ABSTRACT
To support the successful integration of civilian and military domestic disaster medical response, the Yale New Haven Center for Emergency Preparedness and Disaster Response (YNH-CEPDR) and US Northern Command (USNORTHCOM) have established the National Center for Integrated Civilian-Military Domestic Disaster Medical Response (ICMDDMR). As part of the ICMDDMR, YNH-CEPDR has conducted research to determine the requirements of a national operational epidemiological modeling process to integrate modelers with operational decision makers during an infectious disease event of national significance. This article presents a proposed process that is based on research and consultation with a workgroup of interagency and organizational stakeholders.

INTRODUCTION
The National Health Security Strategy (NHSS) recognizes that in order to protect the nation from public health threats, it is critical for responders, the private sector and federal, state, and local government to work together. During a public health emergency, decision makers often require prospective epidemiological information that can be provided by epidemiological models. Without a coordinated process linking decision makers with modelers, leaders may become overwhelmed with the amount and complexity of information received, or the proper information may not be provided in a timely manner. Additionally, it is difficult for the non-specialist to rapidly confirm the validity of each model, potentially undermining confidence in the information from the models to make critical decisions.

There is currently no formalized process among US government agencies and departments to support effective coordination between modelers and decision makers. Moreover, there is no way for decision makers to request operational epidemiological models unless their respective organization has pre-existing capabilities and/or relationships to solicit operational epidemiological models. And yet, the nature of a complex biological event requires decision makers to have access to the kind of information that can be provided by such models. Articulating this point, the Institute of Medicine (IOM) identifies the need to “improve information management, including scenario modeling and forecasting.” An integrated national process for operational epidemiological modeling would support improved information management in a health emergency.

DETERMINING THE REQUIREMENTS OF A NATIONAL OPERATIONAL EPIDEMIOLOGICAL MODELING PROCESS
This study sought to understand the nature and scope of existing relationships between modelers and decision makers prior to determining the requirements of a national operational epidemiological modeling process (NOEMP). The research team conducted a literature review, which included reviewing government publications and reports, peer-reviewed articles, and agency/organizations’ policies and mandates. The literature review focused on describing the scope of the policy landscape for the use of operational models, roles, and
responsibilities in an infectious disease disaster response. Associated mission statements, organizational structures, and operational capabilities of various agencies were also captured.

Concurrently, stakeholders were engaged through an interagency workgroup that included members of the epidemiological modeling community as well as the health and medical consequence management communities. (Workgroup members served as subject matter experts, but their participation should not necessarily be considered an endorsement or acceptance of findings.) Workgroup members were recruited through existing relationships and included subject matter experts employed by federal agencies (including the Departments of Agriculture, Defense, Health and Human Services, and Homeland Security), state and local public health agencies, national laboratories, academia, and private sector “think-tank” organizations. The workgroup identified information sources for agency/organizational research and reference, and provided reviews of preliminary documents from this study.

The research indicated that a national operational epidemiological modeling process should be structured around three distinct priorities:

1. Develop an interagency process that establishes and cultivates relationships between model developers and operational coordination structures for incorporation of models into response planning, execution, and evaluation;

2. Increase availability of models and model outputs that support operational decision making;

3. Enhance ability of operational coordinators to integrate models into their information analysis processes for decision support.

Once the study team completed the literature review, the stakeholder workgroup convened in Arlington, VA, on August 11, 2011, to determine the requirements of a national operational epidemiological modeling process. This meeting identified the following components of a successful National Operational Epidemiological Modeling Process (NOEMP):

1. Functions via diverse interagency workgroup rather than single organization;

2. Operates with administrative and fiscal management provided by a lead agency;

3. Develops and aligns modeling guidance and standards with available funding streams;

4. Directs funds to models designed to support decision making;

5. Channels funds to local and state public health departments and other similar users to mitigate shortfalls;

6. Leverages existing federal modeling infrastructures;

7. Accommodates the diverse missions of stakeholders;

8. Enhances the use of models during an operational response, including sharing models and model outputs within and between agencies/organizations.

