disease
2) High visibility biological event

Significant Features:
First occurrence of disease in West Africa since 1995

The NBIS Reporting List is updated daily with the most recent disease statistics.

EXECUTIVE SUMMARY

Health authorities confirmed the agent responsible for an outbreak of hemorrhagic fever affecting Guinea since early February is Ebola virus disease (EVD). As of 2 April 2014, the World Health Organization (WHO) has been notified of 137 cases including 90 deaths (66% case fatality ratio) of confirmed and suspected EVD in West Africa. In terms of risk to the United States, while unlikely, it

Figure 14. NBIC Biosurveillance Event Report for the Ebolavirus outbreak in West Africa.

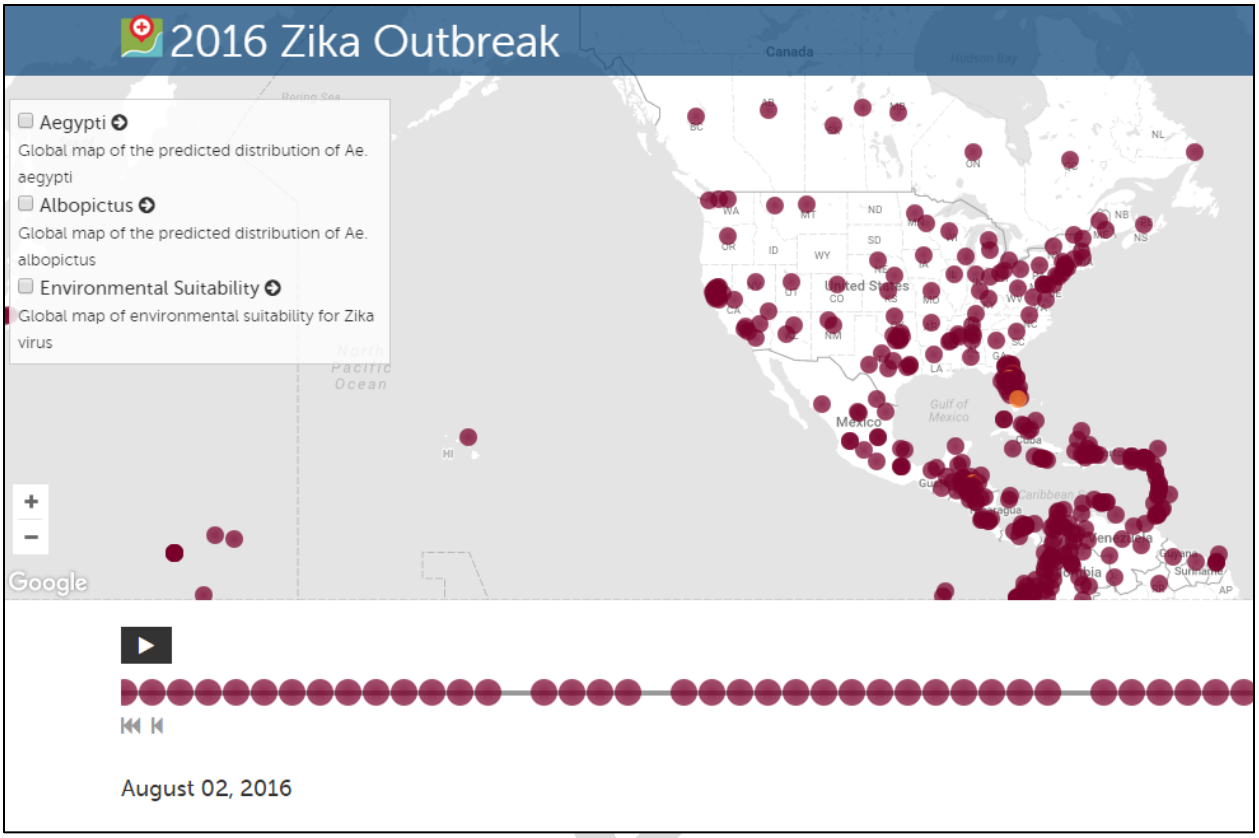


Figure 15. HealthMap event-specific page for the 2016 Zika Outbreak. HealthMap view showing a timeline of the geographic spread of the media coverage.

DisasterAWARE

The Disaster All-hazard Warning, Analysis, and Risk Evaluation (DisasterAWARE) is a Pacific Disaster Center (PDC) platform that provides access to numerous country-level geospatial data feeds relevant to public health events. DisasterAWARE monitors over 65 authoritative sources for potentially hazardous incidents, and it is integrated into social media platforms such as Twitter and Facebook.

DisasterAWARE can be used as a situational awareness viewer, automatically ingesting and displaying several of the biological event data sources mentioned previously, including CDC and WHO reports of case counts by country. It also provides alerts to users when new biological events are added or updated. Custom map views and situation reports can be shared between users to promote a common operating picture during events.

Biological event data are only available in the limited access version of DisasterAWARE and access must be requested in advance; the MoDI provides the link to the access request website.

Phase 2b: Deployment

In the deployment phase, the primary tasks are to maintain situational awareness of the event and initiate life-saving medical response activities drawn from plans or developed during the immediate response phase. Subject matter experts within the Federal government and in the academic research community remain important resources to interpret event data and predict the scope of the unfolding emergency.

Key questions during deployment include:

- How is the event progressing?
- Is the planned medical response deployment sufficient?

Continue tracking reported event spread and impacts

Each of the biosurveillance tools and situation reports used to characterize event spread and project impacts discussed in the normal operations and response phases remain useful for the event throughout the deployment phase. In addition to these tools, data describing current response activities will begin to be published by agencies who are responding to the event.

Refine analysis of what happened

For intentional airborne release events, the IMAAC will produce updated products that incorporate any additional data refining the precise release location and amount as it is collected and made available by deployed on-scene responders. Event characterization and consequence analysis products requested from DTRA, such as ICWater and CNIMS products, will need to be updated by request, if available for the specific event.

For natural biological outbreaks, subject matter interpretation of biosurveillance data, epidemiology, and modeling (coordinated though mechanisms such as interagency conference calls) will be needed continually to refine understanding of the event.

Initiate medical response

During the deployment phase, the medical response is fully mobilized based on the information gathered from all of the tools described in the previous phases for predicting medical surge capacity and planning medical countermeasure deployment (e.g., Healthcare Surge Evaluation Tool, CIT Dashboard and SNS TourSolver).

