Division of Strategic National Stockpile (DSNS) Program Review

A Report from the Board of Scientific Counselors (BSC)

Office of Public Health Preparedness and Response (OPHPR)

Centers for Disease Control and Prevention (CDC)

Department of Health and Human Services (DHHS)

- **Thomas Inglesby, MD, Chair**
- **Barbara Ellis, PhD, DFO**

Approved by Vote of the BSC: September 14-15, 2011

Respectfully Submitted: March 19, 2012

Table of Contents

1.0 Executive Summary…………………………………………………………… 3

2.0 Review Objectives and Process.. 6

3.0 Scope of the Review….. 9

- Background ………………………………………………………………… 9
- Review Objectives ………………………………………………………… 11

4.0 Panel Findings and Observations…………………………………………… 12

- Introduction ………………………………………………………………… 12
- Review Methods …………………………………………………………… 13
- The Response Supply Chain………………………………………………… 13
- Analysis of Review Objectives: The Way Forward ………………………… 15
- Recommendations…………………………………………………………… 20
- Strong Considerations……………………………………………………….. 21
- Conclusions………………………………………………………………….. 22
- References…………………………………………………………………… 23

5.0 Appendices

A. Panel Member Biographies.. 24

B. Pre-Meeting Teleconferences (Agendas, Presentations)................................ 29

C. Meeting Agenda (Atlanta, July 28-30, 2009)……………………………….. 68

D. Pre-Meeting Panel Findings and Observations……………………………… 70

E. Table of Contents for Background Materials Provided to Reviewers……..... 73

F. *Evaluating Consequences of Planned Capacities for a Public Health Emergency Supply Chain, Technical Report 1475* (King and Muckstadt, 2010)………... 76

G. List of Acronyms…………………………………………………………….. 89

1.0 EXECUTIVE SUMMARY

Background

The Office of Public Health Preparedness and Response (OPHPR; previously known as the Coordinating Office for Terrorism Preparedness and Emergency Response, or COTPER[1]) Board of Scientific Counselors (BSC) asked six logistics and preparedness experts to convene and answer four questions aimed at improving Strategic National Stockpile (SNS) response to an aerosolized anthrax event. The BSC wanted to know:

1) Assuming a community can begin forwarding material to their Points of Dispensing (PODs) at hour 12 after making a request, is the current hub-and-spoke model adequate for responding to a Cities Readiness Initiative (CRI) event?
2) If the community can begin using material at 3, 6, or 9 hours after making a request, and taking into account the 72 CRI cities and their populations, along with the requirement of having to respond to simultaneous events in three cities, how much material should be forward deployed and in what locations in order to support this type of programmatic change, if it were deemed beneficial?
3) What are the pros and cons associated with the procurement of additional inventory, storage locations, and manpower that would be needed to manage the storage locations, perform annual inventories, and provide security; and the potential need for movement of material from multiple locations to one location where it would be needed?
4) Would there be other more efficient alternatives to the hub-and-spoke model in a CRI event?

Findings

The expert panel was unable to answer these questions given the data it was provided. Even though OPHPR gave the panelists extensive background materials and in-depth briefings, the panelists found they had insufficient data to inform their answers. Indeed, the specific data needed to answer the questions does not exist (or has not been provided to OPHPR in a usable form) at this time. The panelists unanimously agreed that DSNS must aggressively grow its modeling, simulation, and data collection efforts. Low-cost, simple "flow" modeling would help OPHPR answer its four critical

[1] CDC began undergoing an organizational realignment of some offices and centers in the fall, 2009. Since this review was conducted prior to the change in name from COTPER to OPHPR, some of the documents in this report reference COTPER (not OPHPR).

questions – and much more. Both analytic and simulation (experimental) modeling activities should be increased substantially.

Modeling will allow DSNS to make quantitatively-based decisions on how much inventory to hold and where to hold it. An end-to-end model capturing the flow of materials in the SNS, as well as costs and logistical and health measures, should begin at the SNS-managed inventory site and go all the way to the point of dispensing to the public. Using such models will reveal bottlenecks, provide cost estimates, and help SNS properly evaluate the costs and consequences of alternative Response Supply Chain configurations.

Recommendations

1. Expand and further develop models that can evaluate the logistical consequences, health benefits, and costs of alternative supply chain configurations. The models should be experimental (simulation) and analytic, and should include optimization models. Examples can be found in the appendices.
2. Collect the data needed to support model-based decision making.
3. Use the models to answer the questions in the scope of review.
4. Expand the use of continuous improvement techniques in all aspects of DSNS response.

Considerations

1. Continue to focus on the 'last mile' of the response system.
2. Identify and eliminate barriers to efficient medication distribution and dispensing.
3. Consider cost and resource consequences of alternative supply chain configurations and inventory management procedures (warehouses, material, locations, response times) to DSNS overall.
4. Partner with universities to enhance simulation and analytic modeling capabilities.

Conclusion

To minimize morbidity and mortality after a bioterrorist attack, the US needs a flawless system to distribute medications from strategic storage sites to the affected public. This requires a tested, reliable end-to-end delivery system. Robust modeling and simulation efforts will enhance the CDC's capability to make the right decisions about inventory, distribution, and budgeting for its Strategic National Stockpile.

DSNS has successfully created a comprehensive stockpile, procedures for procurement, and partnerships with federal, state, local, and private entities. DSNS has established a range of initiatives to ensure preparedness, and has created a culture of emergency preparedness within a public health agency. DSNS is using many types of models and simulation to inform its decision making. These are significant accomplishments. DSNS now has the opportunity to improve its preparedness efforts with the creation and implementation of simple end-to-end models of the flow of materials in its Response Supply Chain as well as more complex simulation and optimization models.

2.0 REVIEW OBJECTIVES AND PROCESS

Background

External peer review is a highly regarded mechanism for critically evaluating the scientific and technical merit of research and scientific programs. This rigorous process identifies strengths, gaps, redundancy, and research or program effectiveness in order to inform decisions regarding scientific direction, scope, prioritization, and financial stewardship. External peer review will address program quality, approach, direction, capability, and integrity and will also be used to evaluate the program's public health impact and relevance to the missions of the Centers for Disease Control (CDC) and the Office of Public Health Preparedness and Response (OPHPR).

OPHPR has established standardized methods for peer review of intramural research and scientific programs in order to ensure consistent and high quality reviews. A more detailed description of CDC's and OPHPR's peer review policy is available on request.

CDC policy requires that all scientific programs[2] (including research and non-research) that are conducted or funded by CDC be subject to external peer review at least once every five years. The focus of the review should be on scientific and technical quality and may also include mission relevance and program impact. The OPHPR Board of Scientific Counselors (BSC) provides oversight functions for the research and scientific program reviews. The BSC primarily utilizes ad hoc workgroups or expert panels to conduct the reviews. It is anticipated that the BSC will be engaged in most of the reviews and they may elect to utilize workgroups, subcommittees or workgroups under subcommittees to assist in the review. The BSC will evaluate findings and make summary recommendations on all reviews, including those they engage in, as well as reviews performed by other external experts.

Review Objectives

[2] Scientific program is defined as the term "scientific program" includes, but is not necessarily limited to, intramural and extramural research and non-research (e.g., public health practice, core support services).

This review focused on the comparison of the current SNS "hub and spoke" model for inventory storage and delivery versus the forward deployment and maintenance of assets under federal control, in the context of a CRI inhalation anthrax-related event. The following points should be taken into consideration:

1. Assuming a community can begin forwarding materiel to their PODs at hour 12 after making a request, is the current hub-and-spoke model adequate for responding to a CRI event?
2. If the community can begin using materiel at 3, 6, or 9 hours after making a request, and taking into account the 72 CRI cities and their populations, along with the requirement of having to respond to simultaneous events in three cities, how much materiel should be forward deployed and in what locations in order to support this type of programmatic change, if it were deemed beneficial?
3. What are the pros and cons associated with the procurement of additional inventory, storage locations, manpower that would be needed to manage the storage locations, perform annual inventories, and provide security; and the potential need for movement of materiel from multiple locations to one location where it would be needed?
4. Would there be other more efficient alternatives to the hub and spoke model in a CRI event?

Although the hub-and-spoke vs. forward deployment review could apply to any type of threat agent, for the purposes of this review, the scope will focus on the inhalation anthrax scenario that would require prophylaxis of the potentially exposed populations within 48 hours.

Review Process and Timeline:

The peer review was conducted by a 6-member external expert panel with one member of the OPHPR Board of Scientific Counselors (BSC) serving as chair and 5 invited expert reviewers external to the OPHPR BSC. Facilitation and logistical assistance was provided by the DSNS Associate Director for Science (ADS) and the OPHPR Office of Science and Public Health Practice (OSPHP).

1. Pre-meeting: OSPHP convened a pre-panel teleconference with members of the panel on Friday, April 17, 2009 from 2:00 pm to 3:30 pm. The agenda included an overview presentation on the Division of Strategic National Stockpile as well as presentations from the Division's Response and Logistics Branches. OSPHP convened a second pre-panel teleconference with members of the panel on Friday, July 17, 2009 from 1:00 pm to 3:00 pm. The agenda included a presentation on the Cities Readiness Initiative. Reviewers were given the option of submitting written individual comments in response to the review questions. These comments and questions were intended to assist OPHPR in providing the panel with the necessary information in advance of the panel meeting.

2. Workgroup meeting: The panel met for two and one-half days from July 28, 2009 through July 30, 2009 in Atlanta, GA. On the first day and on the morning of the second day, there were presentations by DSNS staff as well as external stakeholders, discussions, and question and answer sessions. On the afternoon of the second day and the morning of the third day, the panel convened privately to deliberate, formulate findings, and write a draft panel report

3. Post-meeting: The panel Chair took the lead on completing the panel report. Panel members and OPHPR and DSNS program leadership were given the opportunity to review and comment on the contents of the panel report before it was finalized. The DSNS program will have the opportunity to provide program responses to any findings and individual recommendations in the report at the BSC meeting. The full BSC will deliberate on the final panel report during the April 2010 meeting, reach a consensus on recommendations, and present these recommendations as summary determinations to OPHPR management. OPHPR will respond to the BSC recommendations in writing and present their response and implementation plan at the next BSC meeting.

3.0 SCOPE OF THE REVIEW

Background

The Strategic National Stockpile (SNS) is a national repository of antibiotics, chemical antidotes, antitoxins, life-support medications, intravenous administration, airway maintenance supplies, and medical and surgical items. The SNS is designed to supplement and re-supply state and local public health agencies in the event of a national emergency, anywhere and at anytime, within the United States or its territories.

The SNS was established as the National Pharmaceutical Stockpile in 1999 as a response mechanism for potential bioterrorism events related to Y2K. Its merit was tested and validated with the events of 9/11 and the post-9/11 anthrax attacks. Since those early years, the Stockpile has seen many changes, and although the response focus has shifted to an "all hazards" approach, mitigating the effects of an anthrax attack directed against a major U.S. city, or multiple U.S. cities simultaneously, is among one of the key DSNS preparedness planning and response efforts.

Initially, through consultation with experts in the field of logistics and transportation, a response time of 12 hours was determined to be an achievable objective in providing assets to the site of a national emergency; strategic analysis was conducted to establish SNS warehouse locations throughout the nation that would allow delivery of medical assets within this timeframe.

As the SNS matured, so too did its response concept. Structured for a flexible response, the SNS now includes both the rapid response capability of pre-configured medical assets deliverable in the 12-hour timeframe, and a more deliberate capability of configuring medical materiel specific to the needs of a response. Naturally, time is traded for specificity with this method. Details of each of these methods are discussed below.

The SNS first line of support lies within the immediate response capability provided with the "12-hour Push Package" (Push Package). A Push Package is a pre-configured cache of pharmaceuticals (including antibiotics) and medical supplies designed to provide rapid delivery of a broad spectrum of assets for an ill-defined threat in the early hours of an event. Individual Push Packages are positioned throughout the nation, in strategically located, secure warehouses, ready for deployment and designed to arrive at a designated state receiving site within 12 hours of the federal decision to deploy SNS assets. Once the assets are delivered to this pre-planned site, state officials are responsible for further distributing the supplies to designated points of dispensing (PODs) throughout their state. Push Packages account for approximately 3 to 5 percent of the total SNS inventory. Each Push Package contains several hundred thousand units of use bottles of antibiotics.

Approximately ninety-five percent of the inventory is maintained in Managed Inventory (MI). These assets are either managed directly by DSNS at storage facilities located around the nation or through contracts with vendors. This capability provides the DSNS with a means to tailor pharmaceuticals, supplies and products specific to the suspected or confirmed agent(s) if the cause of the incident has been identified and is one of the threats for which DSNS has response capabilities. MI may also be utilized as the first option for *immediate* response from the SNS or as a follow-on to an initial deployment of a Push Package. MI assets are scheduled to begin arriving at a site 24-36 hours after the federal decision to release them. A large-scale inhalation anthrax attack involving a Cities Readiness Initiative (CRI) metropolitan statistical area (MSA) is one example of a specific scenario that would utilize MI. The CRI is a federally funded effort administered by CDC (DSNS) to prepare 72 major U.S. cities and MSAs to effectively respond to a large-scale bioterrorist event by dispensing antibiotics. The goal of CRI is to dispense prophylaxis to the entire potentially exposed population within 48 hours. PODs traditionally serve as the primary method of dispensing antibiotics to a large number of people in a short period of time.

Currently DSNS manages its logistical operations using the “hub and spoke” model for inventory storage and delivery. Under this concept, the DSNS maintains assets at centralized locations or hubs, and, when requested, pushes them out to pre-planned sites within the affected state(s). Many of these centralized locations are established near major transportation hubs that allow for ground or air transportation of the twelve Push Packages to any location in the continental United States in as few as 12 hours of the federal decision to deploy these assets, as well as managed inventory that could be used for initial delivery or as a follow-on delivery. To date, there has not been a comprehensive comparison of the efficiency and cost-effectiveness of the “hub and spoke model” delivery of antibiotics for a CRI event versus federally maintaining SNS assets in a more forward-deployed manner so that delivery times could be shortened if a CRI event occurs. The correlation between the time it takes for DSNS to deliver assets and the time it takes to activate a dispensing site has yet to be determined. It is unknown if PODs could be established and would be ready to use assets before SNS delivery (using the hub-and-spoke model) takes place.

Review Objectives

This review will focus on the comparison of the current SNS "hub and spoke" model for inventory storage and delivery versus the forward deployment and maintenance of assets under federal control, in the context of a CRI inhalation anthrax-related event. The following points should be taken into consideration:

1. Assuming a community can begin forwarding materiel to their PODS at hour 12 after making a request, is the current hub-and-spoke model adequate for responding to a CRI event?
2. If the community can begin using materiel at 3, 6, or 9 hours after making a request, and taking into account the 72 CRI cities and their populations, along with the requirement of having to respond to simultaneous events in three cities, how much materiel should be forward deployed and in what locations in order to support this type of programmatic change, if it were deemed beneficial?
3. What are the pros and cons associated with the procurement of additional inventory, storage locations, manpower that would be needed to manage the storage locations, perform annual inventories, and provide security; and the potential need for movement of materiel from multiple locations to one location where it would be needed?
4. Would there be other more efficient alternatives to the hub and spoke model in a CRI event?

Although the hub-and-spoke vs. forward deployment review could apply to any type of threat agent, for the purposes of this review, the scope will focus on the inhalation anthrax scenario that would require prophylaxis of the potentially exposed populations within 48 hours.