Several events were held with stakeholders to gain direction and input as the NOEMP was being refined. Near the end of this phase of the research, the study team presented and discussed the draft NOEMP to the stakeholder workgroup on November 10, 2011, via a web-based tool (WebEx™ Training Session 5.5). The stakeholders provided substantive feedback leading to additional revisions. The study team presented the revised process in a scenario-based, exercise environment to a small group during the Public Health Preparedness Summit in Anaheim, CA, on February 21, 2012 in a blended web-based and in-person format (also utilizing WebEx™ Training Session 5.5). Exercise players included workgroup members as well as external public health stakeholders with no previous knowledge of the NOEMP. The NOEMP was revised further and is presented below.
PROPOSED NATIONAL OPERATIONAL EPIDEMIOLOGICAL MODELING PROCESS

PURPOSE AND SCOPE

The NOEMP is defined as a national “process” that aggregates efforts of people, tasks, and organizations operating for the common purpose of effectively integrating models with prospective infectious disease response decision-making. The purpose of the NOEMP is to establish and maintain a national capability to produce infectious disease modeling outputs that are supportive of a broad range of information requirements among agency/organizational consequence management Operational Coordinators (OC). OC are defined in this study as the staff responsible for coordinating the flow of information to and from policy decision makers and tactical capabilities within an agency or organization. They are also responsible for identifying external sources of information and providing sufficient analysis of the information to allow decision makers at policy and agency/organizational tactical levels to make well-informed decisions. The NOEMP will allow the OC to integrate this prospective information into their decision support process and give them the ability to include not only the information provided by the NOEMP but also other models developed and executed outside of the NOEMP.

The process recognizes the following types of models as providing information that is relevant across a broad spectrum of decision types and decision makers:

- **Impact Models**: Forecast the impact of an infectious disease on such activities as the ability to continue essential services, maintain Critical Infrastructure and Key Resources (CI/KR), and the economy.
- **Intervention Models**: Predict the impact of intervention strategies on a disease’s direction, intensity, and impact on a population. These models provide insight into potential countermeasure policy and operational questions (e.g., awareness, preparation, prevention, response, and recovery mitigation strategies).
- **Spread Pattern Models**: Forecast the spread patterns of disease, utilizing relevant demographic, social, and geographic information of the population, in a given time frame.
- **Intensity Models**: Forecast the severity of the disease burden in terms of morbidity and mortality within a given time frame.

To better establish regular and sustainable progress in disseminating model information products, a phased approach to incorporating the process should be considered. The first phase should be limited to models that forecast the impacts of infectious disease outbreaks and of intervention strategies at a national level and, where data is made available, at state and local levels. The second phase should expand to include spread and intensity models. The models should not be exclusive to human models, but should also include models on diseases in animal populations and vegetation that potentially impact human health (consistent with the One Health concept). The process should aggregate and disseminate model outputs to a broad spectrum of operational coordination structures within response agencies. The process should include a catalogue of relevant models in order to maintain awareness of national capabilities for operational epidemiological modeling, as well as to facilitate potential modeler and OC relationships.

Outlined below is a proposed inter-agency/organizational structure with tangible capabilities that can be effectively coordinated and implemented during an emergency for the benefit of all stakeholders.