In addition, Healthcare Ready is available to monitor near-real-time status (open or closed) of participating pharmacies in the continental US. It is used by HHS ASPR during an event to determine which communities may need additional support for prescription medication needs based on pharmacy closures. The searchable Open Pharmacies Map (Figure 16) includes the pharmacy name, address, phone number, and status. The locations of open American Red Cross shelters are also included. Healthcare Ready is open access and available online. Users can access and use it during events at the website listed in the MoDI.

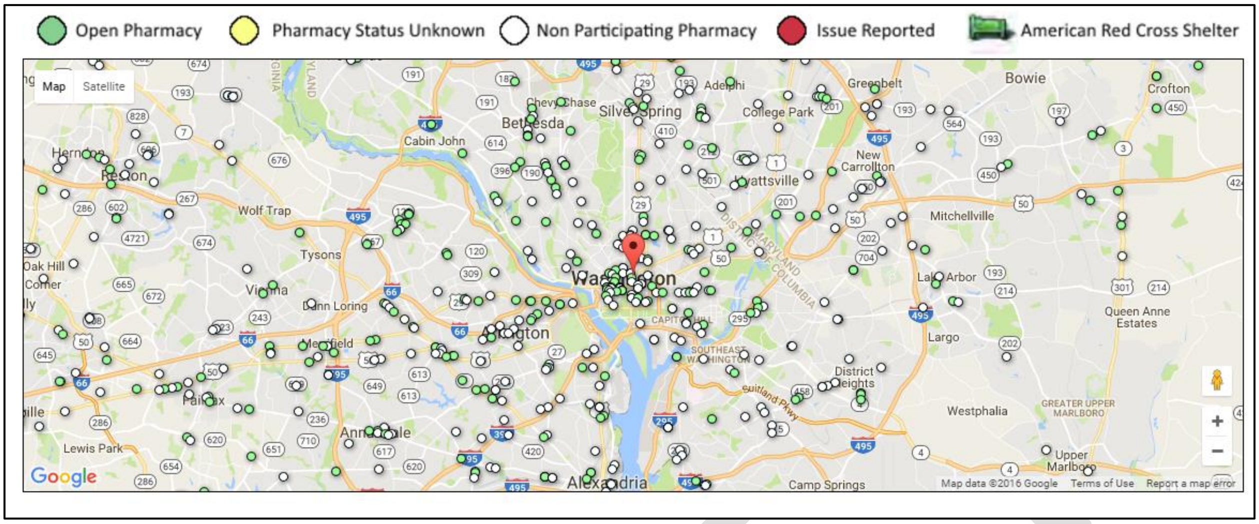


Figure 16. Healthcare Ready Map. Map displaying pharmacies and Red Cross shelters in the Washington, DC area.

Phase 2c: Sustained Response

In the sustained response phase, the datasets and models used in previous phases should continue to be used and updated as new information becomes available from on-scene responders. Additionally, the medical response continues in this phase and may shift focus to individuals not directly affected by the outbreak but who are medically vulnerable due to the demands on the healthcare system, such as those dependent on electrically-powered medical equipment. Official data from the CDC regarding illnesses and deaths may become available from deployed personnel and published, which can be used to track the response.

Phase 3: Recovery

Data requirements to support biological incident recovery phase operations are less well defined than for other hazards due to rarity of biological emergencies and the diversity of biological scenarios. One clear recovery phase requirement is decontamination the impacted area, especially for intentional release events, but potentially for large-scale natural outbreaks of an agent that persists in the environment.

Decontaminate area and remove hazardous waste

Intentional biological releases

SAM and VSP

As described previously, the SAM and the VSP can be used to support environmental sampling and data collection efforts post-event. These tools would be used similarly during recovery to support decontamination activities to help determine whether a pathogen is still present in an impacted area.

I-WASTE DST

The Incident Waste Decision Support Tool (I-WASTE) provides planning and operational information on the handling, transportation, treatment, and disposal of contaminated waste and debris. It is used by the EPA during events to estimate the amount of waste generated by an event and disposal and transportation requirements. I-WASTE contains information on the characteristics of potential waste, decontamination agents, a waste quantity estimator, debris transportation, packaging, and staging information, and worker protection information. Many diverse sources of information are referenced or incorporated, including data from federal databases, commercial websites, official reports, and existing guidance documents.

I-WASTE requires an account that must be requested in advance. Account requests can be made at the website listed in the MoDI. Users can then access the application online.

Anthrax release: DeconST

The Decontamination Strategy and Technology Selection Tool (DeconST) provides cost-benefit information on possible biological event decontamination methods and on managing waste generated by using the technologies. The tool currently addresses contamination of a building with *Bacillus anthracis* (anthrax) spores, but could be used for contamination by other agents. Based on user-input building type, contents, size, sampling frequency, and weather, DeconST compares candidate decontamination technologies. The cost comparison includes the costs of the decontamination process plus waste it produces. The DeconST is intended to be used by the EPA to provide recommendations to the Incident Command on decontamination technologies appropriate for a given building and scenario. The DeconST presents a series of options and recommendations, but requires an analyst to choose which technology will ultimately be used.

DeconST is intended for use by EPA mission experts and requires advance requests for access outside of the EPA. Requests for information should be made to the technical contact listed in the MoDI. The tool itself is provided as a standalone Excel spreadsheet.

In addition to decontamination, sustained support across all ESFs and Recovery Support Functions (RSFs) will build upon the information and tools outlined in the previous sections and many of the ESF mission models (Appendix C) will continue to be used to support recovery data requirements. Recovery from a large-scale biological event may take years, so the continued use of all of the previously described datasets and models will be important to support recovery operations.

Conclusions and Recommendations

Who coordinates the federal response for biological events?

The timeline of naturally-occurring biological outbreaks creates significant uncertainty for the federal emergency management community. Most critically, while HHS CDC is responsible for both international and domestic public health monitoring and response, HHS ASPR is responsible for managing public health emergencies. However, the point at which an event becomes a public health emergency domestically is often ambiguous, and the hand-off of responsibility between the two organizations creates a climate of uncertainty for the rest of the emergency management community regarding the current lead agency and appropriate source of data or decision making as the event unfolds.