4.0 PANEL FINDINGS AND OBSERVATIONS

Introduction

In 1999, Congress tasked the CDC to develop the National Pharmaceutical Stockpile, which later became the Strategic National Stockpile. This is a national resource that contains antibiotics, antivirals, vaccines, antitoxins and other medical material that can be used in the event of a large-scale public health emergency when state or local resources become overwhelmed. The SNS can respond in several ways during an emergency: with a 12-hour Push Package, managed inventory, or technical assistance. The 12-hour Push Packages are designed to arrive at any location in the US or its territories within 12 hours of the Federal decision to deploy. Managed inventory typically has a 24-36 hour window for delivery; however, in a CRI event, this timeline is shortened to 12-24 hours. The SNS formulary includes doxycycline and ciprofloxacin in 10-day unit -of-use bottles that could be used to respond to a CRI event. The SNS also includes additional follow-on oral antibiotics, IV antibiotics, anthrax vaccine, and other medical supplies that could be used in an anthrax event.

Thus far, DSNS has successfully created a comprehensive stockpile, procedures for procurement, and partnerships with federal, state, local, and private entities. DSNS has established a range of initiatives to ensure preparedness, and has created a culture of emergency preparedness within a public health agency. DSNS is also using many types of models and simulation to inform its decision making. These are significant accomplishments. In discussions with DSNS personnel we were informed the DSNS is investigating ways to improve its existing operations by examining processes and information system limitations that affect the time to respond. We note that ultimately the DSNS must determine what processes prohibit the current hub-and-spoke system from responding to three simultaneous MSA events in 6 rather than 12 hours and what could be done to improve or eliminate the offending processes.

Review Methods

The panel was provided extensive background materials, and two webinars were conducted prior to the meeting. The webinars were given by DSNS program staff and provided an overview of the SNS and described specific logistical issues, as well as state and local preparedness. Prior to the meeting, panel members provided responses to the four questions; the panel’s responses are summarized in Appendix D. During the meeting, presentations were given by DSNS program staff and state and local stakeholders on topics including various dispensing modalities, technical assistance reviews (scoring of state plans), and modeling and simulation programs that are used for training and exercises. During the meeting the panel interacted with program staff and speakers and asked many questions to help inform their discussions regarding the objectives. Given the diversity of the backgrounds of panel participants, there were many insights and fruitful discussions during the brainstorming sessions. A wide range of expertise and experience was brought to bear during the discussions. The panel had extensive discussions with OPHPR staff and among themselves, but found that detailed data required to address the four objectives were not available. Thus, the panel was unable to provide quantitative analysis of the suggested alternatives – analysis that is needed in order to properly address the review questions and suggest an appropriate course of action for DSNS. Instead, the panel has proposed a process that DSNS should undertake to enable them to conduct the needed analyses. The panel unanimously agreed on the four recommendations presented in this report, as well as the other considerations we present for the OPHPR BSC.

The Response Supply Chain

In order to answer the four questions posed to the panel, we must consider the entire Response Supply Chain. A supply chain is the movement and storage of material between physical entities, operational linkages, information flows, and the collaborative decision making processes that link these.[1,2] The DSNS Response Supply Chain consists of external suppliers of material; procurement, receipt, and storage of material at SNS locations; logistics activities performed by DSNS and third-party partners to transport material to state and local partners; the processing of material at the state/local sites (RSSs); the movement of material to PODs and other locations; and the dispensing of medications to individuals. It is important to emphasize that the Response Supply Chain not only consists of physical activities, but also includes the policies and procedures for managing the activities, including command, control, and communications. Before we address our plan by which DSNS can answer the review questions, we first state three important laws of supply chain management that are relevant to DSNS's decision making.[1,2]

The first law is:

> *To forecast is to err.*

Fundamentally, this law states that no matter how carefully a system plan is constructed, the actual operation of the system will deviate from the plan, and in many cases quite substantially. There is a considerable amount of uncertainty in the Response Supply Chain. The nature, timing, and extent of the event and the operation of many components of the response system are all highly uncertain.

This fact leads to the second law:

> *Assets should be kept in their most flexible form for as long as it is economically and operationally possible.*

When the nature of a disaster is unknown, it is imperative to construct a quick response system. Such a system permits the rapid deployment of critical assets to the location of the event. Placing assets in many locations prior to the occurrence of an event normally increases the cost of response and timeliness of total response by a substantial amount. Given the uncertainty surrounding a potential event, it seems unlikely that stocking much if any material closer to a potential MSA site will be cost effective or even beneficial.

The third law that is worthy of note is as follows:

> *Local optimization leads to global disharmony.*

Simply put, if a truly robust and effective response system is to be created, then a system perspective must be taken when designing and operating the Response Supply Chain. If some element of the system is designed to operate flawlessly in an emergency, and another will likely be ineffective, then the entire system will fail.

Analysis of Review Objectives: The Way Forward

DSNS has a strong tradition of basing its policies on objective methods of assessment. DSNS has made impressive progress in modeling and simulating many operational details of its logistics operations and those of local areas – and making informed decisions based on such analyses. Furthermore, the physical facilities DSNS has created, its relationships with suppliers, its systems of command and control, and its attention to detail pertaining to security, are all noteworthy.

In order to evaluate the Response Supply Chain – and, in particular to address the four review objectives posed to the expert panel – the panel believes that a new modeling effort must be undertaken, and appropriate data must be gathered to support such a modeling effort. Specifically, the panel believes that a high-level model (as opposed to a highly complex and detailed simulation model) is needed to represent flows and capacities and to estimate the consequences of different system design alternatives.

Figure 1 depicts the sequence of major events (represented by boxes) that occurs from the point of recognition of a bioterrorism event to the onset of dispensing. The arrows represent the progression of time. Some arrows are marked as variable, dependent upon, for example, the geographic proximity of an affected jurisdiction to the nearest RSS or other regional distribution center, or the capacity to activate RSS or dispensing operations. All of these variations in time affect the decision about whether or not the hub-and-spoke model or forward deployment of assets is advantageous. It should be noted that some of these activities occur simultaneously: for example, transportation of SNS assets from the federal government to the RSS, local preparation of the RSS, and local preparation for dispensing all occur simultaneously.

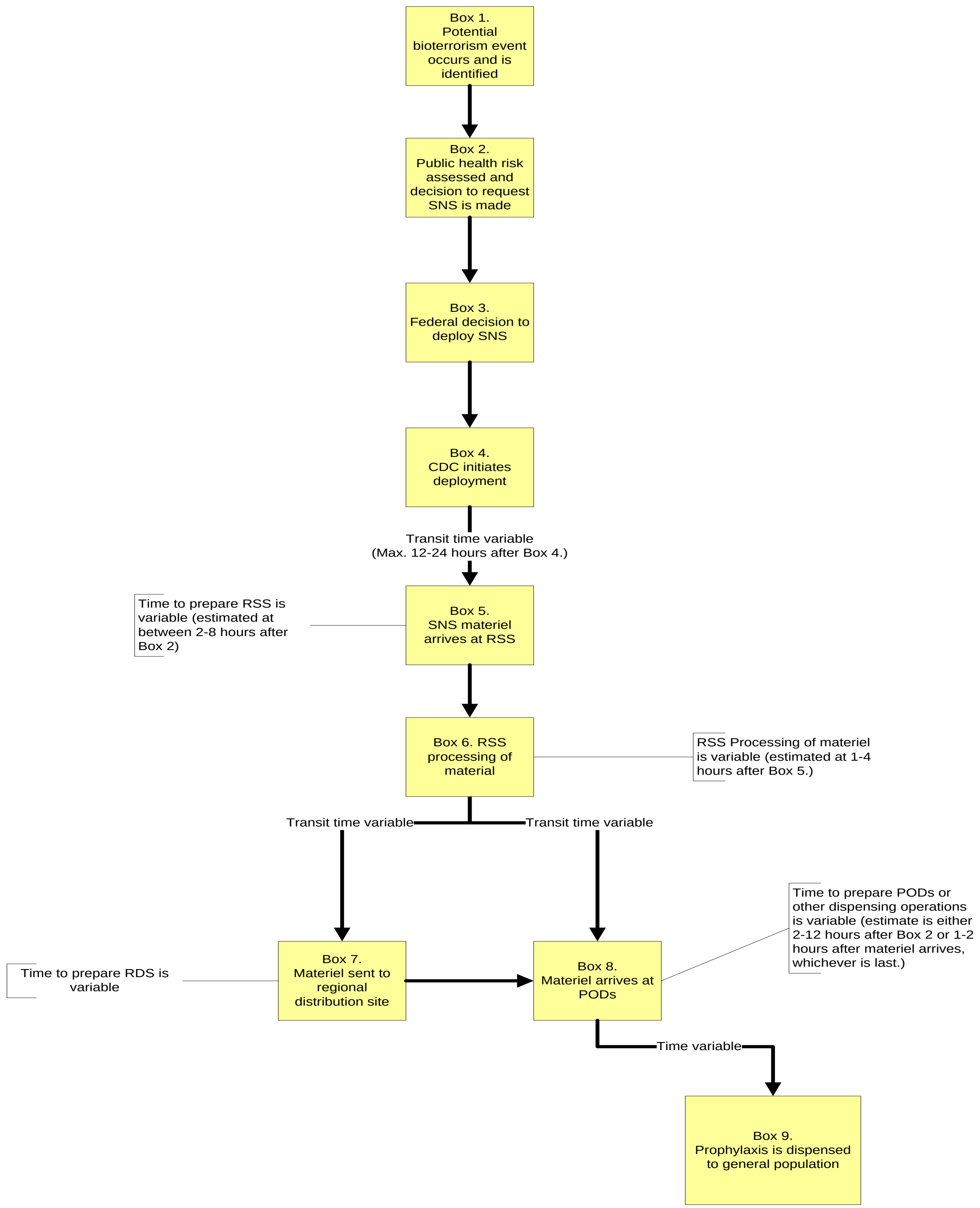


Figure 1. Schematic of the SNS Response Supply Chain

A description of the events in the figure is as follows (note that times indicated in boxes 5-9 are panel member estimates):

Box 1: A bioterrorism event occurs that is identified either through environmental detection, criminal intelligence, animal surveillance, or the existence of disease in humans.

Box 2: Local or state public health officials assess risk related to the event and determine appropriate public health actions, which could include the request for SNS assets. If the event indicates a probable risk to public health, a request for these assets is made through the governor's office to the federal government.

Box 3: The federal government makes the decision to deploy SNS assets to the affected MSA(s).

Box 4: The CDC initiates deployment from DSNS-managed inventory for distribution to the affected area. At this point, distribution time is variable based on the distance and travel conditions from the SNS warehouse to the RSS within the affected MSA(s). It is estimated that material will begin to arrive within 12 hours after the federal government's decision to deploy (Box 3).

Box 5: All material from the SNS arrives at a state-designated RSS. The time to prepare the RSS for receipt of this material (e.g., assembling personnel, clearing warehouse space, arranging for security, positioning material handling equipment) will vary among MSA(s). The time to prepare an RSS site might range, for example, from 2-8 hours after the decision to conduct mass prophylaxis (Box 2).

Box 6: Material is off loaded, broken down, apportioned, staged, and loaded onto trucks for distribution to PODs or other dispensing operations. This task might take 1-4 hours after material arrives at the RSS (Box 5).

Box 7: Some states may send material to another regional distribution site (RDS) from the RSS. An RDS would serve as a local distribution site if the event encompasses multiple MSA(s) over a large geographic area. The use of an RDS will increase the time before dispensing occurs at the POD. RDS operational readiness time is variable, similar to that of the RSS. The time to prepare an RDS site may range, for example, from 2-8 hours after the decision to conduct mass prophylaxis (Box 2).

Box 8: Material is received at the POD or other functional dispensing operations (e.g., closed PODs, USPS) either directly from the RSS or from the RDS. The time it takes to prepare dispensing operations is variable based on the time it takes to assemble personnel, provide just-in-time training, set up a facility, provide security, transport material from the RSS/RDS, and inform the public. POD setup time is estimated between 2-12 hours after the decision to conduct mass prophylaxis (Box 2), or between 1-3 hours after receipt of material, whichever is later.

Box 9: Prophylaxis is dispensed to the affected population. The rate of prophylaxis dispensing is variable, depending on a variety of factors including the capacity to dispense (which depends on availability of resources and systems in place) and the demand for prophylaxis at a particular site.

The panel envisions the creation of a simple model that would capture the flow of materials and the sequence of events as they occur in the Response Supply Chain, as outlined in Figure 1. The model would be designed to evaluate the logistical, health, and cost consequences (as appropriate) of alternative logistical decisions regarding the Response Supply Chain. For example, such a model would be able to assess the effects (that is, the logistical, health, and cost consequences) of alternative network designs, alternative locations and amounts of SNS and local inventory, different POD dispensing capacity and configurations, and different decisions regarding inventory deployment.

It is important to emphasize that the type of model we envision is not intended to be a highly complex stochastic simulation model (such as the SIMAN simulation model) but instead a straightforward means of calculating throughput as a function of capacities, inventory levels, transportation times, and dispensing activities. An example of such a model was developed by one of the panel members in half a day. This Excel spreadsheet captures the relevant costs and operational parameters associated with storing material in a given warehouse (for example, as in a regional distribution center; see Figure 1). This type of model is required to accurately estimate the cost consequences of placing material forward in the supply chain. Importantly, the model is very simple to understand and use. Another example of a simple response planning model was developed by one of the panel members. This Excel spreadsheet, designed for use by local planners, evaluates the costs and health consequence of alternative antibiotic inventory and dispensing strategies in the event of a large-scale aerosolized anthrax attack in a single city.[3, 4] Other spreadsheets could be created to inform different steps of the response process. The model that we envision to represent the system shown in Figure 1 would be of a similar level of complexity: it would be complex enough to capture the flows and sequence of events indicated in the figure, but would still be relatively simple. We envision that such a model could be created in several weeks. An example of what a more comprehensive optimization model might contain, along with the computer code to implement it, can be found in Appendix F. Similar optimization models could be created in a matter of weeks as well.

The difficulty in using models to address the four objectives resides in the acquisition of the data, not in the model creation. For example, instantiation of a simple flow model requires data including, but not limited to the following: time-varying rates of capacity at the SNS to prepare and ship material, at each RSS to receive, store, and ship material, and at each POD or other dispensing location to receive and dispense material; times to move material between and among the SNS, RSSs, RDSs, and PODs; initial inventories at each location; and costs of all inventory and activities.

An example of a mathematical model that can be employed to estimate the operating cost over time as well as the delay in emergency response for a given warehousing network was shared with state SNS coordinators and other planners via the SNS listserv in June 2010. We do not envision a lengthy and expensive study to collect such data; rather, we envision that reasonable estimates of required data could be obtained from knowledgeable personnel within the different areas of the Response Supply Chain. For example, personnel operating an RSS should be asked to provide estimates of the rate at which they would be able to receive, store, and ship material. As another example, personnel responsible for local dispensing activities should be asked to estimate the rate at which medications could be dispensed at different PODs in their region. Data could also be collected from current and future exercise efforts.

We recommend that the model be used to address the review objectives posed to the panel: specifically, to determine whether a 3, 6, 9, or 12-hour response will make any difference in throughput given the constraints on the system, and whether forward placement of inventory (that is, placement of SNS-managed inventory in a regional warehouse located in close proximity to a designated MSA) will improve response. This type of model combined with a cost model gives decision makers the opportunity to assess cost-benefit relationships. In order to address such questions, the model must be customized to reflect conditions in different states and MSAs. While the model could be used to look at many different MSAs and attack scenarios other than anthrax (e.g., smallpox), the DSNS would be well advised to concentrate its modeling efforts on high-risk areas and the most likely attack scenarios.

