FEMA

Modeling and Data Working Group

Systems Analysis of the Data and Models Used for Federal Emergency Management

Phase III: Inventory of Models and Initial Analysis for Hurricane and Earthquake Scenarios

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Executive Summary

The Modeling and Data Working Group (MDWG) was established in August of 2012 by the Emergency Support Function Leadership Group (ESFLG) to identify and assess the data and modeling resources that are used across the U.S. interagency during emergency management. The membership was chosen by the ESFLG, and includes subject matter experts, program managers, and program directors representing each of the federal Emergency Support Functions and is chaired by the Director of FEMA's Planning Division, Response Directorate. The working group is supported by Gryphon Scientific, whose role is to collect the information required to identify data and modeling resources available to federal emergency managers and to determine when and how those resources are used in the context of U.S. emergency management. This information has been, and will continue to be, gathered during extensive interviews with the MDWG members and the subject matter experts they recommend. The scenarios addressed by the MDWG during the first iteration of the project are limited to earthquakes and hurricanes. Additional natural and manmade disaster scenarios will be addressed during future iterations of the project.

This project is divided into four phases as follows:

- **Phase I:** determine how, when, and for what data and modeling resources are used during operational decision-making for all phases of emergency management;
- **Phase II:** determine how and which data and information sources inform those decisions;
- **Phase III:** identify and characterize the models and data analysis tools and the linkages between them that are required to support operational decision making;
- **Phase IV:** produce an interactive inventory of available data and modeling resources, accessed via a graphical user-interface, to facilitate the use of the available data and modeling resources. The inventory will include metadata describing each resource, and will provide information about the linkages between each resource and how the producers and consumers of the resources use the information to support their missions related to emergency management.

This report discusses the methods and findings from Phases I, II, and III of the project. Information on data and modeling resources used for federal emergency management was collected through a series of extensive and on-going interviews with emergency managers and resource-specific subject matter experts. Over the course of this project, 181 interviews have been conducted with 238 emergency managers and subject matter experts. Based on these interviews, over 450 resources were identified and vetted, 217 of which are included in the final inventory of hurricane and earthquake data and modeling resources used for federal emergency management. Each resource in the inventory is labeled with a series of metadata tags that describe the resource's function, use, and availability. This metadata includes the resource's owner, users, and any upstream and downstream resources that help define the flow of information between resources in the inventory. A list of the resources included in the inventory can be found in Appendix 10.

The types of resources available to address critical information requirements for hurricane and earthquake scenarios are organized into a framework that describes the flow of information through iterative steps of data collection and processing. Raw data are initially collected, describing the hazard and its environment, and undergo multiple transformations and analysis to produce mission specific information used by emergency managers to support operational decision making. To identify the time-dependent information requirements that can be supported by various resources, this flow of information framework can also be mapped to a general timeline of the phases of emergency management. This framework provides a powerful method to parse the roles that data and models play and to identify the linkages between them; all together, this network of resources produces information that supports a wide range of missions across all phases of emergency management.

The network of resources has been analyzed to reveal trends in how information is processed. A systems analysis was performed based on the upstream and downstream connections for the resources and was used to evaluate the interconnectedness and robustness of the hurricane and earthquake networks. Additional analysis of the resource metadata was performed to characterize the types of resources used, identify the users of data and models, and better understand the mission spaces that the available resources support. Each analysis was completed separately for both hurricane and earthquake resource networks to uncover results specific to the different scenarios. The primary results from these analyses include:

- Resources within the earthquake and hurricane inventories form highly connected networks that can be organized into resource communities that describe the function of the resources.
- Some resources are more highly linked to other resources in the network and are important information conduits within the network. These resources are integral to the flow of information and play a key role in providing hazard- and mission specific information to support operational decision making.
- In both hurricane and earthquake networks, there are a number “orphaned” resources that are completely unlinked to the network and neither share nor receive information from any other resources in the inventory.
- As data are processed through the flow of information, they become progressively less hazard-specific and tend to become more mission specific, and useful for multiple hazards.
- There are very few repositories of impact estimates; those that do exist are poorly linked to downstream resources.
- The available decision support tools and mission specific requirements do not cover all mission areas and are not as well-connected into the network.

Based on these results and specific information provided by interviewees, gaps in the availability and capabilities of currently used data and modeling resources were identified. Four major systems-level gaps were identified:

1. Resource integration within the network needs to be improved, specifically for the most widely-used resources and for “orphan resources” that are currently completely unlinked.

2. Both hurricane and earthquake networks rely on a handful of highly central resources; maintenance of these resources will require more robust interagency coordination and support to ensure longevity and network integrity.
3. The resources used more often to directly support operational decision making (impact estimates, decision support tools, and mission specific requirements), need to be expanded to support a wider range of missions and need to be better-integrated with the rest of the network.
4. The inventory of resources needs to be expanded to include other hazards, including nuclear detonation, biological, and cyber-security scenarios.

The final product of this project will be an interactive inventory of the data and modeling resources used by the interagency, accessible via a graphical user-interface. The web-based user interface will be built in phase IV of the project. Due to the ongoing nature of the research and analysis informing this report, this Phase III report will be updated and expanded during Phase IV to include an in-depth analysis of the network, identification of relevant gaps, and recommendations to close the gaps. In addition, the report will capture any additional feedback from MDWG members and will continue to incorporate resources, stakeholders, and capabilities across the interagency emergency management community. Ultimately, this effort will enable the entire emergency management community to identify and use the resources available to support operational decision making during all phases of hurricane and earthquake events.

Introduction

Introduction Overview

- Effective coordination and leveraging the information produced by data and models in support of federal interagency emergency management remains a challenge.
- The Modeling and Data Working Group (MDWG) was appointed by the Emergency Support Function Leadership Group (ESFLG) to identify and characterize the data and models used to support operational decision making during emergency management across the interagency.
- In this context, data are defined as repositories of information; models are defined as any program, algorithm, or computational tool that transforms or processes data to produce new information.
- The MDWG chose to focus initially on hurricane and earthquake disaster scenarios; the methods developed will be subsequently applied to additional scenarios.
- The final product will be a readily-accessible, web-based interactive inventory of the data resources, models, and analysis tools currently used by the interagency during all phases of emergency management.

Emergency management requires managing complex systems and multidisciplinary personnel to address all hazards through the phases of prevention, protection, mitigation, response and recovery. Critical decisions will have to be made quickly to save lives and minimize the impact of any incident through each of these phases. Informed decision making, therefore, is key to successful emergency management; however, appropriate decisions cannot be made without timely, accurate, and well-coordinated information. An effective response to any disaster will rely upon the accurate synthesis of, access to, and timely dissemination of information to facilitate decision making at all levels.

New data resources and modeling tools, as well as ready access to these resources, have led to a rapid expansion in the amount of information available to decision-makers across the interagency during emergency management. However, the information produced is not always available in a timely, readily-digestible format designed to facilitate operational decision making. In addition, insufficiently verified information or conflicting results have undermined the utility of the information for decision-makers. Furthermore, a lack of coordination of efforts has led to situations in which conflicting results undermined the ability to effectively leverage available data or information to support effective decision making.

In recognition that informed decision making is key to successful emergency management, the Emergency Support Function Leadership Group (ESFLG) established the Modeling and Data Working Group (MDWG) in August of 2012 to engage stakeholders from across the interagency to collaborate more effectively on issues related to the data and models used to support emergency management. The goal of the working group, as defined by the charter, is to establish an authoritative list of the most useful and effective resources available to support decision makers across the U.S. interagency during all phases of emergency management. The membership of the working group was chosen by the ESFLG and includes a wide range of emergency managers and subject matter experts from across the interagency, including members from each of the federal Emergency Support Functions as identified by PPD-8. Membership is continually expanded upon request by current ESFLG or MDWG members. The MDWG charter and membership can be found in Appendices 2 and 3.

The MDWG has been tasked with identifying and characterizing the authoritative data and models required to support high-level operational decision making during emergency management across the interagency. The working group is supported by Gryphon Scientific, whose role is to collect and analyze the information required to identify the data and modeling resources available and determine when and how those resources are used in the context of U.S. emergency management. The resulting information will be collated into an interactive inventory of available data sets, models, and analysis tools accessible via a web-based user-interface that will facilitate an understanding of the flow of information during emergency management and allow the rapid identification of the producers and consumers of those models and tools.

Role of Data and Models in Emergency Management

Models and data have been used to support operational decision making during emergency management for many years. However, with advances in computing power and mobile computing capacity over the last decade, data and models have become increasingly available to support decision making in real-time and in the field. Though the number of such resources has expanded, effectively coordinating them and harnessing the information they produce remains a challenge. This challenge is evidenced by widespread interest in Big Data and has been addressed by a wide variety of efforts across the interagency, including the GeoCONOPS effort and other work specifically focused on improving access to operationally relevant information during emergency management.

The MDWG was initiated not to supplant ongoing efforts, but to incorporate and expand upon them. The strength of this effort lies in the breadth of the membership and the inclusion of all phases of emergency management. In addition, while there are many efforts that have compiled lists of all available resources, the goal of this effort is to identify those resources used by the interagency, and to build an interactive inventory of these tools that can be used as a resource during all phases of emergency management across all missions.

Defining Data and Models

Models and data are extensively employed across the interagency throughout all phases of emergency management. Given the breadth of information resources used, definitions for the terms 'model' and 'data' are described below.

Data are defined as repositories of information which may be used for emergency management. This definition of data encompasses tools which assist in the presentation or visualization of data without transforming the data itself (e.g., FEMA GeoPlatform, see Appendix 10). Data are classified as raw data, situational awareness data, impact estimates, or mission specific requirements. The data within these categories may be steady-state data describing features of the environment during normal operations. Alternatively, they may be event-specific assessment data collected as an event unfolds.

Models are defined as any program, algorithm, or computational tool that transforms or processes data to produce new information. Models are classified as event characterization models and analysis tools, consequence models, and decision support tools. Models accept, as inputs, data that are transformed to provide a new type of information (e.g., SLOSH, ShakeMap, and HAZUS, see Appendix 10).

Use Cases: Hurricanes and Earthquakes

All emergency scenarios require a comprehensive understanding of the data and modeling requirements for planning and operational decision making. In order to ensure this effort produces a useful and effective framework, it will initially focus on two use cases. The resulting framework will be tested in the future as the effort is expanded to less frequent types of events, and can be used to identify and characterize gaps in the data and modeling resources available for management of those scenarios. Using a pre-defined framework will also increase the efficiency with which the necessary information is collected and analyzed for the new scenarios.

The MDWG chose to focus on large-scale hurricane and earthquake natural disaster scenarios typified by Hurricane Ono and the New Madrid Earthquake scenarios, which were used as the basis for recent national level exercises. While many planning efforts have previously focused on these types of scenarios, they provide a useful starting point to assess the data and modeling requirements, develop a methodology, build a framework, and define authoritative resources for decision making based on the utility of the resources identified. Because these scenarios are well-understood and frequently practiced, decision-makers are better able to articulate their information requirements and clearly define their needs; therefore this initial effort can be focused on organizing the available resources so they can be more efficiently and effectively shared, enhancing collaboration and resource-sharing across the interagency. As we build a framework that describes the flow of information and the time-dependent aspects that define the utility of this information, the analysis can be verified because the users of the tools can ensure that all the resources available can be captured within the framework. This understanding will allow us to build a comprehensive inventory that captures all requirements and their corresponding resources. Furthermore, because the gaps are likely to be limited, they can be clearly defined, and the Courses of Action developed to fill those gaps are more likely to be of a scope that can be readily addressed.

Project Outline

The project has been divided into four phases (see Figure 1). This report summarizes the results of phases I, II and III. The goal of phase I was to identify how, when, and for what data and modeling resources are used during planning and operational decision making during emergency management, with a focus on the questions those resources are used to address. Phase II identified the information required to support operational decision making and to catalog the data resources that provide relevant information. Phase III focused on identifying, characterizing, and evaluating the existing data processing tools, including predictive models and assessment tools, that are used to process data collected prior to, during, and after an event to produce operationally-relevant information. During phase IV, the analytical framework will be completed and an interactive catalog of the data and modeling resources identified and characterized during earlier phases of the project will be built. This inventory will provide information about the identified resources. A gap analysis will inform a series of recommended Courses of Action to address the gaps identified, and outline paths forward to best leverage the strengths, collaborations, and resources already in place across the interagency.

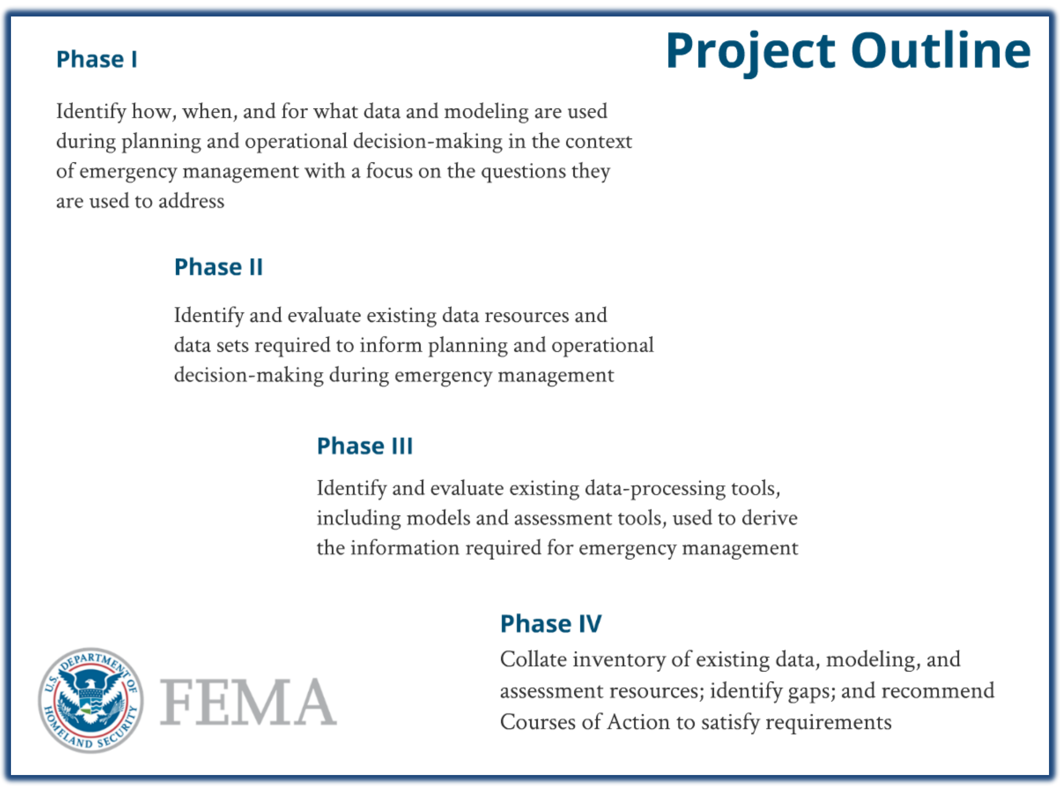

Figure 1. Project overview with a brief description of each phase.

Final Product

The information collected through this project will be collated into an interactive inventory of the available data sets, models, and analysis tools, accessible via a user-interface that will facilitate an understanding of the flow of information during emergency management and allow for the rapid identification of the producers and consumers of those models/tools. The product will provide a description of each resource and its operationally-relevant characteristics. The database version of the inventory backbone will be exportable for use during planning activities and will provide a comprehensive list of available resources. In order to make this database accessible and useful during emergency management, a user-interface will be designed that will facilitate queries of the inventory to identify the available resources relevant to the question, mission, or organization. The details of this product will be defined and refined to ensure that the information collected will be available in a useable format, specifically designed to support operational decision making. Importantly, the final product of this effort is intended to be used and maintained by the end-user community, which will be defined over the course of this project.

Methods

Methods Overview

- The information required to analyze the available data and modeling resources has been collected through a series of in-person and phone interviews with high-level decision makers, program managers, and users of data and modeling outputs, including select state and local emergency managers.
- Based on the interviews conducted, a comprehensive inventory of resources used across the federal interagency and those resources that connect them was created, along with metadata describing essential characteristics, such as how these resources are accessed, used, and updated.
- The metadata in the inventory was processed by quantifying characteristics of the resources and the relationships among them to aid visualization of the network. A series of analyses on the resulting network, as well as the metadata characteristics were performed.

The workflow of analysis performed for this project is divided into three parts: data collection, data processing, and analysis. The workflow is depicted in Figure 2. Data collection was performed through interviews of the members of the MDWG, other emergency managers, and subject matter experts to compile an inventory describing data and models that are used. Processing of these data included running algorithms to measure the interdependency of all the resources to aid in further analysis. Two types of analysis were completed: a network analysis based on the upstream and downstream connections of each resource, and a statistical analysis of the resource metadata. The network analysis makes use of network maps, which are visualizations of the resources and the data flow between them that enable trends and relationships to become apparent at a glance. The statistical analysis provides descriptive measures of the types and number of resources in the inventory and their characteristics. Each of the components of this workflow is described in more detail in the subsequent sections.

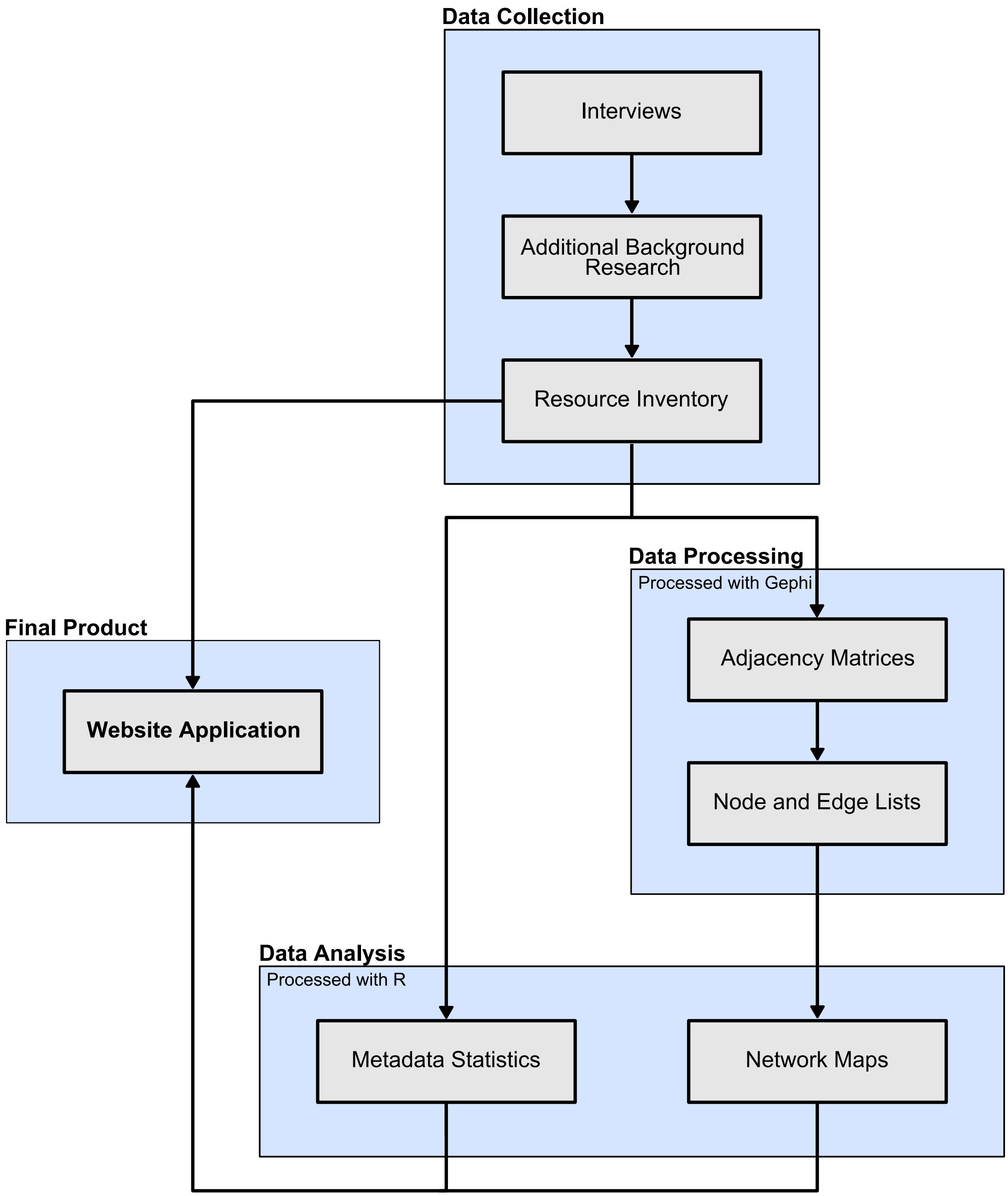

Figure 2. Analysis Workflow. A depiction of the sequence of work involved in producing quantitative analysis of the resource inventory, based off of the metadata tags and network maps of the flow of information.

Data Collection

Interviews

The information required to analyze the available data and modeling resources was collected through a series of in-person and phone interviews with the members of the MDWG and the subject matter experts they recommended. During these interviews, the users and producers of each resource identified and characterized the ways in which each resource 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. In addition to federal officials, a number of state and local emergency managers were interviewed to assess their use of data and models in their respective agencies. Directors of state emergency management departments and other key personnel in their departments were interviewed based on the recommendations of MDWG members. The presidents of major associations of emergency managers (IAEM and NEMA) were also interviewed. Interview questions for state and local entities were similar to those for federal officials, with added emphasis on interaction with federal agencies.

During phase I, there was an emphasis on interviews with high-level decision-makers, program managers, and users of the data and modeling outputs, with a focus on how data and models are used to support operational decision making. The conversations focused on the role of each agency, division, or group during each phase of emergency management and the questions they use data and modeling to address during that work. During phase II, interviews were more targeted and were used to capture and categorize the technical details about an agency, division, or group's information requirements. During phases II and III, emphasis was placed on targeted interviews with subject matter experts who use, develop, or maintain data resources, analysis tools, and quantitative models. Informed by the results of phase I, phases II and III were more targeted efforts during which the technical characteristics of each resource were captured, characterized, and collated into an interactive library. By the end of phase III, 181 interviews were conducted with 238 people representing 54 federal agencies, divisions, or groups. In addition, 10 interviews were completed with 15 individuals representing six states. During phase IV, interviews will focus again on the users of the resources in the interactive library, with follow-up interviews with subject matter experts to ensure accuracy.

Interviews were opened with an introduction to the project. A questionnaire (see Appendices 4, 5 and 6) was developed for each phase to outline the topics to be addressed during the interviews. These questionnaires were used as a general guide for the discussions. 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 data and modeling resources; and those who have roles that include a combination of tool-development, analysis, and decision making. Interviews are 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, support 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 interviews completed can be found in Appendix 7.

Resource Inventory

A comprehensive inventory of resources used across the federal interagency and the linkages between them was generated on the basis of the resources discussed during interviews, followed by background research to identify inputs and outputs of each resource.

Only those resources meeting one or more of the following conditions were kept in the network:

1. The resource has direct federal users;
2. The resource feeds more than one other resource; or
3. The resource is fed by at least one resource and feeds another resource.

Those resources identified through interviews and research that were inputs for only one other resource and had no federal users of their own were excluded from the inventory and were “wrapped” into their downstream resources. For example, the Second-order Closure Integrated Puff (SCIPUFF) model is an input for the Hazard Prediction and Assessment Capability (HPAC), but it is only used for emergency management through HPAC. In this case, SCIPUFF was not included in the inventory, and a description of its role was included in the summary of HPAC.

The first condition ensures that all resources known to be used by the interagency for emergency management are shown in the inventory. The second two conditions ensure that all those resources that directly contribute to the flow of information between resources are captured and can be analyzed as part of the resource networks. For instance, the Global Seismograph Network has no direct federal users, but it is an input for four earthquake models and datasets, so is included in the inventory. Likewise, the North American Mesoscale Model (NAM) has no direct federal users, but two upstream resources feed into NAM, which in turn feeds 11 downstream resources. These rules focus the analysis on resources directly used by the interagency for emergency management and the resources that connect those resources. In this way the inventory can both act as an accessible catalog of useful resources for emergency management as well as a means to analyze the flow of information between resources and how data is processed into information useful to support federal decision making.

Many resources under development or not currently used to support emergency management activities were identified, but not included in the inventory. Information about these resources has been retained and will be used in future iterations of the report to suggest mechanisms to fulfill any gaps identified in the network of resources.

Metadata

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

Metadata categories include: the resource's full name, abbreviation, model/data, owner, users, upstream resources, downstream resources, relevant hazards, core capabilities supported, emergency support functions (ESFs) supported, recovery support functions (RSFs) supported, key words, function tags, resource type, data collection method, phase specific utility, access information, access type, processing requirements, refresh rate, last known version, programming language, file type, contact information, contact during activation, website, and a brief summary of its function and use. Complete descriptions of each metadata tag are included in Appendix 9.

All metadata categories are tagged from a defined list of tags. For instance, for the model/data category each resource must be tagged as a model and/or a dataset. No other options are available. In every one of these metadata categories, unless otherwise noted, the resource can be tagged as one or more of the available tags. Some of the categories can also be left blank if none of the options are applicable. For instance, if the resource does not support any of the ESFs directly, that metadata entry would be left blank.

Data Processing

To build network maps describing the linkages between resources in the inventory, the metadata defining the upstream and downstream linkages between each resource was quantified in 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.[1] The adjacency matrix was then converted into separate node and edge lists. A node is a point on a network, and in this case, each node represents a single resource in the inventory. The nodes list contains the metadata of each node in the network, allowing that information to be visualized on the network map and analyzed in the context of the network. An edge is a line in the network that connects two nodes, and in this case, represents the transfer of information from one resource to another. The edge list contains a list of connections

[1] A short, rigorous definition of an adjacency matrix: For a network of n nodes, the adjacency matrix A is an n x 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.

between nodes in the network. These node and edge lists were imported into Gephi,[2] an open source network visualization and analysis software, to create the network maps used in the analysis.

All data processing was performed using R, an open source, statistics-based programming language.[3] R was chosen because of its ease and efficiency in calculating basic and network-based statistics. An open source language, this coding language facilitates transfer of the analysis scripts to another party.

Data Analysis

To visualize the data contained in the resource inventory, network maps were generated from the node and edge lists in Gephi. Separate networks were created for both hurricane and earthquake resources to analyze differences between hazards. In each network map, every node represents a single resource in the inventory and is sized proportionally to the number of users of the resource. Edges represent a flow of information from one resource to another and are graphically displayed as a clockwise arc, from the source node to the target. In this case, the source node is the upstream resource. A downstream resource is defined as the one that the target resource feeds. Figure 3 illustrates an example of a simple network map. Unless explicitly stated otherwise, the nodes in each network are arranged by a Force-Direction algorithm that groups closely linked nodes. This algorithm treats each node as a charged particle that repels all other nodes, and each edge as a spring, pulling the nodes back together. Three attributes of the network—community structure, betweenness centrality, and resource connectivity—were explored using network maps – each described below.