Critically, response to biological outbreaks needs to be more effectively coordinated across the federal government. In the event of a declared public health emergency, HHS ASPR is assigned the lead role. However, there is no clear coordinator of the federal response, nor information collection and coordination early in an event. This situation is in contrast to other hazards for which, for instance, NOAA has the lead scientific role in identifying, assessing risk, and informing the federal emergency management community of an impending hurricane or large-scale storm. FEMA is then tasked with coordinating the subsequent response, including coordinating information exchange within the emergency management community. A corollary structure is needed for biological hazards, but is not currently established, particularly early in an event when it is not yet clear that emergency status will be reached, but preparation, planning, and initial response efforts need to be coordinated.

The lead role for intentional or large-scale biological attacks is less ambiguous and is expected to be mediated through IMAAC, a construct well-established in federal policy and integrated with corresponding data collection and analysis experts. However, the role of IMAAC is only clearly articulated for atmospheric releases, and, according to interviewees, there remains significant uncertainty about the most appropriate sources of information and the coordination of non-atmospheric releases of biological agents intentionally, including, most notably, contagious agents.

Recommendations

- Establish a clear set of policy mandates for information sharing for naturally-occurring biological outbreaks, including mandates for coordination with the broader emergency management community
- Establish a clear line of authority between HHS CDC and HHS ASPR that defines the handoff and ensures seamless information exchange for when an event transitions from a day-to-day public health response to a public health emergency under ESF #8
    - Establish APIs and a standard of record for how to effectively share patient and case data to facilitate coordinated public health response efforts between HHS CDC and HHS ASPR
    - Define and establish more effective and rapid information sharing with the broader emergency management community
    - Define the information coordination and response coordination roles for HHS ASPR as part of their ESF #8 function to better support a coordinated federal response for large scale events

Datasets and models are needed to meet response-relevant data requirements

One of the greatest challenges in emergency management is effectively translating the complex scientific data and computational modeling generated by the scientific and expert communities into the practical, pragmatic information required for response and recovery operations. This challenge has largely been met by NOAA for hurricanes and USGS for floods; meeting this challenge is still nascent for biological hazard scenarios. As highlighted throughout this analysis, the majority of event characterization and consequence analysis is performed by and designed for the expert and academic communities. These analyses, though both powerful and critical, do not meet (and are not designed to meet) the needs of the emergency management community. This gap is in part because academic datasets and models meet only a small fraction of data requirements and do not often share data, but also because the academic process and publishing is too slow to make the relevant data available in time for response operations. Finally, experts may be in midst of academic disagreements over even the most fundamental modeling parameters (for example, the infectious dose of anthrax), and concerns over these data preclude the analysis necessary to support response operations. Because the existing modeling capabilities are not concentrated or coordinated at the federal level, it is not clear to most members of the emergency management community interviewed who the authoritative source is for data and information during each stage of an outbreak.

Challenges also emerge during these events because case reports or medical records are the primary source of raw data. Personally identifiable information and other health data considerations limit the dissemination and sharing of information. Given these challenges with formal case report data, Twitter feeds, informal data sharing, and reliance on individual subject matter experts were all identified by interviewees as key sources of information for biological scenarios (e.g., the HHS ASPR BARDA modeling coordination call). These information sources lack the permanence and clarity of roles that have been established for other scenarios.

Confusion over agency roles affects planning in addition to response. It is not clear when or if academic research should be used to set modeling parameters or what scenarios should be incorporated into plans. This contributes directly to the lack of contagious agent modeling for intentional scenarios and planning for attacks other than dispersion.

Recommendations

- As for hurricane forecasts that are accompanied by clear recommendations and guidance for both the public and the emergency management community, products should be standardized and a clear set of outputs defined for biological outbreak data analysis and modeling that directly meets the information needs of the public health response and emergency management communities
- Establish a clear flow of information from the academic experts and data collection efforts of epidemiologists to the emergency management community that articulates data standards for coordinated analysis and information sharing requirements for sensitive data (e.g., standardized, sanitized metadata that meet privacy requirements)
- Continue improving data collection, collation, and publication to better support and inform coordinated analysis and subsequent response efforts

Biological emergencies will overwhelm capabilities

Biological incidents are inherently catastrophic disasters. Focus must be placed on determining if and when an event has occurred or warrants a federal response. Delays in biological response have exponential consequences and the opportunity for containing damage at the early stages is arguably greater than any other hazard. Therefore, once declared, decision-makers must be empowered, and the response must "Go Big, Go Early, Go Fast, Be Smart," as with other events, even when under conditions of significant uncertainty. This type of response will necessitate new tools and analysis to support more clear decision-making for such events.

Recommendations

- Continue to improve biosurveillance efforts and analysis to support and tailor these analyses to inform rapid, well-supported activation of public health emergencies, even under conditions of ambiguity
- Establish more effective data sharing and information coordination efforts across the federal interagency to support collaborative decision making
- Improve data sharing and exchange between datasets and models and better support the analysis required for rapid, large-scale response to biological outbreaks.
- Invest in models and decision support tools that are agent-agnostic (useful across a broad range of agents) and targeted toward the response-relevant characteristics that will ensure a better informed decision making process across the interagency
    - Develop tools that can tolerate uncertainty in input parameters while still informing operational decision making

Appendix A: Interviewees

Name	Agency or Organization
McNamee, Shannon	American Red Cross
Decker, KC	Booze Allen Hamilton (BAH)
Macintyre, Anthony	Department of Homeland Security Headquarters (DHS HQ)
Buckley, Kara	DHS National Protection and Programs Directorate Office of Cyber and Infrastructure Analysis (DHS NPPD OCIA)
Crockett, Katie	DHS Office of Health Affairs BioWatch (DHS OHA BioWatch)
Scheuer, Amy	DHS OHA BioWatch
Walter, Mike	DHS OHA BioWatch
Bouker, Sarah	DHS OHA National Biosurveillance Integration Center (DHS OHA NBIC)
Firoved, Aaron	DHS OHA NBIC
Hawkins, Natasha	DHS OHA NBIC
Herd, Tim	DHS OHA NBIC
Mahgoub, Soha	DHS OHA NBIC
McGinn, Tom	DHS OHA NBIC
Quitugua, Teresa	DHS OHA NBIC
Rogers, Phillip	DHS OHA NBIC
Wood, Chad	DHS Office of Public Affairs (DHS PA)
Coller Monarez, Susan	DHS Office of Policy (DHS PLCY)
Dickerson, Bradley	DHS PLCY
Epstein, Gerry	DHS PLCY
Middleton, Jason	DHS Science and Technology Directorate (DHS S&T)
White, Scott	DHS S&T