Furthermore, we believe strongly that the weak link in the Response Supply Chain is at the POD or dispensing level. That this is likely is not surprising. This step in the process is the most human-resource-intensive and the most difficult to test thoroughly. In fact, it is impossible to test this portion of the system completely. Hence, we believe that considerable attention and resources should be placed on this portion of the system. Incremental education and training would be of incalculable value. Although this is outside the scope of the responsibility of DSNS, our view is that OPHPR must address this issue. DSNS can improve all facets of its processes and yet lives may be lost due to the bottlenecks in dispensing. Studies have shown that dispensing capacity bottlenecks are problematic in a CRI event[3, 4] so it is essential that effective dispensing methods continue to be developed. Capacities at the local level must be evaluated relative to response that could realistically be achieved. Local areas must develop dispensing methods that are robust relative to the timing of the event. Realistic and robust ways to dispense are needed; this is a critical part of the process and without it, the capacity to save lives will be diminished.

In evaluating the Response Supply Chain, we strongly believe that a systems-level view is essential. As we have highlighted, the different components of the Response Supply Chain are inextricably connected. The benefits of better inventory management and better response time in any one part of the supply chain ripple throughout the entire supply chain. For-profit companies have learned this lesson well; the DSNS can benefit from these experiences.[5] Moreover, a process of continuous improvement – of all aspects of DSNS response – is needed. The continuous improvement process should address the timely dispensing of medications to affected individuals. Timely dispensing depends on the time required to perform all processes in the Response Supply Chain. Reducing any of these times can reduce the time until medications are dispensed, and the consequent morbidity and mortality. Our experiences in industrial settings strongly suggest that by reducing these response times, the DSNS can also reduce the inventory it requires and other operating costs.

<u>Recommendations</u>

1. Expand and further develop models that can evaluate the logistical consequences, health benefits, and costs of alternative supply chain configurations.

DSNS has made impressive progress in their modeling efforts and the use of such modeling efforts to support informed decision making, from the design of PODS to the detailed evaluation of nationwide SNS deployment. We recommend that these efforts be broadened to include the evaluation of additional logistical consequences, health benefits, and costs of alternative supply chain configurations. Specifically we recommend that DSNS:

A. Create models that are simple, focused and inexpensive, while still oriented toward the operations of the entire Response Supply Chain.
B. Use such models to improve the design and operation of the Response Supply Chain. Develop more advanced simulation and analytic models to assist in the creation and evaluation of components of and the entire Response Supply Chain.

C. Apply portions of their existing detailed simulation models for training and simulation.
D. Create cost-based models to evaluate consequences of alternative supply chain configurations.

2. Collect the data needed to support model-based decision making.

3. Use the models to answer the questions in the scope of review.

4. Expand the use of continuous improvement techniques in all aspects of DSNS response.

Strong Considerations

1. Continue to focus on the 'last mile' of the response system.

This involves enhancement of dispensing capacity, including the use of models to help evaluate consequences of design, and develop realistic modes of dispensing (for example, to understand when and how various components of dispensing can become operational in an emergency).

2. Identify and eliminate barriers to efficient medication distribution and dispensing.

For example, DSNS may wish to have legal counsel revisit the interpretation of the Public Readiness and Emergency Preparedness (PREP) Act liability coverage in order to find a better solution for legal use of SNS countermeasures in existing packaging (rather than the current system involving Emergency Use Authorization).

3. Consider cost and resource consequences of alternative supply chain configurations and inventory management procedures (warehouses, material, locations, response times) to DSNS overall.

DSNS funds are limited and decisions about investments and the Response Supply Chain must be evaluated in the context of the overall DSNS budget.

4. **Partner with universities to enhance simulation and analytic modeling capabilities.**

The DSNS should consider working more closely with faculty and students from several universities to augment and enhance its modeling capabilities. Student interns would be an excellent and cost effective source of assistance.

Conclusions

DSNS has successfully created a comprehensive stockpile, procedures for procurement, and partnerships with federal, state, local, and private entities. The DSNS has established a range of initiatives to ensure preparedness, and has created a culture of emergency preparedness within a public health agency. The DSNS is using many types of models and simulation to inform its decision making. These are significant accomplishments.

To minimize morbidity and mortality after a bioterrorist attack, the US needs a flawless system to distribute medications from strategic storage sites to the affected public. This requires a tested, reliable end-to-end delivery system. Robust modeling and simulation efforts will enhance the CDC's capability to make the right decisions about inventory, distribution, and budgeting for its Strategic National Stockpile.

References

1. Muckstadt JA. 2003. *Laws of Supply Chain Physics.* Cayuga Partners, Wayne, NJ.
2. Muckstadt JA, Murray DH, Rappold JA, Collins DE. 2001. Guidelines for collaborative supply chain system design and operation. *Information Systems Frontiers*, Vol. 3, No. 4, pp. 427-454.
3. Bravata DM, Zaric GS, Holty JE, *et al*. 2006. Reducing mortality from anthrax bioterrorism: strategies for stockpiling and dispensing medical and pharmaceutical supplies. *Biosecurity and Bioterror,* Vol. 4, pp.244-62.
4. Zaric GS, Bravata DM, Holty J-EC, McDonald KM, Owens DK, Brandeau ML. 2008. Modeling the logistics of response to anthrax bioterrorism. *Medical Decision Making*, Vol. 28, pp. 332-50.
5. Brandeau ML, Hutton DW, Owens DK, Bravata DM. 2007. Planning the bioterrorism response supply chain: learn and live. *American Journal of Disaster Medicine,* Vol. 2, pp. 231-48.

6. King K. and Muckstadt JA. 2010. Evaluating Consequences of Planned Capacities for Public Health Emergency Supply Chains. *School of Operations Research and Information Engineering, Cornell University, Technical Report 1475.*

5.0 APPENDICES

Appendix A
Workgroup Member Biographies

John Muckstadt, Ph.D. (*Workgroup Chair*) Professor of Engineering, Cornell University School of Operations Research & Industrial Engineering.

Jack Muckstadt is the Acheson-Laibe Professor of Engineering in Cornell University's School of Operations Research and Industrial Engineering. He is also the Director of the Operations Research Manhattan Program where he is leading a group of operations research and medical professionals addressing supply chain issues related to response logistics for mass-casualty events. Dr. Muckstadt joined the Cornell faculty in 1974. He was the school's Director for nine years. He also established and was the first director of the Cornell Manufacturing Engineering and Productivity Program. His teaching, research and consulting interests are in the areas of manufacturing systems and manufacturing logistics, supply chain systems, and manufacturing system design and analysis. Organizations he has or is currently consulting for include: Avon, Accenture (Andersen Consulting), Eaton-Aeroquip, Aspen Technology, General Electric, Xerox, General Motors, U.S. Navy, U.S. Air Force, Chicago Pneumatic Tool, SAS Air Lines, Rand Corporation, Logistics Management Institute, IBM, General Foods, ClickCommerce (XELUS), Sunoco, United Rentals and Bell Atlantic.

He holds an A.B. in Mathematics from the University of Rochester, a M.A. in Mathematics, a M.S. in Industrial Administration, and a Ph.D. in Industrial Engineering from the University of Michigan. Dr. Muckstadt was an active duty officer in the U.S. Air Force for 12 years, primarily working in the logistics field where he focused on spare parts planning. He is retired from the U.S. Air Force Reserves.

His research interests lie in the areas of manufacturing systems, supply chain and logistics systems, production control and inventory theory and practice. His current research focus is on supply chain problems in a variety of settings. First, he is interested in developing models for response logistics for mass casualty events. These models capture the dynamic behavior of multi-hospital and regional systems. Additionally, he is examining service parts problems through the development of mathematical and simulation models that address a wide range of strategic, tactical, and operational issues faced in a variety of application areas. Finally, he is studying a purely theoretical inventory control problem. The goals of all these research efforts are to identify characteristics of an optimal policy, establish the behavior of cost functions, examine the effectiveness of simple policies, and to construct algorithms for finding solutions to the various optimization problems that have been constructed.

Aruna Apte, Ph.D. - Assistant Professor, Graduate School of Business and Public Policy, Naval Postgraduate School, Monterey, CA

Aruna Apte is a highly successful researcher with projects involving application of mathematical models and optimization techniques. Her research interests include development and application of mathematical models to real world operational problems, especially in the field of humanitarian logistics. She has over twenty years of experience teaching operations management, operations research, and mathematics courses at the undergraduate and graduate levels.

Dr. Apte received her Ph.D. from Southern Methodist University in operations research and has a M.A. in mathematics from Temple University. She is currently an assistant professor in the Graduate School of Business and Public Policy at the Naval Postgraduate School in Monterey, California where she developed and teaches a course entitled Modeling Business Analysis. She was selected as an emerging scholar in 2007 by the Production and Operations Management Society at the annual conference in Dallas.

Margaret L. Brandeau, Ph.D. - Professor of Management Science and Engineering and Professor of Medicine, Stanford University

Margaret Brandeau has been on the Stanford faculty since 1985. Her research focuses on health policy modeling, operations management, management science applications, and bioterrorism preparedness planning. She has been Principal Investigator or Co- Investigator on numerous grants, including three consecutive five-year grants from the National Institute on Drug Abuse (NIDA) aimed at developing and applying policy models for HIV/AIDS and drug abuse prevention and treatment. She has also edited two books: Modeling the AIDS Epidemic: Planning, Policy and Prediction; and Operations Research and Health Care: A Handbook of Methods and Applications. She has served as Area Editor for the journal Operations Research, Associate Editor for the journals Management Science and IIE Transactions, and is on the Editorial Board of Health Care Management Science.

She holds a B.S. degree in Mathematics and an M.S. degree in Operations Research from M.I.T., as well as a PhD in Engineering-Economic Systems from Stanford. She has been a recipient of the President's Award from INFORMS (for contributions to the welfare of society); the Pierskalla Prize (for Research Excellence in Health Care Management Science) from INFORMS; the Best Paper Award from the Society for Computer Simulation; a Presidential Young Investigator Award from the National Science Foundation; the Graduate Teaching Award in the Department of Management Science and Engineering at Stanford; and the Eugene L. Grant Teaching Award in the Industrial Engineering Department at Stanford. She holds a patent for Optimal Operation Assignment in Printed Circuit Board Assembly.

Patricia Kelly, M.S., M.B.A. - Research Fellow, LMI Government Consulting

Ms. Patricia Kelly is currently a research fellow with Logistics Management Institute (LMI) Government Consulting where she provides consultation to government clients in logistics and distribution. Ms. Kelly previously served as the Director of Force Projection and Distribution, HQ Department of the Army, G-4. Ms. Kelly has worked in numerous key assignments during her more than 26 years of DoD service. Prior to joining the Army staff in October 2005, she served as Chief of the Resources and Integration Division at Headquarters Air Mobility Command. From 2001 to 2004, she was deputy division chief for deployment and distribution at Headquarters Air Force. She served in several logistics positions at United States Transportation Command from 1993 until 2001, including team chief for the J5 mobility infrastructure, and as transportation systems specialist in both the J4 and J6. From 1989 until 1993, Ms Kelly was Chief of Civilian Proponency in the Army's Office of the Chief of Transportation. She began her logistics career as an Army transportation intern in 1983 in the Military Traffic Management Command Transportation Engineering Agency.

Ms. Kelly holds a B.A. from the University of North Carolina at Chapel Hill, an M.S. from the National War College, and an M.B.A. from the College of William and Mary. She is a graduate of the Army Logistics Executive Development Course and the Federal Executive Institute's Leadership for a Democratic Society Course. Her awards include the Army Decoration for Exceptional Civilian Service, Air Force Decoration for Exceptional Civilian Service, Joint Civilian Service Commendation Award, Air Force Meritorious Civilian Service Award, Army Meritorious

Civilian Service Award, Army Superior Civilian Service Award (2), and the Army Transportation Corps Ancient Order of Saint Christopher.

Steven A. Mier, M.P.H. - Exercise and Emergency Response Coordinator at the University of Minnesota Center for Infectious Disease Research and Policy and President of the Mier Consulting Group, Inc.

Steven Mier is currently the exercise and emergency response coordinator at the University of Minnesota Center for Infectious Disease Research and Policy and President of the Mier Consulting Group, Inc. which supports Homeland Security Exercise and Evaluation Program (HSEEP) exercises for public health, pandemic influenza planning, medical surge planning with healthcare systems and bioterrorism response.

Mr. Mier has over 17 years of experience in the field of public health, with a career spanning many different program areas including his most recent focus on emergency preparedness and response to large-scale disasters and emerging infectious diseases. His major areas of expertise include: (1) Planning for public health emergencies including mass delivery of antibiotics or vaccine; releases of biological threat agents into the environment; and decontamination and restoration of facilities following anthrax detection; (2) Development of four continuity of operations plans in the event of pandemic influenza; (3) Participation in the assessment, design, and implementation of environmental health detection systems; (4) Coordinating public health emergency response to bioterrorism incidents, with multiple first responder agencies; (5) Design and implementation of data integration systems for public health emergencies; and (6) Design, execution and evaluation of Homeland Security Exercise and Evaluation Program (HSEEP) compliant public health/emergency management exercises.

Mr. Mier has an M.P.H. from the University of Illinois at Chicago. From 2005 to 2008 he served as Assistant Commissioner for the Office of Public Health Preparedness and Emergency Response in Chicago. In this position he coordinated the Cities Readiness Initiative/Strategic National Stockpile assuring joint planning for various disciplines including law enforcement, emergency management, emergency medical, legal, and transportation agencies and developing and implementing operational plans for the receipt, storing, and staging of medical materiel, mass dispensing/prophylaxis, command and control.

Kenneth Sturrock, M.A., M.P.H.

Ken Sturrock previously served as a Regional Emergency Response Advisor for the Florida Department of Health from 2002-2008. In this role, he served as a state field emergency manager for health and medical operations, worked with federal, state and local partners to analyze hurricane threats, ground truth situations and restore medical and social services in Florida. Sturrock also served in Mississippi during Hurricane Katrina. He also served as the manager for the State of Florida Strategic National Stockpile and CHEMPACK programs. In this position he served as the state liaison to federal partners, managed local personnel and oversaw the strategic direction and budget for the program. As a Trainer and Interagency Liaison at the Center for Biological Defense, College of Public Health, University of South Florida, Ken served to bridge the first response community and the laboratory component of the Center for Biological Defense.

Mr. Sturrock has an M.P.H. from the University of South Florida, (2000) with an emphasis on Tropical Medicine and Infectious Disease. He also holds an M.A. in Anthropology (1997) from the University of Florida. He is currently seeking a doctoral degree from the University of Florida, Department of Anthropology. He is a Certified Incident Command System instructor and hazardous materials technician. He has taught Introductory Emergency Management at the University of South Florida, and has presented at numerous national and state conferences.