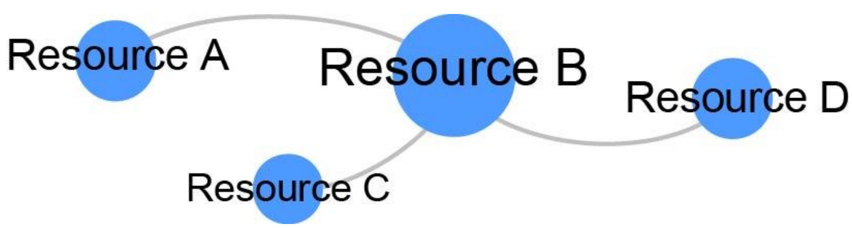

Figure 3. Example of a simple network map. Individual resources are represented by blue discs (nodes). Direct connections between resources are represented by gray curved lines (edges). The flow of information travels clockwise. In this example, information flows into Resource B from Resources A and D. Information from Resource B flows into Resource C. The size of each node can convey additional information; for the network maps presented in this report, nodes are sized relative to the number of users of that resource.

2 Bastian M., Heymann S., Jacomy M. (2009). ***Gephi: an open source software for exploring and manipulating networks.*** International AAAI Conference on Weblogs and Social Media.Bastian M *et al* (2009) Gephi: an open source software for exploring and manipulating networks. In *ICWSM*.

3 R Core Team (2013). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Community Structure

To study the natural groupings of the data and modeling resources, a community analysis was performed. A computer algorithm was used to divide resources into distinct groups of densely connected resources. The algorithm used was an implementation of the Louvain Method.[4] This algorithm iteratively places individual nodes into growing communities if doing so increases network modularity (a measure of community structure),[5] until no additional increase in modularity can be achieved. The communities were each assigned a different color to enable visualization.

Betweenness Centrality

The importance of specific nodes was also investigated using the betweenness centrality measure.[6] Betweenness centrality is a network measure of how often a node appears on shortest paths between any two other nodes. This measure provides insight into the importance of each resource as a bridge between other resources. Nodes were colored on a gradient such that more central nodes were darker and less central nodes were lighter.

Resource Connectivity

Other network measures used in the analysis include in-degree and out-degree. A node's in-degree is defined as the number of nodes feeding into it (in this case the number of upstream resources) and a node's out-degree is the number of nodes it feeds into (the number of downstream resources). A node's degree is the sum of its in-degree and out-degree, signifying the total number of connections that node makes to another node. These measures were used in an analysis of the flow of information to organize the nodes in space, comparing their relative in-degree and out-degree.

[4] Blondel, Vincent D. et. al. Fast unfolding of communities in large networks. Journal of Statistical Mechanics: Theory and Experiment. 2008. P10008.

[5] The modularity of a subset of a graph is a scalar (from -1 to 1) that measures the density of edges between nodes within that subset to the density of edges from nodes within the subset to nodes outside of the subset, compared to what would be expected at random. The modularity of a graph is the average modularity of every subset contained in the graph. Newman, M. E. J., *Modularity and community structure in networks.* 2006. PNAS. 103(23). 8577-8582Newman ME (2006) Modularity and community structure in networks. *Proceedings of the National Academy of Sciences* 103**:** 8577-8582

[6] Freeman, Linton C., *A Set of Measures of Centrality Based on Betweenness.* 1977. Sociometry. 40(1). 32-41.

Flow of Information

Flow of Information Summary

- The use of data and modeling in emergency management is an iterative process.
- Types of data include raw data, situational awareness data, impact estimates, and mission-specific requirements.
- Types of models and analysis tools include event characterization models/analysis, consequence models, and decision support tools.
- Although, the primary unidirectional flow of information is shown in Figure 4, there are many interconnections among the categories, which highlights the flexibility of the framework.

Data and models are used extensively in emergency management across the interagency and throughout each phase of an emergency. Notably, these data and models are not monolithic, and there is a cascade of information that flows through iterative steps of data collection and data processing. At each step, raw observational data and outputs from earlier iterations of modeling are aggregated. These data are then processed using analysis tools of varying sophistication, ranging from computationally intensive predictive weather forecast models, to simple, computationally-conservative tools that produce the information required to inform more narrowly-defined mission-specific decisions. Data generated as the outputs of models are not included as independent data sets, but are implicitly included with the models that produce them. A broad overview of the flow of information framework is shown in Figure 4.

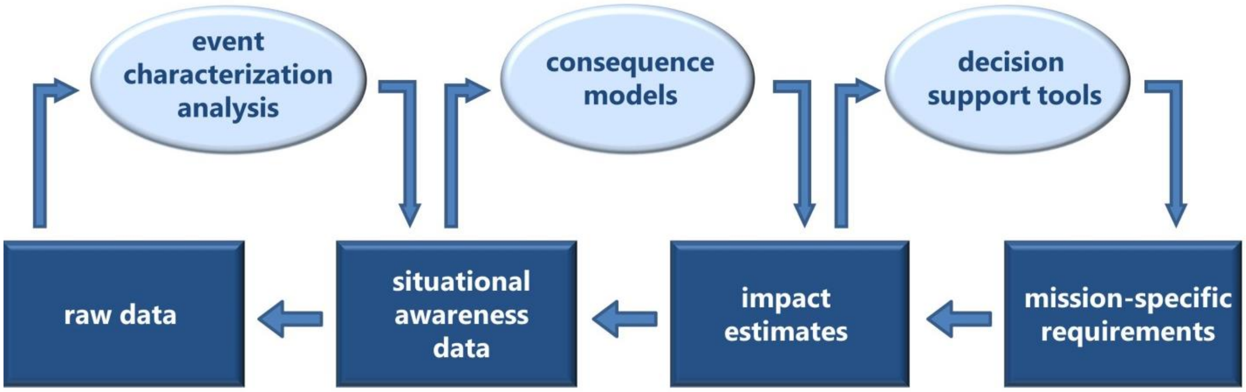

Figure 4. Framework describing the flow of information through iterative rounds of data and modeling. Data sources are shown in dark blue; models and data processing tools are in light blue. Arrows indicate the flow of information. Note: Additional resources provide data and are incorporated into each step but are not shown for simplicity. Examples are described in the text.

The categories of models and data provide an ontological framework through which the use of information resources across the interagency can be understood. Briefly, raw data describe the current state of the world, including real-time weather conditions, locations of fault lines, and absolute magnitude of seismic activity. These data serve as inputs to event characterization models and analysis tools that characterize or predict the location, timing, and severity of an event (e.g., weather forecasts, flood predictions, and when and where an earthquake has occurred). The information produced by these models or produced by the processing of raw data is termed situational awareness data. Situational awareness data are used by situational awareness viewers and can also serve as inputs to consequence models. Consequence models are used across the interagency to estimate impacts to human health, the economy, and infrastructure. The outputs of these models, called impact estimates, can be used directly to support decision making or can serve as inputs for decision support tools that guide specific response activities (e.g., determining evacuation timing, purchasing and allocating disaster relief supplies, and deploying search and rescue teams). The information produced by decision support tools is called mission-specific requirements. This information quantifies the personnel and resources needed to support narrowly defined emergency response missions.

The flow of information described in Figure 4 is designed to create a framework by which to understand the ways in which different types of resources produce useful information. Though the flow of information culminates in the generation of mission-specific requirements, emergency managers often refer to situational awareness data and impact estimates when making decisions. For example, FEMA establishes initial evacuation zones and timelines with situational awareness data derived from the SLOSH inundation model at NOAA. Similarly, FEMA Individual Assistance consults Preliminary Damage Assessment data (an impact estimate) collected during an event to predict the size of its recovery programs. In this way, all categories of data with the exception of raw data can be used as the basis for decision making.

Importantly, this flow of information is not unidirectional. In some cases, and often optimally, as information about the event is collected in real time, these data can be fed back into the predictive models to improve their fidelity. This verification and validation process can be particularly important for those models whose outputs continually feed mission-specific tools that define response requirements. For example, as high water marks or surge data are collected during and after a hurricane, inundation models can be re-run with these updated inputs instead of the model-predicted levels used during the event. The resulting outputs can then be used to guide evacuation decisions further up the coast. Incorporation of assessment data into the flow of information ensures that decision making and quality control benefit from awareness of conditions on the ground.

Notably, a model may be fed by data types other than the one immediately upstream of it in the flow. For example, HAZUS is a consequence model that accepts US Census Data (raw data) and situational awareness data as inputs. In addition, steady-state raw data describing infrastructure or road maintenance do not inform most event characterization models, but are important data feeds underlying many of the consequence and decision support tools. These data, though not shown in the overview image in Figure 4, are incorporated from additional sources at each iterative step of modeling. For instance, the National Shelter System provides the locations and capabilities of open shelters in the United States. These situational awareness data come directly from the American Red Cross rather than from a model.

Each category in the flow of information is described in more detail below, including examples specific to hurricanes and earthquakes. These examples are not intended to be all inclusive and are used here for the purpose of illustration. A comprehensive inventory of the modeling and data resources is included in the Data and Models Resource Catalog (Appendix 10). This inventory will continue to be updated during Phase IV of the project.

Raw Data

Raw data are defined here as unprocessed data that define the physical characteristics of a specific hazard or steady-state data that characterize the environment prior to and during an event. These data can take the form of static look-up tables, on-the-ground assessment data, steady-state data (bridge location databases), or real-time data (observational weather data). Notably, in order to be used in support of decision-making, raw data must first be processed by models or data analysis tools. The majority of the modeling performed for the purposes of emergency management relies heavily on raw data produced by a small number of specialized agencies.

Across the interagency, raw data are collected in a variety of ways, ranging from the use of pre-deployed instrumentation assets to phone calls over which proprietary and privileged information is exchanged. All social media or crowd-sourced data are collected as raw data. While most raw data is open access and available online, some raw data is proprietary and only selectively shared, if shared at all. While many types of event-specific raw data are collected before, during, or immediately after an event, steady-state raw data such as the Quaternary Fault and Fold Database produced by USGS are also used regularly in support of emergency management.

Although raw data, once processed, provide support for nearly all the decisions made by emergency managers across the interagency, they are rarely accessed directly. In the case of hurricane and earthquake scenarios, raw data are generally produced and accessed by similar communities, as the agencies and divisions which collect and provide raw data are also heavily involved in the development and dissemination of event characterization modeling resources.

Many raw data are useful beyond their most obvious applications. For example, precipitation data are important not only for predicting the path of a hurricane, but also for estimating the severity of an earthquake, as the degree of ground saturation changes ground shaking dynamics. Additionally, temperature is critical for informing the response to any emergency in which homes are lost or survivors require housing as housing requirements vary dramatically if temperatures are expected to be near freezing or to fluctuate significantly between daytime and nighttime.

Examples of raw data applicable to both hurricane and earthquake scenarios appear in Table 1. These examples are not intended to be all inclusive, and they are used here for the purpose of illustration. An inventory of the raw data sources identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 1. Examples of raw data.

Category	Owners	Resources
Topography; bathymetry	NOAA, USGS	National Elevation Dataset
Fault line mapping	USGS	Quaternary Fault and Fold Database
Seismic data	USGS	USGS Earthquake Feeds & Data
Precipitation	NOAA	Observational weather data
Wind speed	NOAA	
Temperature; pressure	NOAA	
Special populations	HHS	Internal HHS data shared through partnerships with states and locals
Demographics	Census	US Census
Population size	Census	
Power (electric and natural gas)	DHS IP; DOE	Proprietary petroleum and natural gas data; Proprietary data from private power companies
Hospitals	HHS, DHS IP	Internal HHS data shared through partnerships with states and locals
Roads	Regional DOT Offices, private digital map companies	Locally-maintained road network data through Regional DOT Offices, Navteq Road Network Data

Event Characterization Models and Analysis

Event characterization models and analysis tools characterize or predict the location, timing, or severity of an event. These models are used to consider specific characteristics of past, impending, or current hazards. They often compile raw data to identify patterns that define an event, or they characterize attributes of a developing event. Event characterization models include weather forecast models such as those produced by NOAA, but also include models such as SLOSH (Sea, Lake, and Overland Surges from Hurricanes), which incorporates observational weather data to estimate which areas are going to be inundated with flood waters when, and with how much water. These forecasts are required to guide the vast majority of downstream decisions, regardless of the specific mission.

The outputs of event characterization models provide an indication as to what will happen as a result of the event. These outputs can drive high-level decisions, including whether or not an event requires an emergency response. They also drive concrete decisions, such as the choice to evacuate patients from hospitals where generators will likely be flooded by a storm surge. SLOSH (described above), for example, is often suitable to inform early decisions like patient evacuation.

Examples of event characterization models and analysis tools applicable to both hurricane and earthquake scenarios appear in Table 2. These examples are not intended to be all inclusive, and they are used here for the purpose of illustration. A complete inventory of the event characterization models and analysis tools identified is included in the Data and Models Resource Catalog in Appendix 10.

Table 2. Event characterization models. Examples specific to hurricane and earthquake scenarios.

Category	Owners	Resources
Atmospheric forecast	NOAA	Global Forecast System; North American Mesoscale Forecast System
Inundation prediction	NOAA	Sea Land and Overland Surge from Hurricanes
Ground shaking	USGS	ShakeMap

Situational Awareness Data

Situational awareness data are used during or after an event to characterize the location, time, or severity of an event. They provide answers to who, what, when, and where for a specific event. While many types of situational awareness data are event specific, such as the National Hurricane Center's Hurricane Forecasts or the output of USGS' ShakeMap model, situational awareness data also include resources such as OnTheMap for Emergency Management and the Homeland Security Infrastructure Protection dataset, which are used to characterize the environment, population, or infrastructure impacted by a specific event.

Situational awareness data can be the outputs of event characterization models that process raw data or may be obtained through the extraction, transformation, or analysis of raw data such that they can be used to describe or characterize the event. For example, raw data inputs for weather forecast models can produce situational awareness data in the form of weather forecasts used to predict the location, time, and severity of a hurricane. Similarly, seismographic instrumentation networks can be processed to produce ground-shaking maps that illustrate the geographic extent and severity of ground shaking data.

While situational awareness data serve as inputs to consequence models, many enter a feedback loop in the flow of information described above and serve as inputs for event characterization models. This flow is commonly observed in hurricane forecast systems, where situational awareness data, in the form of weather forecasts (such as local NWS forecasts from NOAA), are fed into hurricane event characterization models (e.g., HURRTRAK) which produce refined situational awareness data that better predicts hurricane tracks and wind velocities.

In addition to being produced by event characterization models, these data can also be collected by instrumentation, reporting, social media, or crowd sourcing. For example, both the weather forecast and inundation maps that show predictions for the location and scope of flooding of a hurricane would be considered situational awareness data. For events without advance notice such as earthquakes, these data would include information about the size of an earthquake, as collected by seismometers, and by social media tools such as “Did You Feel It?”, a tool developed by USGS to provide additional data used to estimate the size and scope of an earthquake, particularly in regions where seismometers are far apart. Notably, in regions where no instruments are deployed, situational awareness data can be generated using predictive ground-shaking models that calculate the likely magnitude based on extrapolations from existing seismometer data.

Unlike raw data, situational awareness data can be used to support decision making, although it is often processed further through the use of consequence models. Examples of situational awareness data are included below as Table 3. These examples are not intended to be all inclusive, and are used here for the purpose of illustration. A complete inventory of the raw data sources is included as the Data and Models Resource Catalog in Appendix 10.

Table 3. Situational awareness data. Examples specific to hurricane and earthquake scenarios.

Category	**Owners**	**Resources**
Forecasts; affected regions	NOAA	NHC Forecasts; Local NWS Forecasts
Worker characteristics	Census	OnTheMap; OnTheMap for Emergency Management
Locations of affected critical infrastructure	FEMA	FEMA GeoPlatform

Consequence Models

Consequence models predict the impacts of a hypothetical or actual event. Impacts that can be modeled include, but are not limited to, economic loss, infrastructure damage, health effects, and supply chain disruptions. These models are typically event-specific, though some support consequence predictions for multiple hazard types. For example, HAZUS is a consequence model produced by FEMA Mitigation designed to predict the economic impacts of earthquakes, floods, and hurricanes. It is a flexible platform that accepts a wide variety of data feeds. By contrast, PAGER, a USGS product, models only the losses from structural damage caused by earthquakes.

In some cases, the applications of consequence models have been extended well beyond the uses for which they were originally intended. For instance, HAZUS was designed to provide economic loss estimates for FEMA Mitigation. However, this consequence model is being used throughout the interagency to estimate more general event impacts in support of a wide array of mission areas. Its outputs, either as-is or with further processing, are used to guide estimates of the volume of temporary housing resources that will be required, the populations affected, and even the number of loan officers required to field the applications that are expected to be filed with the Small Business Administration. This expansion in utility suggests that HAZUS serves as an important backbone for decision making in emergency management across the federal interagency.

Examples of consequence models applicable to both hurricane and earthquake scenarios appear in Table 4. These examples are not intended to be all inclusive, and they are used here for the purpose of illustration. An inventory of the consequence models identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 4. Consequence models. Examples specific to hurricane and earthquake scenarios.

Category	Owners	Resources
Economic	FEMA	HAZUS
Health effects	USGS	PAGER
Electrical infrastructure	Department of Energy	EAGLE-I

Impact Estimates

Impact estimates define the consequences of a specific event. This information can either be derived from post-event assessment data or as the outputs of consequence models that predict impacts, including economic loss, infrastructure damage, health effects, or supply chain disruptions. Impact estimate data resources include libraries of consequence model outputs (e.g., the Coastal Flood Loss Atlas) and archives of historical assessment data. These data directly inform the response and recovery phases of an emergency and are collected, processed, and used broadly across the interagency.

Impact estimates support nearly all mission areas. They can aid in identifying which states are most likely to request federal assistance, which regions are most likely to be without power given critical infrastructure impacts, which populations are specifically affected, or cascading hazards of greatest concern (such as nuclear power plants likely to have sustained damage from an earthquake). Each agency, and often each division, may collect, process, and use these data differently.

Assessment data collected post-event (a form of impact estimate) should be incorporated into iterative model runs update the inputs of characterization and consequence models as the event progresses. In the best case scenario, these data should be made available to those making response and recovery decisions, to facilitate the verification of the predictive modeling outputs and to continually re-assess response and recovery activities over the course of the event. For example, earthquake damage assessment data can be used to verify the outputs of consequence models like PAGER. Impact estimate assessment data also permit the continual reassessment of response and recovery activities over the course of an event.

Examples of impact estimates applicable to both hurricane and earthquake scenarios appear in Table 5. These examples are not intended to be all-inclusive, and they are used here for the purpose of illustration. An inventory of the impact estimate sources identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 5. Impact Estimates. These examples are specific to hurricane and earthquake scenarios.

Data	**Application**	**Resource Provider(s)**
PAGER output, ShakeCast, HAZUS output	event severity and scale	USGS, FEMA
HAZUS output (rerun every 6 hours based on NHC Forecast releases)	time-specific impacts	FEMA
PAGER output, HAZUS output, CIPDSS output	location-specific impacts	USGS, FEMA, DHS IP, EPA, Red Cross
HAZUS output, data from local medical services	population-specific impacts	FEMA, HHS, Red Cross

Decision Support Tools

Decision support tools are models or analysis tools that calculate the resources, including materials or personnel, necessary to support mission-specific activities. These models are often developed and employed by agencies or divisions with relatively narrow mission areas. For example, the Army Corps of

Engineers has developed a tool that predicts the amount of debris likely to be left in public roadways in regions impacted by flooding and calculates the number of dump trucks and other equipment required to remove that debris.

Decision support tools can use the data produced by event characterization or consequence models to determine the specific actions required to respond to an event. For instance, HURREVAC, a decision support tool developed through a partnership between FEMA, NOAA, and USACE, calculates when specific regions will need to be evacuated based on predictions of hurricane track, severity, and landfall time on the basis of the National Hurricane Center's forecasts and the outputs of the SLOSH inundation model. As another example, SAROPS, a decision support tool used by the US Coast Guard, leverages data to generate optimal locations for maritime search and rescue activities.

Examples of decision support tools applicable to both hurricane and earthquake scenarios appear in Table 6. These examples are not intended to be all inclusive, and they are used here for the purpose of illustration. An inventory of the decision support tools identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 6. Decision support Tools. These examples are specific to hurricane and earthquake scenarios.

Model	Application	Resource User
Debris Estimating Model	Debris	USACE
HURREVAC	Evacuation	FEMA
SAROPS	Search and Rescue	USCG
ODA Scalability Model	Surge Personnel	SBA

Mission-Specific Requirements

As indicated by the name, mission-specific requirements define the types of resources and the amounts of those resources necessary to support a given mission, including materials and personnel. Most often, mission-specific requirements consist of the outputs of decision support tools like the USACE debris estimating model. Others are standalone resources that track the availability of disaster relief supplies, like the LCMIS database maintained by FEMA. Still others, like the DSARS database used by the Red Cross, report staffing needs.

Mission-specific requirements help to inform what needs to be done, provide guidance on how it will be done, and can be determined on the basis of either predictive modeling or post-event assessment. During an event, most mission-specific requirements will be calculated on the basis of post-event assessment data. For example, USACE calculates the number of tarps required to provide temporary roofing on the basis of impact estimate data collected post-event. However, an analysis of historical data combined with predictive modeling can also be used to guide pre-event purchasing decisions and provided an evidence-basis for resource allocation during the planning and preparedness activities.

Examples of mission-specific requirements appear in Table 7. These examples are not intended to be all-inclusive, and they are used here for the purpose of illustration. An inventory of the data sources is included as the Data and Models Resource Catalog in Appendix 10.

Table 7. Mission-specific Requirements. These examples are specific to hurricane and earthquake scenarios.

Data	Application	Resource User(s)
Ice/Water Commodities Model output, Debris Estimating Model output, Temporary Housing Model output	equipment requirements	FEMA, USACE, HHS, Red Cross
Debris Estimating Model output, ODA Scalability Model output	personnel requirements	FEMA, USACE, SBA

Time-dependent Information Requirements

Summary of Time-dependent Information Requirements

- The information required to support the full range of emergency management missions is used differently and at different levels of resolution over the course of an event.
- However, the iterative steps of data collection and modeling described in the flow of information are independent of hazard type and can be mapped to the phases of emergency management.

The critical informational requirements filled by data and modeling during large-scale emergencies vary by mission and by the timeline of the event more than by the event type. During normal operations, data and modeling are used to help define the questions that will need to be addressed during future events, identify the specific information resources available to address those questions, and train the personnel who will need to use those resources. As an event occurs, whether advance-notice (e.g. hurricanes) or no-notice (e.g. earthquakes), the previously identified data and models are used to address questions about the specific, impending threat. Following the event, these questions address mission-specific, actionable requirements. As the response to the event progresses, accurate situational awareness data become increasingly important, preferably at the highest resolution available. After the acute emergency has passed, there is an opportunity to reflect on lessons-learned, as well as a chance to use assessment data to verify, validate, and evaluate the models, data assessment tools, and specific actions taken during the event to improve the efficiency and effectiveness of emergency management efforts for future events.

Questions Associated with Each Phase of Emergency Management

An overview of the time-specific questions that data and models are used to address across the interagency for emergency management are shown below. These questions are examples, and are not intended to provide a comprehensive outline of the questions asked at the federal level during emergency management. However, by considering specific questions and their relationship with the timeline of emergency response, it is possible to develop a more holistic understanding of the ways that information requirements change and develop over the course of an emergency.

Normal Operations

- How can resources be best allocated to prepare for future events?
- How can we most effectively develop systems, programs, and infrastructure to support all phases of emergency management?

Immediate Response

- What is the current hazard and how severe will the hazardous event be?
- When and where will the event occur?
- Who and what will be affected by the event and at what time?

Deployment

- What needs to be done?
- What and who were *actually* impacted, and how severely?
- What resources are available for response?
- How should we allocate existing resources and set priorities for response?

Sustained Response and Recovery

- What resources are still needed to allow those impacted to recover from the event?
- When is our mission complete and withdrawal appropriate?

Verification, Validation, and Evaluation

- What went well?
- What could have been improved?
- How can we improve our existing systems, programs, and infrastructure to address future emergencies?

Time-dependent Information Requirements

The flow of information during emergency management can be mapped onto an event timeline to highlight how information requirements change as the event unfolds (Figure 5). The timeline is a cycle and is usually depicted as a circle, which includes mitigation and preparedness phases as well; it has been linearized here to simplify the correlation of data and model use during each time period and only includes the pre-event preparedness, response and recovery phases. The timeline shown is for an advanced-notice event, such as a hurricane.

The raw data required to characterize an event, to inform pre-event planning, and to guide the early post-event response are similar across events of the same type. These data and the event characterization models used to process the data are typically collected, generated, and run by a small number of agencies who have the most event-specific expertise. For example, NOAA and the National Hurricane Center are the widely acknowledged experts who collect weather data and produce hurricane forecasts. The USGS plays a similar role in the characterization of earthquakes.

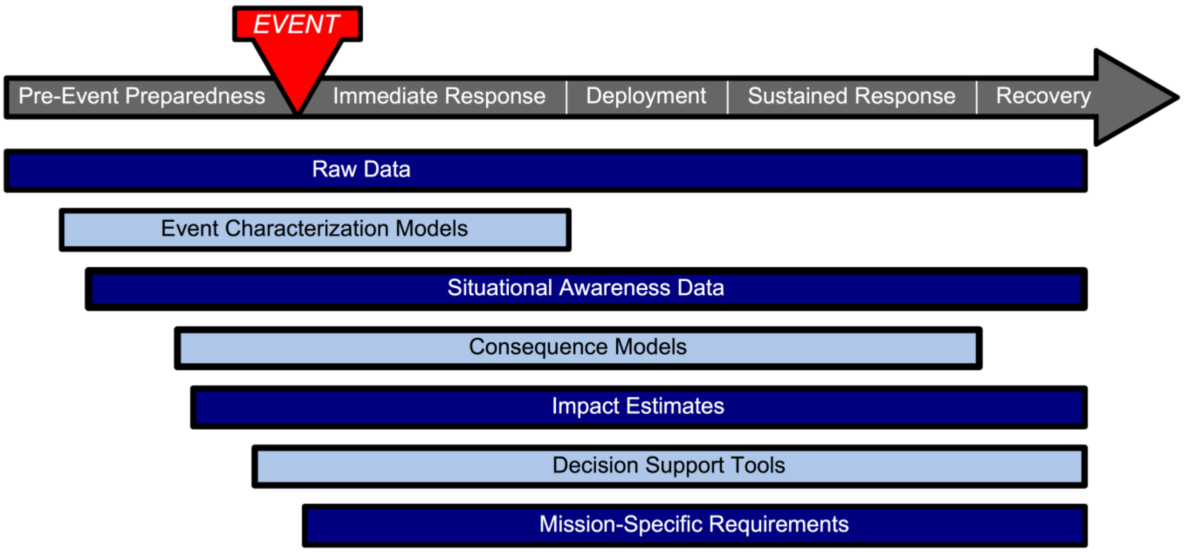

Figure 5. Flow of information required during emergency management organized along the timeline of an advanced-notice event, such as a hurricane. The timeline of the event is shown in black with the event indicated by the red arrow head. The organization of the timeline is based on that described in the Response Federal Interagency Operational Plan. Data sources and phases of the event are shown in dark blue; models and data processing tools are in light blue.