Asadurian, Alis	Department of Commerce Economics and Statistics Administration (DOC ESA)
Cooke-Hull, Sandra	DOC ESA
Henry, David	DOC ESA
Rivers, Caitlin	Department of Defense Army (DoD Army)
Chretien, Jean-Paul	DoD Defense Health Agency Armed Forces Health Surveillance Branch (DoD DHA AFHSB)
Harris, Stic	DoD DHA AFHSB
Argenta, Edward	DoD Defense Threat Reduction Agency (DoD DTRA)
Grose, Andy	DoD DTRA
Hill, Terrence	DoD DTRA
Kiley, Christopher	DoD DTRA
Wu, Aiguo	DoD DTRA
Androsky, Dawn	DoD Navy Bureau of Medicine and Surgery (DoD Navy BUMED)
Jeffs, Steve	DoD Navy BUMED
Wireman, Jody	DoD US Northern Command (DoD USNORTHCOM)
Strocko, Ed	Department of Transportation Office of the Assistant Secretary for Research and Technology Bureau of Transportation Statistics (DOT OST-R BTS)
Greenberg, Jeremy	DOT OST-R Office of Intelligence, Security and Emergency Management (DOT OST-R OISEM)
Ridge, Matt	DOT OST-R OISEM
Canzler, Erica	Environmental Protection Agency Office of Emergency Management Consequence Management Advisory Division (EPA OEM CMAD)
Snyder, Emily	EPA Office of Research and Development National Homeland Security Research Center (EPA ORD NHSRC)
Bannan, Jason	Federal Bureau of Investigation (FBI)
SampollRamirez, Gabriel	FBI

Vollmers, Julia	FBI
Battle, Ashley	Federal Emergency Management Agency (FEMA)
Berman, Eric	FEMA
Ignacio, Lito	FEMA
Koziol, Lauralee	FEMA
Tinsman, Mark	FEMA
Bensimon, Dov	Government of Canada Environment and Climate Change Canada (GC EC)
Berthiaume, Philippe	GC Health Canada (GC HC)
Bourgouin, Pierre	GC Public Health Agency of Canada (GC PHAC)
Ogden, Nicholas	GC PHAC
Yan, Ping	GC PHAC
Perkins, Dana	Department of Health and Human Services Office of the Assistant Secretary for Preparedness and Response (HHS ASPR)
Lant, Tim	HHS ASPR Biomedical Advanced Research and Development Authority (HHS ASPR BARDA)
Bennett, Kelly	HHS ASPR Office of Emergency Management (HHS ASPR OEM)
Bossler, Sumner	HHS ASPR OEM
Bourg, Mike	HHS ASPR OEM
Curren, Steve	HHS ASPR OEM
Hopper, Ken	HHS ASPR OEM
Lamana, Joe	HHS ASPR OEM
Seikierski, Edmund	HHS ASPR OEM
Seiler, Brittney	HHS ASPR OEM
Shankman, Rob	HHS ASPR OEM
Smith, Matthew	HHS ASPR OEM
Vineyard, Mike	HHS ASPR OEM

Nurthen, Nancy	HHS ASPR OEM Fusion
Brannman, Shayne	HHS ASPR Technical Resources, Assistance Center, and Information Exchange (HHS ASPR TRACIE)
Mazurek, Audrey	HHS ASPR TRACIE
Adhikaria, Bishwa	HHS Centers for Disease Control and Prevention (HHS CDC)
Atkins, Charisma	HHS CDC
Beard, Ben	HHS CDC
Biggerstaff, Matt	HHS CDC
Burkholder, Jacqueline	HHS CDC
Campbell, Caresse	HHS CDC
Carias, Cristina	HHS CDC
Cassell, Cynthia	HHS CDC
Coletta, Michael	HHS CDC
Fischer, Leah	HHS CDC
Greening, Bradford	HHS CDC
Jernigan, Dan	HHS CDC
Johansson, Michael	HHS CDC
Kahn, Emily	HHS CDC
Kersh, Gil	HHS CDC
Kite-Powell, Aaron	HHS CDC
Levitt, Alexandra	HHS CDC
Luber, George	HHS CDC
Marston, Barbara	HHS CDC
Massung, Rob	HHS CDC
McQuiston, Jenny	HHS CDC

Meltzer, Martin	HHS CDC
Redd, Stephen	HHS CDC
Rainisch, Gabriel	HHS CDC
Reed, Carrie	HHS CDC
Reynolds, Mary	HHS CDC
Rollin, Pierre	HHS CDC
Rzeszotarski, Peter	HHS CDC
Thomas, Jason	HHS CDC
Tyson, Jim	HHS CDC
Walke, Henry	HHS CDC
McKenzie, Ellis	HHS National Institutes of Health (HHS NIH)
Ravichandran, Ravi	HHS NIH
Lim, Matthew	HHS Office of Global Affairs (HHS OGA)
Ziaya, David R.	Department of Housing and Urban Development Office of Administration (HUD OA)
Oxford, Sean	Institute for Defense Analyses (IDA)
George, Dylan	In-Q-Tel
Alai, Maureen	Lawrence Livermore National Laboratory (LLNL)
Nasstrom, John	LLNL
Raber, Ellen	LLNL
Rose, Patrick	National Association of County and City Health Officials (NACCHO)
Bausch, Doug	Pacific Disaster Center (PDC)
Green, Joe	PDC
Gray, Jessica	Pacific Northwest National Laboratory (PNNL)
Lesperance, Ann	PNNL

Morgan, Larry	PNNL
Steele, Robert	PNNL
Dial, Patrick	Small Business Administration (SBA)
Simrall, Robert	United States Army Corps of Engineers (USACE)
Boyd, Valerie	United States Coast Guard (USCG)
Nguyen, Jason	USCG
Cross, Paul	United States Geological Survey (USGS)
Lewis, Bryan	Virginia Tech Biocomplexity Institute (VT BI)
Barnes, Joshua	White House National Security Council (NSC)
Schafer, Julie	White House NSC
Morgan, Oliver	World Health Organization (WHO)

Appendix B: Methods

The workflow of data collection, processing, and analysis performed for this project is shown in Figure A1 and described briefly in the Methods section in the main text. Each step is described in detail below.