Appendix B
Pre-Meeting Teleconference Agendas

Agenda
Pre-Meeting Webinar #1
Division of Strategic National Stockpile (DSNS) Program Review:
Hub-and-Spoke Model vs. Forward Deployment of Assets in a Cities Readiness Initiative (CRI) Setting
Coordinating Office for Terrorism Preparedness and Emergency Response (COTPER)
Centers for Disease Control and Prevention (CDC)

Roybal Campus, Building 21, Room 6116
Friday, April 17, 2009
2:00 – 3:30 p.m. (EDT)

2:00 – 2:05 p.m.	**Welcome and Introductions** Dr. Jack Muckstadt, DSNS Workgroup Co-Chair; BSC, COTPER Dr. Clarence J. (C.J.) Peters, DSNS Workgroup Co-Chair; BSC, COTPER
2:05 – 2:10 p.m.	**Charge for Reviewers** Dr. Sue Gorman, Associate Director for Science, DSNS
2:10 – 2:35 p.m.	**Overview of Strategic National Stockpile (SNS)** Greg Burel, Director, DSNS
2:35 – 2:45 p.m.	**Questions**
2:45 – 2:50 p.m.	**SNS Response and Operations** Todd Piester, Branch Chief, Response, DSNS
2:50 – 3:10 p.m.	**SNS Logistics – 12 Hour Push Package and Managed Inventory** Shirley Mabry, Branch Chief, Logistics, DSNS
3:10 – 3:30 p.m.	**Questions**
3:30 p.m.	**Adjourn** Workgroup Co-Chairs

Division of Strategic National Stockpile Overview

Greg Burel, Director
Division of Strategic National Stockpile
Coordinating Office for Terrorism Preparedness and Emergency Response
Centers for Disease Control and Prevention

References: I A,B,C,D; II A; VI A; VIII C,D,G

1 SAFER • HEALTHIER • PEOPLE™

Outline

- Mission
- Background & Overview
- Organization
- Operational Approach
- Distribution and Dispensing
- Current Initiatives
- Future Measurement

2 SAFER • HEALTHIER • PEOPLE™

Division of Strategic National Stockpile (DSNS) Mission:

Deliver critical medical assets to the site of a national emergency

- Work within the U.S. Department of Health and Human Services (HHS) Public Health Emergency Medical Countermeasures Enterprise (PHEMCE) requirements process to assure we have the most appropriate countermeasures
- Create pathways to move the materiel to the area of need, in the timeframe that is clinically relevant
- As medical response is local, assure integration with local planning

3

SAFER • HEALTHIER • PEOPLE™

DSNS Mission (cont.):

Deliver critical medical assets to the site of a national emergency

- Provide technical assistance to assure that state/local partners who receive Strategic National Stockpile (SNS) assets are ready to effectively use them
- Maintain materiel in a manner that assures viability

4

SAFER • HEALTHIER • PEOPLE™

Public Health Emergency Medical Countermeasures Enterprise (PHEMCE)

Mission of the PHEMCE is to:

- Define and prioritize requirements for public health emergency medical countermeasures;
- Integrate and coordinate research, early- and late-stage product development, and procurement activities addressing the requirements; and
- Set deployment and use strategies for medical countermeasures held in the SNS

5

SAFER•HEALTHIER•PEOPLE™ CDC

PHEMCE (cont.)

- A coordinated interagency effort by Assistant Secretary for Preparedness and Response
- Includes 3 primary HHS internal agencies: Centers for Disease Control and Prevention, U.S. Food and Drug Administration, National Institute of Health
- The PHEMCE considers medical countermeasures to address chemical, biological, radiological and nuclear incidents as well as naturally emerging infectious diseases and pandemic threats, including pandemic influenza

6

SAFER•HEALTHIER•PEOPLE™ CDC

Background & Overview

- Program created in 1999
- Legislative Policy and Authorities
  - 1999 HHS Operating Plan for Anti-Bioterrorism Initiative
  - 2002 Public Health Security and Bioterrorism Preparedness and Response Act
  - 2004 Project BioShield Act
- $3.5 billion portfolio of antibiotics, medical supplies, antidotes, antitoxins, antiviral, vaccines and other pharmaceuticals
- Network of strategically located repositories
- Commercial partnerships for storage, maintenance, and rapid transport
- Federal partnerships for purchasing and security

7

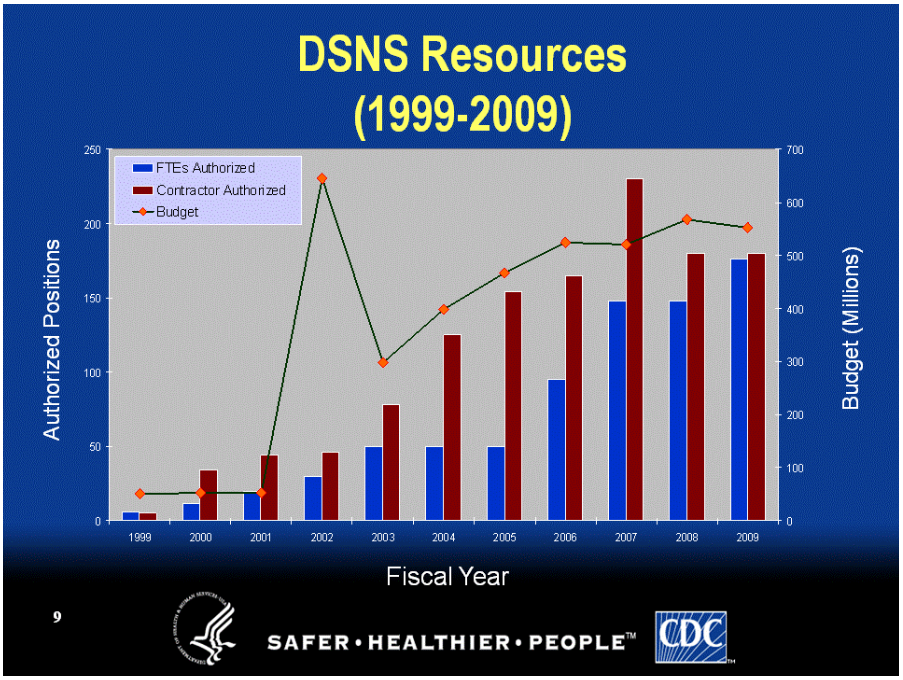
SAFER • HEALTHIER • PEOPLE™

Background & Overview (cont.)

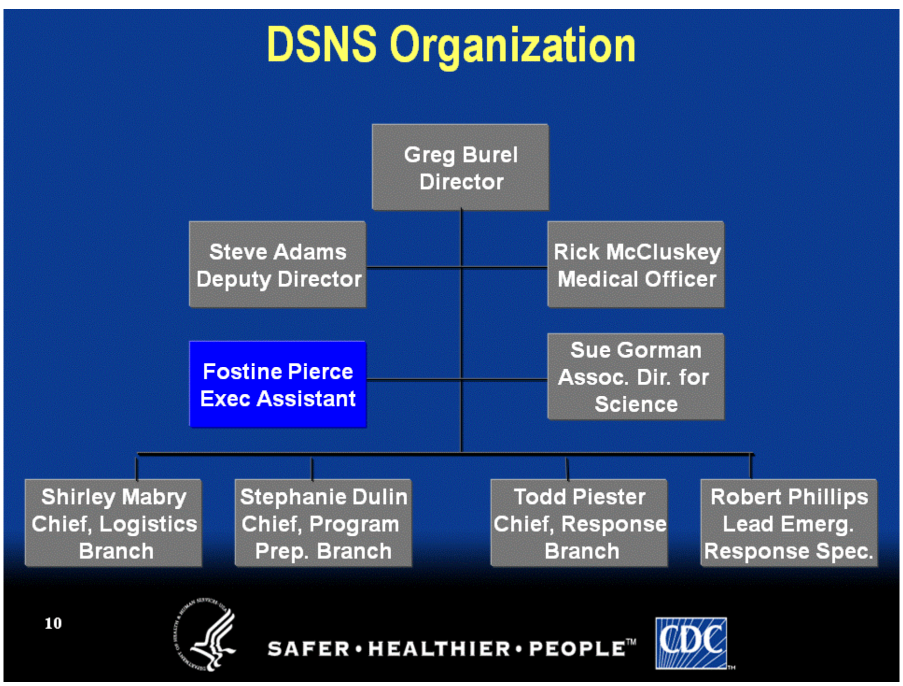
- Evolving formulary
- Supplements and re-supplies state and local medical materiel response
- Provides extensive training and technical assistance to local officials
- Integrated into broader national public health preparedness effort

8

SAFER • HEALTHIER • PEOPLE™



DSNS Resources
(1999-2009)
FTEs Authorized
Contractor Authorized
Budget
Authorized Positions
Budget (Millions)
250
200
150
100
50
0
700
600
500
400
300
200
100
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Fiscal Year
9
SAFER • HEALTHIER • PEOPLE™
CDC



DSNS Organization
Greg Burel
Director
Steve Adams
Deputy Director
Rick McCluskey
Medical Officer
Fostine Pierce
Exec Assistant
Sue Gorman
Assoc. Dir. for
Science
Shirley Mabry
Chief, Logistics
Branch
Stephanie Dulin
Chief, Program
Prep. Branch
Todd Piester
Chief, Response
Branch
Robert Phillips
Lead Emerg.
Response Spec.
10
SAFER • HEALTHIER • PEOPLE™
CDC


DSNS Organization
Program Preparedness Branch
Ensure that each state, territory, county and city is ready to receive, distribute and dispense SNS assets
Assessment of States
Modeling for PODs
Response Branch
Coordinate and integrate all aspects of DSNS training, exercises and operations
Manage Technical Advisory Response Unit (TARU)
Logistics Branch
Responsible for coordinating and managing all aspects of DSNS logistics activities and actions
Materiel Management and Transportation
Office of the Director
Quality Control Unit – ensure assets are stored and transported under cGMP
Project Management Team - manages the receipt, development, integration and transition of significant DSNS program changes from beginning to completion.
11
SAFER • HEALTHIER • PEOPLE™
CDC


DSNS Operational Approach
Forward placed caches (CHEMPACK)
12-hour Push Package
Vaccines, antivirals, and other SNS managed inventory
Vendor Managed Inventory
Direct order prime vendor contracts
12
SAFER • HEALTHIER • PEOPLE™
CDC

Forward Placed Caches: CHEMPACK

- Nationwide "joint venture" program
- Forward placement of nerve agent antidotes
- Integrated into local hazardous material response
- Containerized storage
- Uniform formulary
- Two configurations

13 SAFER • HEALTHIER • PEOPLE™ CDC

Broad Spectrum Support: 12-hour Push Packages

- Pre-packed and configured materiel in transport-ready containers
- Pre-positioned in secure facilities near major transportation hubs
- Delivered rapidly by our world class transport partners
- Color coded and numbered containers for rapid identification by state and local authorities

14 SAFER • HEALTHIER • PEOPLE™ CDC

12-hour Push Packages

15 SAFER • HEALTHIER • PEOPLE™ CDC

Managed Inventory

- Stockpile managed inventory
  - Civil service model versus 3rd party logistics (3PL)
- Vendor managed inventory
  - Supply "Bubbles"
  - "Virtual Stockpiles"

16 SAFER • HEALTHIER • PEOPLE™ CDC

DSNS Core Functions

- Management and Operation of SNS
  - Command & control
  - Resource and materiel management
  - Public information and communication
  - Security (daily and during distribution)
  - Distribution (move materiel to states as required)
- State Support
  - Technical assistance and review for state/local planning
  - Public information and communication
  - Receive, Stage, and Store (supporting a primary state function)
- Training, Exercise and Evaluation – internal and external

17

SAFER • HEALTHIER • PEOPLE™ CDC

Medical Countermeasure Distribution and Dispensing

State and Local Planning Functions

- Critical component of state planning is countermeasure distribution
- Critical component of local planning is countermeasure dispensing

DISTRIBUTION: FEDERAL → STATE →

DISPENSING: LOCAL → PEOPLE

18

SAFER • HEALTHIER • PEOPLE™ CDC

DSNS Technical Assistance

- **Pre Event**
  - *Version 10.02: Receiving, Distributing and Dispensing SNS Assets*
  - Cities Readiness Initiative (CRI)
  - Technical assistance to 62 project areas
  - State and local exercise support and evaluations
  - Classroom instruction
  - Satellite Educational Broadcasts
  - SNS field staff
- **Post Event**
  - Technical Advisory Response Unit (TARU)

19

SAFER • HEALTHIER • PEOPLE™

Cities Readiness Initiative

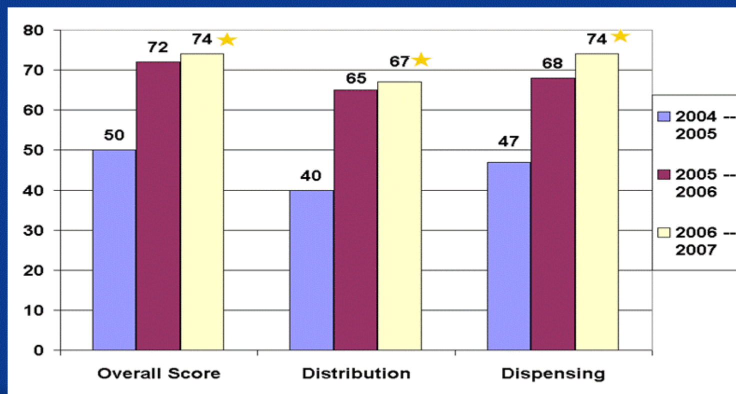
- Provide mass prophylaxis to 100% of the identified population within 48 hours of the decision to do so.
- Strengthen preparedness capabilities of 72 U.S. cities and their metropolitan statistical areas
- Decrease the time it takes to dispense prophylaxis by increasing points of dispensing (POD) capacity and throughput by offering alternate modalities of dispensing, such as:
  - Existing social services
  - Community strike teams
  - Employer-Based PODs
  - Postal Service Option
  - Drive Thru PODs

20

SAFER • HEALTHIER • PEOPLE™

Original 21 CRI Cities

Aggregate Technical Assistance Review Scores, 2004 - 2007



★New Technical Assistance Review Tool Implemented September 2006

21

SAFER•HEALTHIER•PEOPLE™ CDC

Technical Assistance Plans

- Additional DSNS field assignees (7)
- Continue to promote promising practices
- Working to promote “closed PODs”
  - Private corporations
  - Government agencies
  - Tribal nations
- Increase access to modeling tools
  - DSNS simulation project
- Improved preparedness measurement
  - POD standards
  - Capabilities Drills
- Encouraging additional involvement with the private sector

22

SAFER•HEALTHIER•PEOPLE™ CDC

Key Current Initiatives

- Distribution and dispensing models
  - RealOpt
  - Toursolver
- Exercise and operations simulation
  - (Proof of Concept July 2009)
- Improved measurement
- Activity based costing
  - FY-2008 Report at April 2009 SNS Steering Committee
- Fund replacement and other evolving costs
  - Implement activity based budgeting – FY-11 Cycle
  - Modify HealthImpact.net projects to align