As the event occurs and the response progresses, the modeling and data resources used become less event-specific and increasingly mission-specific. For example, it is largely irrelevant why someone was displaced from their home: their needs for food and shelter are the same regardless of whether a hurricane, earthquake or other event was responsible. Thus, the information required to perform missions associated with filling these needs are generally independent of the type of event and are, instead, determined by the task.

Example Scenario: Hurricanes

With the approach of a hurricane, planning relies heavily on the raw weather data collected by NOAA. These data are processed by weather models to produce accurate forecasts of the storm track, size, forward speed, and intensity. The outputs from these models are used as inputs for inundation models, such as SLOSH, to predict the scope of the event. In turn, the predictions generated by SLOSH are used as inputs to the models required to inform specific decisions that have to be made before landfall. For example, pre-landfall evacuation is informed by decision support tools such as HURREVAC and the pre-deployment of resources can be informed by the outputs of consequence models such as HAZUS. During the event itself and during the early response to the event, raw data are rapidly gathered to provide real-time situational awareness. The consequence models are re-run based on this updated information. Incoming assessment data are used as inputs for decision support tools that define mission-specific requirements, such as the numbers of temporary housing shelters required each day or the number of dump trucks required to remove debris from specific areas. These efforts continue throughout the sustained response and recovery periods during which assessment data that provide information about the ongoing status of post-event activities, such as data about power outages and fuel availability, are continually collected and analyzed. Some of this analysis is performed with the aid of data analysis tools; much of it is performed on the ground by the emergency managers and disaster relief effort specialists who are leading the response and recovery efforts themselves.

The dissemination of information to decision makers at the senior level and those involved directly in operations occurs through a wide variety of avenues. In some cases, data are entered directly into fillable PDF documents or uploaded to websites that are hosted and curated by the agency (e.g. the Environmental Protection Agency.) In other cases, data are transmitted to the Emergency Operations Center, NRCC, JFO, or other coordinating facility by phone. Information sharing platforms such as WebEOC are used by many at the state and local level, though these systems tend not to be well-integrated with their counterparts in the federal government. There appear to be a number of these types of systems available, but only a few interviewees described using them during recent storms.

Example Scenario: Earthquakes

The data and modeling used to support operational decision making following a large-scale earthquake are incorporated in the same basic framework that describes the flow of information for hurricane scenarios. The greatest differences between the specific data and modeling resources used during earthquakes and hurricanes are the raw data and event characterization models. These data sets and models reside almost entirely with the USGS, which, like NOAA, makes all their data publicly accessible on the web. The raw data, much like those collected by NOAA in support of hurricane preparedness, are collected ahead of time: mapping of fault lines, analysis of historical earthquakes to anticipate scope and magnitude of future events, and mapping of building codes associated with infrastructure across the US and abroad to help model the potential impacts of events. Seismometers collect the real-time earth shaking data that determine when an earthquake has occurred. A series of models calculate the magnitude and scope of the event based on those real-time data. This information about magnitude and scope are incorporated as inputs for a number of earthquake-specific consequence models, including PAGER (USGS) and HAZUS (FEMA). Once the impact of the event has been estimated, the vast majority of decision support tools and mission-specific requirements used are the same as those used by decision makers regardless of the event type. The focus of post-event efforts are on ensuring that lifelines are secured for those affected, that critical infrastructure is secured to prevent or limit the scope of cascading effects (e.g. preventing chemical releases from industrial sites or securing nuclear reactors in the affected area), and that debris is cleared from the roadways, electricity restored, and transportation infrastructure repaired. The data and modeling required to support these missions are as varied as the missions themselves.

Coordination with State and Local Partners

Summary of Information Requirements for State and Local Governments

- The flow of information and phases of disaster management affecting state and local emergency managers correspond to those at the federal level.
- Efficient allocation of resources is the primary concern for state and local emergency management.
- State and local emergency managers often require a higher resolution of information than what is currently available for the federal level, specific to their region.

Emergency management is largely driven by those at the state and local level. To ensure that the results of this project incorporated their requirements and information resources, a number of stakeholders at the local, state, and regional levels have been interviewed. These interviews have focused on conversations with state emergency managers and a small number of additional contacts who have provided an overview of how data and modeling are used to support decision making during emergencies at the state and local level. Appendix 8 lists those interviewed thus far.

Because each state has its own emergency management structure, the findings may not capture the entirety of the methods used by each state and likely oversimplify the differences between states and localities. The adage that “every emergency is a local emergency” applies, and the ways in which emergencies are managed differ widely. For example, this analysis compiles information collected from states with either centralized or home-rule emergency management and with widely varied emergency management capabilities. Therefore, this discussion serves solely as an initial assessment and generalization of the ways in which data and modeling resources are used and how state and local governments fit into the larger framework of national-level emergency management.

Based on the phase I interviews, the mission of greatest concern to those at the state and local levels involved in emergency management is to efficiently and effectively allocate resources during response and recovery. These groups focus their efforts on collecting information regarding what assistance is needed and what resources are available. Some of this information may be collected in the planning phase, when outputs from federal models are used to predict the level and type of resources likely to be needed. Some states have developed their own tools to analyze the model outputs and provide these estimates. Once the event occurs, however, the majority of data-related efforts from the state and local agencies are in collecting assessment data to monitor and direct response activities.

The progression of emergency management activities for state and local emergency managers includes planning and preparedness, response, recovery, and mitigation, as it does at the federal level. Likewise, the flow of information, from raw data through mission-specific requirements, remains the same. The primary difference is in whether the state and local entities are using or producing that information. The upstream data, including outputs from event characterization models and consequence models, primarily come from the federal agencies that produce them. These data are provided by the lead federal agency for the information that produces and publishes official model outputs, from which the state and local consumers of the information either pull the data themselves or receive it, “pushed,” from the federal agency. In this way, states are operating on the basis of the same information that the federal government is. State emergency managers rely heavily on the data and model outputs produced by the federal government, and these data are generally shared effectively and in a timely fashion.

According to the interviewees, while the available data are at sufficient resolution for planning at the federal level, the requirements for accuracy and resolution are much higher for state and local planning and response departments, and those needs are not always met by the resources provided by the federal government. In many cases, these resources are still used, for lack of better alternatives, but others are not. For example, many states use the consequence outputs from HAZUS. Often, they use the runs performed and published by FEMA, but these are not well-suited for state and local use because of issues with resolution, accuracy, and timeliness of the data. Other states use HAZUS outputs generated through independent runs of the model using customized datasets. These datasets have been created to provide a more accurate representation of the local conditions (including soil type and facility locations) than what accompanies the standard HAZUS release. Of note, the forecasts generated by the National Hurricane Center were repeatedly described as being heavily used and useful. The predictions of location and severity of a hurricane at landfall are used invariably by state and county emergency response agencies, and the information provided is accurate and timely.

The critical infrastructure data made available through the Homeland Security Infrastructure Program (HSIP) also has several issues that prevent it from being used effectively by state and local emergency managers. Most of these problems arise due to inaccuracies in the geo-tagging of local resources in the federal-level maps. Also, because of the federal bias within the dataset, many of the facilities of importance to local officials are not included. In addition, once the emergency is over, states often lose access to HSIP Gold and cannot use it for planning or mitigation activities. Some states have begun addressing these gaps by compiling more detailed and locally-relevant critical infrastructure data sets of their own, but others are hopeful that this issue can be addressed at the federal level. Should designing a system intended for use by states and localities be undertaken, close collaboration between these entities and federal agencies would be necessary.

State and local entities contribute a larger percentage of the data for mission-specific activities than for event characterization. The primary responsibility of states and localities during response to an emergency is to efficiently and effectively allocate resources, including police, fire, and rescue crews. Tracking the availability of these resources is a major local issue. In order to support these missions, real-time assessment data regarding, for example, the status of critical infrastructure elements, power availability, and traffic flow, are critical. These data, when available, are usually collected by the service providers (e.g. DOT, power companies) and provided through collaboration with emergency management offices. However, access to these data is often lacking for states and localities; in some cases, this information is not available (not collected), and in others, it is collected by a number of entities and not shared effectively, if at all, with emergency officials. These data sets are critical to managing an effective response, but most states are not in a position to use them to their full potential. Structured management systems such as WebEOC generally have not been found useful to state emergency managers, partly because they are not used frequently enough. While efforts are beginning at the federal level to aggregate some of these data (e.g. the Department of Energy's EAGLE-I), it remains a gap, and one that will require cooperation with states, localities, and the private sector to be sufficiently addressed.

Results: Network Analysis

Over the course of this project 178 interviews were conducted with 238 emergency managers and subject matter experts. From these interviews, over 450 resources were identified and vetted, 167 of which are included in the final inventory of hurricane, earthquake, and all-hazards resources (see Appendix 10). Resources identified but not included in the final inventory were either not operational (in development or no longer supported) or "wrapped" together with other resources and treated as a single resource (described in detail in the Methods section under "Resource Inventory"). Results from a preliminary analysis of these resources follows here.

Resource Network

Summary of Resource Network Results

- Networks visually describe the flow of information between components of a network (nodes), and the connections between the nodes (edges).
- In the inventory, each resource is a node in the network, and each edge depicts the connections between nodes and the directionality of the flow of information.
- In both hurricane and earthquake networks information is broadly available and widely shared within the existing resources used by the emergency management community.
- Although both networks are highly connected, there are far more resources in the hurricane network than the earthquake.
- Of the many resources in the network, only a handful are heavily-used.

Network analysis is the study of complex systems based on the connections between individual network components. Each component of a network is called a node, representing the individuals (e.g. people or resources) within a network. The connections or links through which information flows between the nodes are called edges. Information can flow either unidirectionally or bidirectionally between any two linked nodes within the network. Networks have often been used to describe the flow of information between nodes and edges, where nodes describe people and the edges describe the sharing of economic or social information. In the context of the MDWG effort and the inventory of data and models described here, each dataset or model is a node in the network with each edge representing the flow of information and processing of data as it passes between those nodes. Both the inputs (upstream resources) and outputs (downstream resources) of each resource in the network were identified based on in-depth analysis of interview data and a review of the technical documentation of the resource, when available.

The networks created for this effort provide a visual representation of how information flows between resources used to support decision making in the context of emergency management at the federal level. Networks describing those information resources used in the context of hurricane and earthquake scenarios are shown in Figures 6 and 7, respectively. Each resource (node) in the network is sized proportionally to the number of federal agencies identified as a user, an indicator of the relative utility of each resource, which is defined by the number of federal agencies that directly use the resource in the context of their work.[7] Resources (nodes) are shaded by where they fall in the flow of information: resources early in the flow of information, tagged as raw data or event characterization models are the lightest in color; resources tagged as decision support tools or mission specific requirements are darkest in color.

Both hurricane and earthquake networks are highly connected with most resources integrated into the flow of information between all resources: weather, ground-shaking, infrastructure, population, logistics, management, and many other types of resources are all interconnected. A cursory overview of the network suggests that information is broadly available and widely shared within the existing resources used by the emergency management community.

Immediately obvious from a rapid qualitative analysis of the figures is that, while there are many resources in the network, only a relatively small subset dominate the user community: a few resources are heavily used by federal agencies in the context of emergency management. The most heavily-used resources ordered by the number of federal agencies tagged as users of the resource for the hurricane and earthquake networks are listed in Table 8.

Although both networks are highly connected, the hurricane network has far more resources and connections between resources than the earthquake network. This observation could be attributed to differences between the hazards and the absolute number of resources that are required for planning and response. A more likely explanation is that hurricanes are more frequent than earthquakes, which forces the emergency management community to continually develop and refine response and recovery strategies.

[7] Note that users could also be calculated by including not only the number of direct users, but also those users of all resources that provide inputs for a given resources. We refer to this latter method as calculating "cumulative users", a method that significantly increases the number of users for resources that fall in the Raw Data and Event Characterization categories, for example.

Flow of Information within the Network

Summary of Results from the Flow of Information Within the Network

- A qualitative analysis of the resource network highlights that many more resources are categorized as raw data, event characterization models, and situational awareness data.
- There is a bulk flow of information from raw data to event characterization models and situational awareness tools, which then feed consequence models toward the bottom of the network.
- There is no clear trend to show flow of information beyond consequence models.

In a robust system in which raw data are collected and processed through iterative steps of data procession, modeling, and analysis for use in providing mission-specific decision support, it could be reasonably anticipated that resources would be relatively evenly distributed across the flow of information categories; however, a qualitative analysis of both the hurricane and earthquake networks highlights a noticeable abundance of lightly colored nodes, indicating a concentration of resources categorized as raw data, event characterization models, and situational awareness data. While this result is analyzed quantitatively in Figure 14 and the accompanying section, it is portrayed visually in both Figures 6 and 7 in context of the network as a whole and the utility of the individual resources. Notably, there is no clear trend of information flow beyond the consequence models. While a few darkly-colored nodes indicate that there are decision support tools and mission specific requirements within both networks, these resources are not heavily used (small nodes) and are located randomly around the network. A large percentage of decision support and mission-specific resources are totally unattached to the rest of the network (see Table 9 and Figures 8 and 9 for a more in-depth discussion of “orphan resources”.) This lack of resource integration in the network suggests a breakdown in the sharing of information from consequence models to the more operationally-targeted resources that would are used by operations personnel prior to or during an event.

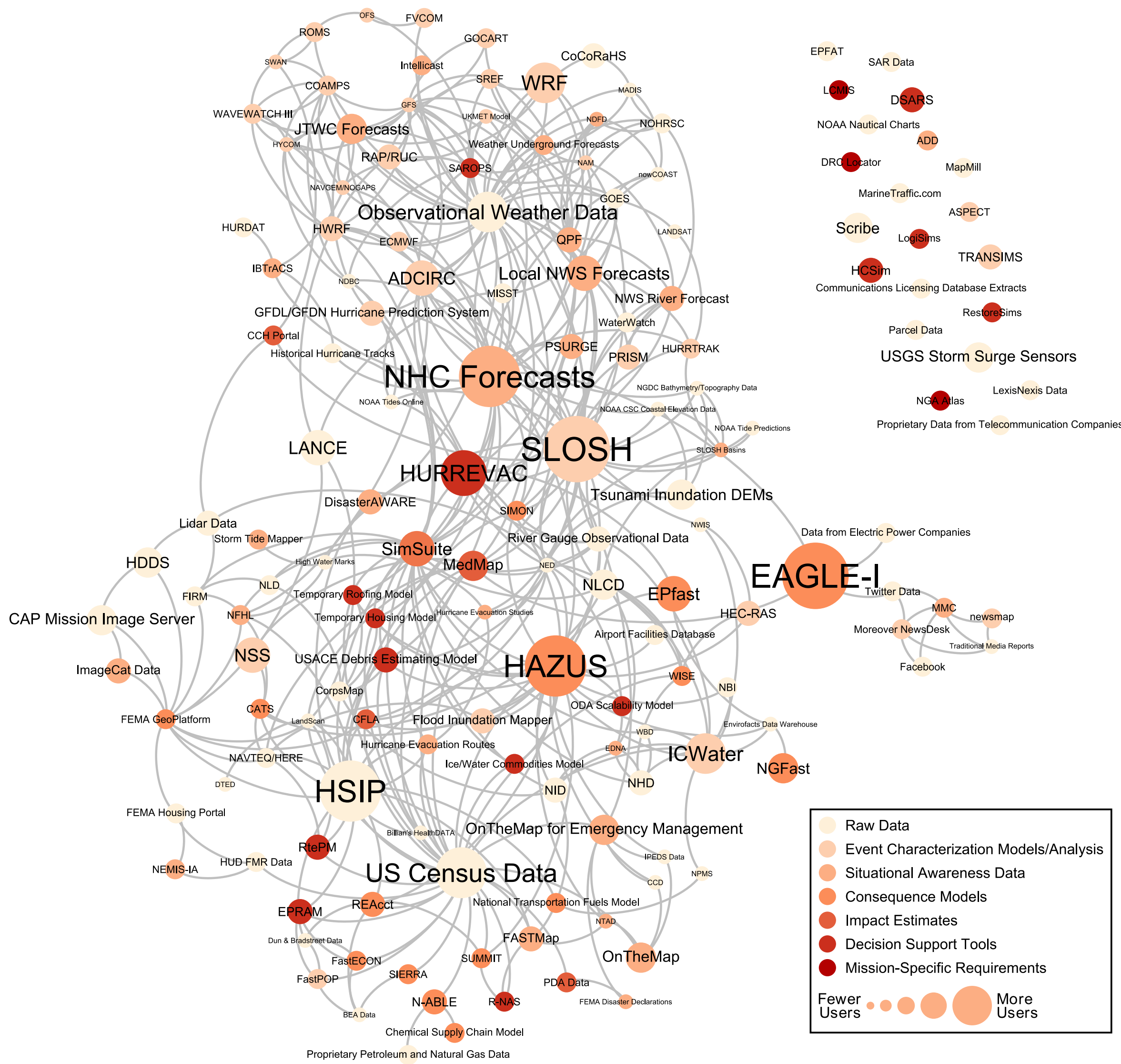

Figure 6. Hurricane Resource Network. In this network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only hurricane and all-hazards resources from the inventory appear in the networks.

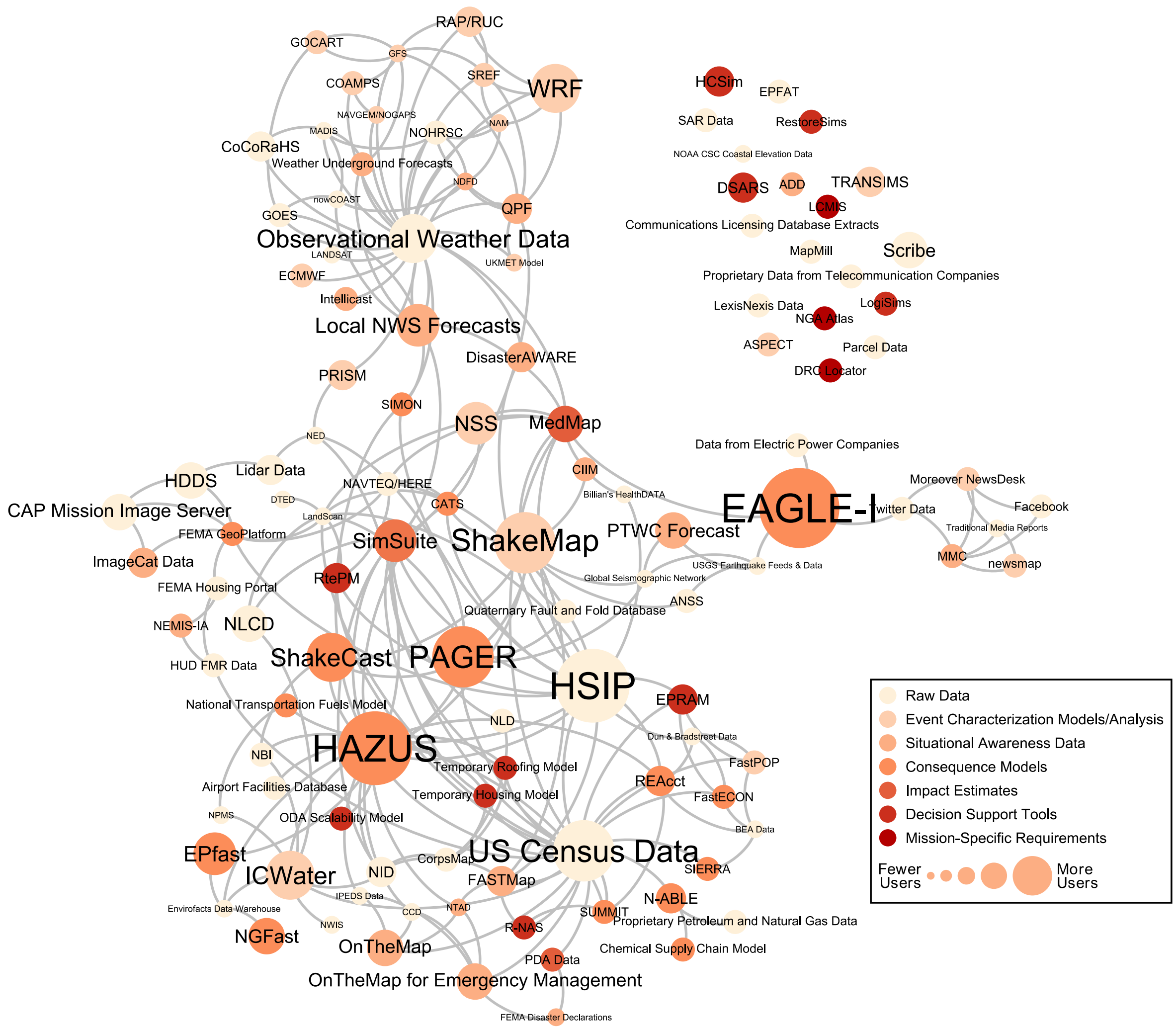

Figure 7. Earthquake Resource Network. In this network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only earthquake and all-hazards resources from the inventory appear in the networks.

Most Heavily Used Resources

In both networks, despite the large total number of available resources, a few are noticeably more heavily used than others. These resources are listed in the table below (Table 8) for both the hurricane and earthquake networks.

Of the most heavily used resources in both the hurricane and earthquake networks, the majority are multi-hazard tools. Most of these are used to predict or respond to cascading effects, demonstrating that the information used most widely in the context of emergency management is not about the event itself, but about the damage and additional hazards it produces. Notably, the most heavily used resource in both networks is EAGLE-I, the recently-developed consequence model from the Department of Energy that provides real time information about electricity outages. EAGLE-I is heavily used in part because it provides information that was not previously available about the stability of a sector with consequences that have a large impact on all other sectors. While the majority of other resources on these lists are also highly central (see Figures 10 and 11), EAGLE-I is not yet well integrated into the interagency information networks, perhaps because it is a relatively young resource for which technical solutions to link to other resources have not yet been developed. Weather also features prominently in the most-used resources not only for hurricane scenarios, as would be expected, but also for earthquake scenarios. This finding highlights the role and impact of weather across hazards and the importance of maintaining a robust weather forecasting infrastructure to support all-hazards emergency management, not just hazardous weather events.

Table 8. Earthquake and Hurricane Resources with the most federal users. Resources with at least 5 federal users are listed in decreasing order of number of users. Resources with the same number of users are listed alphabetically.

Resources	Users	Hazards	Resource Type	Descriptions
EAGLE-I	10	Multi-Hazards	Consequence Model	Models and monitors electric grid impacts
SLOSH	10	Hurricane	Event Characterization Model/Analysis	Models sea, lake, and overland hurricane surge
HAZUS	9	Multi-Hazards	Consequence Model	Models event impacts through economic loss
HSIP	9	Multi-Hazards	Raw Data	Critical infrastructure and key resource data
NHC Forecasts	9	Hurricane	Situational Awareness Data	National Hurricane Center storm forecast data
PAGER	7	Earthquake	Consequence Model	Models losses due to earthquakes
ShakeMap	7	Earthquake	Event Characterization Model/Analysis	Models the severity of earthquake shaking
US Census Data	7	Multi-Hazards	Raw Data	Regional populations, demographics, and survey items
HURREVAC	6	Hurricane	Decision Support Tool	Models hurricane evacuation timing recommendations
ICWater	5	Multi-Hazards	Event Characterization Model/Analysis	Models surface behavior of toxic spills
Observational Weather Data	5	Multi-Hazards	Raw Data	Current weather conditions which feed forecasts
ShakeCast	5	Earthquake	Situational Awareness Data; Impact Estimates	Automated, customized ShakeMap reports and notifications
WRF	5	Multi-Hazards	Event Characterization Model/Analysis	Numerical weather forecasting model

Community Structure

Summary of Community Structure Results

- Some areas of the network are more densely connected than others and form communities.
- In both hurricane and earthquake networks, there are a number "orphaned" resources that do not share information with the rest of the network.

While the hurricane and earthquake networks both largely form one interconnected web of resources, some areas of the networks are more highly connected than others. Communities, which can be loosely defined as groups of resources that share more connections amongst themselves than with resources outside the community, are often comprised of resources that fulfill a similar function in the flow of information. These tightly knit communities were identified using an automatic community detection algorithm[8] and displayed in color on the hurricane and earthquake networks (Figures 8 and 9, respectively).

In each network, the communities typically cluster around a single highly used and highly linked resource based on the information feeds for that resource. For example, in the hurricane resource network, one community is organized around observational weather data and the National Hurricane Center Forecasts; another community is organized around Eagle-I and the media datasets that serve as its inputs. In the earthquake resource network, a community is formed around HSIP (the Homeland Security Infrastructure Protection database) and a series of resources associated with identifying damage to infrastructure; likewise, another community is formed around HAZUS (a widely used multi-hazard consequence model) and US Census Data, both resources used to identify human and economic impacts of an event.

While these communities cannot be used to identify the role of specific resources, they are useful to analyze which types of resources are more interconnected than others. Much of the community structure discovered is generally the same for both the hurricane and earthquake networks, with a few differences. A community organized around atmospheric weather, the electric power resource EAGLE-I, and a very small community of housing resources exist in both networks. By contrast, but as expected, the inundation and oceanic resource communities only appear in the hurricane network while the ground-shaking community only appears in the earthquake network.

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8 The specific algorithm used was a modularity optimization algorithm based on the Louvain Method. Blondel, Vincent D, Jean-Loup Guillaume, Renaud Lambiotte, and Etienne Lefebvre. *Fast Unfolding of Communities in Large Networks.* Journal of Statistical Mechanics: Theory and Experiment, no. P10008 (2008).