GOVERNANCE STRUCTURE

This study recommends that the NOEMP be governed by the Interagency Operational Modeling Advisory Group (IOMAG). The IOMAG should be led by and include representatives from the federal interagency, and have representation from state, local, county, and tribal governments, and private and academic sectors (see Figure 1).
advisory body should be integrated into an existing strategic, federal interagency biosurveillance governance structure under the rules and regulations established by the Federal Advisory Committee Act (FACA). The role of this advisory committee should be to provide guidance and recommendations to its affiliated inter-agency governance structure on strategic topics to:

- Provide strategic direction of the national operational epidemiological modeling capability;
- Review and approve guidance for operational model development for inclusion in the NOEMP;
- Review and approve NOEMP policy;
- Determine measures of effectiveness and regularity of reporting (e.g., steady state and response);
- Facilitate interagency coordination;
- Advise on operational epidemiological model funding priorities, and research and development strategies;
- Ensure existing epidemiological modeling capabilities are leveraged and redundancies are avoided;
- Coordinate and advise on operational priorities for epidemiological modeling during an event of national significance.

**Figure 1 – NOEMP Proposed Structure**

**ADMINISTRATION AND MANAGEMENT**

The administration and management of the NOEMP should be integrated into an existing management structure that can coordinate the human resource and financial needs of this process. Additionally, this management structure should be able to provide overarching quality assurance and quality control processes and will have pre-existing relationships and complimentary information products for supporting a common operating picture among the biosurveillance community. The creation of a program manager position for Model Integration and Dissemination may be required to ensure the functioning of a Model Integration and Dissemination Unit (see below) into the existing management structure.

**OPERATIONAL CAPABILITIES**

Operational activities should be carried out by a newly created Model Integration and
Dissemination Unit (MIDU) with the existing management structure under the leadership of the Model Integration and Dissemination Program Manager. The MIDU should include analytical staff that is responsible for all operational activities of coordinating among stakeholders, integrating model outputs into the NOEMP, analyzing model parameters and outputs, and developing/disseminating information products to stakeholder OC. The positions and general responsibilities are outlined in Table 1.

Table 1 – MIDU Position Expertise and Duties

<table>
<thead>
<tr>
<th>Health and Medical Operations Analyst</th>
<th>Information Product Analyst</th>
<th>Epi Modeling Technical Analyst</th>
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<tbody>
<tr>
<td><strong>Expertise includes:</strong></td>
<td><strong>Expertise includes:</strong></td>
<td><strong>Expertise includes:</strong></td>
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<tr>
<td>• Coordination of health and medical response operations</td>
<td>• Health and medical operational decision making processes</td>
<td>• Mathematical model development</td>
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<td>• Identification of information requirements and information sources for operational decision making</td>
<td>• Visual analytics</td>
<td>• Epidemiology or infectious diseases data standards</td>
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<tr>
<td>• Integration of model information with health and medical response operation</td>
<td>• Technical/graphical systems for communicating information</td>
<td>• Data management and aggregation</td>
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<td>• Communications policy and guidance development</td>
<td>• Technical policy and guideline development</td>
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<tr>
<td><strong>Duties include:</strong></td>
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<tr>
<td>• Support model output analysis and summarization</td>
<td>• Coordinate with Operational Coordinators to determine information requirements from model outputs</td>
<td>• Draft model validation and verification requirements for IOMAG review/approval</td>
</tr>
<tr>
<td>• Draft content for information products</td>
<td>• Develop templates for dissemination of model outputs</td>
<td>• Develop model output technical requirements (in collaboration with all MIDU analysts)</td>
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<td>• Maintain relationships with Operational Coordinators</td>
<td>• Develop/maintain list of Operational Coordinators to receive information products</td>
<td>• Run existing models, or solicit model outputs from external model developers as needed</td>
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<tr>
<td>• Draft policy/guidance to prioritize research and develop initiatives based on information requirements of Operational Coordinators</td>
<td>• Disseminate model outputs as needed</td>
<td>• Determine/review model parameters based on surveillance information</td>
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<td>• Coordinate the integration of models into the NOEMP</td>
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<td>• Provide technical assistance to external partners developing models for the NOEMP</td>
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<td>• Determine data input standards for the receipt and integration of data into NOEMP models</td>
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The MIDU will also require the capability to provide operational epidemiological model outputs for information products. Some models will need to be procured or may be submitted from external partners and may be run by the MIDU modeling technical analyst(s). The MIDU analyst(s) must have an understanding of how the models operate and their associated limitations, so the models can be utilized to provide information during response operations. The models’ outputs should be in a format that allows for analysis by the MIDU health and medical operations analyst(s) and information product analyst(s). External partners may be leveraged for the model development, data input, and model running processes as well; however, these external partners must be able to provide appropriate model outputs as requested by the NOEMP. In order for information products to be provided to the OC, the model outputs must be analyzed by the MIDU’s health and medical operations analyst and information product analyst. After analyzing outputs the analysts will create information products for use by the OC.