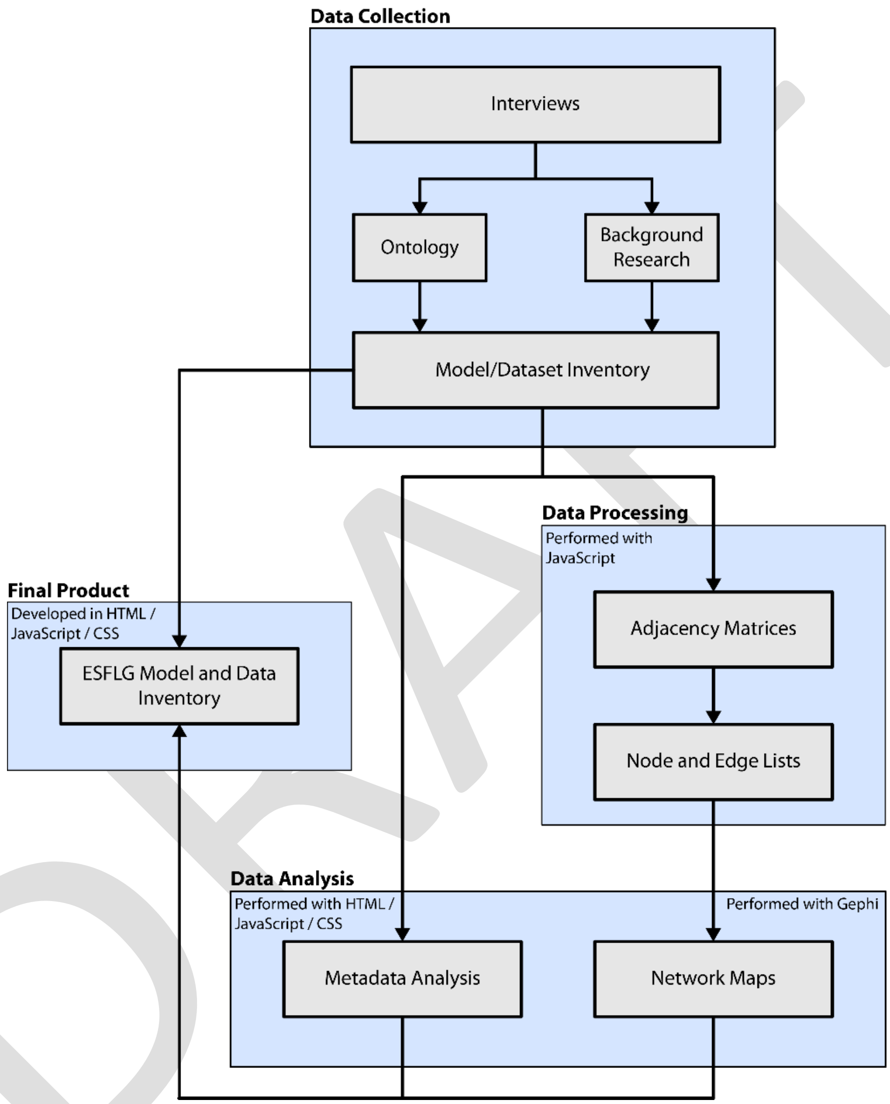


Figure B1. Analysis workflow. A depiction of the sequence of work involved in producing quantitative analysis of the model/dataset inventory.

Data Collection

Interviews

The information required to analyze the available data and modeling tools was collected through a series of in-person and phone interviews. Interviews were performed with the members of the MDWG, the subject matter experts and stakeholders they recommended, and additional individuals suggested by those interviewed. During these interviews, the users and owners of each tool identified and characterized the ways in which it is used to support planning and operational decision making. In most cases, the MDWG members were interviewed initially. Interviews with additional subject matter experts or leadership were scheduled upon recommendation to provide further breadth or depth of information, depending on the size of the agency or division represented and the expertise of each interviewee.

Interviews were opened with an introduction to the project. Throughout the project, interviewees have included those who are providers of data or are tool developers; those who are analysts and users of those data and tools; those who make operational decisions informed by datasets and models; and those who have roles that include a combination of tool development, analysis, and decision making. Interviews were designed to capture an overview of the roles and responsibilities of each group and the ways in which data and data processing tools, including modeling, supported those roles. The flow of the conversation varied widely based on the expertise of the interviewee and attempted to capture both the general and specific information requirements from each interviewee across the spectrum of emergency management missions and the phases of an emergency. A comprehensive list of the interviewees can be found in Appendix A.

Ontology

Initial iterations of the MDWG effort were focused specifically on hurricane and earthquake hazards. Interviewees were asked about the types of information they need to support their emergency management mission in the context of those hazard scenarios. Based on the responses, a systems-level analysis of the information requirements was conducted and a framework to capture the flow of information between the different types of data and modeling tools was developed. This ontology describes how the information required is collected and processed over several iterations of collation and analysis. This analysis provides a framework to understand the role and value of both computationally intensive predictive modeling and the rapid calculations provided by simple algorithms to determine mission specific requirements. This information ontology or flow of information framework was vetted and validated by the working group and is described in detail in the main text of this report in the context of biological hazards. It has been used to describe the flow of information in support of emergency management for all hazards analyzed since the initial hurricane and earthquake efforts, which now also include flood, nuclear detonation, and biological hazard scenarios.

Model/Dataset Inventory

A comprehensive inventory of tools used across the federal interagency and the linkages between them was generated on the basis of the tools discussed during interviews, followed by background research to identify inputs and outputs of each tool. Only tools with federal users were included in the inventory. Tools under development or not currently used to support emergency management activities were identified, but not included in the inventory. Information about these tools and how they function within the flow of information has been retained in an archived library. This information allows for more a more detailed analysis and verification of the analyses. Additionally, these tools can be used in future to suggest mechanisms to fill gaps identified in the current inventory. The inclusion of only used and operational tools in the inventory enables an analysis of how information currently travels within the interagency and results in a streamlined inventory containing the information immediately useful for emergency managers.

Metadata

The flow of information framework captures the functional, time-dependent, and mission-specific variation between tools used across the federal interagency. However, it does not describe other essential characteristics, such as how those tools are accessed, used, and updated. These additional characteristics, or metadata, must also be collected to properly organize and analyze the tools to maximize effective usage during all phases of emergency management. These metadata will appear in the interactive inventory of tools, the Model and Data Inventory (MoDI), upon completion of the project.