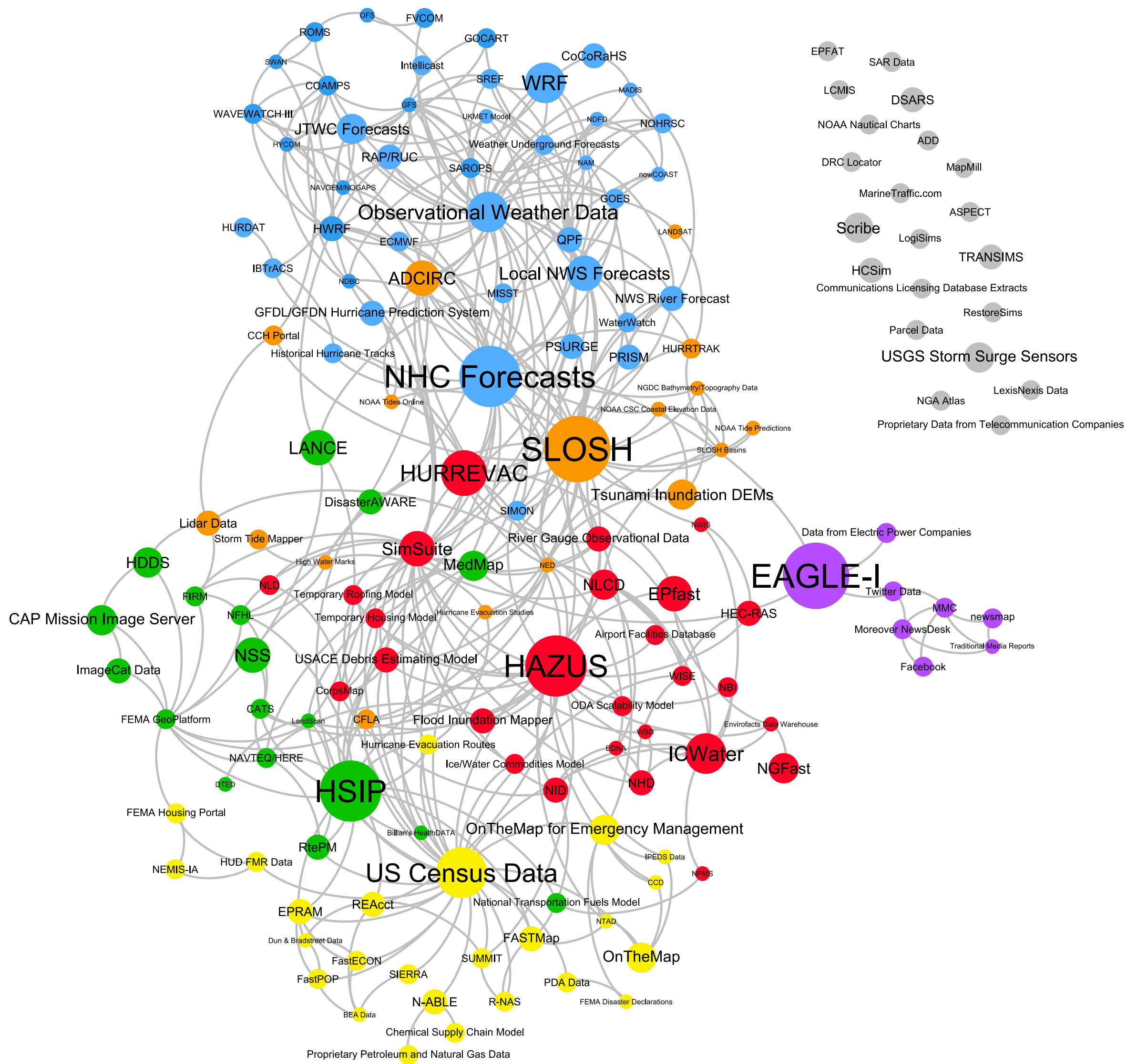


Figure 8. Hurricane Community Structure. In this network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Colors represent different communities. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only hurricane and all-hazards resources from the inventory appear in the networks.

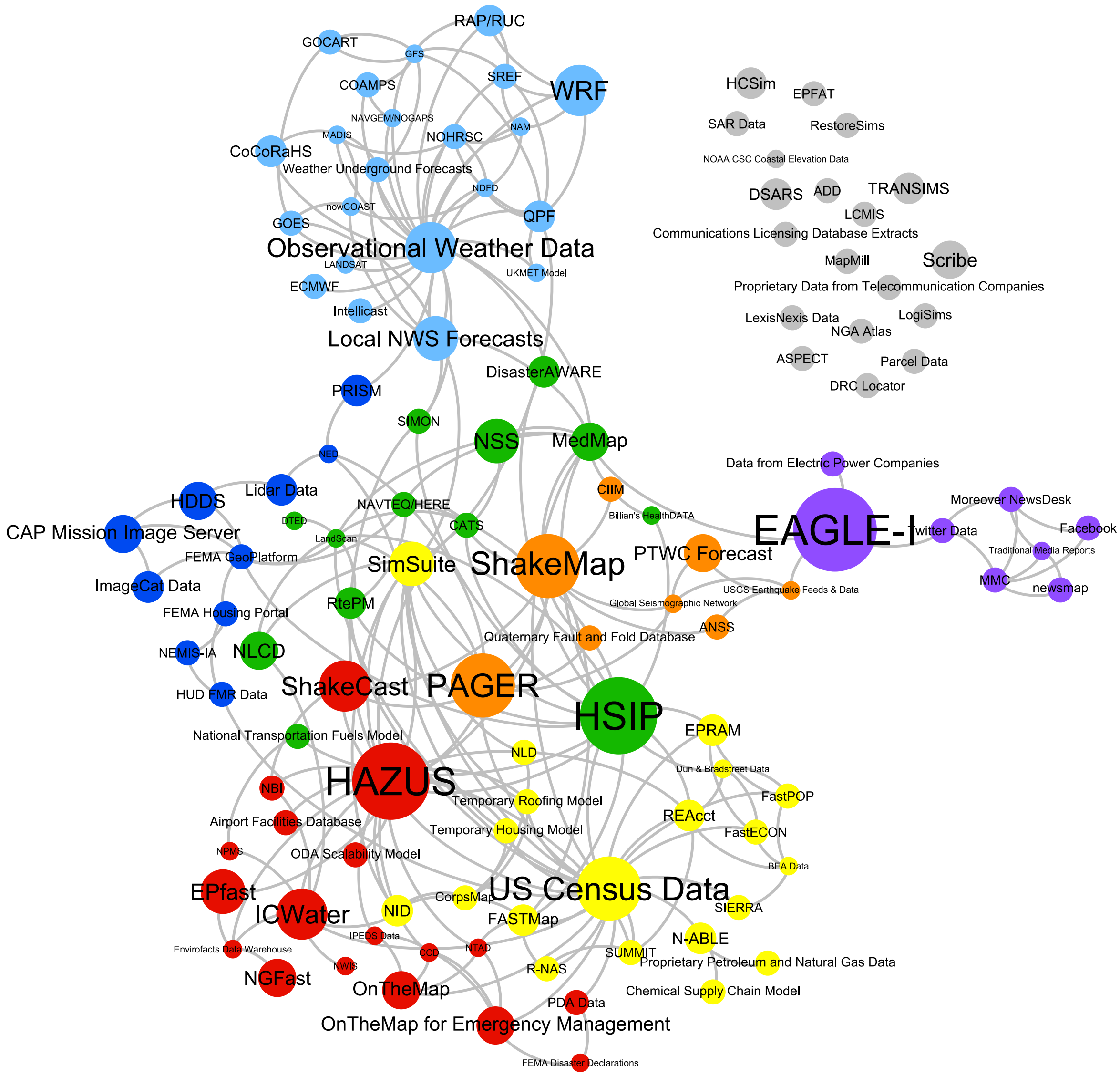


Figure 9. Earthquake Community Structure. In this network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Colors represent different communities. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only earthquake and all-hazards resources from the inventory appear in the networks.

"Orphan" Resources

In both of these networks, there are a number of resources not connected to the rest of the network (between 15 and 20 resources for both hurricanes and earthquakes, see Table 9). These "orphan" resources do not share information with or receive information from any other resources in the inventory. Therefore, while they are all identified as being used within the federal interagency, none of their results are linked electronically to other resources to be processed and analyzed, nor are their results derived from hazard-specific information. Interestingly, the majority of orphaned resources are either raw data or mission-specific requirements. The raw data resources are, most likely, data that, though available, have not yet been incorporated into event characterization or consequence models. These datasets may be useful to refine and improve the parameters of existing models. Effective mission-specific requirements should be linked to upstream datasets to ensure that the information provided is based on event-specific empirical evidence. This gap is described in more detail in the Gap Analysis.

In order for the emergency management community within the federal interagency to effectively utilize these orphaned resources, they must be joined with the rest of the networ. Linking to upstream hazard-specific data would make each resource more relevant for disaster planning and response and linking the outputs of each to downstream resources would ensure that the data generated by each resource would be further processed and refined for use by a broader community.

Table 9. Orphaned resources. These resources do have any upstream or downstream linkages within either hurricane or earthquake networks. Resources are ordered by where they fall in the flow of information.

Resources	Hazards	Resource Type	Descriptions
EPFAT	Multi-Hazards	Raw Data	Dataset of facility emergency power requirements
LexisNexis Data	Multi-Hazards	Raw Data	Census block-level insurance information from LexisNexis
MapMill	Multi-Hazards	Raw Data	Aerial imagery converted to maps by crowdsourcing
MarineTraffic.com	Hurricane	Raw Data	Data for vessels with on-board identification systems
NOAA Nautical Charts	Hurricane	Raw Data	National Oceanic and Atmospheric Administration charts for nautical navigation and data tracking
Parcel Data	Multi-Hazards	Raw Data	Commercially available data on real estate features

Proprietary Data from Telecommunication Companies	Multi-Hazards	Raw Data	Selectively shared, proprietary telecommunication data
SAR Data	Multi-Hazards	Raw Data	Synthetic Aperture Radar data describing the Earth's surface
Scribe	Multi-Hazards	Raw Data	Online field sampling database of the Environmental Protection Agency
USGS Storm Surge Sensors	Hurricane	Raw Data	Pre-deployed hurricane flooding monitors from the US Geological Survey
ASPECT	Multi-Hazards	Event Characterization Models/Analysis	Airborne, real-time environmental sampling and data collection
TRANSIMS	Multi-Hazards	Event Characterization Models/Analysis	Transportation Analysis and Simulation System for regional transportation modeling
ADD	Multi-Hazards	Situational Awareness Data	Federal Emergency Management Agency automated database for personnel tracking
DSARS	Multi-Hazards	Impact Estimates, Mission-Specific Requirements	Automated reporting system for Federal Emergency Management Agency disaster services
LogiSims	Multi-Hazards	Decision Support Tool	Resource allocation decision support software
DRC Locator	Multi-Hazards	Mission-Specific Requirements	Locations and statuses of Disaster Recovery Centers
LCMIS	Multi-Hazards	Mission-Specific Requirements	Federal Emergency Management Agency database for disaster relief supplies tracking
NGA Atlas	Multi-Hazards	Mission Specific Requirements	National Geospatial-intelligence Agency atlases for search and rescue

Resource Centrality

Betweenness Centrality

Summary of Betweenness Centrality Results

- Only a limited number of resources for each event type are highly used and a limited number are highly central, acting as information bridges between other resources.
- While centrality is a useful indicator of resources critical for the integrity of the network, it is not the only indicator of resource value within the network.
- While many of the most used resources have the most linkages with other resources in the network, this pattern does not always hold. Where heavily used resources are not well-linked, this indicates resources that could be targeted for efforts to better integrate them into the system.

Data in the hurricane and earthquake resource networks are processed in iterative steps of data collection, modeling, and analysis, as described by the flow of information (Figure 4). Each resource can be described by how central it is to the network, termed betweenness centrality.[9] This network measure defines how often a node acts as a bridge between other nodes; each connection is additionally weighted based on the centrality of the resources it links. In the resource networks shown below, resources with high betweenness centrality measures play an integral role in the processing of raw data to mission-specific requirements. Resources with low betweenness centrality scores may also be important resources, but instead lie earlier (raw data resources and event characterization models) or later (decision support tools and mission-specific requirements) in the flow of information.

The centrality measures for each resource are shown in Figure 10 and 11 for hurricanes and earthquakes, respectively (larger centrality = darker blue). In the hurricane network, the two most central resources are overwhelmingly HAZUS and the National Hurricane Center Forecasts. The next most central resources are, in order of centrality, SLOSH, HURREVAC, ADCIRC, HSIP, QPF (Quantitative Precipitation Forecast), and NFHL (the National Flood Hazard Layer).[10] For earthquakes, the overwhelmingly most central resource is HAZUS, followed by PAGER and ShakeMap. Despite their wide use, resources like EAGLE-I and Observational Weather Data have very low centrality values, highlighting the fact that, while centrality is a useful indicator of resources critical for the integrity of the network, it is not the only indicator of resource value within the network.

9 A node's betweenness centrality is more rigorously defined as the number of times that node appears on the shortest path between any other two nodes in the network.

10 Details about each resource mentioned here can be found in the complete inventory of resources in Appendix 9.

Based on the flow of information, consequence models would be expected to be the most central resources because they act as the essential link between event characterization and decision support tools. Indeed, HAZUS is the most heavily used consequence model for both hurricane and earthquake scenarios and has an exceedingly high centrality measure, which also helps illustrate its integral role in the flow of information. Conversely, raw data and mission-specific requirements have very low centrality values regardless of how heavily used they are, because they represent the sources (raw data) and sinks (mission-specific requirements) of information. For example, Observational Weather Data is a highly linked source of information for the network (39 direct downstream resources), but has a centrality of zero because it has no upstream resources. Surprisingly, even heavily used consequence models, like EAGLE-I, have a low average centrality value as well, even though it would be expected that consequence models would have both upstream links to event characterization models and situational awareness data and downstream links to decision support tools and mission specific requirements. This lack of centrality indicates that the some of the available heavily-used consequence models are not highly linked and are not highly integrated into how information is processed, analyzed, or used by the interagency.

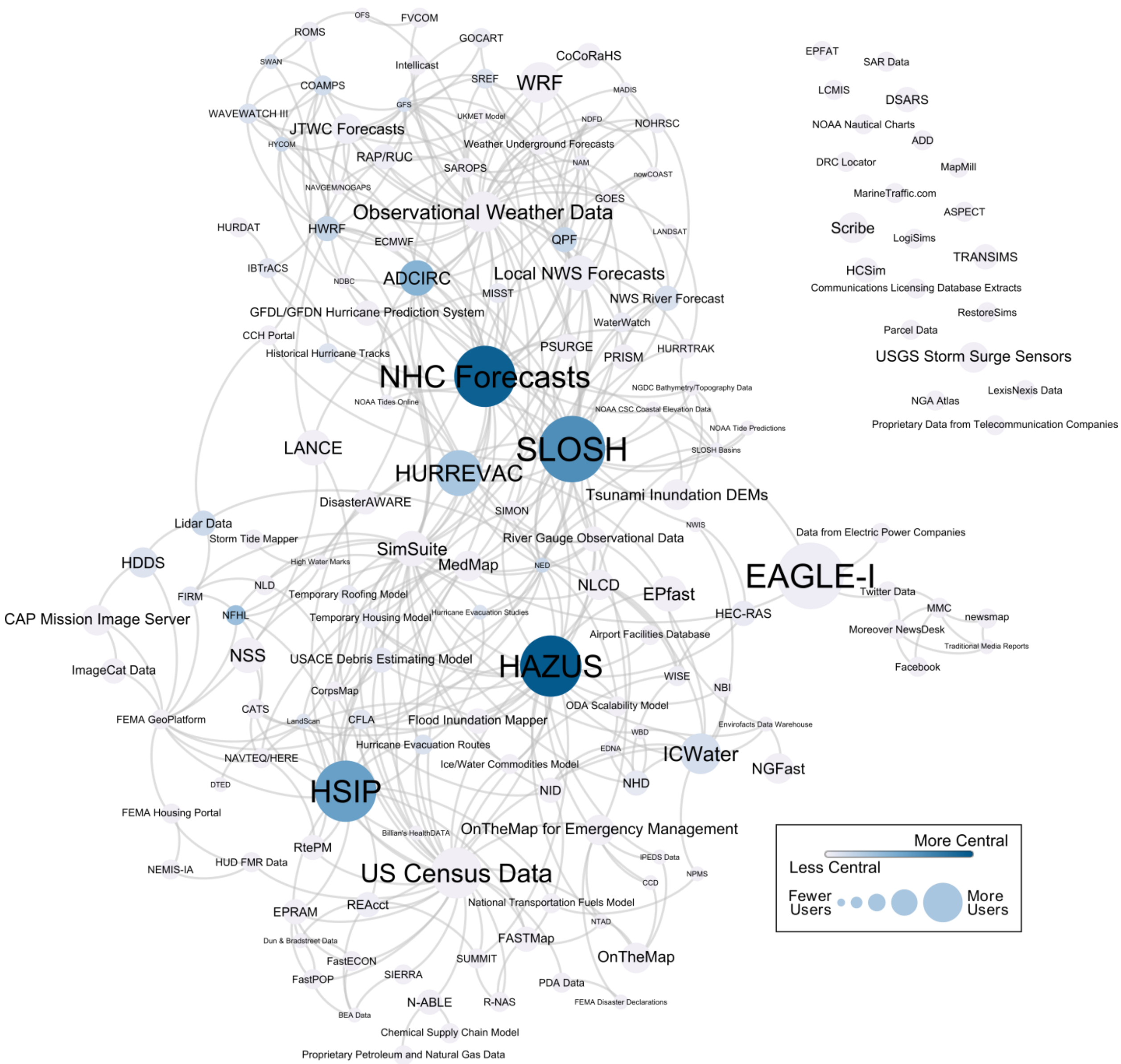


Figure 10. Hurricane Betweenness Centrality. In the hurricane network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Darker blue represents more central resources, while lighter blue represents less central resources. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only hurricane and all-hazards resources from the inventory appear in the networks.

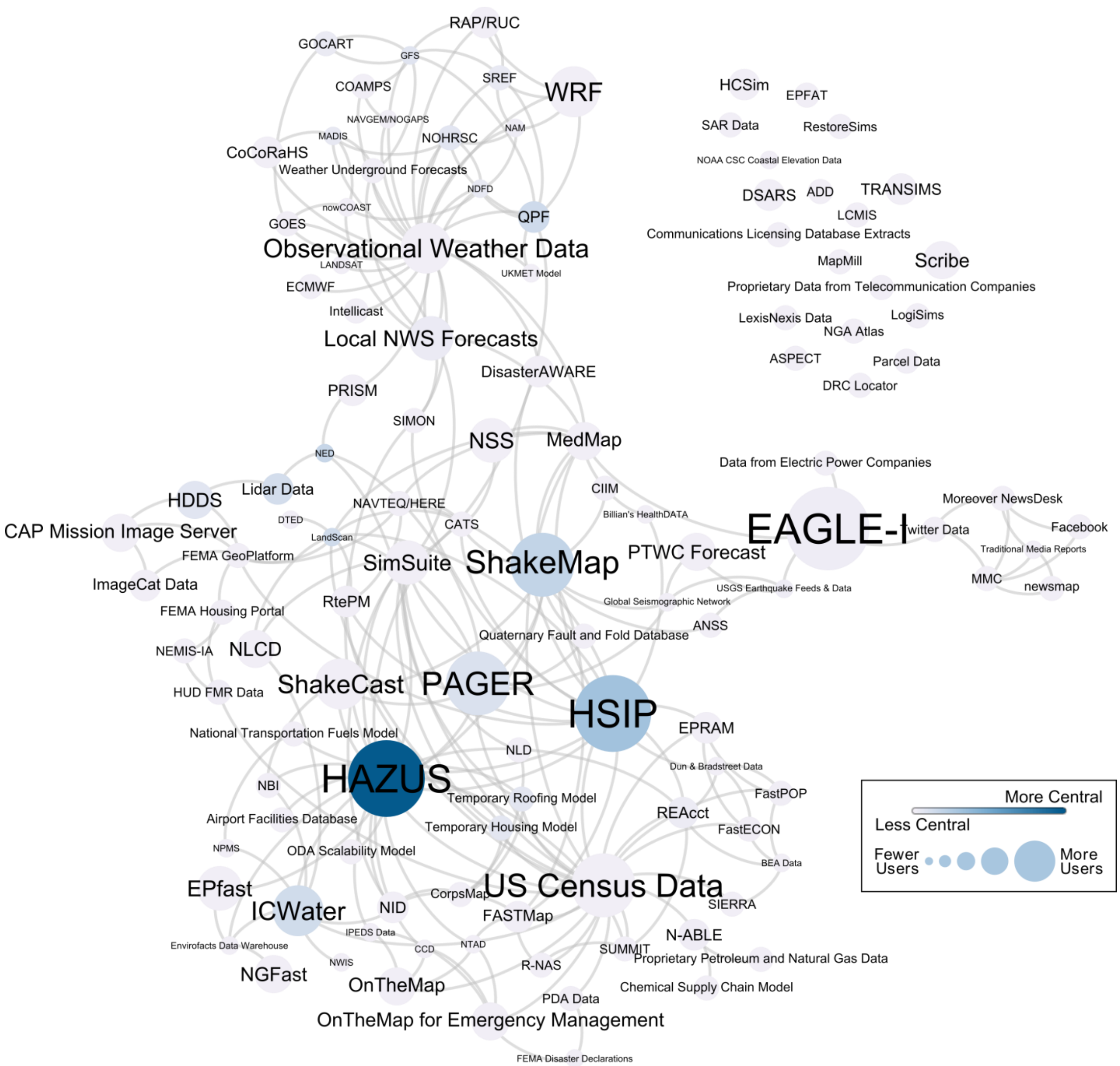


Figure 11. Earthquake Betweenness Centrality. In the earthquake network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Darker blue represents more central resources, while lighter blue represents less central resources. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only earthquake and all-hazards resources from the inventory appear in the networks.

Upstream and Downstream Resource Connections

Summary of Upstream and Downstream Resource Connections

- The most central resources tend to be the most highly connected, with a few exceptions.
- Resources at the beginning of the flow of information (raw data) serve as sources of information, while resources at the end of the flow of information (mission-specific requirements) serve as sinks of information.
- Resources in the middle of the flow of information, like the consequence model HAZUS, are expected to have the most amount of connections, as information flows in and out of them.

As shown in Figures 12 and 13, resources can also be characterized more simply by their number of upstream and downstream connections. While the most central resources tend to be those that are most highly connected within the network, this does not have to be the case. For example, in the hurricane network, NFHL (National Flood Hazard Layer) has a higher centrality score than all but seven other resources despite the fact that it only has two inputs and four outputs, both less than many other resources in the network. The high centrality score of NFHL reflects the fact that while it only directly interacts with a small number of resources, it is an essential bridge within the overarching flow of information. Moreover, NFHL's high centrality score indicates that its few direct connections represent essential routes of information from event characterization (ADCIRC in this case) to consequence models and decision support tools. Without NFHL, the resources downstream of it would have no other way to get the outputs of event characterization models that are needed to effectively calculate consequences and provide decision support.

By contrast, Observational Weather Data, US Census Data, SimSuite, and FEMA GeoPlatform are outliers relative to their centrality measures in both the hurricane and earthquake networks: these resources are all directly connected to a large number of other resources (as shown in Figures 12 and 13), but have either only downstream connections (Observational Weather Data and US Census Data) or only upstream connections (MedMap and SimSuite). These resources represent sources and sinks of information in the network. Information first enters the network through the sources (e.g., Observational Weather Data and US Census Data), is processed and transformed by various intermediate resources, often including the highly central resources such as HAZUS and NHC Forecasts, and ultimately feeds the sinks (e.g., MedMap and SimSuite), where the information can be accessed by users.

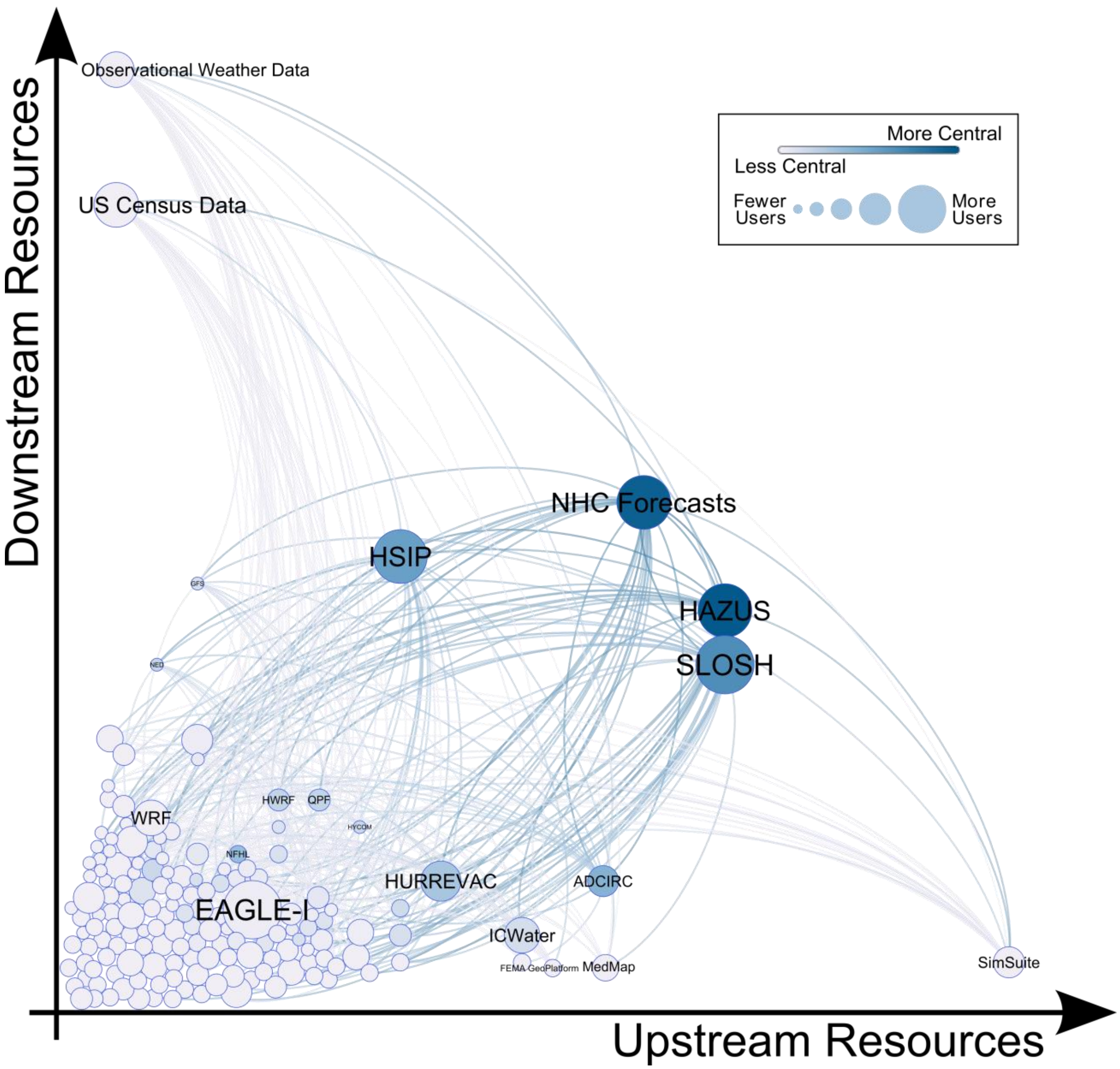


Figure 12. Hurricane Connectivity and Centrality. In this figure, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Darker blue represents more central resources, while lighter blue represents less central resources. The resources are graphed according to the number of upstream resources and the number of downstream resources. Node locations were adjusted slightly in order to display all resources in the network, and should not be interpreted absolutely but rather only relative to other nodes. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only hurricane and all-hazards resources from the inventory appear in the networks.