The activities performed would be distinguished between two types of operations: steady-state operations and response operations (see Figure 2). The steady-state operational period is considered to be the time period when the MIDU is not activated by a federal agency. The response operational period is the time period when the MIDU has been activated by a federal agency to provide epidemiological information.

**Figure 2 – MIDU Activities**

**Steady-State Operations**

During steady-state operations the NOEMP should work with stakeholders to determine how information results will be produced and presented to the requester once the information provided by the model has been analyzed. By engaging stakeholders early in the process, the NOEMP can then leverage these established relationships to conduct exercises and provide modeling support during small-scale incidents in order to refine the process that will be used during response...
operations of national significance. Stakeholders will then be able to provide guidance and insight into the validation and verification processes they currently use and assist in determining the minimum acceptable validation and verification standards for the NOEMP.

The NOEMP should also have the ability to operate as a referral service for those agencies having specific model requests that could not be fulfilled by the organization. This ability will be gained through the relationships established with model development organizations. During the steady state period the organization may provide support to communities to provide targeted infectious disease outbreak support.

During the initial phases of the implementation of the NOEMP, research priorities will need to be established based on identified epidemiological modeling gaps and the MIDU should work to close those gaps by developing in-house models. As stated earlier, standards will be identified for the type and amount of data gathered for the model process, model run-time, and the levels of analysis to be conducted on the model outputs. Decision makers and OC will have such a variety of information that it may not be possible for the NOEMP to close all identified gaps, therefore, some models may be submitted for use to the MIDU but will need to be executed by external organizations. Policies and procedures will need to be created for the submission of models by external agencies. Examples of these policies and procedures may be the amount of time it takes for a model to create outputs, on-going model maintenance, and type of information being analyzed. As discussed above, validation and verification standards will also need to be developed/adopted for both model outputs from internal and external models. The stakeholders will need to be involved in this process in order to ensure that information products are accepted by their agencies.

**Response Operations**

The MIDU will need to establish response triggers, which will pre-determine how involved the MIDU will become with an infectious disease outbreak. The established triggers may be based on population size, proximity to borders, or the MIDU may provide information based on direct orders from federal officials. These triggers for transition to response operations should be distinct from decision making for outbreak support and exercise participation during steady-state operations. (It is also understood that other variables beyond triggers will also influence level of effort by MIDU).

When the NOEMP is “triggered” or otherwise called upon during a response, MIDU staff members should be redirected from steady-state operations to focus on processing all collected information and creating information products for dissemination. The information should be gathered by running models within the organizations or by reaching out to modeling organizations and requesting specific model outputs. This data will be integrated into information products that will be provided to external OC. Information product development will be based on the collaboration with OC during the steady-state operational period. The NOEMP should maintain its role as a referral agency if information requests were made that could not be fulfilled with cataloged models or if the organization was unable to develop the appropriate model within the operational time period. The stakeholder relationships established during the steady-state operational period will be critical during the response period. Those that have interacted with the organization prior to a response situation will be educated on the processes and will be familiar with the information products produced by the MIDU.