Metadata categories include: the tool's name; summary; resource type; applicable hazards; supported Core Capabilities, Emergency Support Functions, and Recovery Support Functions; keywords; data collection method; owner; users (federal agency-level) by hazard and phase; upstream inventory resources by hazard; downstream inventory resources by hazard; phase specific utility by hazard; access information; processing requirements; refresh rate; last known version; programming language; output file types; technical contact; real-time contact; geographic coverage; and website. Additionally, for tools applicable to biological hazards, these metadata were collected: natural or intentional event; contagious or non-contagious agent; known or unknown agent; medical countermeasures available or not; domestic or international event; and environmentally persistent agent. Complete descriptions of each metadata category are included in the MoDI.

As metadata were collected and input into the inventory, scripts written in the R language were used to automatically populate certain metadata categories based on the contents of other metadata categories. For example, certain Core Capabilities were automatically tagged based on the Emergency Support Functions and Recovery Support Functions that were tagged for the tool. R was chosen because of its flexibility and suitability for repetitive text processing tasks. [8]

In addition to the data collection methods shown in Figure B1, a data validation step was performed. After the initial drafts of analyses and the inventory were completed, the metadata gathered from interviewees describing tools they own or use were submitted to those interviewees for review and feedback. All feedback received was adjudicated and incorporated into the inventory and results.

Data Processing

In the data processing phase, the model/dataset inventory data were processed into a format that could be imported and analyzed by network analysis software. All data processing was performed using JavaScript. JavaScript was chosen because the inventory data could be readily represented in JavaScript Object Notation (JSON) format, which is widely used in data visualization and web-based applications. Additionally, many robust open source libraries are available for JavaScript-based data analysis, facilitating reuse of the analysis scripts and their transfer to other parties.

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8 R Development Core Team. (2016). R: A Language and Environment for Statistical Computing. Vienna, Austria. Retrieved from http://www.r-project.org

Networks

A network is defined as a system consisting of interconnected components. Network analysis is the process of understanding the connections between those components. Individual components of the network are called nodes, and the connections between them are called edges, with information moving through the network by a defined, or directed, flow. Networks can be represented by objects called adjacency matrices, node lists, and edge lists, as described in the following sections.

Adjacency Matrices

To build network maps describing the linkages between tools in the inventory, the metadata defining the upstream and downstream linkages between tools were used to build an adjacency matrix. An adjacency matrix is a mathematical method of representing a network that provides a simple way to calculate many network measures and statistics.[9]

Node and Edge Lists

The adjacency matrix was then converted into an edge list. An edge is a line in the network that connects two nodes, and in this case, represents the transfer of information from one tool to another. The edge list contains a list of connections between nodes in the network. In addition, the inventory metadata were used to prepare a node list. A node is a point in a network, and in this case, each node represents a single tool in the inventory. The node list contains the metadata of each node in the network, allowing that information to be visualized on a network map and analyzed in the context of the network. These node and edge lists were imported into Gephi,[10] an open source network visualization and analysis software program, to create and analyze the network maps used in the analysis.

Data Analysis

The inventory data, including the tools and their associated metadata, and the networks based on this inventory, were used to perform an analysis of the biological hazard inventory, as described in the results section. Two main types of analyses were performed: network analysis and metadata analysis.

Network Analysis

The majority of network analysis presented in this report describes the connections between the datasets and models used by the federal interagency in the context of emergency management. Two metadata categories (upstream inventory resources and downstream inventory resources) describe linkages between the tools based on the flow of information between those tools. These linkages were used to build flow-based tool networks. Additionally, each tool was tagged with a federal agency owner. This ownership information was used to build agency networks showing the flow of information between federal agencies, based on the tools owned by each agency and the linkages between those tools.

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9 A short, rigorous definition of an adjacency matrix: For a network of n nodes, the adjacency matrix A is an $n \times n$ matrix where the i,j^{th} entry in the matrix represents the number of connections from the i^{th} node in the network, to the j^{th} node in the network.

10 Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An Open Source Software for Exploring and Manipulating Networks. Retrieved from http://www.aaai.org/ocs/index.php/ICWSM/09/paper/view/154

Tool Networks

Tool network maps were generated in order to visualize and analyze the connections between tools described in the inventory. A simple, notional example of a tool network map is shown in Figure B2. In tool network maps, each node represents a single tool in the inventory. The size of a tool's node and its label is proportional to the number of federal agency-level users of the tool. Here, the number of users of a tool is defined as the total number of federal agencies that directly use the tool in the context of their work supporting interagency emergency management efforts. Edges connecting nodes in the tool network represent the flow of information and processing of data as it passes from one tool to another. Information flows in a clockwise direction, with edges curving clockwise from tools that act as source of information toward tools that consume that information. Both the inputs (upstream tools) and outputs (downstream tools) of each tool were identified based on in-depth analysis of interview data and a review of the technical documentation of the tool, when available.

Nodes were arranged by a force direction algorithm that groups closely linked nodes.[11] This algorithm treats each node as a charged particle that repels all other nodes, and each edge as a spring, pulling the connected nodes back together. The ForceAtlas2 implementation of the force direction algorithm was used, as made available in Gephi. The force direction algorithm was chosen because it has been shown to highlight underlying community structures that exist in data.[12] The force direction algorithm was run and re-run numerous times, with the initial positions of nodes randomized at the beginning of each run. Additionally, the strength of repulsion between nodes was varied from weak to strong. Randomly restarting the algorithm and systematically varying node charge allowed the structure of the graph to be fully explored under a variety of conditions. The tool network maps shown in the results section are the result of multiple runs of the force direction algorithm that consistently converged on a particular layout of the nodes.

Each tool network map used a specific node color scheme to convey information. Tool network maps used one of three color schemes: resource type, betweenness centrality, and modularity cluster, as described in the following sections.

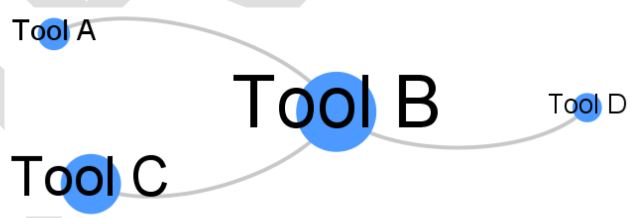

Figure B2. Example of a simple tool network map. Individual tools are represented by blue discs (nodes). Direct connections between tools are represented by gray curved lines (edges). The flow of information travels clockwise. In this example, information flows into Tool B from Tools A and D. Information from Tool B flows into Tool C. The

11 Jacomy, M., Venturini, T., Heymann, S., Bastian, M. (2014). ForceAtlas2, a Continuous Graph Layout Algorithm for Handy Network Visualization Designed for the Gephi Software. *PLoS ONE*, *9*(6), e98679.