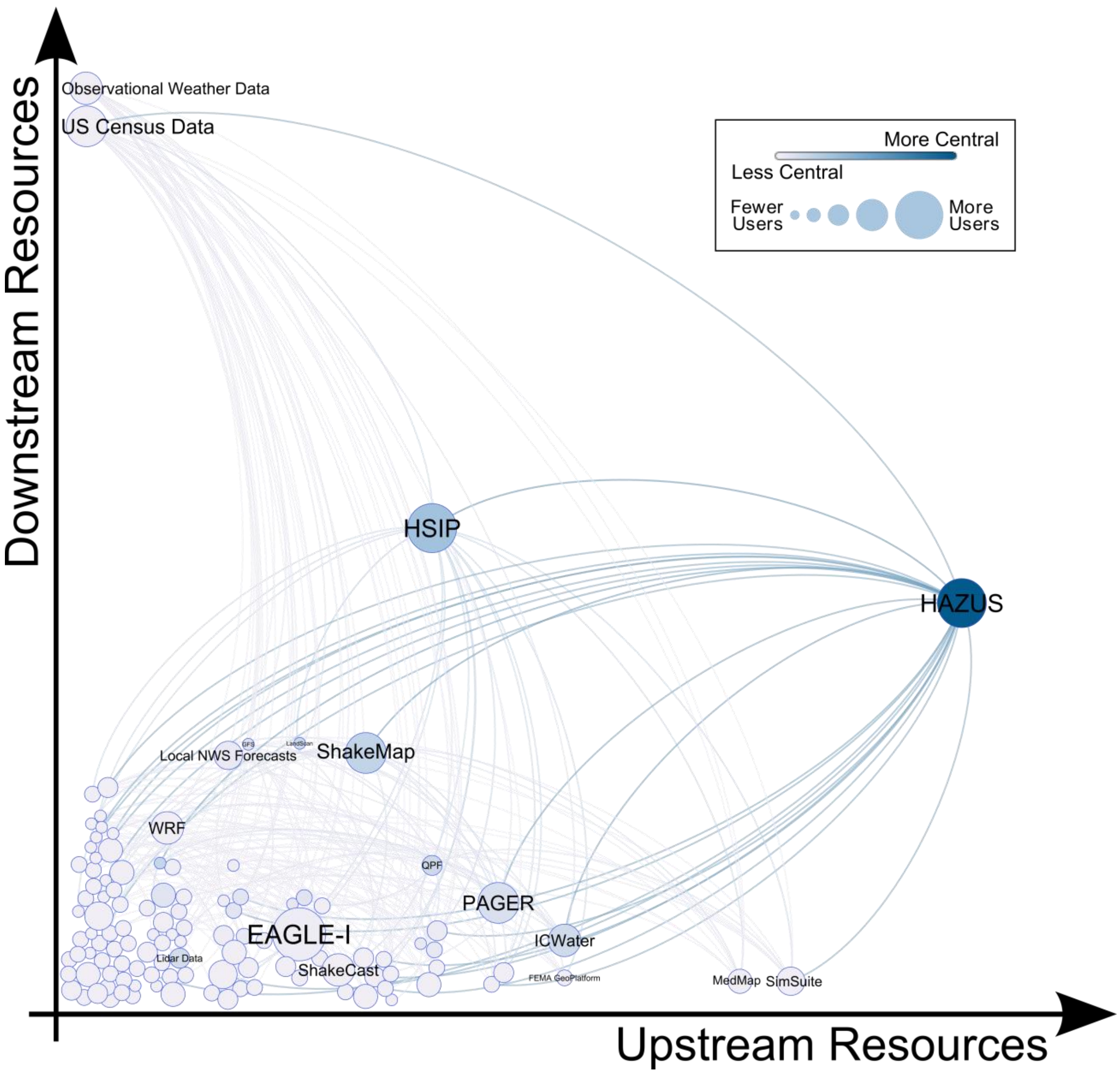


Figure 13. Earthquake Connectivity and Centrality. In this figure, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Darker blue represents more central resources, while lighter blue represents less central resources. The resources are graphed according to the number of upstream resources and the number of downstream resources. Node locations were adjusted slightly in order to display all resources in the network, and should not be interpreted absolutely but rather only relative to other nodes. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only earthquake and all-hazards resources from the inventory appear in the networks.

Conclusions from Centrality Analysis

From these centrality measures, it becomes clear that for both hurricanes and earthquakes, the flow of information is dominated by a few select resources. While resources like Observational Weather Data and US Census Data may indirectly feed a large portion of the network and MedMap and SimSuite may ultimately be fed by a large number and diversity of other resources, the centrality scores indicate that information most often flows through resources like HAZUS and NHC Forecasts. In both hurricane and earthquake networks, HAZUS is the resource that transforms the event characterization and forecasting data into consequence predictions needed by emergency managers to inform their decisions. These highly central resources are important information bridges within the flow of information; the other resources with a large number of upstream or downstream connections are still crucial to the flow of information, but represent the beginning or the end of the continuum.

Results: Metadata Analysis

In addition to the network analysis, the details and characteristics, or metadata, of each resource were also analyzed. These analyses investigate the types of resources and information that are available to support operational decision making in the context of emergency management.

Resource Type

Summary of Resource Type

- While each resource type is needed for efficient and informed disaster planning and response, the resources identified in the inventory are unevenly distributed between resource types.
- Resources tagged later in the flow of information tend to be mission-specific and useful for multi-hazards.
- The vast majority of the resources in the inventory are tagged by a single resource type. However, nine resources are most accurately described as functioning in multiple resource categories
- More hurricane-specific raw data are available as compared to earthquakes. This discrepancy highlights the complexity of hurricane event-characterization, as well as the advanced-notice nature of the event, which requires forecasting models.

Number of Resources Based on the Flow of Information

Resource types are defined by the categories described in the flow of information. While each resource type is needed for efficient and informed disaster planning and response, the resources identified in the inventory are unevenly distributed between resource types (see Figure 14). For both hurricane and earthquake scenarios, there are many more resources tagged by the resource types early in the flow of information (raw data, event characterization, and situational awareness). To some degree, this trend is not surprising. It is intuitively obvious that a great deal of raw data from a wide range of sources is necessary to feed robust event characterization models. For example, the hurricane forecasts published by the National Hurricane Center are generated by collecting and processing large volumes of observational weather data and combining and comparing the outputs of a large number of weather models, a process that significantly improves the accuracy and resolution of the forecasts. Similarly, consequence models collate many different types of information to effectively predict and characterize the hazard across sectors. For example, HAZUS pulls from raw data sources including infrastructure and population statistics, event characterization models, and information from situational awareness data to calculate the economic consequences of an event.

Also not surprising, resources tagged later in the flow of information are more likely to be useful for multiple event types (see Figure 14, white hatch marks). For example, seven of eight consequence models are used and useful in the context of both hurricane and earthquake scenarios, with only one being earthquake-specific (PAGER). Some of these models, such as HAZUS and SimSuite, are large multi-sector and multi-hazard models built to generate a comprehensive overview of the consequences of any specific event. Interestingly, consequence models that calculate sector specific consequences, such as EPFast (electrical power consequences) and REAcct (economic consequences), use the outputs of the multi-sector models such as HAZUS as upstream data feeds to provide a comprehensive consequence overview. The only hazard-specific consequence model identified, PAGER, however, is a data feed of HAZUS, providing earthquake specific consequences that allow HAZUS to accurately generate the comprehensive consequence prediction needed by emergency managers and decision support tools in the context of that event type.

Moreover, categories at the end of the flow of information, like decision support tools and mission-specific requirements, are almost always mission-specific, rather than hazard-specific. For example, LCMIS (a logistics tracking mission-specific requirement resource) and RtePM (an evacuation decision support tool) are both useful in any hazard. This finding confirms the value of the Emergency Support Function structure, as described in the National Response Framework,[11] a system founded on the idea that on-the-ground activities that need to be completed during emergency response are generally mission-driven rather than dependent on the hazard type.

[11] (2008) National Response Framework. Federal Emergency Management Agency

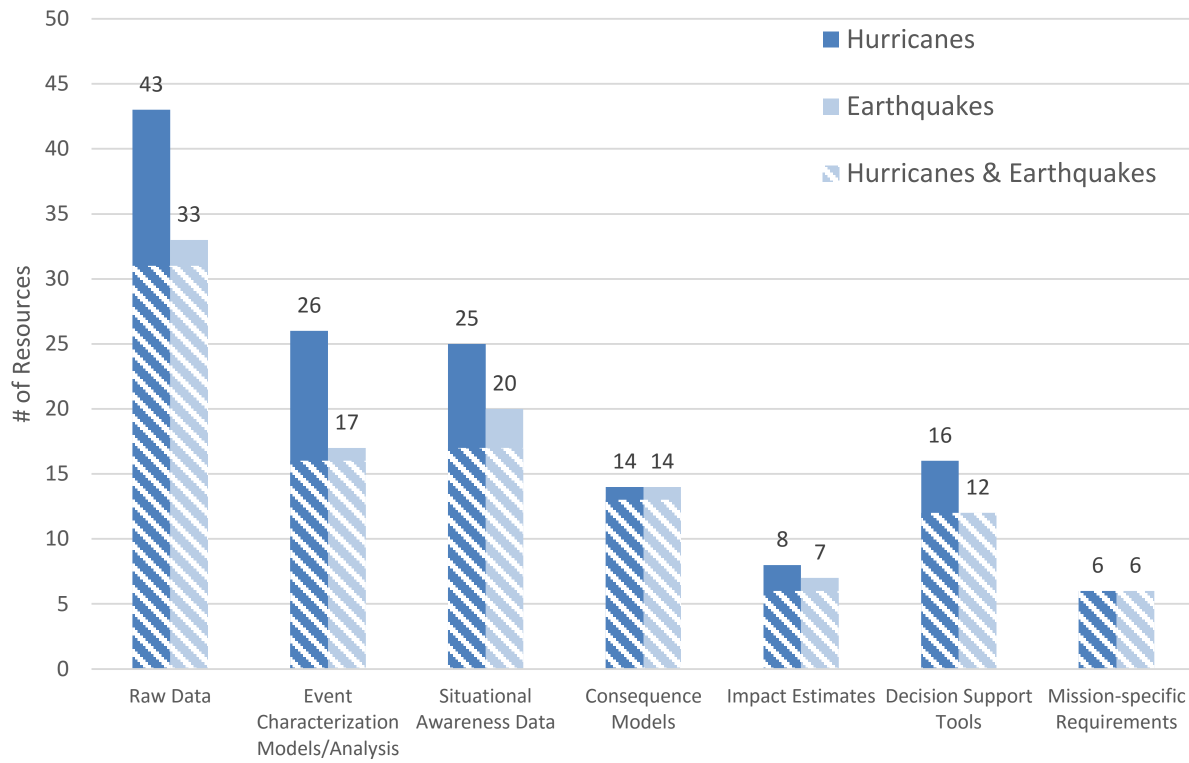


Figure 14. Number of Resource by Type. The number of used resources are shown for each resource type from the Flow of Information. Resources only relevant to hurricanes are shown in dark blue. Resources only relevant to earthquakes are shown in light blue. Resources relevant to both hurricanes and earthquakes are shown as white hatch marks. These resources are either resources tagged as relevant to all-hazards or resources tagged as relevant for both hurricanes and earthquakes.

Resources Described by Multiple Resource Types

The vast majority of the resources in the inventory are tagged by a single resource type. However, nine resources are most accurately described as functioning in multiple resource categories (see Table 10).

Table 10. Resources with multiple resource types. All listed resources are applicable to Multi-Hazard scenarios except for ShakeCast, which is applicable only to earthquake scenarios.

Resources	Raw Data	Event Characterization Models/Analysis	Situational Awareness Data	Consequence Models	Impact Estimates	Decision Support Tools	Mission-Specific Requirements
FEMA GeoPlatform			X		X		
MedMap			X		X		X
ShakeCast			X		X		
SIMON			X		X		
SimSuite	X	X	X	X	X	X	X
SUMMIT		X		X		X	

Of the resources tagged by multiple hazard types, five are agency-specific situational awareness viewers that incorporate the outputs of consequence models, and so are tagged as both situational awareness data and impact estimates: FEMA GeoPlatform (FEMA), MedMap (HHS), ShakeCast (USGS), SIMON (State), and SimSuite (USACE). CATS (DTRA) and SUMMIT (DHS/FEMA) are both tools designed to combine multiple model types to generate comprehensive modeling outputs with code calculating results related to each category.

Resource Types: Hurricane vs. Earthquake Scenarios

One distinction between hurricanes and earthquakes is seen when resources towards the beginning of the flow of information are examined (Figure 14). While there are many hurricane-specific raw data (19), event characterization (13), and situational awareness resources (13), few exist for earthquakes. Specifically, there are 5 earthquake-specific raw data resources, 1 event characterization model (ShakeMap), and 1 situational awareness data resource (Community Internet Intensity Map). This discrepancy highlights some of the differences between modeling hurricane and earthquake scenarios. For one, earthquakes are a no-notice event, inherently removing any need or ability to forecast the hazard, a fundamental aspect of hurricane characterization. Second, in many ways, hurricanes are a more complex hazard than earthquakes. Earthquakes can be accurately characterized by processing seismic data, while characterizing a hurricane involves modelling wind currents, ocean surge levels, precipitation, and flooding, among other factors. This results in many specialized characterization models feeding each other, resulting in a comprehensive hurricane characterization, something that is accomplished in an earthquake scenario with a single model. A consequence of this is that ShakeMap, and to a much lesser extent the Community Internet Intensity Map (CIIM), is the only resource able to characterize an earthquake. ShakeMap is one of the most used and central earthquake resources, and unique in its event characterization function for earthquakes. Therefore an informed earthquake response is completely dependent on it, more so than any other resource in any hazard considered.

Agency-Specific Use of Data and Modeling Resources

Summary of Agency-Specific Use of Resources

- Although several lists of available resources have been collated previously, none of these lists identify which resources are actually used and by whom. To address that gap, interviewees across the federal interagency were asked not only which resources they have developed or produced, but which resources they use in the context of their mission in emergency management.
- For both hurricanes and earthquakes, FEMA is the largest user of interagency resources, followed by DHS (excluding FEMA), the US Army Corps of Engineers, and DoD.

There has been an explosion of data and modeling tool development within the last few years as a recognition for the power of and need for rapid sharing of real-time information during emergencies has coincided with a rapid increase in technological developments that support access to and the processing of that information. Lists of the information resources available within the federal emergency management community have been generated previously; none of these have, to our knowledge, identified which of those resources are used and by whom. To address that gap, interviewees across the federal interagency were asked not only which resources that they have developed or produced, but which resources they use in the context of their mission in emergency management. Only those resources identified as used were included in the inventory, and each resource was tagged by the federal agency identified as using the resource directly.[12] The results of this analysis are shown in Figures 15 and 16.

[12] Note that users can be defined as either individuals or agencies; for the purposes of our analysis, users are defined as federal government agencies or organizations explicitly included in the Emergency Support Functions, as described in the National Response Framework. Users can also be calculated by including not only the number of direct users, but also those users of all resources that provide inputs for a given resources. We refer to this latter method as calculating "cumulative users."

The Federal Emergency Management Agency (FEMA) is the largest user of interagency resources, followed by the Department of Homeland Security (excluding FEMA), the US Army Corps of Engineers, and the Department of Defense (including both the Defense Threat Reduction Agency and the North American Command, or NORTHCOM) for both hurricane and earthquake scenarios.[13] Because FEMA is tasked with coordinating efforts between all other agencies involved in emergency management, it is not surprising that they are heavy users of these resources from across the interagency. Other organizations have more specific missions and therefore use only a subset of resources relevant to that mission.

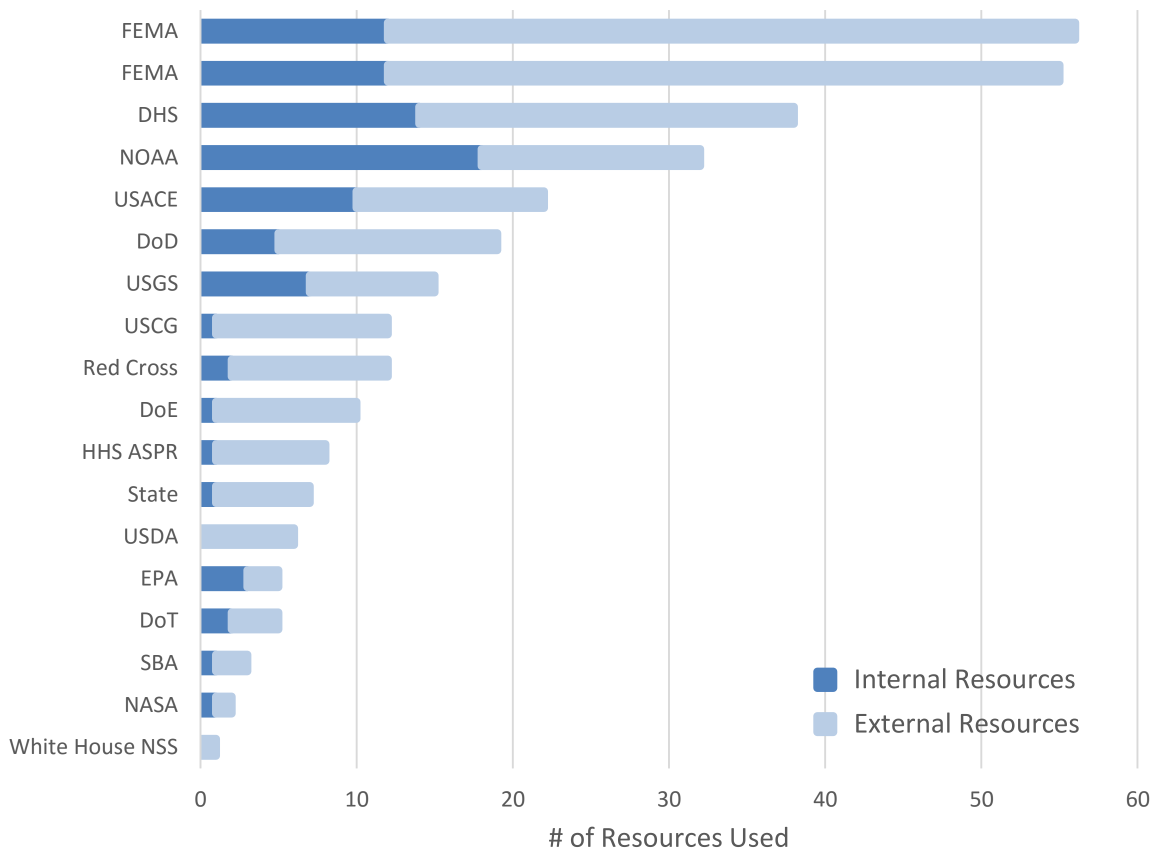


Figure 15. Number of Hurricane Resources Used by Organization. The number of hurricane resources each federal organization, agency or department uses is shown. The number of resources owned (internal) is shown in dark blue. The number of resources used, but not owned (external), is shown in light blue.

13 The order of the 3 organizations differs slightly between earthquakes and hurricane, thought the top 4 users remain the same.

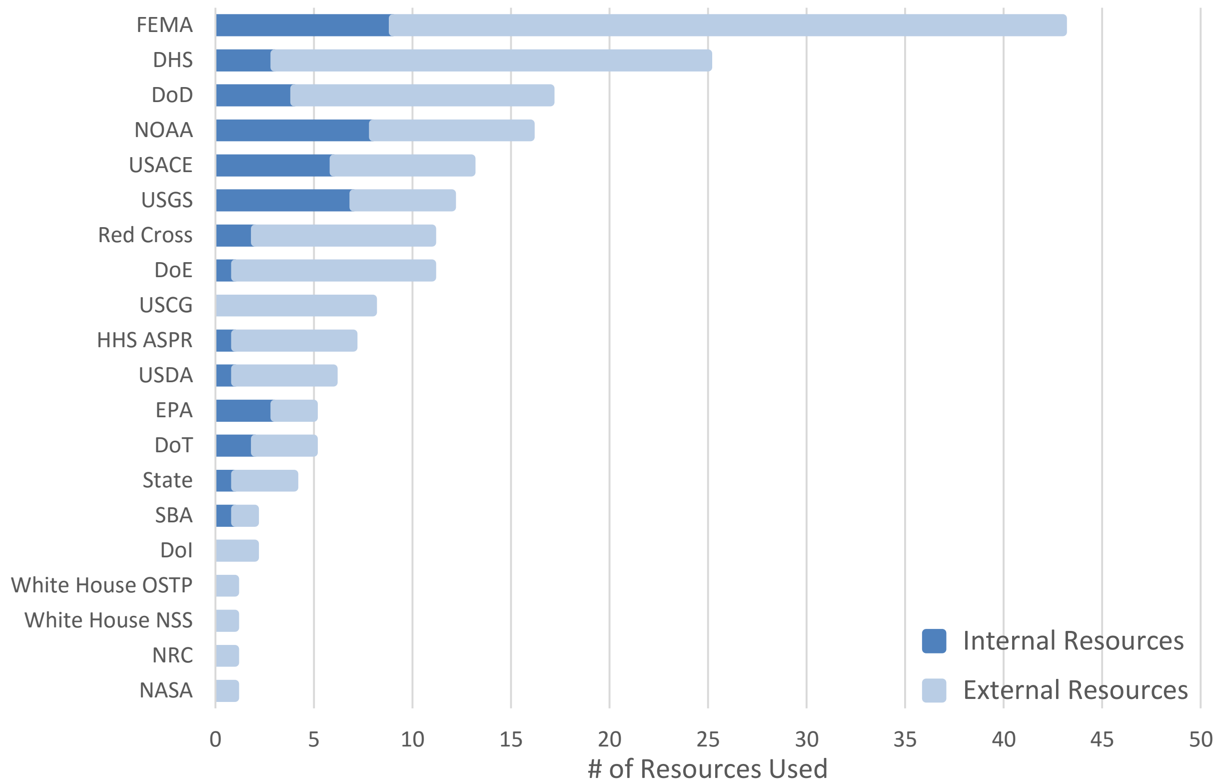


Figure 16. Number of Earthquake Resources Used by Organization. The number of earthquake resources each federal organization, agency or department uses is shown. The number of resources owned (internal) is shown in dark blue. The number of resources used, but not owned (external), is shown in light blue.

Gap Analysis

This section details gaps that were identified from network analysis of the resource inventory and from interviews with subject matter experts, emergency managers, and senior-level decision makers. Importantly, these are broad systems-level gaps that impact the entire federal interagency and emergency management community. In addition, a few specific gaps were raised as points of concern by multiple interviewees. These gaps are not ranked by order of importance. Addressing these gaps, in particular the systems-level gaps, will improve the data and access to the information that supports operational decision making and serves the broader emergency management community.

Need More Robust Connections between Resources

Resources need to be linked to the rest of the network to ensure that the information generated is used efficiently and integrated effectively by decision makers during all phases of emergency management. Network analyses of both hurricane and earthquake resources have identified lists of resources unlinked to the network ("orphan resources"), in addition to a subset of resources that would be expected to be more highly linked, in part because they are heavily used.

"Orphan Resources"

A network analysis of hurricane and earthquake resources identified several resources that are not linked. As shown in Figures 8 and 9, and listed in Table 9, although these resources are used, no information is exchanged between these resources and any other resource in the inventory. These resources do not use real-time, event-specific data, nor are the outputs further processed or analyzed. If these resources remain unconnected to other resources, then the flow of information is severed, resulting in an incomplete picture of the event as a whole. These orphaned resources must be linked to the rest of the network, both to incorporate hazard-specific inputs to ensure that they are processing information based on the most up-to-date and validated data, as well as to ensure that the information they produce is accessible to downstream users to better inform decision makers.

Comprehensive Integration of Widely-Used Resources

Widely-used resources are expected to be central and well-integrated into the network; however, both the hurricane and earthquake networks contain resources that are widely-used, but poorly linked to the rest of the network. For example, EAGLE-I is one of the most widely-used resources in the inventory, yet has few upstream and downstream linkages and is not well-integrated into the network (Figure 10 and 11). By contrast, HAZUS, another widely-used consequence model, is also one of the most highly linked and central resources.

When widely-used resources are not well-linked, this disrupts the flow of information, and results in the resource not being leveraged to its full potential. Therefore, just as orphan resources need to be linked, these widely-used resources also need to be better integrated into the network to prevent gaps in the flow of information and to ensure maximum availability and usage of information produced by these resources.

Networks Rely on a Few Highly Central Resources

Analyses of hurricane and earthquake networks have identified a handful of highly central resources, such as HAZUS (a FEMA-owned, multi-hazard consequence model) and the National Hurricane Center Forecasts. These resources not only have a large number of upstream and downstream resources, but they are also linked to other central resources, like the Homeland Security Infrastructure Program dataset (HSIP), which makes them highly integral to the network. If these resources were to be removed from the network, important nodes that are necessary to sustain the flow of information through these networks would be lost. Therefore, the onus is on the interagency to maintain and ensure the long-term viability of these highly central resources within the earthquake and hurricane networks. HAZUS, described below, is a great example of a highly central resource that will require robust interagency support to ensure that it or its replacement remains an integral part of the network.