23

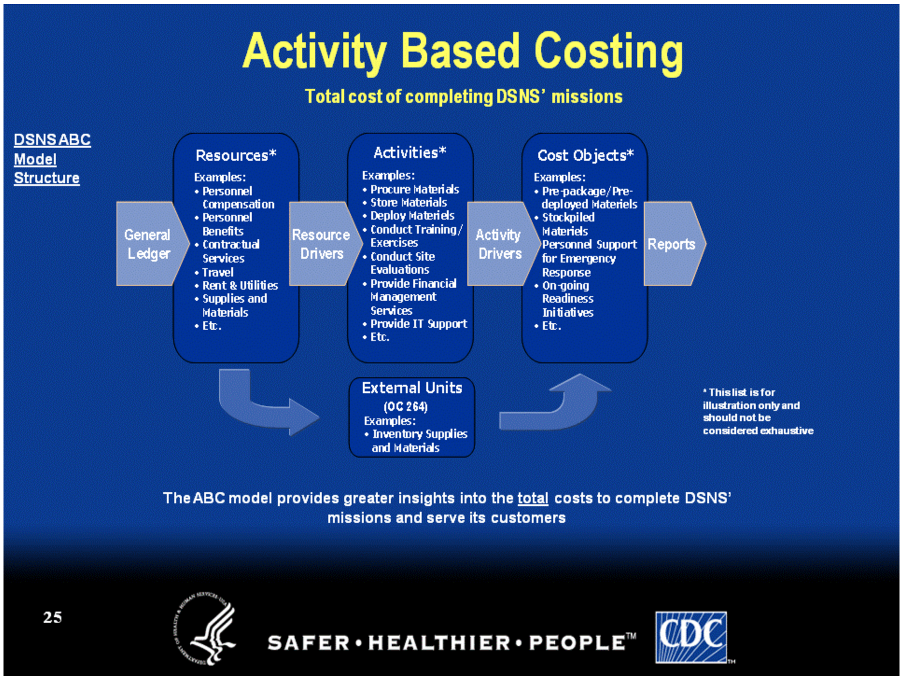
SAFER • HEALTHIER • PEOPLE™ CDC

Future Measurement

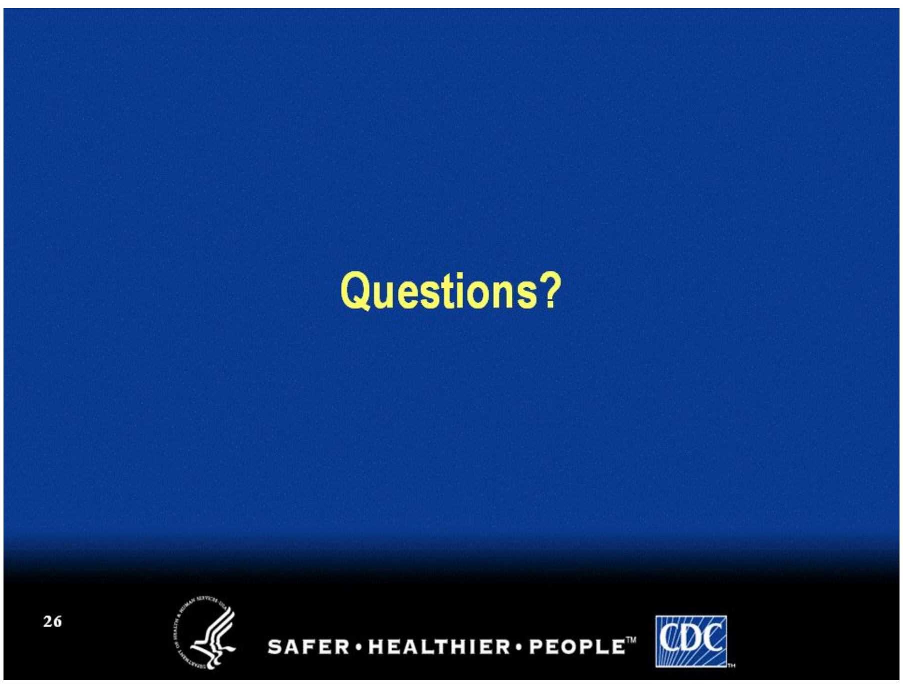
- Operational capability measurement
  - Merging with planning measures
  - Currently using suite of drill-based metrics
  - Second suite under development
  - Working with RAND Corporation

24

SAFER • HEALTHIER • PEOPLE™ CDC



Activity Based Costing
Total cost of completing DSNS' missions
DSNS ABC Model Structure
General Ledger
Resources*
Examples:
• Personnel Compensation
• Personnel Benefits
• Contractual Services
• Travel
• Rent & Utilities
• Supplies and Materials
• Etc.
Resource Drivers
Activities*
Examples:
• Procure Materials
• Store Materials
• Deploy Materiels
• Conduct Training/ Exercises
• Conduct Site Evaluations
• Provide Financial Management Services
• Provide IT Support
• Etc.
Activity Drivers
Cost Objects*
Examples:
• Pre-package/Pre-deployed Materiels
• Stockpiled Materiels
Personnel Support for Emergency Response
• On-going Readiness Initiatives
• Etc.
Reports
External Units
(OC 264)
Examples:
• Inventory Supplies and Materials
* This list is for illustration only and should not be considered exhaustive
The ABC model provides greater insights into the total costs to complete DSNS' missions and serve its customers
25
SAFER • HEALTHIER • PEOPLE™
CDC



Questions?
26
SAFER • HEALTHIER • PEOPLE™
CDC

Technical Advisory Response Unit

Todd Piester, Branch Chief, Response
Division of Strategic National Stockpile
Coordinating Office for Terrorism Preparedness and Emergency Response
Centers for Disease Control and Prevention
References: I C; VII A; VIII C,D

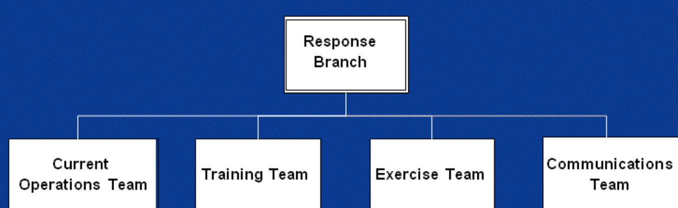
27

SAFER • HEALTHIER • PEOPLE™

DSNS Response Branch

Mission

Coordinate and integrate all aspects of DSNS training, exercises, and operations.



28

SAFER • HEALTHIER • PEOPLE™

TARU Primary Mission

- Receive SNS materiel at designated location
- Facilitate transfer of SNS materiel to state/local authorities

29

SAFER • HEALTHIER • PEOPLE™ CDC

TARU Secondary Missions

- Assist with breakdown of materiel
- Assist with dispensing and distribution issues
- Advise state/local authorities on needs and requests
- Advise on storage and transportation issues
- Manage SNS materiel not released to state/local authorities

30

SAFER • HEALTHIER • PEOPLE™ CDC

TARU Composition

- TARU Lead
- Logistics Officer
- Operations Officer
- Liaison Officer
- USMS (x2)

31

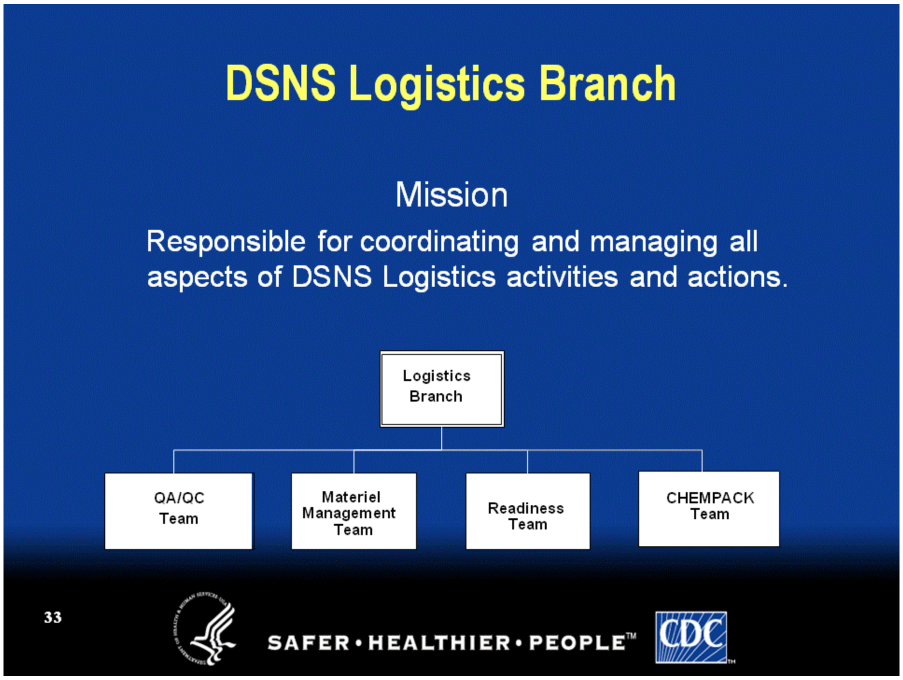
SAFER • HEALTHIER • PEOPLE™ CDC

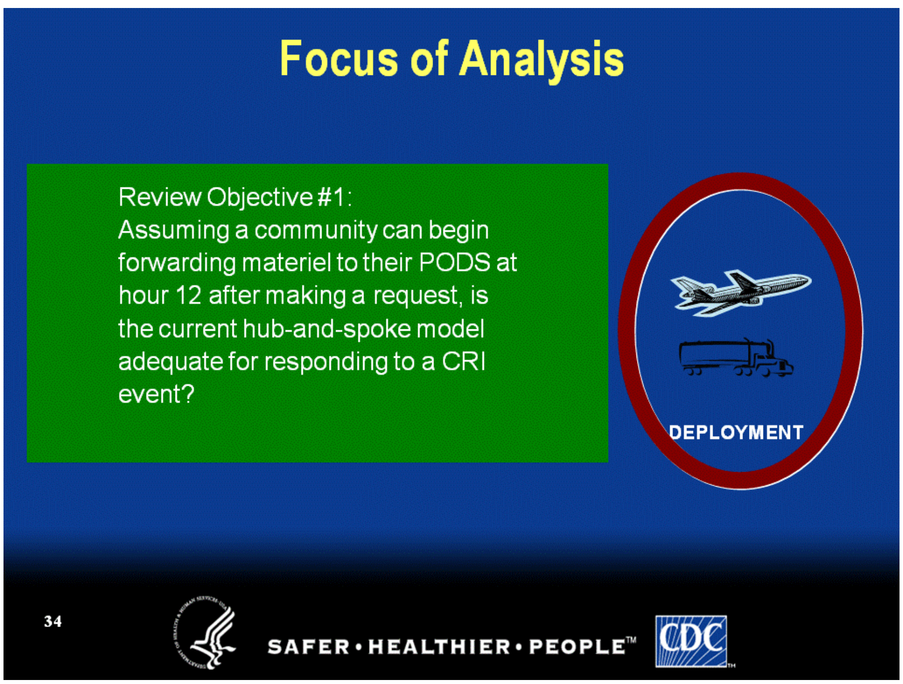
Logistics Branch

Shirley Mabry, Branch Chief, Logistics
Division of Strategic National Stockpile
Coordinating Office for Terrorism Preparedness and Emergency Response
Centers for Disease Control and Prevention
References: I C; III A; IV C; V C,D; VI A; VII A, VIII C,D,G

32

SAFER • HEALTHIER • PEOPLE™ CDC


DSNS Logistics Branch
Mission
Responsible for coordinating and managing all aspects of DSNS Logistics activities and actions.
Logistics Branch
QA/QC Team
Materiel Management Team
Readiness Team
CHEMPACK Team
33
SAFER • HEALTHIER • PEOPLE™
CDC


Focus of Analysis
Review Objective #1:
Assuming a community can begin forwarding materiel to their PODS at hour 12 after making a request, is the current hub-and-spoke model adequate for responding to a CRI event?
DEPLOYMENT
34
SAFER • HEALTHIER • PEOPLE™
CDC

DSNS Deployment Strategy Supporting CRI

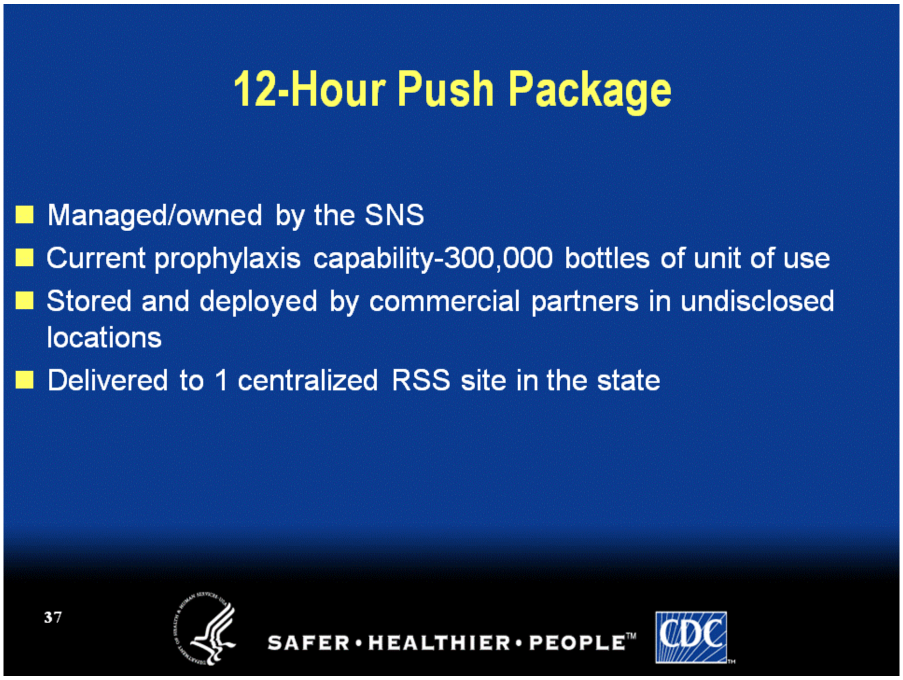
- 12-hour Push Package
- Stockpile Managed Inventory

35 SAFER • HEALTHIER • PEOPLE™ CDC

12-Hour Push Package

- Tailored response package containing a broad spectrum pharmaceuticals, antidotes, and medical supplies
- 130 air cargo containers weighing over 50 tons
- Delivered anywhere within the United States in 12 hours or less
- Strategically located in 10 different locations in the United States
- Designed for rapid movement by ground or air

36 SAFER • HEALTHIER • PEOPLE™ CDC


12-Hour Push Package
Managed/owned by the SNS
Current prophylaxis capability-300,000 bottles of unit of use
Stored and deployed by commercial partners in undisclosed locations
Delivered to 1 centralized RSS site in the state
37
SAFER•HEALTHIER•PEOPLE™
CDC


Stockpile Managed Inventory (SMI)
Delivered within 24-36 hours after approval to deploy
Regionalized storage of materiel in 4 large facilities in the United States
Materiel purchased, managed and maintained by the DSNS
Standardized pallet configuration
Stored by commercial partner
Delivered to 1 centralized RSS site
38
SAFER•HEALTHIER•PEOPLE™
CDC

Differences in Deployment

12-hour Push Package	Managed Inventory
-deployed in order to arrive at RSS within 12 hours after a federal decision to deploy	-deployed in order to arrive 24 to 36 hours after a federal decision to deploy
-broad spectrum of materiel	-specific type of materiel
-sent when nature of the event is unknown	-sent when the nature of event is known
	-may be sent as a follow-up to the 12-hour Push Package

39 SAFER • HEALTHIER • PEOPLE™ CDC

Focus of Analysis

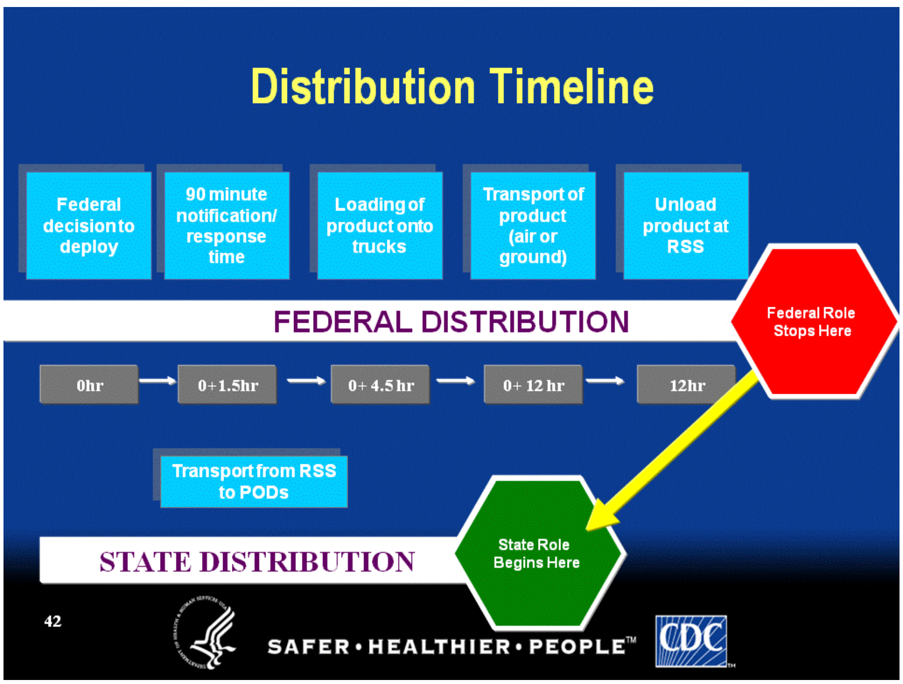
Review Objective #2:
If the community can begin using materiel at 3, 6, or 9 hours after making a request, and taking into account the 72 CRI cities and their populations, along with the requirement of having to respond to simultaneous events in three cities, how much materiel should be forward deployed and in what locations in order to support this type of programmatic change, if it were deemed beneficial?