The timeframe for making decisions is variable, so is the time required for running models. It is recommended that the NOEMP provide information products on a daily schedule initially. This will narrow the scope of models that can be run to those that can produce usable outputs in less than twenty-four hours, and will target decisions that can be informed by daily updates of information. As the NOEMP is developed further and the understanding of health and medical decision making and the field of operational epidemiological modeling matures, the frequency and types of reporting may be expanded with a long term goal of being able...
to accommodate four to six hour decision cycles for events of national significance.

**Data Collection/Management**

The output of the models for information dissemination will only be as good as the surveillance data that is provided to run the models. Additionally, the timely collection of data will be required in order to rapidly receive and aggregate model outputs. In order to accomplish this it will be necessary for the NOEMP to be co-located with a national biosurveillance center or to have a close relationship with those who have pre-existing relationships with sources of biosurveillance data.

Additionally, the NOEMP may need to be able to work with de-personalized data from state and local sources and to ensure the privacy and integration of the data from those OC who are providing it. This may require the use of partially aggregated data from the local and state surveillance systems. Automation of data sharing should also be recognized as an important factor in receiving data from surveillance systems that may not have staffing to devote to providing data during response activities.

In order to collect data, the OC providing it should also have the opportunity to realize jurisdictional value for their efforts. Therefore, it is proposed that they provide epidemiological information to the MIDU through an established process on a set schedule during the steady-state operational period. By providing information to the MIDU, during a response OC may receive data run specifically for their information as well as the aggregate national data. The agencies participating during steady-state operations may also be given a priority status for information dissemination during a response operation.

**LIMITATIONS OF A NATIONAL OPERATIONAL EPIDEMIOLOGICAL MODELING PROCESS**

The NOEMP, as proposed, is intended as the beginning of a process that will grow and mature over time. Specific decision-making questions of a jurisdiction and/or agency may not necessarily be accommodated through a broad reaching national process nor will a national process be able to accommodate every response at the federal, state and local level. Model information will be variable based on the models that are run and the data that is available. This variability should be embraced as a reality of forecasting the spread of disease within a social environment and be integrated into model output information products. Additionally, the science of health and medical operational decision-making is an emerging area of research and will need to continue to grow to provide the NOEMP with critical understanding of the desired impact of information products and model outputs. Epidemiological modeling is a well-established scientific practice; however, the application to operational decision making is not as widespread and will require a coordinated effort among the scientific and academic communities to ensure a supply of appropriate models for the NOEMP. As the fields of health and medical operational modeling and decision making grow, the NOEMP will grow in tandem, providing a critical linkage between scientific analysis and operational decision making. Finally, there are limited opportunities to test models, particularly for rare catastrophic events and incidents of bioterrorism. The parameter sets for infectious disease models will be inherently limited, as they will be based on historic data and subject matter expert conjecture. While efforts can be made to keep parameter information near real-time through advanced surveillance data, this will always be an assumption imbedded into models.

**CONCLUSIONS**

A NOEMP should be structured in a way that engages the interagency and other stakeholders in a manner that is conducive to collaboration among varying sets of capabilities and information requirements. The core function of the NOEMP should be to ensure that OC are able to obtain information products with modeling information within a timeframe that can support operational decision making. Additionally, the NOEMP
should also have awareness of the modeling community and consequence community in order to foster relationships and refer potential partners to one another for long-term collaboration. The creation of the MIDU will provide an operational vehicle that can support these functions as a dedicated resource.

The implementation and operation of the NOEMP should seek to leverage existing funding and operational structures to ensure the prudent use of fiscal resources as well as to integrate effectively within the interagency and other stakeholders. The implementation process should be tiered over several years and have clear capabilities that provide early and sustainable value to response operations.

The successful establishment of the NOEMP will require ongoing collaboration and participation of stakeholder agencies and organizations.

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ACKNOWLEDGEMENTS

This manuscript was developed as part of work performed under DOD Contract No. W911NF-07-D-0001/Delivery Order 1042 for TCN 10-221 Scientific Services Program (SSP). The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Defense position, policy, or decision, unless so designated by other documentation.

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