12 Noack, A. (2009). Modularity clustering is force-directed layout. *Physical Review E*, *79*(2), 26102.

size of each node can convey additional information. For the tool network maps presented in this report, node sizes are proportional to the number of users of that tool.

Resource Type

The connections between tools in the context of the flow of information ontology were examined by creating tool network maps with nodes colored according to their position in the flow of information, or resource type. There are seven possible resource types, as described in the main text. Lighter-colored nodes represent tools that are upstream in the flow of information (relatively unprocessed information), and darker-colored nodes represent tools downstream in the flow (relatively processed information). Tools that function as more than one resource type are colored based on the average position of those types in the flow of information.

Betweenness Centrality

Centrality is a family of measures used to rank the most significant nodes in a network. Different definitions of centrality have been proposed to measure particular qualities of a node's position within a network, and the most prevalent definitions can be classified into one of three groups: degree, closeness, and betweenness.[13] Degree centrality is based on the number of connections that one node has to other nodes, whereas closeness centrality is a function of a node's distance from other points in the network. Here, the significance of individual tools was investigated with a measure of betweenness centrality, which ranks nodes according to the frequency with which they lie between other nodes in the network. Betweenness centrality was analyzed because it provided the means to determine which tools act as information "bridges" between other tools. This "bridge"-like character of a node cannot be readily evaluated by visual inspection of a force-directed network map, whereas properties such as degree and closeness may be.

The relative importance of specific tools as information "bridges" was investigated using the betweenness centrality measure. Betweenness centrality is a common metric of node significance that characterizes how often a node lies between other nodes in a network. Here, the betweenness centrality of a node is defined as the sum of minimum-length paths between other nodes that an individual node lies on, with each path weighted according to the inverse of the number of alternative same-length paths between the corresponding node pair.[14] Only paths in the direction of information flow are considered. High betweenness centrality is assigned to nodes that act as "shortcuts" or "bridges" between different parts of the network, and is an estimate of the amount of information flowing through a node relative to other nodes. [15,16] In the network maps, nodes were colored on a gradient such that more central nodes were darker and less central nodes were lighter.

Betweenness centrality only considers the shortest paths between nodes and therefore does not consider longer, alternative paths over which information could be passed within a network. Here, the weighted version of the betweenness centrality calculation was used in order to highlight the significance of nodes that act as the only information "bridge" between other nodes. These nodes

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13 Newman, M. (2010). *Networks: an introduction*. Oxford University Press.

14 Brandes, U. (2001). A faster algorithm for betweenness centrality. *Journal of Mathematical Sociology*, *25*(2), 163–177.

15 Freeman LC (1977) A set of measures of centrality based on betweenness. *Sociometry*: 35-41

16 Freeman LC (1979) Centrality in Social Networks Conceptual Clarification. *Social Networks* 1: 215-239

represent tools with high information "bridge" character that, if defunded or removed from operational use, could lead to a breakdown in the flow of information between tools.

Additionally, the betweenness centrality of each node may be represented either as its absolute betweenness centrality score, or as its score normalized relative to the score of the most central node. The latter option was chosen so that the most and least central tools in each network map would be apparent from node coloring regardless of absolute betweenness centrality.

Bulk Flow Networks

Bulk flow networks were created to visualize the flow of information between the seven resource types. A bulk flow network consists of seven nodes arranged in a horizontal line with equal spacing. Each node represents a single resource type, with nodes representing resource types upstream in the flow colored lighter (relatively unprocessed information), and downstream colored darker (relatively processed information). Edges connecting nodes in the bulk flow network represent the flow of information from tools tagged as one resource type into tools tagged as another resource type. As with tool networks, information flows in a clockwise direction. The width of each edge is proportional to the number of tools tagged with one resource type that act as inputs for tools tagged with another resource type. Self-edges, or circular edges from a node into itself, are not shown.

If a tool was tagged with multiple resource types, edges were added between resource types based on how the information was processed in the specific tool's case.

Agency Networks

In addition to tool network maps, agency network maps were created to analyze the flow of information between tools owned by different agencies. A simple example of an agency network map is shown in Figure B3. In agency network maps, each node represents a single federal agency-level owner in the inventory. The size of an agency's node and its label is proportional to the number of tools owned by the agency. Edges connecting nodes in the agency network represent the flow of information from a tool owned by one agency into a tool owned by a different agency. As with tool networks, information flows in a clockwise direction. The width of each edge is proportional to the number of tools owned by the source agency that feed information into a tool owned by the target agency. Self-edges, or circular edges from a node into itself, are not shown.

As described previously for tool networks, nodes were arranged by a force direction algorithm that groups closely linked nodes. Each node in the agency network map was colored based on the average betweenness centrality score of the tools it owned in the corresponding tool network map.

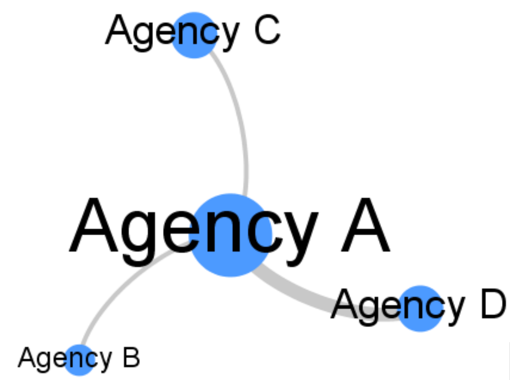

Figure B3. Example of a simple agency network map. Individual agencies are represented by blue discs (nodes). Gray curved lines (edges) represent connections between tools owned by different agencies. The flow of information travels clockwise. Edge thickness is proportional to the number of tools owned by the source agency that feed a tool owned by the target agency. In this example, Agency B and Agency C each own one tool that feeds a tool owned by Agency A. Agency D owns three tools that feed a tool owned by Agency A, so the edge connecting these two agency nodes is thicker. The size of each node can convey additional information. For the agency network maps presented in this report, node sizes are proportional to the number of tools owned by that agency.