40 SAFER • HEALTHIER • PEOPLE™ CDC

Background

- Rationale of 12 hour deployment timeline for 12-hour Push Package
- Rationale of 24-36 hour deployment timeline for Managed Inventory
- Current hub and spoke distribution of assets can support the 12 hour time frame
  - If time frame was to be condensed, how would we support it?

41 SAFER • HEALTHIER • PEOPLE™



Focus of Analysis

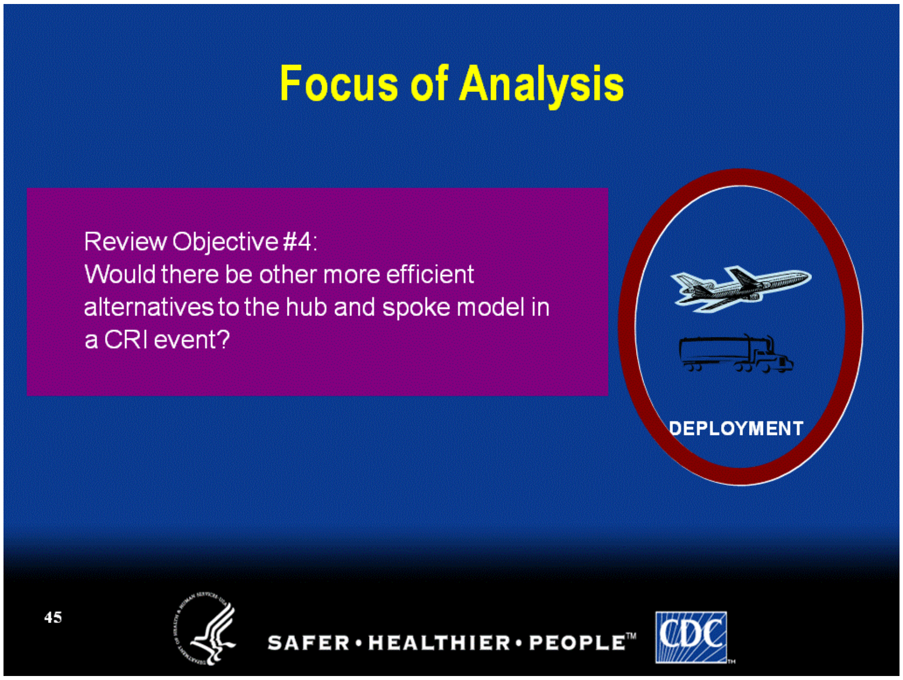
Review Objective #3:
What are the pros and cons associated with the procurement of additional inventory, storage locations, manpower that would be needed to manage the storage locations, perform annual inventories, and provide security; and the potential need for movement of materiel from multiple locations to one location where it would be needed?

43 SAFER • HEALTHIER • PEOPLE™ CDC

Points of Consideration

- Proximity of product to location
- Cost
  - Product
  - Facility
  - Manpower
  - Security
- Coordination of movement for multiple locations

44 SAFER • HEALTHIER • PEOPLE™ CDC


Focus of Analysis
Review Objective #4:
Would there be other more efficient alternatives to the hub and spoke model in a CRI event?
DEPLOYMENT
45
SAFER • HEALTHIER • PEOPLE™
CDC


Keys to Deployment
Robust transportation network
Major air hub
Multiple interstate access
Availability of transportation partner assets
46
SAFER • HEALTHIER • PEOPLE™
CDC

Current Initiatives

- Increase prophylaxis capability in 12-hour Push Package
- Additional multi-use facility in western United States
- Establish separate contract in support of CRI for storage and rapid movement of prophylaxis to 3 major cities simultaneously

47

SAFER • HEALTHIER • PEOPLE™

Questions?

48

SAFER • HEALTHIER • PEOPLE™

Agenda
Pre-Meeting Webinar #2
Division of Strategic National Stockpile (DSNS) Program Review:
Hub-and-Spoke Model vs. Forward Deployment of Assets in a Cities Readiness Initiative (CRI) Setting
Coordinating Office for Terrorism Preparedness and Emergency Response (COTPER)
Centers for Disease Control and Prevention (CDC)

Roybal Campus, Building 19, Room 245
Friday, July 17, 2009
1:00 p.m. – 3:00 p.m. (EDT)

1:00 – 1:05 p.m.	**Welcome and Introductions** Dr. Jack Muckstadt, DSNS Workgroup Co-Chair; BSC, COTPER Dr. Clarence J. (C.J.) Peters, DSNS Workgroup Co-Chair; BSC, COTPER
1:05 – 1:45 p.m.	**Update on Cities Readiness Initiative Status** Stephanie Dulin, Chief, Program Preparedness Branch, DSNS, COTPER
1:45 – 2:00 p.m.	**Questions**
2:00 – 3:00 p.m.	**Discussion: Meeting Planning** Dr. Sue Gorman, Associate Director for Science, DSNS Workgroup Co-Chairs
3:00 p.m.	**Adjourn** Workgroup Co-Chairs

Cities Readiness Initiative (CRI)

Stephanie Dulin, MBA
Chief, Program Preparedness Branch
Division of Strategic National Stockpile

SAFER • HEALTHIER • PEOPLE™

Vulnerability

U.S. intelligence agencies assess that a large-scale aerosol release of anthrax is "well within the technical capability of al-Qa'ida and other foreign or domestic terrorist organizations."

Context

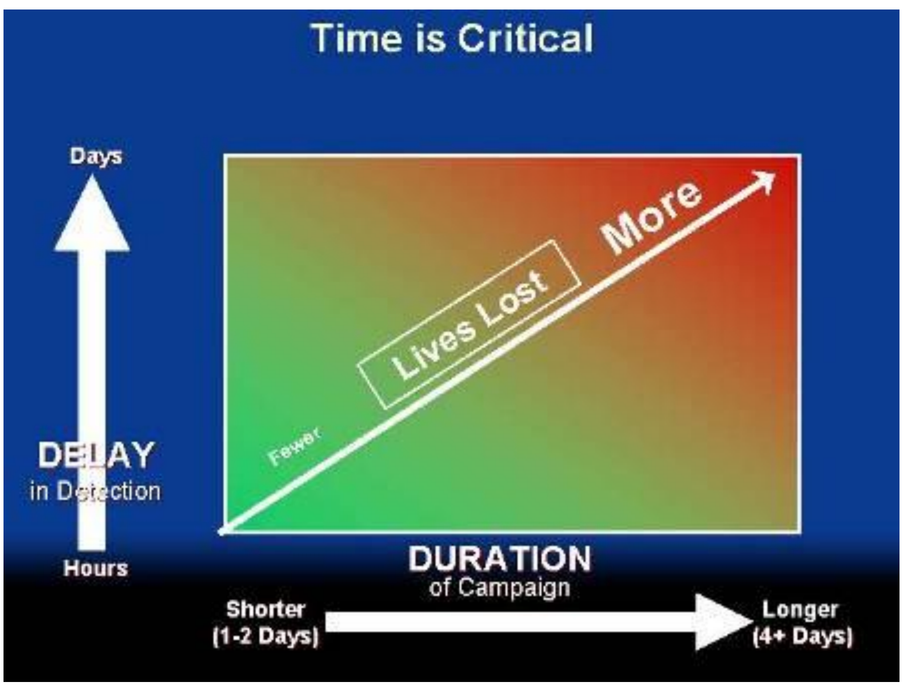
- The Cities Readiness Initiative planning scenario is based on a release of aerosolized anthrax over or throughout a major US population center
- Upon receipt of materiel from the DSNS the affected metropolitan area must rapidly distribute and dispense life-saving medical countermeasures within 48 hours
- DSNS must be able to move the full complement of medical countermeasure to the affected area within 12-24 hours

Basic Microbiology

- Evidence recovered from al-Qa'ida facilities in Afghanistan demonstrate a more mature biological weapons program than we had previously known.
- Al-Qa'ida had constructed at least one laboratory in Afghanistan for small-scale agent production and likely maintains hidden cells elsewhere.

Color-enhanced scanning electron micrograph shows splenic tissue from a monkey with inhalational anthrax; featured are rod-shaped bacilli (yellow) and an erythrocyte (red)


Existing Technology
Aerial dispersion of anthrax over a large geographic area can be accomplished with commercially-available equipment.


Time is Critical
Days
DELAY
in Detection
Hours
Fewer
Lives Lost
More
DURATION
of Campaign
Shorter
(1-2 Days)
Longer
(4+ Days)

Anthrax Exposure: Proportion of Population Saved

DURATION of Campaign	DELAY in Initiation: Immed.	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days
10 Days	84%	78%	71%	62%	54%	45%	36%	28%
7 Days	95%	91%	85%	78%	69%	59%	49%	39%
6 Days	97%	94%	89%	83%	75%	65%	54%	43%
5 Days	98%	96%	92%	87%	80%	71%	60%	49%
4 Days	99%	98%	95%	91%	85%	76%	66%	54%
3 Days	100%	99%	97%	94%	89%	81%	72%	60%
2 Days	100%	99%	98%	96	92%	86%	77%	66%
1 Day	100%	100%	99%	97%	94%	89%	82%	72%

Source: Dr. Nathaniel Hupert, Weill Medical College at Cornell

Gap Analysis

- The 31 most populous cities were contacted and identified **significant** gaps with regard to:
  - Points of dispensing
    - Few PODs and NO alternative dispensing strategies
  - Volunteers
  - Medical Personnel
  - Management Personnel
  - Equipment
  - Public Information and Communication

Technical Assistance Prior to CRI

- Technical assistance limited to states with a primary focus on the RSS and Distribution function
- Access to local jurisdictions was limited to directly funded cities (Los Angeles CA, Chicago IL, New York City NY, Washington DC)
  - Assessment data from only 4 city health departments
  - Highly subjective data, unverified
- SNS assessment based on state provided information, not verified

The CRI Mission

- Provide mass prophylaxis to 100% of the identified population within 48 hours of the decision to do so
- Strengthen preparedness capabilities of 72 U.S. cities and their Metropolitan Statistical Areas
- Decrease the time it takes to dispense prophylaxis by increasing POD capacity and throughput by offering alternate modalities of dispensing, such as:
  - Existing social services
  - Community strike teams
  - Employer-Based PODs
  - Postal Service Option
  - Drive Thru PODs

Group I - CRI (21 Cities)

- 21 Cities/Counties were chosen for a pilot (2004 – 2005)
  - Planning jurisdictions self-determined
- Funded through a Congressional Redirect of Public Health Emergency Preparedness (PHEP) funds
- Technical Assistance Reviews (TARs)
  - Baseline
  - Six-Month
  - Annual

Group II – CRI Expansion (36 MSAs)

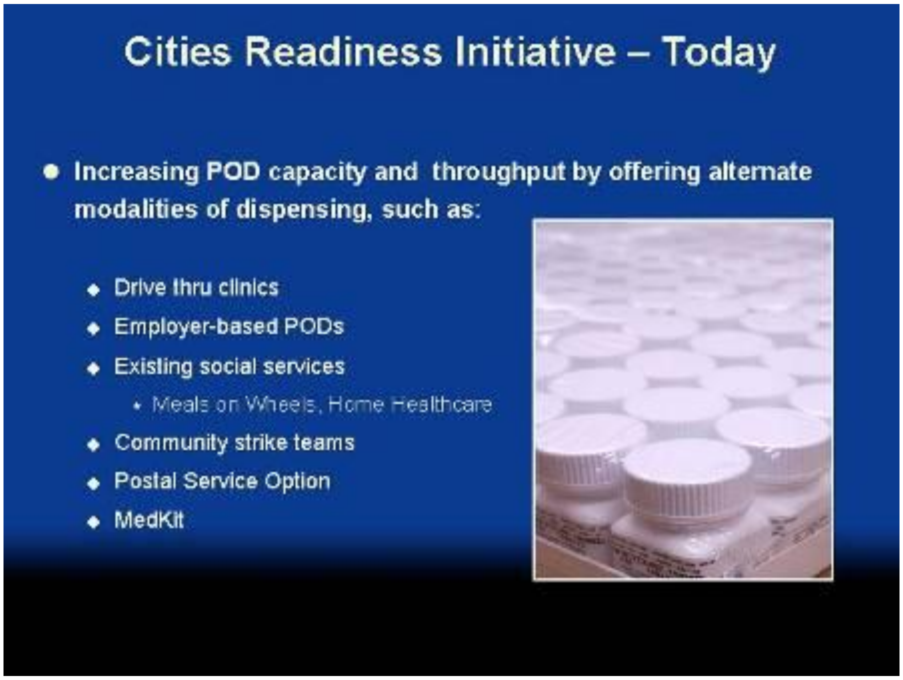
- Expanded to cover Metropolitan Statistical Areas (MSAs) vs. Cities (2005-2006)
- Added the next 15 most populous MSAs (2006-2007)
- Funded through a carve out of PHEP Cooperative Agreement funds
- Technical Assistance Reviews
  - 25% CDC / 75% State
  - Baseline
  - Annual
    - If scored < than 69, reassessed in 6 months

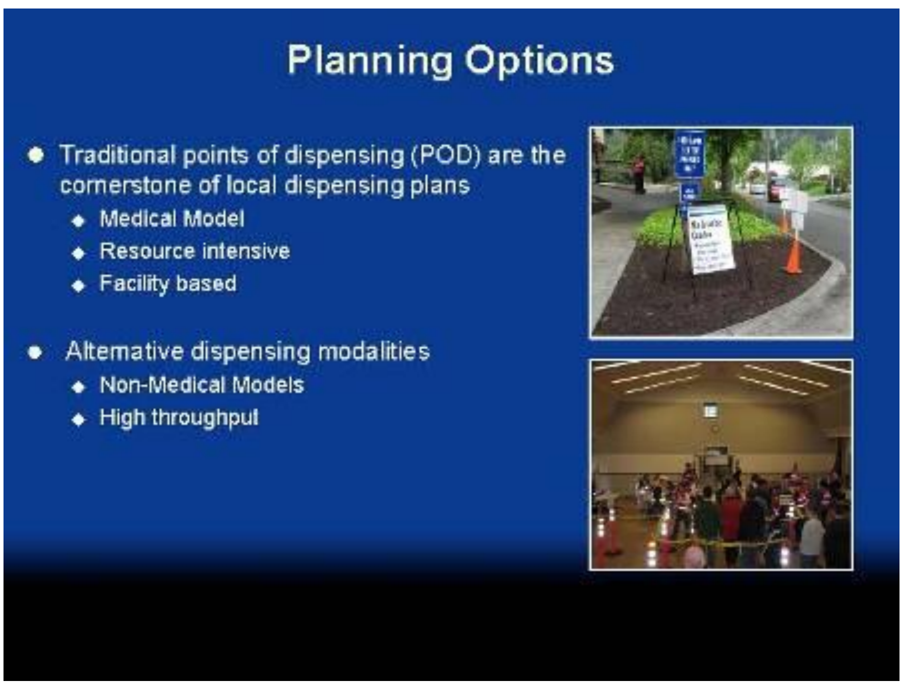
Group III – CRI Current (72 MSAs)