Maintenance of HAZUS

HAZUS is a resource that has been used heavily across the interagency for decades. The tool was designed originally for the Mitigation Division at FEMA as a loss estimation tool to gauge the scope of the financial burden of a specific event and is used during all phases of emergency management, from preparedness and response to recovery and mitigation. The tool calculates event-specific financial burden from several sources, including economic loss (e.g., lost jobs and business interruptions), damage to infrastructure, and debris accumulation. However, HAZUS is now being used throughout the interagency as a tool to estimate consequences of earthquakes, hurricanes, and floods for a wide array of mission areas and as a source of data for other models. HAZUS draws from several shared national databases, and some interagency users have developed methods to extend the use of HAZUS outputs to estimate additional impacts, such as temporary housing resource needs, affected populations, and personnel required to field loan applications for the Small Business Administration. Understanding this expansion in utility of HAZUS is important, as it suggests that the product serves as an important backbone for operational decision making during emergency management.

Interviews with federal, state and local personnel have highlighted HAZUS as an extremely important resource used heavily across the federal interagency and by state and local communities to support risk assessments of economic loss scenarios from natural disasters, as well as to estimate resource requirements during response to an event. Network analysis supports this assessment and suggests that HAZUS is a critical and central resource to the emergency management community (Figures 10 and 11). Although widely used to support decision making across all phases of emergency management and at all levels, HAZUS has been described as no longer being a state-of-the-art modeling tool. Several interviewees described HAZUS as needing to be updated and re-tooled in order to remain a robust resource. While it has previously only been financially supported by FEMA, this resource, like other widely-used resources, should be updated and maintained with interagency support on the basis of its central role in supporting emergency management across the federal government.

Gaps in the Flow of Information

The flow of information framework described in Figure 4 provides a powerful method to parse the roles that resources play in supporting interagency decision making and to identify the linkages between them. Understanding and classifying resources based on the seven major categories within the flow of information allows emergency managers to determine which resources are useful when to inform preparedness and response plans. Classifying resources based on when they are useful in the flow of information, such as raw data or mission specific requirements, provides a framework for emergency managers to identify gaps and to provide targeted recommendations to fill these gaps. The gaps below have been identified both through analysis of the earthquake and hurricane networks, as well as through interviews.

Gaps in Impact Estimates

Availability of Cross-Sector Impact Estimates

A robust response to any event will require a comprehensive response across all mission areas, which depends upon impact estimate data being quickly and readily accessible to emergency managers across all emergency support functions. Metadata analyses show that a total of 8 impact estimate resources are available for earthquake and hurricane scenarios, less than 5% of the total number of resources in the inventory (Figure 14). A closer analysis of these few resources confirms that no single impact estimate resource covers a breadth of consequences, nor, when taken together, do they cover all mission spaces. In both networks, each of the available impact estimates are primarily hazard-specific and are designed to support only a narrow mission space, such as health, infrastructure or housing. In order to ensure a robust response, a wide range of impact estimate data relevant to all mission areas need to be generated to inform decisions such as what resources need to be deployed where.

Libraries of Impact Estimate Data

Based on analysis of used data and modeling resources and gaps specifically described by interviewees, very few impact estimate libraries are available to the emergency management community to support planning and response operations. During an event, impact estimates are generated in two ways: they are the outputs of predictive consequence models, and they are informed by real-time assessment data. Immediately after an event, libraries containing previously-run outputs from predictive consequence modeling over a wide range of event scenarios can be useful to inform early decisions when little to no assessment data are available. Although sufficient to inform a response during an event, predictive impact estimates from consequence models are not archived and accessible so that they can be compared with actual damage assessments post-event. For example, of the 8 impact estimate resources available for both earthquake and hurricane networks, there is only one impact estimate library, the Coastal Flood Loss Atlas (CFLA), which is used to inform decisions in the early hours after a hurricane prior to when HAZUS runs become available approximately six hours post-event.

Ideally, when consequence models, such as HAZUS, are run, the outputs of these runs should be collated into an easily-accessible library that can be referenced for future planning or response operations. A searchable library of impact estimates that collates information on damage assessments to all emergency support functions, including damage to human health, the economy, infrastructure, and the environment, among others, would provide decision makers a measure against which to compare consequences and inform critical early decisions to respond to an event and provide the data required to validate and verify data produced by consequence models.

Impact Estimates Integrated into the Resource Network

Analyses of the earthquake and hurricane networks show that, of the impact estimate data available to the federal government, these resources are not well-linked to the rest of the network resources. Without linkages these resources will remain under-utilized, and prevent efficient and informed operational decision making. For example, neither resources like the Red Cross' Disaster Services Automated Reporting System (DSARS) tool that track and aggregate impact estimates from real-time assessment data nor the only known library of consequence model outputs, CFLA, are linked to both upstream and downstream resources. DSARS is an orphan resource with no linkages, whereas CFLA has no downstream connections (Figures 8 and 9). This lack of linkages is surprising because resources towards the middle of the flow of information framework, like impact estimates, are expected to be highly linked as more information would be expected to flow in and out of these resources. These types of resources are usually not sources or sinks of information and are expected to have upstream and downstream linkages. These impact estimate resources need to be connected to relevant upstream and downstream resources to improve the integrity of the network and facilitate the flow of information to ultimately inform operational decision making.

Gaps in Decision Support Tools and Mission Specific Requirements

Decision Support Tools and Mission Specific Requirements for All Missions

Although several decision support tools and mission specific requirements are available to the federal interagency, these resources were designed to fulfill requirements within only a narrow mission space. For example, these resources are used to estimate evacuation times for an impending hurricane (HURREVAC), or used to estimate the amount of debris and the resources required to remove the debris (USACE Debris Estimating Model). Although extremely useful for the narrow mission space for which the resource was designed, these tools do not span all mission areas. Regardless of whether new resources are developed to address the needs of each specific mission or emergency support function (ESF) or whether the existing resources are expanded to provide information specific to a wider range of missions, all ESFs and missions should be supported by empirical data that is shared broadly within the interagency and available through effective decision support tools and mission specific requirements.

The most effective tools were described by interviewees as being able to use mobile applications for the ready input of assessment data collected by those on the ground in the affected regions, which are pulled into a centralized database from which the data is then analyzed and provided back to those making operationally-relevant decisions across all emergency support functions. These tools are not available to support many of the emergency management missions, and of the available tools, only a few are sufficiently linked to additional resources in the inventory. To fill this gap, critical information requirements of all emergency support functions need to be identified, and decision support tools and associated mission specific requirements need to be designed and developed that will effectively assist those making operationally-relevant decisions during planning and response to any event.

Integration of Mission Specific Requirements to Upstream Resources

In order to develop a robust and integrated network of resources, mission specific requirements need to be linked to the rest of the network: the inventory of data and modeling resources for earthquakes and hurricanes reveal that of the six available resources, four have no upstream linkages. Resources at the end of the flow of information essentially function as sinks and should have many upstream feeds that link to decision support tools and other categories in the framework. All emergency support functions need mission specific information in order to leverage appropriate resources to respond effectively to any event. The lack of any upstream feeds for the majority of mission specific requirements is problematic as it underscores a lack of integration and cohesiveness within the network, regardless of the type of hazard. Therefore, mission specific requirements need to be linked to existing upstream resources to generate a robust and well-integrated network. In addition, when new resources are developed that support specific missions, these need to be connected to appropriate upstream resources to ensure that emergency management personnel have access to event-specific, empirical data upon which to make decisions for planning and response.

Expansion of the Inventory to Other Hazards

To build a comprehensive and cohesive network of data and modeling resources that are "all-hazards," the effort initiated in this iteration of the Modeling and Data Working Group (MDWG) needs to be expanded to include scenarios that will require fundamentally different response strategies. Both the MDWG charter (see Appendix 1) and interviewees stressed the importance of expanding the inventory to include resources relevant to other hazards, particularly improvised nuclear device (IND), biological, and cyber-security scenarios.

Because hurricane and earthquake scenarios are well-understood and frequently practiced, the MDWG chose to initially focus on these scenarios to build and validate the flow of information framework laid out in Figure 4. To ensure that the network of data and modeling resources cover "all-hazards," this effort needs to be expanded to include scenarios that will require vastly different responses. As such, an effort to define the information requirements and the associated data and modeling resources for INDs are currently underway. INDs have no historical precedent and a response to an IND detonation, especially in the early hours, will completely rely on predictive modeling and quick collection and analysis of post-event assessment data. Therefore, it is crucial to identify what data and modeling resources are available so that emergency managers can become familiar with how these resources can be used to facilitate operational decision making.

In addition, interviewees recommended a further expansion of the inventory to include resources useful for biological and cyber-security scenarios. These events unfold in fundamentally different ways than hurricanes, earthquakes, or INDs. For example, biological events will be delayed-notice, and will require ongoing surveillance in order to identify and characterize the event. Unlike hurricanes or earthquakes, there will be no immediate notice of either a biological event or a cyber-attack. As such, event characterization tools useful for other disasters are most likely not relevant. For both these types of scenarios, it will be critical to determine what information is required, what resources are available, and how the existing resources will be used to ensure continuity of operations. Therefore, expanding the resource inventory to include these additional scenarios will make the networks more robust, extend our understanding of how the different resources interact with each other, and highlight potential hazard-specific and mission specific gaps.

Other Gaps

Over the course of interviews across the interagency, gaps related to specific missions, datasets, or models were identified. These gaps, though not systems-level, are described below. While efforts are underway to fill many of the gaps identified early in the effort, continued investments in closing these gaps should be an ongoing effort and will require continued support from the interagency. Moreover, as these gaps are closed, it is critical that this information is disseminated to the users of these resources, so that existing emergency management plans can be updated to reflect these changes.

Data Gaps

Integration of Post-Event Assessment Data

Assessment data must be processed, formatted, and presented in ways that facilitate analysis and decision making. These data are important both to ensure that decisions made during an event are based on the event-specific data collected in real time and to ensure that the predictive models used during planning and the early phases of a response are verified and validated to improve their accuracy and fidelity. Based on the interview results, reporting delays, a lack of standard operating systems for data collection, or a lack of analysis (for example, geocoding or time stamping of aerial photographs) have previously prevented the use of assessment data. In other examples, some assessment data such as real-time surge data can be collected only if the equipment necessary to collect the information is pre-deployed in anticipation of the event. Such data collection requires pre-event funding and coordination efforts that do not yet appear to be fully in place.

It is of note that the incorporation of assessment data into iterative model runs is particularly critical for the verification, validation, and ongoing use of predictive event characterization and consequence models. For example, SLOSH is a widely-used and validated flood inundation model, but a combination of high water marks or, better, surge gauge data must be incorporated after each event to improve the fidelity of the model with each storm. Similarly, earthquake damage assessment data should be used to validate the outputs from models such as PAGER, providing robust and data-driven verification and validation of modeling outputs to ensure that the tools improve with each new event and the availability of new data.

The use of assessment data is challenging, partially due to difficulties in defining standardized methods for data collection, centralization, and organization to facilitate data-mining or analysis. This lack of standardization and the subsequent lack of effective use of assessment data prevents the incorporation and adjustment of response or recovery activities based on those data and also prevents effective verification and validation of the models.

Lack of Real-Time Surge Data

A specific gap associated with the integration of post-event assessment data was described by a large number of interviewees with regard to hurricanes and tropical storms: current surge models are unable to accurately predict the scope of flooding or inundation. Both Hurricane Isaac and Tropical Storm Debby from the 2012 hurricane season highlight this gap: in both storms, storm surge caused extensive flooding at times and in locations that could not be predicted by the wind strength alone. Surge models, like SLOSH, are used to predict storm surge vulnerability and to inform evacuation zones by relying almost entirely on the timing of wind speed to identify when and at what strength a storm will hit. But, these models failed to capture rises in sea level not directly attributable to rainfall and high winds at that location. Recognizing this gap, USGS deploys storm tide and wave height sensors prior to the arrival of hurricanes to quantify storm-surge dynamics, which can then be used to refine the accuracy of storm-surge models and inform evacuation zones. The ongoing deployment and collection of such storm surge data provides valuable information to calibrate surge models, inform flood insurance maps and building codes, among others. Interviewees pointed out that as Stafford Act funding cannot be used to deploy storm gauges prior to an event, a dedicated funding mechanism for deployment of storm-surge sensors ahead of hurricanes and tropical storms would be invaluable to collect information that can ultimately inform community response and evacuation plans. An important consideration when deploying tide and wave sensors is that these instruments themselves can become collateral damage in the wake of hurricanes, like Katrina and Sandy.[14] Support for research and development of sensors that can withstand tidal waves will be critical to support ongoing efforts to collect assessment data that serve as inputs into storm-surge models.

Population-Specific Raw Data

Several interviewees also expressed a desire to acquire population data at a higher resolution than currently available, which is mostly at the census block level. Although LandScan data does include

14 Gillis J. (2014) Tide Gauges Needed for Research Are Often Victims of Storms. *The New York Times*.

population distribution for both day- and night-time populations, several groups expressed the need for a greater than census-block-level resolution of these data, such as the ability to distinguish between commercial and residential buildings. In addition, interviewees also expressed a desire for greater resolution of population data in high-density urban areas where response efforts must be scaled to reflect the population density. For example, an event that impacts 500 people spread out over 100 square miles requires an inherently different response than a similar event that impacts 500 people in a single high-rise building.

Gaps in the Use of Social Media and Crowd-Sourced Data

Although social media and crowd-sourced data are not being used or developed as replacements for traditional data resources, there is growing interest to determine how best to take advantage of these types of data to supplement existing data streams. The use of social media data provides a unique opportunity to generate accelerated situational awareness data. For example, based on social media analysis, the NOC Media Monitoring Capability was able to inform the Secretary of DHS about the Boston Marathon bombings minutes before the event was reported through traditional news media. Such situational awareness data is associated with a relatively high degree of uncertainty, where its primary utility lies in its speed, sensitivity, and ability to collect data from geographically and demographically diverse audiences in an ongoing fashion.

Although social media and crowd-sourced data are a rich resource, there is a wide range of error associated with these data. Many agencies and divisions are still developing structures, analysis tools, and processes through which to best consider and communicate the error inherently associated with the use of social media and crowd-sourced data.

Gaps in Access to Data

Emergency managers need access to the data they need when they need it to make informed decisions during all phases of emergency management. Many interviewees stated that they do not have sufficient access to data resources, which could be due to a variety of challenges, including unfamiliarity with existing or recently developed data resources. For example, HSIP Gold is only available to state and local emergency managers during an emergency, precluding the ability for these entities to become familiar with this vast data resource during normal operations. Security restrictions also pose a challenge, as some individuals have experienced constraints when accessing classified or For Official Use Only (FOUO) information quickly and efficiently during a response to an event. In addition, interviewees said that accessing, sharing, and communicating proprietary information, including data regarding private telecommunication resources, electric energy, and natural gas, has also posed a challenge across the interagency. In some instances, these data are shared to a specific, mandated agency not authorized to share the data externally. In other cases, the data are simply not available, or are only available at whatever resolution, accuracy, or time private companies decide to share the information.

Recommendations to Address Systems-level Gaps

Network analysis has identified several systems-level gaps. These gaps identify areas of the network and the flow of information that should be better linked and integrated. In addition, network analysis has identified a few highly central resources that need to be updated and maintained by the interagency. The recommendations below would help address those gaps identified, with the goal of building a robust and well-connected network of resources that will be useful in providing the necessary information to those who need it when they need it in the context of emergency management.

Improve Network Integration

- Link and integrate orphan resources into the rest of the network
- Connect and integrate widely-used resources, such as EAGLE-I

Increase Support for Highly Central Resources within each Network

- Update and maintain highly central resources, like HAZUS, with interagency support and input
- Ensure the long-term viability of these highly central resources

Improve the Flow of Information within Each Network

- Build resources that provide impact estimates, decision support tools, and mission specific requirements to support all mission spaces
- Develop repositories of impact estimate data that are easily accessible
- Link existing impact estimate resources that are not connected to upstream and downstream resources
- Identify critical information requirements of all emergency support functions in order to develop relevant decision support tools and mission specific requirements that address these requirements
- Link existing mission specific requirements resources that are not connected

Expand the Inventory to other Hazards

- Identify and catalogue resources useful for additional scenarios, including:
    - INDs
    - Biological scenarios
    - Cyber-security scenarios

Conclusions

Conclusions

- Data and/or modeling are used across the interagency and by those involved at all levels of emergency management.
- Producing operationally-relevant information requires iterative steps of data collection and processing.
- The information required to support operational decision making are phase-specific and diverge by mission areas as the event progresses.
- Raw data, situational awareness data, and impact estimates are largely event-specific and used similarly across the interagency, while each agency, division, or group uses their own tools and resources to define mission specific requirements.
- Geospatial data is critical, but information requirements that require quantitative data are not well-captured by existing geospatial tools.
- Modeling resources that provide effective translation of modeling outputs for use during operations is needed.

What is modeling?

When asked about what data and modeling they use, many people initially responded that they do not use models for operational decision making during emergency management. However, nearly all use data, and the vast majority have some type of data processing tool that helps to perform mission specific analysis of data collected over the course of their work prior to or during an emergency. While agencies such as NOAA and USGS require and use computationally intensive, highly complex models to produce the information they are tasked with providing, the majority of the tools used by the federal government to perform data analysis in support of response and recovery missions require, by necessity, only limited computing power and limited training. This difference suggests that the tools available are, at least in most cases, tailored to the needs of the users.

The Questions

The goal of this project is to determine the types of questions that those involved in emergency management across the interagency use data and modeling to address, and to identify existing resources that are useful for operational decision making during emergency management. Despite the breadth of the emergency management community, the questions that data and modeling are used to address during large-scale hurricanes and earthquakes differ more by phase than by mission. The similarity of the questions asked is most marked during the early phases of the emergency when everyone simply needs to know what is going to happen, when, and where. These questions are, for the most part, answered by the work of a few agencies that specialize in event characterization. Similarly, consequence tools that incorporate the situational awareness data produced by the event characterization models are used widely. However, it is of note that these tools are often not used for their intended purpose. Most notably, while HAZUS is a model designed to calculate economic impact, it is used much more broadly; it is used by the vast majority of groups with whom we spoke, and its outputs serve as inputs for a wide array of assessment tools in support of widely varied missions.

The questions that data and modeling are used to address once the event is characterized and the general sense of scope understood are more divergent. However, the data required between missions differ more in resolution than in source. For example, given a single high-rise apartment building, one group may need to know if it has power, another if it has a roof or is structurally sound, and another the special populations who live there. These data interact closely; even if these data are not available from the same source. Therefore, efficient information sharing between agencies is critical.

Iterative analysis

Data collection and analysis are iterative. There is a flow of information between each step of data collection and processing. As the modeling or data analysis becomes more operationally relevant, it becomes less computationally intensive. This progressive simplification and reduction is what allows those in the field to call up mission specific data analysis tools or input assessment data directly via their mobile devices and is also what limits the complexity of each single piece of information so that it can be processed by those who are responsible for tremendous breadth (e.g. the Federal Coordinating Officers and state and local emergency managers), as opposed to those responsible for tremendous depth (e.g. the meteorological scientists at NOAA).

This iteration of data collection and analysis has important implications for the tools themselves. While there was originally a perception that there are many overlapping tools, these results suggest that, just as there are critical roles for both the meteorological scientists and the FCOs in emergency management, so too are there tailored roles for data collection and analysis tools. The key is that information can flow directly from one resource into another, that everyone who needs information at the same level of resolution or detail is able to share information with each other, and that when any one person needs access to information at a different level of resolution, that they know where to find that information.

Notably, this framework applies to state and locals as well as those in the federal government. Upstream data are very often the same feeds that the federal government is producing. The states' major contribution is in providing decision support information—in the form of real-time assessment data—and mission specific requirements. Information from all sources (federal, state, and local) is shared in the same data stream. The extent to which the data come from the federal agencies versus the state and local entities will vary by state. No matter the information balance, the key element in this relationship is the ability to easily share data in both directions. A standard, consistent mechanism to facilitate the sharing of information resources at the federal level would allow states to design their own systems that would integrate with the federal system.

Network and Metadata Analysis

Network analysis can be a powerful instrument to identify important resources within a network and to understand how different resources link to each other and to the entire network as a whole. Such analyses can be used to identify resources that need to be better integrated into the flow of information, so that information generated by these resources are used efficiently by decision-makers when preparing for and responding to an event. Although, analysis of the hurricane and earthquake networks has revealed that these networks are robust and well-connected, several systems-level gaps have been identified. Addressing these gaps, as detailed in the recommendations section, will ensure that the network of resources are better connected and will facilitate the flow of information through them. Ultimately, this will better inform operational decision making and serve the broader emergency management community.

Data Translation for Decision-makers

The first large-scale datasets to become widely available in many fields were maps. Mapping and the use of geo-tagging as a method to organize and process data rapidly became a foundational technology, and has been successfully leveraged to support emergency management operations. The availability of these resources has driven a large number of efforts to develop platforms to make geospatial technologies readily available to decision-makers across the interagency. GeoCONOPS is a powerful example of the potential of these capabilities. The results of this project confirm the value of those efforts in both demonstrating what is possible and developing best-practices that can be followed by subsequent efforts. However, not all data is geospatial or are best conveyed using mapping technology. Specifically, quantitative data are often more effectively communicated through the use of graphs, trend lines, or tables. These methods of data visualization have not been as well-developed for use in emergency management, and the standard mechanisms of sharing these data result in a loss of resolution and of context.

Particularly with the maturing of geospatial technology and data-sharing mechanisms, there is new potential for the development of systems to support the sharing of quantitative data that are as sophisticated, rapid, and successful at conveying information as geospatial methods. This translation will require both understanding the outputs of the models themselves (the quantitative data and associated error) and understanding the time-sensitive and information-overloaded environment faced by operations leads in the field. Furthermore, methods to convey those data in readily-accessible images that can be used on situation reports, published on WebEOC or other information-sharing platforms as data files, and used to brief senior leadership must be developed and matured.

Next Steps

Phases I, II and III of this project focused on elicitation interviews with relevant subject-matter experts, emergency managers and high-level decision-makers to identify the resources used across the federal interagency to support operational decision making during all phases of emergency management. The goal is to produce an interactive inventory of the data and modeling resources used by the interagency. This inventory will be accessible via a graphical user-interface that will facilitate user run queries that will identify the data sets and tools used, as well as the producers and consumers of those resources. The final product will be built in phase IV of the project and will serve to identify the resources that are used most widely or are foundational for other decision support tools. In addition, an in-depth analysis of the hurricane and earthquake resource networks will also be performed, which will continue to highlight gaps in the currently used resources. Ultimately, the goal of the project is to ensure that those involved in emergency management across the interagency have access to the information they need when they need it to more effectively accomplish their missions.

Point of Contact Information

The points of contact for this report are:

Joshua Dozor
Project Lead
Planning Division; Response Directorate
FEMA Headquarters
500 C St. SW
joshua.dozor@fema.dhs.gov

Report prepared by:

Gryphon Scientific, LLC
Ellie Graeden, PhD
Gryphon Scientific, LLC
6930 Carroll Avenue, Suite 810
Takoma Park, Maryland 20912
ellie@gryphonscientific.com
(301) 270-0645

Appendix 1: The ESFLG Modeling and Data Working Group (MDWG) CHARTER

August 6, 2012

1.0 PURPOSE

This charter provides the framework for the establishment and structure of the Modeling and Data Working Group (MDWG). The MDWG is comprised of Emergency Support Function Leadership Group (ESFLG) members or designees and chaired by the Director of FEMA's Planning Division, Response Directorate. The MDWG will:

- Analyze the catastrophic scenarios to be addressed and prioritized;
- Define and assess information requirements for response planning and operational decision making;
- Evaluate existing modeling resources to support the range of scenarios and determine modeling input and output requirements;
- Identify gaps and recommend solutions to meet the modeling input and output requirements.

2.0 MISSION

The MDWG mission is to identify consistent, reliable, authoritative models and data sets for response planning and operational decision making for catastrophic events.

3.0 BACKGROUND

Scientific based models and empirical information products and programs are increasingly used to predict the effects of and inform response planning and operations, particularly when faced with complex, cascading "maximum of maximums" threats and incidents. These models and programs enable decision makers with enhanced situational awareness and heightened visualization of the operational environment to prepare and assess the response to catastrophic events. For example, the benefits of prompt and accurate modeling include improved incident warning, reduction of public anxiety through effective risk communications, and delineation of hazard areas. Both real world events and exercises alike have highlighted a need to standardize these processes and products. However, currently no central mechanism exists to address the doctrine, organizational, training, materiel and leadership requirements necessary to exploit the effective use and coordination of such models and products.

The lack of a formal and standardized approach to integrating scientific modeling and coordinating related technical programs is a challenge to information sharing as well as to the development of effective preparedness plans and responses. The need to develop a standardized framework of modeling across the Emergency Support Function Leadership Group (ESFLG) structure is essential to closing core capability gaps, and improving the overall effectiveness of models for both planning and operations. The MDWG will address modeling and analysis requirements and the most effective ways to exploit emerging data generation products, to include scientific modeling and data sets to meet those requirements.

4.0 MEMBERSHIP

The Modeling and Data Working Group (MDWG) members were nominated by the Emergency Support Function Leadership Group (ESFLG) and will meet on a monthly basis. A list of the voting organizations of the MDWG is attached. The MDWG will address the most effective ways to exploit emerging data generation products, to include scientific modeling and data sets. The working group will determine the most effective programs to incorporate into the ESFLG structure as well as to evaluate implementation success.

5.0 ROLES AND RESPONSIBILITIES

- The MDWG voting members will provide primary and alternate representatives to contribute throughout the process.
- Each primary organization of the MDWG will have a voting responsibility when dealing with modeling and data issues that affect the interagency working group.
- The MDWG gathers and assesses modeling and information requirements for catastrophic scenarios and will provide regular updates to the ESFLG for evaluation.
- The ESFLG will then use the information compiled to work with the Office of Science and Technology Policy (OSTP) and the National Security Staff (NSS) to develop and formalize interagency modeling capability governance and coordination.

6.0 DELIVERABLES

The working group will provide an update status to the ESFLG on a monthly basis.

The working group will provide the following deliverables:

1. Identify and analyze the catastrophic scenarios to be addressed and prioritized;
2. Define and assess information requirements for response planning and operational decision making;
3. Define information requirements for response planning and operational decision making.
4. Develop criteria to evaluate and determine modeling and data source that support requirements
5. Evaluate authoritative modeling and data sources to support catastrophic scenarios; and
6. Identify gaps and recommend solutions to solve the identified modeling and information requirements.
7. Utilize the results from each scenario to inform subsequent scenarios.

7.0 RESOLUTION OF ISSUES AT MDWG MEETINGS

- The working group will utilize the ESFLG structure to resolve interagency coordination issues.

- Any interagency issues that cannot be resolved at the ESFLG level will consult the National Security Staff (NSS) and the Office of Science and Technology Policy (OSTP) for resolution of policy issues.
- Finalize resolution of policy issues will be handled by the Domestic Readiness Group (DRG).