Metadata Analysis

In addition to network analysis of the tools' linkages, quantitative analyses of inventory metadata were performed to characterize the tools available to support emergency management in terms of other attributes. These analyses included the number of tools owned by each agency, by resource type; the absolute number and percentage of orphan tools (tools with no connections to other tools), by hazard; the absolute number and percentage of tools available for each phase; and the most-used tools, by hazard. These analyses were presented in tabular form, or visualized in bar graphs prepared with the d3.js framework.[17]

Additional, more sophisticated visualizations were prepared for some metadata analyses, including owner dot-and-dot-and-whisker plots and Sankey diagrams, described in the next sections.

Owner Dot-and-whisker plots

Owner dot-and-whisker plots were created to visualize the number of tools owned by each agency, the average resource type of those tools, and the range of resource types spanned by those tools.

In the plots, each owner agency is represented by a dot. Each dot's vertical position is determined by the number of tools owned by the federal agency, with agencies owning more tools being positioned higher on the vertical axis. Each dot's horizontal position is determined by the average resource type of the tools owned by that agency, with agencies owning tools that are on average more upstream in the flow of information positioned toward the left, and downstream positioned toward the right. The color of each dot represents the average resource type of the tools owned by that agency, with lighter dots

[17] Bostock, M. (2012). Data-Driven Documents (d3.js), a visualization framework for internet browsers running JavaScript. Retrieved from http://d3js.org/

representing agencies owning tools that are on average more upstream in the flow of information, and darker dots more downstream. Finally, a black horizontal line transects each dot, with its left and right end points defined by the most upstream and most downstream resource type owned by that agency. Agencies owning only tools with only one resource type do not have horizontal lines.

Owner dot-and-whisker plots were created using custom JavaScript scripts based on the d3.js framework.[18]

Sankey Diagrams

Sankey diagrams were used to visualize the number of tools of each resource type owned by different federal agencies. Sankey diagrams are flow diagrams that show what components make up the whole of a particular element, and in what proportions.

Here, the Sankey diagram consists of two sets of rectangles. The left set of rectangles each represent one of the seven resource types, with the height of each rectangle proportional to the number of tools tagged with the resource type. Each resource type rectangle is colored based on its position in the flow of information: resource types upstream in the flow are lighter, and types downstream in the flow darker.

The right set of rectangles represent the federal agencies that own tools, with the height of each rectangle proportional to the number of tools owned by the agency. Each agency owner rectangle is colored based on the number of tools it owns: agencies owning fewer tools are lighter, and agencies owning more tools are darker.

The bands signify what proportion of the tools owned by each agency are tagged with each resource type. The thickness of the band between an agency rectangle and a resource type rectangle is proportional to the number of tools that agency owns that are tagged with that resource type.

The library used to create Sankey diagrams is a plug-in for the d3.js framework called Sankey.js.[19]

18 Bostock, M. (2012). Data-Driven Documents (d3.js), a visualization framework for internet browsers running JavaScript. Retrieved from http://d3js.org/

19 Bostock, M. (2012). Sankey Diagrams. Retrieved from https://bost.ocks.org/mike/sankey/

Appendix C: Mission Models for Biological Events

Mission models support specific Emergency Support Functions during an event to provide estimates of material and personnel requirements. Key mission models specifically relevant to a natural biological event are outlined below where appropriate for response operations. The complete list of mission models identified that are available to support biological event response operations are presented in Table C1.

Table C1. Additional Mission Models by Emergency Support Function (ESF). “None” is written where no biological hazard scenario-applicable mission models are available for a given ESF.

ESFs	Models/Datasets	Owner	Description
#1 – Transportation	Homeport	USCG	US port status viewer (open/closed)
#2 – Communications	None	n/a	n/a
#3 – Public Works and Engineering	None	n/a	n/a
#4 – Firefighting	None	n/a	n/a
#5 – Information and Planning	None	n/a	n/a
#6 – Mass Care, Emergency Assistance, Housing and Human Services	Disaster Services Automated Reporting System (DSARS)	Red Cross	Tracks actual and needed Red Cross supplies and staff
#7 – Logistics Management and Resource Support	Office of the Assistant Secretary for Preparedness and Response Logistics Resource Management System (ALRMS)	HHS ASPR	Tracks HHS ASPR asset cache contents, locations, and status
	Deployment Tracking System (DTS)	FEMA	Tracks locations/availability of disaster assistance employees in near real-time
	Global Air Transportation Execution System (GATES)	DoD	Automated tracking and manifesting system for DoD transportation
#8 – Public Health and Medical Services	emPOWER Map	HHS ASPR	Map of total population in an area using electricity-dependent medical and assistive equipment
	Hospital Available Beds for Emergencies and Disasters (HAvBED)	HHS ASPR	Online database of hospital bed availability counts
	Joint Patient Assessment and Tracking System (JPATS)	HHS ASPR	Tracks patient movement data during an NDMS response event

	National Disaster Medical System Electronic Medical Records Data (NDMS EMR Data)	HHS ASPR	Tracks and stores patient electronic medical records during an NDMS response event
#9 – Search and Rescue	None	n/a	n/a
#10 – Oil and Hazardous Materials Response	Selected Analytical Methods for Remediation and Recovery (SAM)	EPA	Interactive database of sampling and analysis methods for CBRN materials
	Scribe	EPA	Database of environmental sampling results
#10 – Oil and Hazardous Materials Response (intentional biological release only)	Decontamination Strategy and Technology Selection Tool (DeconST)	EPA	Decontamination cost-benefit analyzer for anthrax releases
	Incident Waste Assessment and Tonnage Estimator (I-WASTE)	EPA	Guides decisions on how to decontaminate or safely transport contaminated waste
	Threat Ensemble Vulnerability Assessment Sensor Placement Optimization Tool (TEVA-SPOT)	EPA	Tool that optimizes contaminant sensor placement in water systems
	Visual Sample Plan (VSP)	Pacific Northwest National Laboratory	Visual sample planning software that determines optimal environmental sampling approach
#11 – Agriculture and Natural Resources	None	n/a	n/a
#12 – Energy	None	n/a	n/a
#13 – Public Safety and Security (natural biological outbreak only)	Do Not Board List	HHS CDC, DHS	List of individuals with illnesses that pose a public health threat of spreading during travel
#13 – Public Safety and Security (intentional biological release only)	Chemical Biological Response Aide (CoBRA)	Davis Defense Group Inc.	Reference database for CBRN render-safe methods and prevention and protection
#15 – External Affairs	None	n/a	n/a