- Expanded CRI to include at least one MSA in all 50 states (2006-2007)
- Funded through a carve out of PHEP Cooperative Agreement funds
- Technical Assistance Review
  - 25% CDC / 75% State
  - Baseline
  - Annual
    - If scored < than 69, reassessed in 6 months

Cities Readiness Initiative - Today

- **CRI includes 72 U.S. Metropolitan Statistical Areas**
  - based on population, geographical location, and potential vulnerability
  - 57% of the US Population
  - Assessment data from over 500 county/city health departments
    - Evidence based, less subjective
- **Strengthening the POD Infrastructure**
  - Thousands of PODs identified
  - POD specific security assessments
  - ICS training for POD management
  - Developed Job Action Sheets and Just-in-Time Training
  - POD go-kits (equipment and supplies)
  - POD exercises


Cities Readiness Initiative – Today
Increasing POD capacity and throughput by offering alternate modalities of dispensing, such as:
Drive thru clinics
Employer-based PODs
Existing social services
Meals on Wheels, Home Healthcare
Community strike teams
Postal Service Option
MedKit


Planning Options
Traditional points of dispensing (POD) are the cornerstone of local dispensing plans
Medical Model
Resource intensive
Facility based
Alternative dispensing modalities
Non-Medical Models
High throughput

Alternate Methods of Dispensing

- Drive-through PODs
  - Eliminates need to walk through a POD
  - Individuals remain in vehicles
- Mobile dispensing units
  - Reaches remote areas
  - Provides access to population unable to reach PODs

Alternate Methods of Dispensing

- Closed PODs
  - Dispenses to a specific identified population
  - Such as employees of large organization/business
  - Can include federal organizations

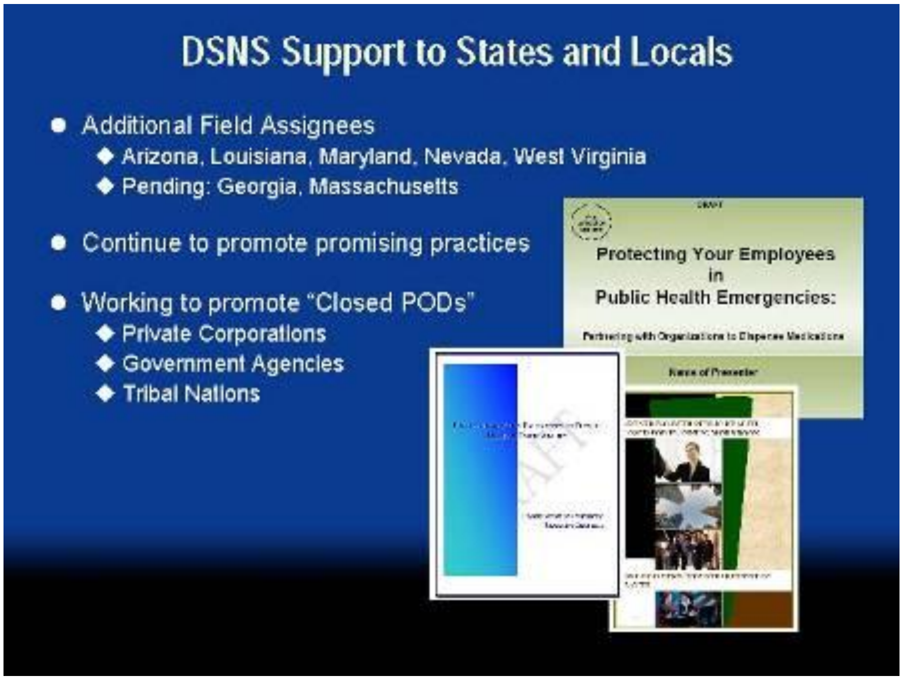
- Community based organizations
  - Uses existing infrastructure to dispense countermeasures to identified population
  - Reaches remote areas
  - Provides access to population unable to reach PODs

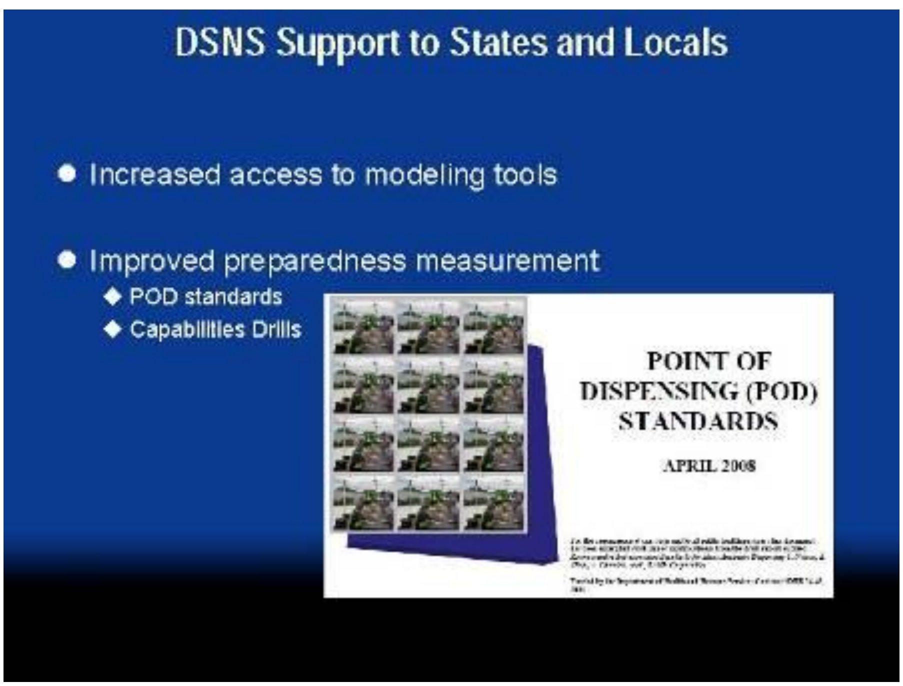
Alternate Methods of Dispensing

- **Postal Service Option**
  - Volunteer Mail Carriers deliver a bottle of antibiotics (20 tablets) to homes in selected ZIP codes
  - An approved USPS Security Plan is needed to move from strategic to tactical/operational planning
  - Three drills conducted using postal carriers to rapidly dispense medical countermeasures
  - Tactical planning and volunteer mail carrier recruitment in Minneapolis

DSNS Support to States and Locals

- Technical Assistance
  - Program Services Consultants
  - State Field Assignees
- SNS Planners Guide V 10.2
- SNS Extranet
- Modeling Forum
  - www.snsmodeling.org
  - 74 registered users
- SNS Sponsored Training Courses
- Exercise Support


DSNS Support to States and Locals
Additional Field Assignees
Arizona, Louisiana, Maryland, Nevada, West Virginia
Pending: Georgia, Massachusetts
Continue to promote promising practices
Working to promote "Closed PODs"
Private Corporations
Government Agencies
Tribal Nations
Protecting Your Employees in Public Health Emergencies:
Partnering with Organizations to Dispense Medications
Name of Presenter


DSNS Support to States and Locals
Increased access to modeling tools
Improved preparedness measurement
POD standards
Capabilities Drills
POINT OF DISPENSING (POD) STANDARDS
APRIL 2008

DSNS Support to States and Locals

- Videos in Development
  - Public Readiness and Emergency Preparedness Act
  - Hospitals/Alternate Care Facilities
  - TAR Tool Series
  - Security

- Tribal Coordination
- At Risk Populations
  - Workbook – in clearance
  - Electronic Toolkit – collaboration with emergency communications systems (NCHM)
- Public Information and Communication Tools

Challenges

Political

- Lack of political buy-in at all levels of government
- Evidence of credible threat. Many state and local governments do not believe the basic premise or requirements
- Difficult relations with Emergency Management and Law Enforcement Agencies

Legal

- Liability issues related to employing rapid/non-medical dispensing models

Challenges

Operational

- POD staffing requirements are beyond the capacity of many jurisdictions
- Limited Health Department staffing at state and local levels dedicated to countermeasure dispensing planning
- High turnover rate at state and local levels
- Difficulty in measuring the capacity to achieve the 48 hour "challenge"

Questions?

OMB Disclaimer

The findings and conclusions in this presentation are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention.

SAFER • HEALTHIER • PEOPLE™

Appendix C
Workgroup Meeting Agenda

Agenda
Division of Strategic National Stockpile (DSNS) Program Review
Ad Hoc Expert Panel Meeting
Hub-and-Spoke Model vs. Forward Deployment of Assets in a Cities Readiness Initiative (CRI) Setting
Coordinating Office for Terrorism Preparedness and Emergency Response (COTPER)
Centers for Disease Control and Prevention (CDC)

Roybal Campus, Global Communications Center
Building 19, Room 254/255
July 28-30, 2009

Tuesday, July 28, 2009

9:00 – 9:15 a.m. **Welcome and Individual Introductions**
Dr. Jack Muckstadt, DSNS Expert Panel Chair; Board of Scientific Counselors, COTPER

9:15 – 9:20 a.m. **Workgroup Charge and Logistics**
Dr. Sue Gorman, Associate Director for Science, DSNS, COTPER

9:20 – 9:50 a.m. **CDC Preparedness Activities**
CAPT Daniel Sosin, Senior Advisor for Science, COTPER

9:50 – 10:20 a.m. **SNS Technical Assistance Review (TAR): States' Preparedness**
Dr. Linda Neff, Team Lead, Program Preparedness Branch, DSNS, COTPER

10:20 – 11:00 a.m. **Discussion and Questions**

11:00 a.m. – 12:30 p.m. Lunch

12:30 – 2:30 p.m. **Program Preparedness – Modeling and Time Studies**
- Bernie Benecke, Team Lead/Lead Public Health Advisor
- Dr. Kas Salawu, Public Health Logistics Preparedness and Response Coordinator
- Rick Pietz, Public Health Analyst, Program Preparedness Branch, DSNS, COTPER

2:30 – 3:00 p.m. **Discussion and Questions**

3:00 – 3:15 p.m. **Break**

3:15 – 4:15 p.m. **Points of Dispensing (PoD) Panel**
- Dana E. Henderson, Senior Health Program Planner-Mass Prophylaxis, SNS Communicable Disease Prevention Unit, San Francisco Department of Public Health, San Francisco, CA
- Zerlyn Ladua, Bioterrorism/Public Health Emergency Preparedness, Division of Communicable Disease Control and Prevention, Alameda County Health Department, Oakland, CA
- Shannon Fitzgerald, Director, Office of Public Health Preparedness

Pennsylvania Department of Public Health, Harrisburg, PA

4:15 – 4:45 p.m.	**Discussion and Questions**
4:45 – 5:00 p.m.	**Discussion (Closed Session)**
5:00 p.m.	**Adjourn Day 1** Dr. Jack Muckstadt, DSNS Expert Panel Chair; Board of Scientific Counselors, COTPER
6:00 p.m.	**Meet in Lobby for Optional dinner with COTPER staff**

<u>Wednesday, July 29, 2009</u>

9:00 – 9:05 a.m.	**Welcome** – Workgroup Convenes for Day 2 Dr. Jack Muckstadt, DSNS Expert Panel Chair; Board of Scientific Counselors, COTPER
9:05 – 10:05 a.m.	**Stockpile in Motion Across the Nation (SIMAN) Simulation Program** Mike Moore, Exercise Team Lead, Response Branch, DSNS, COTPER
10:05 – 10:45 a.m.	**Discussion and Questions**
10:45 – 11:00 a.m.	**Break**
11:00 a.m. – 12:00 p.m.	**Deliberations and Report Writing (Closed Session)**
12:00 – 1:00 p.m.	**Lunch**
1:00 – 3:00 p.m.	**Deliberations and Report Writing (Closed Session)**
3:00 – 3:15 p.m.	**Break**
3:15 – 5:00 p.m.	**Deliberations and Report Writing (Closed Session)**
5:00 p.m.	**Adjourn Day 2** Dr. Jack Muckstadt, DSNS Expert Panel Chair; Board of Scientific Counselors, COTPER

<u>Thursday, July 30, 2009</u>

9:00 – 9:05 a.m.	**Welcome** – Workgroup Convenes for Day 3 Dr. Jack Muckstadt, DSNS Expert Panel Chair; Board of Scientific Counselors, COTPER
9:05 a.m. – 12:00 p.m.	**Deliberations and Report Writing (Closed Session)**
12:00 p.m.	**Adjourn Day 3** Dr. Jack Muckstadt, DSNS Expert Panel Chair; Board of Scientific Counselors, COTPER

Appendix D
Pre-Meeting Panel Findings and Observations

Part of the panel's review process involved providing comments on the review questions in advance of the meeting. This Appendix summarizes these initial responses.

Overall, the panel found that sufficient data are not available to fully answer the four questions. Based on the available information, the panel has identified data that would be needed elsewhere in this report. More precisely, in order to answer these questions, we must consider these questions in a supply chain environment, both upstream to the suppliers and downstream all the way to the points of dispensing. For the purposes of our discussion, the supply chain consists of external suppliers of material, the procurement process; receipt by the Federal SNS component; storage of material at SNS locations; logistics activities to transport material to state and local partners; processing material at the state/local sites (RSS); moving material to PODs and other locations, as well as dispensing medications to individuals. The supply chain in this case not only consists of physical activities, but also the policies and procedures for managing the activities, including command, control, and communications.

Specific comments from the panel regarding the assigned questions follow.

Review Objective 1: Assuming a community can begin forwarding material to their PODS at hour 12 after making a request, is the current hub-and-spoke model adequate for responding to a CRI event?

The current SNS distribution system is not really a traditional two-way "hub-and- spoke" model. More properly, the current SNS system should be referred to as a "Multiple Distribution Center" model. It is the panel's belief that the current model is adequate provided that the current goal of supplying SNS assets to three MSAs is not dramatically expanded. However, an important consideration is that the capability to supply RSS operations within 12 hours may rely on the utilization of both 12 hour Push Packages as well as managed inventory assets. Although it is believed that managed inventory assets can begin shipments as rapidly as Push Packages, there is no officially stated goal of doing so.

In addition to operational capability, the current SNS model offers a number of other advantages. Specifically, the current model offers: smoother supply-side deliveries, relatively few facilities to coordinate, lower staff and security-to-product ratio, reasonable resiliency if some storage facilities are removed from service (counting both Push Package and managed inventory facilities), easier inventory, and quality control.

These advantages are balanced by several disadvantages. Fewer facilities require longer, slower, and more expensive transport distances to some MSAs compared to a more distributed model. Fewer facilities shipping large quantities of material may require more transportation resources which must be located then travel to, and around, the facility.

Review Objective 2: If the community can begin using material at 3, 6, or 9 hours after making a request, and taking into account the 72 CRI cities and their populations, along with the requirement of having to respond to 3 events simultaneously, how much material should be forward deployed and in what locations in order to support this type of programmatic change, if it were deemed beneficial?

The precise amount of material, if any, to be forward deployed cannot be determined based upon the information available to the panel. Specifically, there must be a standard measure of a jurisdiction's ability to handle additional SNS supplies. This ability must be used along with the location of the high-risk and high-population-density MSAs as well as potential storage locations in order to create a model that could calculate an optimal quantity of "forward placed" material. We must keep in mind that not all 72 CRI MSAs are at equal risk of threat. Once the optimal quantity of material is derived, the quantity of material must be balanced according to cost of the facility per unit of storage. Furthermore, the cost of the additional material must fit sustainably within DSNS's budget limits. Perhaps it may be possible to simply increase the quantity of material stored at already existing SNS facilities; however, the ability of facilities to store more material will depend upon the format of the material (e.g., pallets or Push Pack containers) and the efficiency of the facility's storage (e.g., rack density and layout).