8.0 ESFLG WORKING GROUPS

The MDWG is an ESFLG working group, in accordance with the ESFLG Charter. ESFLG working groups will include appropriate expertise and representation to guide the development of the requisite procedures for response and recovery activities under the National Response Framework (NRF) and National Disaster Recovery Framework (NDRF), as well as Federal Interagency and National planning efforts. Representation on working groups will be open to selected departments and agencies and FEMA Regions as appropriate.

The working group's purpose is to:

- Convene on an ad-hoc basis as designated for specific issues, and disband upon completion of the specific assigned task;
- Address issues that require appropriate department/agency participation for researching and developing procedures to operationalize and execute policy decisions;
- Identify and suggest process improvements to the ESFLG for approval;
- Provide input from subject matter experts; and
- Provide expertise to the Federal response community to address tasks including the research and development of potential options/courses of action and drafting of documents, recommendations, and procedures to improve Federal interagency coordination, integration, and incident response.

9.0 MDWG Primary Voting Organizations

Department of Agriculture

Department of Agriculture/Forest Service

Department of Commerce

National Oceanic and Atmospheric Administration

Department of Defense (OSD, Joint Staff)

Department of Defense/U.S. Army Corps of Engineers

Department of Energy

Department of Energy/National Nuclear Security Administration

Department of Health and Human Services

Department of Homeland Security

Federal Emergency Management Agency

U.S. Coast Guard

Transportation Security Administration
Immigration and Customs Enforcement
Customs and Border Protection
United States Secret Service
Office of Science & Technology
United States Citizenship & Immigration Services

Department of Housing and Urban Development
Department of the Interior
Department of the Interior/National Park Service
Department of Justice
Department of Transportation
Environmental Protection Agency
Small Business Administration

Appendix 2: The ESFLG Modeling and Data Working Group Project Plan

DHS/FEMA

The ESFLG Modeling and Data Working Group (MDWG)

Project Plan

RD-Planning/ESFLG/MDWG/MDWG Project Plan.doc/svc
8/6/2012

Introduction

In July of 2012, both the Department of Homeland Security (DHS) and Federal Emergency Management Agency (FEMA) agreed that FEMA would coordinate the creation and implementation of an interagency Modeling and Scientific Workgroup (MDWG), with the full support and involvement of the Emergency Support Function Leadership Group (ESFLG). At the July 19, 2012 ESFLG meeting, there was concurrence by the ESFLG to form the Modeling and Data Working Group (MDWG) and designate a representative from their department/agency to participate on the MDWG. On July 31, 2012, the MDWG was formed from ESFLG nominations and the August 6th kickoff meeting was announced. The MDWG will assess the current state of modeling systems used, including their owners, requirements, consumers, production processes and means of public messaging. The working group will utilize the ESFLG structure to resolve routine interagency coordination issues. The working group will consult the National Security Staff (NSS) for resolution of policy issues. The purpose of the MDWG will be information gathering – regular updates will be provided to the ESFLG. The ESFLG will then use the information compiled to work with the NSS to develop and formalize interagency modeling capability governance and coordination.

Background

Scientific based models and data generation products and programs are increasingly used to predict the effects of and inform response planning and operations, particularly when faced with complex, cascading “maximum of maximums” incidents. These models and programs enable decision makers with enhanced situational awareness and heightened visualization of the operational environment to prepare and assess the response to catastrophic events. For example, the benefits of prompt and accurate modeling include improved incident warning, reduction of public anxiety through effective risk communications, and delineation of hazard areas. Both real world events and exercises alike have highlighted a need to standardize these products, programs, and processes. A need exists to understand the strengths and constraints of each scientific model and related technical program; enabling the closing of core capability gaps, however, currently no central mechanism exists to address the doctrine, organizational, training, materiel and leadership requirements necessary to exploit the effective use and coordination of such models and products.

The lack of a formal and standardized approach to integrating scientific modeling and coordinating related technical programs is a challenge to information sharing as well as to the development of effective preparedness plans and responses. The need to develop a standardized framework of modeling across the Emergency Support Function Leadership Group (ESFLG) structure is essential to closing core capability gaps, and improving the overall effectiveness of their use in both planning and operations.

Project Plan

The MDWG will address the most effective ways to exploit emerging data generation products, to include scientific modeling, data requirements, and geospatial analysis for catastrophic scenarios. The working group will determine the most effective modeling and data products to incorporate into the

ESFLG structure as well as to evaluate implementation success. Further, Presidential Policy Directive #8 (PPD-8), and specifically the response core capabilities, will inform this process and support this effort.

The MDWG will:

- Analyze catastrophic scenarios to be addressed;
- Assess data requirements for response planning and operational decision making;
- Evaluate existing resources to support scenarios and address data requirements;
- Identify gaps and recommend solutions to solve the data requirements.

Roles/Responsibilities

- The MDWG voting members will provide primary and alternate representatives to contribute throughout the process.
- Each primary organization of the MDWG will have a voting responsibility when dealing with modeling and data issues that affect the interagency.
- The MDWG gathers and assesses modeling and data requirements for catastrophic scenarios and will provide regular updates to the ESFLG for evaluation.
- The ESFLG will then use the information compiled to work with the OSTP and NSS to develop and formalize interagency modeling capability governance and coordination.

Project Management

1. The membership group will establish a charter.
2. The membership group will establish a work plan.
3. The MDWG will meet monthly to discuss working issues.
4. The MDWG Chair will provide an update to the ESFLG on a monthly basis.
5. The MDWG will provide a formal status update to the ESFLG annually.
6. The MDWG voting members will provide primary and alternate representatives to contribute throughout the process.

Deliverables

The MDWG will provide an update status to the ESFLG on a monthly basis.

The MDWG will provide the following deliverables:

1. Identify and analyze the catastrophic scenarios to be addressed and prioritized
   a. Review the 15 National Planning Scenarios
   b. Review other catastrophic scenarios (i.e. flooding, tsunami, solar storms)
   c. Prioritize scenarios and choose pilot scenarios
   d. Establish process and rating scheme for prioritizing scenarios
2. Define and assess data requirements for response planning and operational decision making
   a. Map the data requirements for the pilot scenarios

  b. Identify the response organizations for each pilot scenario
  c. Collect input from the response organizations on their current modeling and data requirements supporting these pilot scenarios
3. Evaluate authoritative modeling and data sources to support pilot catastrophic scenarios
  a. Review the modeling and data requirements of each response organization
  b. Define the lead agency responsible for the modeling and data products
  c. Identify the consumers of each modeling and data product
4. Identify gaps and recommend solutions to meet the identified modeling and data requirements
  a. Determine if the existing modeling and data products are meeting the needs of the response organizations and stakeholder groups (e.g. White House, Public, etc.) in assisting them to make informed decisions.
  b. Develop a matrix to determine gaps in modeling and data requirements for each pilot scenario
  c. The MDWG will vote upon solution sets for each gap identified and recommend these solutions to the ESFLG for review and approval
5. Utilize the results from the pilot scenarios to inform subsequent catastrophic scenarios
6. Provide a formal briefing to the ESFLG annually on work accomplished during the fiscal year.

Appendix 3: MDWG Membership

Name	Agency
Alt, Rich	DHS NPPD/IP (HITRAC)
Anderson, Debra	DHS S&T
Applegate, David	US Geological Survey
Artz, Richard	NOAA
Barrett, Todd	USDA Emergency Programs Division
Bausch, Doug	FEMA
Bennett, Gerilee	FEMA
Berman, Eric	FEMA
Billado, William	DHS IMAAC
Blumenthal, Daniel	DOE/NNSA
Blunt, Kenyetta	FEMA
Bonifas, Michelle	FEMA IA
Briggs, Kevin	NCS
Brown, Cliff	FEMA
Carroll, Shenan	FEMA
Chacko, Betsie	DHS IMAAC
Crawford, Sean	FEMA
Daigler, Donald	FEMA
Dial, Patrick	SBA
Dickinson, Tamara, Ph.D.	OSTP

Dozor, Josh	FEMA
Ewing, Melvin	FEMA
Flick, Darrin	DTRA
Franco, Crystal	DHS S&T
Gilmore, Lance	FEMA
Gleason, Joseph J CAPT	USCG
Gorman, Chad	FEMA
Griffith, David	FEMA NHC
Hammond, Steve	USGS
Hernandez, Patrick	FEMA
Hill, Laura	USDA USFS
Hinkson, Tasha	FEMA
Hodge, Craig	FEMA
Irwin, William	USACE
King, Steve	DHS
Knabb, Richard	NOAA
Landry, Mary	USCG
Lant, Tim, Dr.	HHS
Legary, Justin	FEMA
Leong, Timothy CIV	DTRA
Magnuson, Matthew	EPA
Mahrous, Karim	FEMA
Maycock, Brett	FEMA/Medical Liaison

McQueen, Jeff	NOAA
Monarez, Susan Dr.	DHS S&T
Montañez, José M. Gil	FEMA
Moore, Brian	USCG
Morgan, D'arcy	DHS S&T
Mueller, Lora	NOAA
Murray, Michelle	Department of State
Nye, William	USACE
O’Neill, Ed	Department of State
Olsen, Jennifer	HHS
Reeves, Toimu (Troy)	NORTHCOM
Remick, Alan	DOE/NNSA
Rhome, Jamie	NOAA
Roohr, Peter	NOAA
Sanderson, Bill	FEMA
Schilling, David	DOT
Scott, Margaret	DOE
Snead, Kathryn	EPA
Sokich, John	NOAA
Springstein, Thomas	FEMA
Tribble, Ahsha, Ph.D	NSS White House
Tune, Greg	Red Cross
Underwood, Patricia, PHD	DHS NPPD/IP (HITRAC)

ValentineDavis, Victor	DHS IMAAC
Valliere, John	SBA
Vaughan, Chris	FEMA
Villoch, Deborah	NPPD/IP
Wiacek, Chris	DOT

Appendix 4: Phase I Questionnaire

ESFLG Modeling and Data Working Group Phase I Questionnaire

The MDWG Charter recognizes the need to "develop a standardized framework of modeling across the… [ESF] structure…" Informed by national preparedness goals and the associated core capabilities, this effort will produce an expansive list of modeling and data resources used during all stages of emergency activities. Based on the list generated through informed interviews with experts in each department, the MDWG will ultimately determine the most effective modeling and data products to incorporate into the ESFLG structure and evaluate implementation success. In addition to unifying modeling and data resources in use, this process will identify gaps in currently available modeling and data resources.
The MDWG will:

- **Analyze catastrophic scenarios to be addressed;**
- **Assess data requirements for emergency planning and operational decision making;**
- **Evaluate existing resources to support scenarios and address data requirements;**
- **Identify gaps and recommend solutions to satisfy the data requirements.**

The project will be separated into three phases. This questionnaire is phase I of the MDWG requirements analysis, designed to elicit both general and specific data requirements to inform phases II and III. It is intended for high-level Emergency Managers and Interagency Policy/Planners (Current MDWG group). This questionnaire focuses on two notional "use cases", the Hurricane Ono scenario and the New Madrid Earthquake scenario; other scenarios will be added by exception. Collection of this information is focused on all hazards; notional disasters are used to elicit specific information where appropriate. Phases II and III will involve additional detail and levels of complexity by engaging SMEs with the goal of assessing the volume, velocity, and variety of modeling and data efforts for disaster preparedness, response, recovery, and mitigation. Data will be collated and provided in a report at the conclusion of each phase.

Project Outline

Phase I

Identify how, when, and for what data and modeling are used during planning and operational decision-making in the context of emergency management with a focus on the questions they are used to address

Phase II

Identify and evaluate existing data resources and data sets required to inform planning and operational decision-making during emergency management

Phase III

Identify and evaluate existing data-processing tools, including models and assessment tools, used to derive the information required for emergency management

Phase IV

Collate inventory of existing data, modeling, and assessment resources; identify gaps; and recommend Courses of Action to satisfy requirements

FEMA

SECTION 1: PARTICIPANT AND AGENCY PROFILE

Last Name: **First Name:**

Phone Number (primary): **Phone Number (alternate):**

Fax: **Email Address:**

Work Address:

Home Organization:

Department, Division or Office Name:

Position Title:

1. **Are you considered a program manager, SME or both?**
2. **For which of the following Emergency Support Functions (ESF) does your division support and what is your role (Coordinator, Primary, Secondary)? Select all that apply**

___ ESF #1 – Transportation ___C ___ P ___ S

___ ESF #2 – Communications ___C ___ P ___ S

___ ESF #3 – Public Works and Engineering ___C ___ P ___ S

___ ESF #4 – Firefighting ___C ___ P ___ S

___ ESF #5 – Emergency Management ___C ___ P ___ S

___ ESF #6 – Mass Care, Housing and Human Services ___C ___ P ___ S

___ ESF #7 – Resource Support ___C ___ P ___ S

___ ESF #8 – Public Health and Medical Services ___C ___ P ___ S

___ ESF #9 – Urban Search and Rescue ___C ___ P ___ S

___ ESF #10 – Oil and Hazardous Materials Response ___C ___ P ___ S

___ ESF #11 – Agriculture and Natural Resources ___C ___ P ___ S

___ ESF #12 – Energy ___C ___ P ___ S

___ ESF #13 – Public Safety and Security ___C ___ P ___ S

___ ESF #14 – Long-term Community Recovery and Mitigation ___C ___ P ___ S

___ ESF #15 – External Affairs ___C ___ P ___ S

3. **For which of the following Recovery Support Functions (RSF) does your division support and what is your role (Coordinator, Primary, Secondary)? Select all that apply.**

___ Community Planning and Capacity Building ___C ___ P ___ S

___ Economic ___C ___ P ___ S

___ Health and Social Services ___C ___ P ___ S

___ Housing ___C ___ P ___ S

___ Infrastructure Systems ___C ___ P ___ S

___ Natural and Cultural Resources ___C ___ P ___ S

4. **For which of the following Mitigation Core Capabilities does your division support? Select all that apply.**

___ Hazard Identification

___ Long-term Vulnerability Assessment

___ Risk and Disaster Resilience Assessment

___ Community Resilience

5. **Please provide contact information for the lead modeling point of contact for your function so we can follow-up with them.**

6. **How does the use of modeling and empirical data add to your division's mission?**

7. **How does your division generally use modeling and the associated data sets required to support pre- and post-emergency activities?**

   a) **event preparedness?** *(e.g. risk assessments and threat hazard identification; estimating available capabilities and determining required capabilities)*

   b) **event mitigation?** *(e.g. identifying characteristics and potential consequences of hazards; identifying the benefit of risk reduction efforts)*

   c) **event response?** *(e.g. improving Situational Awareness; establishing response priorities)*

   d) **event recovery?** *(e.g. determining resource requirements; guiding restoration efforts)*

SECTION 2 - DATA REQUIREMENTS

1. **In a scenario such as Hurricane Ono:**

   a) **What data sets do you use to support your modeling efforts? On what types of data are your modeling parameters typically based?**

   b) **From what sources do you obtain the information and data required to support your division's responsibilities? Check all that apply**

   ___ Commercial database provider

   ___ Public Internet

   ___ Informal social network

   ___ In-house library/archive

   ___ Local Government (SPECIFY):

   ___ State Government (SPECIFY):

   ___ National Agency (SPECIFY):

   ___ Other (SPECIFY):

   c) **With whom do you collaborate in defining your data requirements and/or sources?**

2. **In a scenario such as the New Madrid Earthquake:**

   a) **What data sets do you use to support your modeling efforts? On what types of data are your modeling parameters typically based?**

   b) **From what sources do you obtain the information and data required to support your division's responsibilities? Check all that apply**

   ___ Commercial database provider

___ Public Internet

___ Informal social network

___ In-house library/archive

___ Local Government (SPECIFY):

___ State Government (SPECIFY):

___ National Agency (SPECIFY):

___ Other (SPECIFY):

c) With whom do you collaborate in defining your data requirements and/or sources?

SECTION 3 – MODELING APPLICATIONS

1. **How would modeling be used within your division specifically to support pre- and post-emergency activities in the event of a scenario such as Hurricane Ono?** *(e.g. aid in making pre-landfall evacuation decisions; determining required core capabilities and supporting resources)*

   a) **What specific models would you use?**

   b) **Which questions would these models be used to address?**

   c) **Is there an alternate model available that could be used to address these same questions?**

2. **How would modeling be used within your division to specifically to support pre- and post-emergency activities in the event of a scenario such the New Madrid earthquake?** *(e.g. aid in making post-event evacuation decisions; determining required core capabilities and supporting resources)*

   a) **What specific models would you use?**

   b) **Which questions would these models be used to address?**

   c) **Is there an alternate model available that could be used to address these same questions?**

Appendix 5: Phase II Questionnaire

SECTION 1 - PARTICIPANT AND AGENCY PROFILE

Last Name:

First Name:

Phone Number (primary):

Phone Number (alternate):

Fax:

Email Address:

Work Address:

Home Organization:

Department, Division or Office Name:

Position Title:

SECTION 2 – INFORMATION REQUIREMENTS

What information is required for you to make the decisions you need to make during disaster management?

How do these information requirements differ between stages of disaster management (planning, preparedness, response, recovery, and mitigation)?

At what level of resolution do you need that information?

SECTION 3 - DATA SOURCES

From what sources do you primarily obtain the information and data required to support your agency's responsibilities? Check all that apply.

- ☐ Commercial database provider
- ☐ Public Internet
- ☐ In-house database
- ☐ Local Government (SPECIFY):
- ☐ State Government (SPECIFY):
- ☐ Federal Agency (SPECIFY):
- ☐ Other (SPECIFY)

SECTION 4 – SPECIFIC DATA RESOURCES

What data sources does your department, division, or agency own, maintain, and/or fund?

For each of these data sources, please identify:

GENERAL INFORMATION

A. Specific (or potential) use cases for the data in the context of Emergency Management

B. For which phases of Emergency Management is the data most useful?

C. How the data are collected (Survey? Instrumentation? Observation? Regulatory data?)

D. The owner of the data or database

E. The individual or group responsible for updating and maintaining the data

F. Contact information for the database manager or IT specialist (if applicable)

G. Any relevant security restrictions (Who has access to the data? How?)

MAINTENANCE AND UPDATE INFORMATION

H. Are the data updated in real-time for event response and recovery?

IF YES:

1. How are the data uploaded from the field to the database?

2. What are the delays associated with updating the real-time data?

IF NO:

1. How frequently is the data updated?

2. Who is responsible for updating the data?

I. What, if any, QA/QC practices are in place?

DATA COMPATIBILITY INFORMATION

J. Resolution of the data (Census tract? 1 km? Threat or event-specific characteristics?)

K. Exported data formats

USER INFORMATION

L. Do you know of any specific models that use the data as inputs?

1. If so, do you have any relevant contact information for the individuals responsible for running or maintaining that model?

M. Which agencies or divisions use these data to support their decision making process?

N. Which types of decisions could be made using these data?

ADDITIONAL INFORMATION

O. What are the specific strengths of this source of data?

P. What are the weaknesses of this source of data?

Q. How could the data or database be improved?

SECTION 5 - GAP IDENTIFICATION

What sources of data do not have access to when you need them, and why?

What resources or policies would be most helpful to improve the quality of the data you are already using or maintaining?

Which agencies or organizations would you like to collaborate with more effectively to address your data and information requirements?

What agencies, organizations, or individuals would you recommend as excellent providers of data or information? Are there specific best-practices you have found to be particularly useful?

Appendix 6: Phase III Questionnaire

ESFLG Modeling and Data Working Group

Models and Data Analysis Tools Questionnaire (Phase III)

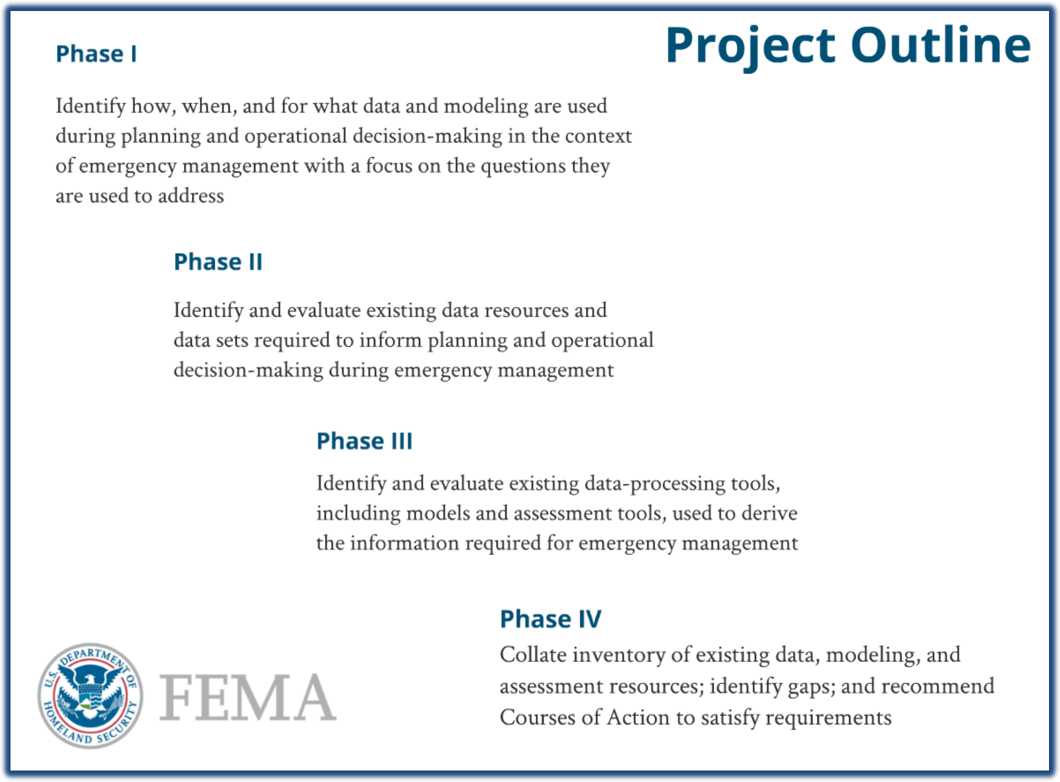
Project Overview

The Modeling and Data Working Group (MDWG) Charter recognizes the need to "develop a standardized framework of modeling across the… [ESF] structure…" Informed by Presidential Policy Directive #8 and the core capabilities, this effort will produce an expansive list of modeling tools and the data resources that underpin those models, categorized by their use in emergency management. This list of resources will be generated through informed interviews with experts in each department and agency represented on or recommended by the MDWG. Ultimately, the group will determine the most effective data and modeling products to incorporate into the ESFLG structure based on their utility across the interagency. Once the data and modeling resources in use have been identified, the gaps in available resources will be defined and courses of action proposed to fill those gaps.

The MDWG will:

- Analyze catastrophic scenarios to be addressed;
- Assess data requirements for response planning and operational decision making;
- Evaluate existing resources to support scenarios and address data requirements;
- Identify gaps and recommend solutions to satisfy the data requirements.

The project will be separated into four phases, as shown in the figure below. This questionnaire is associated with Phase III of the MDWG requirements analysis and is currently used to address the resources available to support operational decision making for emergency management of hurricane, earthquake, and improvised nuclear device scenarios. The goal of this phase of the project is to assess the models and data processing tools used for disaster preparedness, response, recovery, and mitigation. Data will be collated and provided in a report at the conclusion of each phase.



SECTION 1 – PARTICIPANT AND AGENCY PROFILE

Last Name:

First Name:

Phone Number (primary):

Phone Number (alternate):

Home Organization:

Position Title:

Department, Division or Office Name:

SECTION 2 – MODELS AND DATA ANALYSIS TOOLS USED

What models or data analysis tools do you use to support decision making during emergencies?

For each model or data analysis tool you mentioned above, please answer the following.

A. **For which phases of emergency management is the resource most useful to you (planning, preparedness, response, recovery, and/or mitigation)?**

B. **How do you use the resource to support decision making during emergencies?**

C. **Which individual or organization owns the rights to the resource?**

SECTION 3 – MODELS AND DATA ANALYSIS TOOLS OWNED

What models or data analysis tools does your department, division, or agency own, maintain, and/or fund?

3.1 GENERAL INFORMATION

For each model or data analysis tool you mentioned above, please answer the following:

A. **For which phases of emergency management is the resource designed to be used (planning, preparedness, response, recovery, and/or mitigation)?**

B. **During what emergency scenarios is the resource intended to be used?**

C. **Is the output of the resource freely accessible? How is it accessed (i.e. hosted online, downloaded, ordered)?**

D. **Is the resource itself freely accessible? How is it accessed (i.e. hosted online, downloaded, ordered)?**

E. **How frequently is the resource run (i.e. twice a day, once a month, immediately following an event)?** If this depends on the specific phase of emergency management (planning, preparedness, response, recovery, or mitigation) or other factors, please specify.

F. **Who is responsible for producing runs or outputs from the resource?** If this depends on the specific phase of emergency management (planning, preparedness, response, recovery, or mitigation) or other factors, please specify.

G. **Who are the intended users? Who are the known users of the resource?**

H. **Who currently maintains the resource? How is it accessed?**

3.2 TECHNICAL INFORMATION

For each model or data analysis tool you described in the previous section, please answer the following (to the best of your knowledge):

A. **What are the inputs for the resource?**

B. **What are the outputs of the resource?**

C. **Are the outputs of the resource directly fed into any other models or data analysis tools (including your own)? If so, what are they?**

D. **In what file formats are the outputs available (i.e. Excel tables, shapefiles, KML files)?**

E. What are the processing requirements for viewing the outputs of the resource (i.e. supercomputer, desktop/laptop, mobile device)?

F. What are the processing requirements for running the resource (i.e. supercomputer, desktop/laptop, mobile device)?

G. What is the approximate runtime of the resource (e.g. 4-6 hours on a supercomputer cluster)?

H. In what programming language (or on what platform) is the resource coded?

I. What is the current version of the resource and when was it released?

3.3 ADDITIONAL INFORMATION

For each model or data analysis tool you described in the previous section, please answer the following:

A. What are the specific strengths of the resource?

B. What are the limitations of the resource?

C. How could the resource be improved?

D. **What additional data sources would improve the utility of the resource?**

SECTION 4 – COMMENTS AND REFERRALS

Is there anything you would like to mention that was not addressed elsewhere in this questionnaire?

Is there anyone in your group or others that you would recommend that we interview for this study to refine our understanding of these resources and how they are used for emergency management?

Appendix 7: Interviewees

NAME	AGENCY
Buikema, Ed	Argonne National Laboratory
Folga, Steve	Argonne National Laboratory
Gunn, Julia	Boston Public Health Commission
Demarais, John	CAP
St. John, Courtney	Columbia University, Center for Research on Environmental Decisions
Alexander, David	DHS
Billado, William	DHS
Briggs, Kevin	DHS
Chacko, Betsie	DHS
Cole, Ray	DHS
Coller Monarez, Susan	DHS
Cotter, Dan	DHS
Danielson, Glen	DHS
Franco, Crystal	DHS
Klucking, Sara	DHS
Langhelm, Ron	DHS
MacIntyre, Anthony	DHS
Mapar, Jalal	DHS
Maycock, Brett	DHS
Moe, Mathew	DHS
Shepherd, Dave	DHS
Valentine Davis, Victor	DHS
DeCroix, Michele	DHS
Berscheid, Alan	DHS NISAC/HITRAC
Chatfield, Catherine	DHS NISAC/HITRAC
Norman, Mike	DHS NISAC/HITRAC
Stamber, Kevin	DHS NISAC/HITRAC
Aeschelman, Jeremiah	DoD DTRA

Basiaga, Dariusz	DoD DTRA
Blandford, Michael	DoD DTRA
Blandford, Mike	DoD DTRA
Cooper, Charles	DoD DTRA
Grouse, Andy	DoD DTRA
Kahn, Todd	DoD DTRA
Leong, Timothy	DoD DTRA
Lowenstein, Eric	DoD DTRA
Mazzola, Tom	DoD DTRA
Meris, Ron	DoD DTRA
Phillips, Michael	DoD DTRA
Baron, Thomas	DoD NORTHCOM/NORAD
Danaher, Leo	DoD NORTHCOM/NORAD
DeGoes, John	DoD NORTHCOM/NORAD
Friedman, Andy	DoD NORTHCOM/NORAD
Jackson, Mike	DoD NORTHCOM/NORAD
Wireman, Jody	DoD NORTHCOM/NORAD
Allen, Gary	DoD Office of the Secretary of Defense
Gerrig, Dan	DoD Office of the Secretary of Defense
Greenberg, Brandy	DoD Office of the Secretary of Defense
Miller, Brian	DoD Office of the Secretary of Defense
Mullen, Frank	DoD Office of the Secretary of Defense
Sorden, Caryn	DoD Office of the Secretary of Defense
Yu, Leigh	DoD Office of the Secretary of Defense
Blumenthal, Daniel	DoE
Cedres, Stewart	DoE
Clark, Jamie	DoE
Corredor, Carlos	DoE
Favret, Derek	DoE
Fernandez, Steve	DoE
Hsu, Simon	DoE
Lippert, Alice	DoE

Lucas, Anthony	DoE
Rollison, Eric	DoE
Scott, Margaret	DoE
Willging, Pat	DoE
Schilling, David	DoT
Stuckey, Bill	DoT
Vanness, Jeffrey	DoT
Howard, Jeffrey	Dun & Bradstreet
Clark, Steve	EPA
Haxton, Terra	EPA
Hudson, Scott	EPA
Irizarry, Gilberto	EPA
Lemieux, Paul	EPA
Magnuson, Matthew	EPA
Mosser, Jen	EPA
Snead, Kathryn	EPA
Woodyard, Josh	EPA
Almonor, Niclaos	FEMA
Anderson, Lindsey	FEMA
Bahamonde, Marty	FEMA
Bausch, Doug	FEMA
Bellamo, Doug	FEMA
Bennett, Gerilee	FEMA
Berman, Eric	FEMA
Bonifas, Michelle	FEMA
Boyce, Carla	FEMA
Brierly, Mick	FEMA
Brown, Cliff	FEMA
Crawford, Sean	FEMA
Daigler, Donald	FEMA
Decker, K.C.	FEMA
Demorat, David	FEMA

Ewing, Melvin	FEMA
Faison, Kendrick	FEMA
Farmer, Bob	FEMA
Gilmore, Lance	FEMA
Gorman, Chad	FEMA
Griffith, David	FEMA
Harned, Rebecca	FEMA
Hewgley, Carter	FEMA
Hinkson, Tasha	FEMA
Hodge, Craig	FEMA
Huyck, Charles	FEMA
Ingram, Deborah	FEMA
Jackson, Liz	FEMA
Jacques, Richard	FEMA
Juskie, John	FEMA
Kazil, Jacqueline	FEMA
Lawson, David	FEMA
Legary, Justin	FEMA
Longenecker, Gene	FEMA
Lumpkins, Donald	FEMA
McDonald, Blair	FEMA
Pollock, Marcus	FEMA
Preusse, Paul	FEMA
Rabin, John	FEMA
Ransom, Darrell	FEMA
Roberts, Nikki	FEMA
Rogers, James	FEMA
Rozelle, Jessee	FEMA
Sanderson, Bill	FEMA
Schlossman, Mikhail	FEMA
Scott, Kara	FEMA
Sonhaus, Daniel	FEMA

Stanfill, Derek	FEMA
Stuart, James	FEMA
Truax, Wayne	FEMA
Vaughan, Chris	FEMA
Wolfgul, Gus	FEMA
Woodhams, Katrina	FEMA
Wright, Roy E.	FEMA
Wycoff, Kristen	FEMA
Zohn, Ashley	FEMA
Zuzak, Casey	FEMA
Butgereit, Richard	Florida Division on Emergency Management
Baker, Jay	Florida State University
Gabriel, Edward	HHS ASPR
Koerner, John	HHS ASPR
Lant, Tim	HHS ASPR
Lurie, Dr. Nicole	HHS ASPR
Olsen, Jennifer	HHS ASPR
Shankman, Robert	HHS ASPR
Wright, Sue	HHS ASPR
George, David	JHU APL
Taylor, Steven	JHU APL
Waddell, Richard	JHU APL
Alai, Maureen	Lawrence Livermore National Laboratory
Buddemeier, Brooke	Lawrence Livermore National Laboratory
Goforth, John	Lawrence Livermore National Laboratory
Glascoe, Lee	Lawrence Livermore National Laboratory/NARAC
Homann, Steve	Lawrence Livermore National Laboratory/NARAC
Nasstrom, John	Lawrence Livermore National Laboratory/NARAC
Pobanz, Brenda	Lawrence Livermore National Laboratory/NARAC
Simpson, Matthew	Lawrence Livermore National Laboratory/NARAC
Sugiyama, Gayle	Lawrence Livermore National Laboratory/NARAC
Tuttle, Benjamin	NGA

White, Greg	NGA
DiMego, Geoff	NOAA
Draxler, Roland	NOAA
Feyen, Jesse	NOAA
Heffernan, Robyn	NOAA
Knabb, Richard	NOAA
Lapenta, Bill	NOAA
McQueen, Jeff	NOAA
Mitchell, Daisy	NOAA
Mongeon, Albert	NOAA
Roohr, Peter	NOAA
Sokich, John	NOAA
Tallapragada, Vijay	NOAA
Tolman, Hendrik	NOAA
Collins, Andy	Old Dominion University
Jordan, Craig	Old Dominion University
Myer, David	Old Dominion University
Robinson, Mike	Old Dominion University
Tune, Greg	Red Cross
Bynum, Leo	Sandia National Laboratories
John, Charles	Sandia National Laboratories
Jones, Dean	Sandia National Laboratories
Kimura, Margot	Sandia National Laboratories
Knowlton, Robert	Sandia National Laboratories
Kraus, Terry	Sandia National Laboratories
Mahrous, Karim	Sandia National Laboratories
Miller, Trisha	Sandia National Laboratories
Pennington, Heather	Sandia National Laboratories
Pless, Daniel	Sandia National Laboratories
Teclemariam, Nerayo	Sandia National Laboratories
Vurin, Eric	Sandia National Laboratories
Dial, Patrick	SBA

Valliere, John	SBA
O'Neill, Ed	State
Dowell, Earlene	US Census
Pitts, Robert	US Census
Diaz, Steve	USACE
Harris, Dewey	USACE
Hendricks, Joel	USACE
Irwin, Bill	USACE
Keown, Patrick	USACE
Markin, Chad	USACE
Nye, Bill	USACE
Schargorodski, Spencer	USACE
Schuster, Michael	USACE
Town, Patrick	USACE
Gleason, Joe	USCG
Gunning, Jason	USCG
Hunt, Michael	USCG
Landry, Mary	USCG
Lundgren, Scott	USCG
McGlynn, Matt	USCG
Moore, Brian	USCG
Carpenter, Ryan	USDA
Li, Yun	USDA
Collins, Brian	USFS
Erickson, Rod	USFS
Hill, Laura	USFS
Triplett, Sean	USFS
Applegate, David	USGS
Blanpied, Michael	USGS
Gallagher, Kevin	USGS
Haines, John	USGS
Hammond, Steve	USGS

Ludwig, Kris	USGS
Lyttle, Peter	USGS
Mandeville, Charles	USGS
Mason, Robert	USGS
Perry, Sue	USGS
Driggers, Richard	White House NSS

Appendix 8: State and Local Interviewees

Name	Organization	Title
John Madden	National Emergency Managers Association; Alaska Division of Homeland Security and Emergency Management	President, NEMA; Director, Alaska DHS&EM
Jeff Walker	International Assoc. of Emergency Managers; Licking County, OH, Emergency Management Agency	President, IAEM; Director, Licking County EMA
Mark Ghilarducci	California Emergency Management Agency	Secretary
Kathy McKeever	California Emergency Management Agency	Director of Infrastructure Protection
Matthew Hawkins	California Emergency Management Agency	Deputy Commander of the State Threat Assessment Center
Kim Zagaris	State of California Governor's Office of Emergency Services	State Fire and Rescue Chief
James E. Turner III	Delaware Emergency Management Agency	Director
Bryan Koon	Florida Division of Emergency Management	Director
Michael Whitehead	Florida Division of Emergency Management	Florida State Mass Care Coordinator
Richard Butgereit	Florida Division of Emergency Management	Information Management Section Head
John Wilson	Lee County, FL, Emergency Management Agency	Director (retired)
Ken Mallette	Maryland Emergency Management Agency	Executive Director
Jordan Nelms	Maryland Emergency Management Agency	Director of Planning
Michael Fischer	Maryland Emergency Management Agency	Director of Administration

Appendix 9: Metadata Tags

Model/Data

All resources are categorized as either models or data. Models are defined as programs, algorithms, or sets of calculations which may be used for emergency management. Many models accept as input a type of data which they transform into another type to provide new information (e.g., SLOSH, ShakeMap, and HAZUS). Other models collate individual data resources to yield a new dataset with enhanced utility (e.g., WFDSS, which projects the path of wildfires using real-time reports, weather forecasts, and terrain maps). Data are defined as repositories of information that may be used for emergency management. This definition of data encompasses tools which assist in the presentation or visualization of data without transforming the data itself (e.g., FEMA GeoPlatform). Resources that have both modeling capabilities and a repository of their output, or some other data feed, are tagged as both a model and data.

Hazard

Resources are tagged based on the hazards during which they can be used to inform operational decision making. One or more hazards can be tagged for each resource. In prior phases of the project, only hurricanes and earthquakes were considered. Now, resources can be tagged as: hurricane, earthquake, tsunami, inland flood, tornado, chemical release, contagious outbreak, non-contagious outbreak, nuclear detonation, explosion, and radiological release. Resources may be tagged with a single hazard (e.g., NHC Forecasts are tagged only with hurricane) or multiple hazards (e.g., HAZUS is tagged with hurricane, earthquake, tsunami, and inland flood). Additionally, resources that support emergency planning and response for any hazard type are tagged as All-Hazards. The All-Hazards tag is applied to most weather models and forecasts, except those that are specific to a single hazard like HWRF, the hurricane-specific version of the Weather Research and Forecasting model.

Cascading effects were not considered when tagging hazards. Users interested in the cascading effects of a given hazard (e.g., a radiological release from a power plant damaged during an earthquake) would instead search the inventory for the secondary hazard directly.

Supported Core Capabilities, ESFs, and RSFs

The Core Capabilities are designations that represent a list of critical elements within the five mission areas (Prevention, Protection, Mitigation, Response, and Recovery) necessary for Emergency Management.[15] The Core Capabilities are used to assess both the capabilities and gaps over the entire

[15] (2011a) National Preparedness Goal. Department of Homeland Security

federal interagency emergency management community. In order to facilitate this effort, resources are tagged based on which Core Capabilities they support. Each resource may be tagged as supporting one, more than one, or no Core Capabilities. However, it is not always clear which Core Capabilities a given resource may support. This is especially true of raw data, event characterization models, and situational awareness data. For example, it is not immediately obvious which Core Capabilities rely on the National Elevation Dataset (NED) because this data must first be processed before it is useful for emergency management. To address this problem, each resource was tagged with any Core Capabilities it directly supported in addition to any that resources downstream the resource supported. For instance, the NED feeds into PAGER. As PAGER can be used for Planning, Public Information and Warning, Situational Assessment, and Threats and Hazard Identification, the NED is also tagged with those Core Capabilities.

The Emergency Support Functions (ESFs) and Recovery Support Functions (RSFs) provide a coordinating structure for the key functional areas that are most frequently needed in response and recovery, respectively.[16, 17] Identifying the resources that directly support each ESF and RSF will allow emergency managers to ascertain which resources can be used to support their specific missions. Like the Core Capabilities, each resource may be tagged as supporting one, more than one, or no ESFs and RSFs. Resources were only tagged with RSFs if they were also tagged with the Recovery phase (see the 'Phase Specific Utility' subsection). Unlike the Core Capabilities, the ESFs and RSFs are directly used in coordination of federal disaster response and recovery. Therefore, it is only necessary to know which resources directly support each ESF and RSF, and these tags are not inherited from downstream resources as Core Capabilities tags are.

As described in their Framework documents, each ESF and RSF has one Coordinating Agency and one or more Primary Agencies chosen on the basis of authorities and resources. These agency assignments were used in ESF and RSF tagging to help users identify inventory resources useful for their missions. First, based on information from interviews and research, resources were tagged depending on whether those resources were expected to support ESF or RSF missions. In addition, resources were automatically tagged with the ESFs and RSFs for which their federal users were Coordinating and/or Primary Agencies. This approach ensured that the ESF and RSF tags were informed by both interview data and existing policies for emergency management.

Keywords and Resource Functions

In addition to the Core Capabilities, ESFs, and RSFs, resources are further characterized based on their function. Function titles are keywords that are simple titles designed to describe the resources independently of the flow of information. Each resource may be tagged with one or more function titles. For example, observational weather data, a raw data resource, the Global Forecast System (GFS), an

16 (2008) National Response Framework. Federal Emergency Management Agency
17 (2011b) National Disaster Recovery Framework. Federal Emergency Management Agency

event characterization model, and the NHC Forecasts, a situational awareness data resource, are each tagged as with the keyword 'Atmospheric,' even though they have different flow of information categories. Additionally, resources may be tagged with more than one keyword. For instance, the National Bridge Inventory (NBI) is tagged with both 'Infrastructure' and 'Transportation'.

In order to provide an even higher level of resolution for the functions of resources included in the inventory, the keywords are further split into categories based on the flow of information. Each resource may be tagged with one or more resource functions. These resource function tags provide a succinct description of the utility of a resource, both with regards to situations for which the resource is relevant and how it is incorporated into the flow of information. In the previous example, observational weather data is tagged as 'Atmospheric Raw Data,' the GFS is tagged as an 'Atmospheric Event Characterization,' and the NHC Forecasts are tagged as 'Atmospheric Situational Awareness Data.'

Resource Type

Resource types are directly drawn from the flow of information categories. As outlined in the phase II report, data are categorized as raw data, situational awareness data, impact estimates, and/or mission specific requirements, while models are categorized as event characterization models/analysis, consequence models, and/or decision support tools. Each resource may be tagged as one or more resource types. Modeling resources that are useful as multiple resource types can also have multiple tags. Multi-tagged modeling resources represent models that perform multiple, successive steps of data processing. Similarly, data resources that are useful as multiple resource types can have multiple tags.

Data Collection Method

Data can either be generated as model outputs or aggregated and analyzed. There are three primary methods of data collection: instrumentation, reporting, and the use of social media and crowd-sourced data. Data that are collected, aggregated, and processed directly (i.e., not generated as the output of models) fall into one or more of these three categories. It is important to specify the methods used to collect the data within an information resource because collection methods influence the availability, accessibility, and error associated with the resource. Each method of data collection generates observations with varying resolution, uncertainty, delays, and personnel commitments.

Instrumentation Data

Instrumentation data, as its name suggests, are obtained through the use of instruments that are capable of recording repeated observations. Often, but not always, data collected by instrumentation is raw data and requires processing by event characterization models or analysis before it can be used in support of decision making.

Successful collection and aggregation of instrumentation data requires investment in a data collection infrastructure which must be developed and deployed before an event occurs to collect and transmit the data in real time. The collection of instrumentation data, then, requires significant pre-event investments. Observational weather data, seismograph data, and storm-surge data are all examples of instrumentation data. Failure to pre-position assets — for instance, temporary storm surge sensors that are used to collect the information shared through USGS's Storm Tide Mapper — can result in an incomplete network through which to collect, access, and process instrumentation data.

Examples of instrumentation data appear in Table 11. These examples are not intended to be all-inclusive, and they are used here for the purpose of illustration. An inventory of instrumentation data identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 11. Instrumentation Data. These examples are specific to hurricane and earthquake scenarios.

Data Resource	Resource Provider	Hazard(s)	Data Collection Method(s)
USGS Earthquake Feeds & Data	USGS Earthquake Hazards Program	Earthquake	instrumentation, social media and crowd-sourcing
NOAA Tides Online	NOAA National Ocean Service	Hurricane	instrumentation
Storm Tide Mapper	USGS Office of Surface Water	Hurricane	instrumentation
Hazards Data Distribution System	USGS EROS	Earthquake; Hurricane	instrumentation
Post-event aerial imagery	Multiple agencies, coordinated by FEMA	Earthquake; Hurricane	instrumentation

Reporting Data

Data collected through human observation or non-automated data entry are considered reporting data. These data include damage assessments, hospital records, and critical infrastructure locations. While many types of instrumentation data can be continually collected without the need for large numbers of personnel during an event, reporting data generally take longer to collect and aggregate, and they demand larger personnel investments. Thus, reporting data are typically available at different resolutions and after longer delays than instrumentation data.

Examples of reporting data appear in Table 12. These examples are not intended to be all-inclusive, and they are used here for the purpose of illustration. An inventory of instrumentation data identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 12. Reporting Data. These examples are specific to hurricane and earthquake scenarios.

Data Resource	Owner	Hazard	Data Collection Method
Proprietary petroleum and natural gas data	USCG Regional Offices, DoE	Earthquake; Hurricane	reporting
OnTheMap	Census Bureau LEHD	Earthquake; Hurricane	reporting
HSIP	NGA	Earthquake; Hurricane	reporting
Scribe	EPA OSC	Earthquake; Hurricane	reporting, instrumentation

Social Media and Crowd-sourced Data

There is considerable interest across the interagency in developing methods to use social media data to support decision making in a way that accounts for the inherent uncertainty associated with it. Particularly in instances where traditional data feeds are unable to address a question, social media has the potential to serve as a valuable resource.

Crowd-sourced data are also being used to inform and validate operational models and decision support tools. For example, during Hurricane Sandy, when many citizens and disaster relief workers in the Northeast struggled to identify sources of fuel, several FEMA employees reported using Gas Buddy, a crowd-sourced mobile application that allows users to identify gas stations that are up and running. The Department of Energy's EAGLE-I tool is fed in part by data obtained through the Twitter accounts and webpages of private electric power companies. As much of the data regarding electric power outages is proprietary, the use of social media allows the Department of Energy to gather open-source data that otherwise may not be readily available.

The National Operations Center, or NOC, run by the Department of Homeland Security, uses social media as an ongoing way to monitor current events. In the case of the April 15th Boston Marathon Bombings, the NOC Media Monitoring Center was able to provide situational awareness data regarding the bombings several minutes before major media outlets broke the story. In the case of the NOC Media Monitoring Center, Twitter feeds and other forms of social media serve as sources of raw data that are aggregated and processed to provide rapid, first-pass situational awareness data.

The concern expressed most frequently about crowd-sourced and social media data is the difficulty in quantifying error. Although there is ongoing research to develop new ways of quantifying this error, these data are still primarily used as supplemental sources of information, and they are not expected or intended to replace traditional, authoritative data resources.

Examples of social media and crowd-sourced data appear in Table 13. These examples are not intended to be all-inclusive, and they are used here for the purpose of illustration. An inventory of social media and crowd-sourced data identified so far is included in the Data and Models Resource Catalog in Appendix 10.

Table 13. Social Media and Crowd-sourced Data. Examples specific to hurricane and earthquake scenarios.

Data Resource	Owner	Hazard	Data Collection Method
Did You Feel It?	USGS Earthquake Hazards Program	Earthquake	social media
Facebook	Facebook	Earthquake; Hurricane	social media

Owner

The agency, division, or group responsible for updating, maintaining, and validating a given resource is identified. As specific contact information and organizational structures may change over time, specifying the entity in control of a given resource will ensure that it continues to be accessible, regardless of personnel changes or reorganization within agencies. If a resource has more than one organization that is in control of the resource, both organizations are listed as an owner.

User (Agency-Level)

Resources are tagged with known members of their user communities. Here, users are defined as federal level organizations who directly apply information from the resource in order to answer a policy- or operations-related question in support of their missions for emergency management. Therefore, for the purposes of this project, state and local governments as well as private sector or academic organizations were not considered users (with the one exception of the Red Cross).

It is necessary to note that, while it is informative to tag resources with their known users, this is not the only way to judge the utility or reliability of a resource. New or recently updated resources may be underrepresented due to a lack of familiarity within the emergency management community. Similarly, it is also useful to consider the quality control methods used to verify and validate a given data resource. In any case, identifying the existing user communities who regularly use specific information resources in support of decision making allows both users and producers of these resources to work together in a process of ongoing development, evaluation, and maintenance.

Upstream and Downstream Inventory Resources

Based on the understanding that data collection, analysis, and modeling is an iterative process, the data and models that lay upstream of a given resource (i.e., those that serve as inputs for that resource) are defined. Complementary to the upstream resources category, downstream resources list the data and models that are fed by a given resource. This information indicates the datasets and models that use the resource as an input. It is important to identify the data and modeling resources that are interdependent, as validity of any model relies heavily on the accuracy of its inputs.

Phase Specific Utility

To assist users in determining which inventory resources are most relevant to their missions, the resources are tagged with the phases of emergency management for which they are useful. The phase tags are planning, pre-event preparedness (only for advance-notice events), immediate response (within approximately 36 hours following the event), deployment, sustained response, and recovery. Resources are phase-tagged based on their potential uses, not only their known ones. Thus, a resource which has been used for planning but which could likely be used in the immediate response phase would carry both tags. A resource may be tagged by one or more of the listed phases.

Summary

A brief summary of each resource is provided to capture key usage and feature information.

Access Information

The procedures or credentials necessary to view, use, or update a resource are also defined. Resources can either be open access (immediately available to anyone or only requiring a free, automatic registration) or limited access (which can include proprietary data, classified data, or data that requires permission to access). Each resource may only be tagged as limited access or open access. These two tags are mutually exclusive. If possible, specific instructions on how to access the resource are included.

Access Type

There are three primary ways a model can be run: standalone, through reachback, or through interaction with a subject matter expert. Every model is tagged as one or more of these three access types. If a resource can be run through multiple sources, then it is tagged accordingly.

A model tagged as standalone describes any resource that can be run by any individual with access on a personal computer. A model tagged as reachback is accessed through a reachback facility. This tag refers to resources run and managed by specific organizations and accessed through formal Requests for Information. A model tagged as subject matter expert is defined as any model that can only be accessed through personal interactions with the model developer or owner. Often, the outputs from these models can be accessed by the public online but the model itself is restricted for use by the subject matter expert. This also includes models run on a schedule, based on computing limitations, that precludes additional runs of the model outside the set schedule.

Processing Requirements

The processing requirements for viewing a data resource or running a model are given in relatively broad terms. Rather than detailing the exact system specifications needed to use each resource, their processing requirements were generalized into three categories: supercomputer, desktop/laptop, and mobile device. Resources are only tagged with 'mobile device' if they have a dedicated mobile application. Likewise, an Internet-based resource that could be accessed with a mobile browser is not tagged with 'mobile device' unless its website is optimized for mobile viewing. In certain cases, a resource may be tagged with two of the three processing requirements. For instance, a weather model that can be run on a desktop computer but is often run on a supercomputer would be tagged as both 'desktop/laptop' and 'supercomputer.' Similarly, a resource run on a desktop application with the same capabilities would be tagged with both 'mobile device' and 'desktop/laptop.'

Refresh Rate and Last Known Version

During all phases of emergency management, frequently updated resources are necessary to inform all levels of decision making. If the information is available, resources are tagged based on their refresh rate (how often they are updated). For data resources, this category specifies how often new information is uploaded into the dataset. For models, it indicates whether the model is routinely run, and if so, how frequently. For example, NOAA's Deep-ocean Assessment and Reporting of Tsunamis (DART) system updates every 15 minutes during normal operations and approximately every minute during activation. On the other hand, NHC Forecasts are re-run approximately every 6 hours. If possible, the last known version of the resource is indicated.

Not all data used to support decision making during emergency management can or should incorporate real-time data. While ground shaking data and observational weather data must be updated every few minutes to reflect current conditions, data regarding the locations of critical infrastructure or residential building codes do not require the same update frequency to be operationally relevant. For datasets that do not consist of real-time data, the last known version of the dataset (often a release date) is indicated.

Similarly, not all models can or should be automatically run. While automatically refreshing weather forecasts are required for up-to-date situational awareness, many of NOAA and NHC's weather forecasting systems are run on a predetermined schedule because of the processing limitations of their supercomputers. This means that many of these models can only be run on their predetermined schedule and cannot be run more frequently during activation. As with datasets, the last known version of the model is indicated to ensure users are aware of the most recent release.

Programming Language

When possible, the programming language in which a resource is coded is given. This metadata category is not only important for developers interested in updating, modifying, or adapting a resource, but it may also provide essential compatibility information, indicating whether or not a resource can operate on a certain computer platform.

Output File Type

If relevant, the file type for a data resource or the file type for the output of a model is given. This information can be used by a model developer or analyst when determining data compatibility or other technical issues. It can also be used to indicate software requirements. If resources are capable of outputting multiple file types, then every file type it is capable of creating will be listed.

Technical Contact Information and Contact during Activation

The contact information for the group or individual responsible for updating, maintaining, or granting access to each resource is provided. When possible, coordinates for specific individuals are listed. Contact information always contains the organization or agency and, if applicable, the division of the contact in case of personnel changes. Where applicable, an additional contact is listed for use during activation.

Appendix 10: Data and Models Resource Catalog

The resource inventory is attached separately as an Excel table.