Review Objective 3: What are the pros and cons associated with the procurement of additional inventory; storage locations, and manpower that would be needed to manage the storage locations, perform annual inventories, and provide security; and the potential need for movement of material from multiple locations to one location where it would be needed?

Clearly, more storage locations will be more expensive and complicated to maintain, secure, and coordinate. More locations and supplies would potentially allow faster transportation to particular MSAs and would add robustness to the existing system.

One point of consideration involves whether additional inventory needs to be purchased at all. One option would be to simply spread existing inventory to additional locations. Another alternative to procuring additional inventory would be to expand contingency contracting with private vendors who are located closer to MSAs of particular concern. Conceptually, this would be similar to existing vendor-managed inventory agreements but would be more geographically diverse. However, many SNS products are not items that are routinely stored or manufactured.

In addition to tangible products and facilities, procedures may have to be modified to efficiently handle inventories. For example, inventory could be managed by continuous review or by periodic review. Moreover, each facility and its contents must be remotely tracked and controlled by SNS coordinators. Although DSNS has made tremendous advances towards real-time asset coordination and tracking, it remains to be seen if the infrastructure can handle the additional burden of more sites to oversee and if transportation partners are capable of handling the additional shipping requirements.

Security arrangements are another issue to consider. It is unknown to the panel exactly what security arrangements are in place at each SNS storage facility. In fact, the cost of providing security may be the overriding cost factor for additional storage facilities (see attached spreadsheet). If, as an example, the U.S. Marshal's service is required to secure every facility, then expanding facilities would be extremely expensive. On the other hand, if security could be contracted out or partially automated then costs could be reduced.

Another concern, once again, relates to the capability of the MSA in question to handle additional supply shipments systematically. If the nearby RSS is not capable of handling more material delivered more rapidly, then there is little point supplying it. Even if the RSS is capable of handling such material, if the dispensing channels are not up to the task then there is also little point in enhancing supply rate.

Fundamentally, the importance of each of the factors mentioned will depend upon the extent of inventory or facility expansion. The extent of expansion can only be determined by results from modeling based upon data that either does not exist or is unknown to the panel.

Regardless, expansion of stockpile assets or facilities beyond the current level will only make sense if particular MSAs are considered to be especially vulnerable to a massive attack. Furthermore, the attack must be defendable by the use of inexpensive medications or those with long shelf life that can be dispensed very rapidly to a large population. If each of these conditions is not met, then the current system of SNS asset storage will be more efficient than any expansion scenario. Although the capability of MSAs to receive and dispense stockpile material is beyond the scope of this panel's assignment, it must be considered. Otherwise, any expansion of stockpile inventory or storage facilities will fail to enhance the SNS program's ultimate goals.

Review Objective 4: Would there be other more efficient alternatives to the hub and spoke model in a CRI event?

Although it may be possible to increase the efficiency of the current SNS system by forward placing some materials closer to potential target areas, it is impossible to recommend this categorically. For example, items located closer to an affected MSA could, theoretically, arrive faster than items that are positioned farther away. However, the increase in efficiency assumes that the local MSA is an actual target and is capable of realistically deploying those supplies as soon as they arrive.

It may be possible to investigate sharing of facilities with other government agencies in order to forward deploy a small set of resources. An additional option might be to temporarily deploy assets to high risk locations depending on events or intelligence reports. Yet another possibility might be to arrange simpler transfer stations where supply side and local distribution trucks could "cross dock" in order to move supplies from truck to truck rather than involve a discrete staging and storage phase.

In order to determine these factors, model and full-scale exercise data must be collected, analyzed consistently across MSAs, and summarized in order to objectively rate a given MSA's dispensing capability. Furthermore, depending on the current medical countermeasures already in place within the MSA, existing rapid medical deployment plans could be expanded to incorporate additional resources and the storage locations for already existing medication stocks could potentially serve as a storage location for additional forward-deployed SNS-supplied medications. For example, if public safety agencies already maintain antibiotics and have rapid dispensing plans for pre-determined classes of personnel, then additional SNS antibiotics could enhance that existing capability. If an MSA already has a coordinated network of large-scale closed PODs, then forward-deployed medications could be rapidly distributed to those closed PODs with a minimum of additional dispensing overhead. If a particular dispensing center is large enough, it may be feasible to bypass an RSS and deliver medications directly to the dispensing site. However, there are potential downsides to closed PODS such as weekend, evening, and holiday closures. These limitations also apply to other potential dispensing options (e.g., postal delivery).

Appendix E

Table of Contents for Background Materials Provided to Reviewers

Required or optional reading/viewing is indicated in parentheses.

<table>
<tr><th colspan="3">BACKGROUND INFORMATION DESCRIPTIONS</th></tr>
<tr><th colspan="2">INFORMATION RESOURCE</th><th>DESCRIPTION</th></tr>
<tr><td rowspan="5">I. FACT SHEETS (required)</td><td>A. Cities Readiness Initiative (CRI)</td><td>▪ CRI General Fact Sheet
▪ CRI Q&A
▪ Getting Life Saving Medicines to People During Emergencies-Public Health and Private Sector Partnerships</td></tr>
<tr><td>B. Technical Assistance Review (TAR) Tool</td><td>▪ TAR General Fact Sheet</td></tr>
<tr><td>C. Division of Strategic National Stockpile (DSNS)</td><td>▪ DSNS General Fact Sheet
▪ DSNS Q&A</td></tr>
<tr><td>D. Modeling</td><td>▪ TourSolver Software
▪ Stockpile Routing Web Portal
▪ RealOpt
▪ Center for Emergency Response Analytics
▪ Collecting Time Study Data</td></tr>
<tr><td>E. Closed Point of Dispensing (POD)</td><td>▪ Closed POD General Fact Sheet</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>II. EVALUATIONS (optional)</td><td>A. Local TAR Tool</td><td>▪ Sample assessment of a Cities Readiness Initiatives (CRI) metro statistical area (MSA). The name of the jurisdiction has been removed.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">III. GUIDANCE DOCUMENTS (optional)</td><td>A. Receiving, Distributing, and Dispensing Strategic National Stockpile Assets A Guide for Preparedness Version 10.01 - Draft</td><td>▪ The Forward section of a guidance document created for emergency management and public health personnel at the state, regional, and local levels to help them prepare to request and make effective use of Strategic National Stockpile (SNS) medicines and medical supplies (The entire document is available upon request)</td></tr>
<tr><td>B. POD Standards</td><td>▪ Summarizes the Centers for Disease Control and Prevention’s POD standards</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">IV. PAPERS (required papers are noted)</td><td>A. CRI Progress Report (required)</td><td>▪ 2009 progress report of CRI</td></tr>
<tr><td>B. Initial Evaluation of the CRI (required)</td><td>▪ Independent evaluation of CRI by the RAND Corporation to determine whether the program has led to discernible improvements in awardees’ readiness</td></tr>
</table>

BACKGROUND INFORMATION DESCRIPTIONS		
INFORMATION RESOURCE		**DESCRIPTION**
	C. Reducing Mortality from Anthrax Bioterrorism: Strategies for Stockpiling and Dispensing Medical and Pharmaceutical Supplies (required)	▪ Evaluation of cost/benefits of alternative strategies
	D. Facility Location and Multi-modality Mass Dispensing Strategies and Emergency Response for Biodefense and Infectious Disease Outbreaks	▪ A systems approach to analyze mass dispensing of countermeasures
	E. Evaluation of a Mass Dispensing Exercise in a CRI Setting	▪ Abstract evaluating POD based mass dispensing
	F. Optimizing a District of Columbia Strategic National Stockpile Dispensing Center	▪ Exercise to test POD plan
	G. Implementing the CRI Initiative Lessons Learned from Boston	▪ Practical lessons learned from development and implementation of CRI plan
	H. Modeling the Public Health Response to Bioterrorism: Using Discrete Event Simulation to Design Antibiotic Distribution Centers	▪ Modeling to determine POD design
V. PRESENTATIONS (required)	A. CRI	▪ Briefing on CRI
	B. Mass Dispensing Overview	▪ Briefing on mass dispensing
	C. Anthrax Exposure: Proportion of Population Saved	▪ Detailed slide that depicts how delays in either detection (initiation of a campaign) or the amount of time it takes to provide antibiotics to a population will translate in lives lost in persons exposed to anthrax
	D. Anthrax: Time is Critical!	▪ Summary slide that depicts how delays in either detection (initiation of a campaign) or the amount of time it takes to provide antibiotics to a population will translate in lives lost in persons exposed to anthrax
VI. LEGISLATIVE (optional)	A. DSNS	▪ History of authorizations that have affected the SNS
VII. VIDEOS	A. DSNS: An Overview	▪ Overview of the SNS and the division that

BACKGROUND INFORMATION DESCRIPTIONS		
INFORMATION RESOURCE		**DESCRIPTION**
(required videos are noted)	(required)	manages the assets
	B. CRI: A National Priority (required)	▪ An overview of the CRI
	C. Mass Antibiotic Dispensing: A Primer	▪ An overview of the critical aspects of a mass
VIII. MISCELLANEOUS (required items are noted)	A. Data Tables (required)	▪ CRI baseline and current scores by cohort ▪ CRI percentage of MSAs operating within the acceptable range ▪ CRI TAR comparison of 2007 and 2008 provisional data ▪ Aggregate scores of CRI MSAs and the 12 functions for which they are evaluated ▪ Population descriptions of the 72 CRI MSAs
	B. CRI Populations Summary (required)	▪ Listing of the 25% most populous CRI MSAs
	C. DSNS Terminology Guide (required)	▪ Description of common DSNS terms used in guidance documents, presentations, and fact sheets
	D. Org Charts	▪ CDC, COTPER, and DSNS organization charts
	E. Drill Information	▪ SNS-Related Public Health Emergency Preparedness Drills ▪ Linkages Between RAND Drills and State and Local TAR Tools
	F. Postal Drill After Action Reports	▪ After Action Reports on Seattle, Philadelphia, and Boston postal drill exercises
	G. Cost Figures (required)	▪ Cost Figures for SNS Assets and Operations

Appendix F

Evaluating Consequences of Planned Capacities for a Public Health Emergency Supply Chain

Kathleen King and Jack Muckstadt
School of Operations Research and Information Engineering
Cornell University

Technical Report No. 1475

February 22, 2010
Updated March 18, 2010

Abstract

To respond effectively in the event of a public health emergency, careful analysis of preparedness plans is essential. This note describes a linear programming model of the Center for Disease Control Strategic National Stockpile (SNS) supply chain for distributing medical supplies under emergency conditions. The purpose of the model is to evaluate the effects that a specified collection of planned resource availabilities would have on the efficacy of the distribution network. This efficacy is measured in terms of the number of patient-hours waited during the emergency response time horizon. The model's constraints describe the physical system, including the relationships between the SNS, the regional distribution warehouse, and the medical supply distribution clinics. In the following note all model constraints and variables are described in detail, and AMPL code implementing the model is given.

1 Introduction

In the event of a large-scale public health emergency, like an anthrax attack or an influenza pandemic, a supply chain distribution network must provide the necessary medications and supplies to all affected individuals in a timely manner. This network consists of the federally-controlled Strategic National Stockpile (SNS), state or locally run Receiving Storing and Staging (RSS) warehouses, and local Points of Dispensing (PODs) or other dispensing agencies. For this system to be effective, detailed plans must be made in advance. Furthermore, policy makers must have clear ideas about how material will flow through the system and how the planned capacities will affect this flow and meet the needs of the public. In short, we must ask whether the planned distribution network will function as desired.

Our goal is to construct a simple method for obtaining an approximate answer to this question. In this note, we describe a model that minimizes the delay in service to the affected public while recognizing the physical constraints of the distribution network. While the scope of the model we present in this note addresses all elements of the supply chain, smaller portions of the system could be studied in greater detail using similar models. This is essential because the question of "does it work?" will mean different things to different people working within the network. An RSS manager, for instance, likely does not care about how the SNS moves material to the RSS, as long as it arrives on time, nor does he worry about the distribution of staff at individual PODs. However, the RSS manager must ensure that he has enough staff working at the unloading docks to receive material, space to store the material, and the appropriate number of material handling devices necessary to process the material and move it to its assigned locations. He may be concerned with different types of workers who are certified to perform different tasks. A POD manager, while uninterested in the detailed operations of the RSS, may instead be concerned with the movement of patients and inventory through a POD, while the truck dispatcher may want to focus on the flow of trucks through the system. It is essential to develop models that focus on different areas of interest to particular users. Again, these models need not be overly complex in order to address the key questions. They would be quite similar to the model presented here in structure and solution methodology, but many details given here will be removed and others added to tailor the new models to their particular applications.

As mentioned above, the model that we will describe here ranges across all elements of the supply chain. The model is rate-based and uses rates such as "the number of patients processed per hour per POD" or "the number of trucks that can be unloaded at the RSS during each time period." These rates are not calculated by the model, but must be determined separately. For example, one might use a simulation tool such as D-PODS [4], Clinic Generator [1], or RealOpt [5] to estimate staffing requirements consistent with POD processing rates. Given these effective capacities, the proposed model can help planners to understand more clearly how well their system might perform. Specifically, it will identify bottlenecks in the network, that is, capacities at various points in time that delay the delivery of required material.

For the purpose of evaluating the efficacy of existing plans, the simple model we will describe is based on the assumption that all rates and distribution system parameters are known with certainty. In more complex models the impact of uncertainty on these rates and parameter values is considered explicitly. However, the focus of this model is simply to determine whether, given a fixed set of capacities, our emergency response network will be effective. Thus, for now we assume that patient arrival rates, lead times, and inventory shipments to the SNS are assumed to be known. Below we describe the system model and its assumptions and we explain how the "best" performance is determined. We will then present the mathematical model.

2 Model Description

In this model, time is broken down into discrete "periods." Decisions are assumed to be made at the beginning of each time period. Capacity levels are assumed to be constant during a single time period, but they may change between time periods. The length of a period will depend on the type of emergency. For example, in the case of an anthrax attack, we may want time periods to be an hour long, or perhaps even 15 minutes in length. In responding to pandemic influenza, however, we may want to consider time periods of 8 hours (the standard working shift length) or even days. Shorter time periods allow for more detailed modeling, but they also require more input data from the user.

The model that we will describe consists of the SNS, one RSS, and a set of PODs served by the RSS. We assume that each location may have an initial stock of inventory, and as time goes by, external suppliers resupply the SNS, while the SNS supplies the RSS and the RSS supplies the PODs. It would be easy to add more RSSs to the system, or even other SNS warehouses, but doing so would further complicate our already crowded notation, so we focus on a single RSS for simplicity. In this model, we will consider the following capacities:

- the rates at which patients arrive to each POD,
- the rates at which patients can be served at each POD,
- the rate at which cases of inventory can be loaded onto trucks at the RSS,
- the rate at which pallets can be loaded onto trucks at the SNS,
- the rate at which pallets can be unloaded from trucks at the RSS,

- the number of trucks available to transport inventory from the SNS to the RSS,
- the number of trucks available to transport inventory from the RSS to the PODs, and
- the amount of usable storage space (by volume) at the RSS and PODs.

Let us begin now by describing the constraints on the SNS and its shipments. For simplicity, we assume that trucks are used to transport material from the SNS to the RSS, although the use of aircraft is also an option. The shipping capacity of the SNS determines the maximum number of pallets that can be sent to the RSS each day. As mentioned earlier, we assume that all of these data are known in advance. However, we assume that the SNS has enough capacity to receive all arriving inventory immediately, so arriving delivery trucks to the SNS are not considered in the present model.

A fixed number of trucks is available to move inventory between the SNS and RSS; the total number available in the current time period is given by the total number of trucks in the SNS-RSS system less those that are currently en route to or from the SNS. Under a third party carrier, the number of trucks available to move inventory will almost certainly be more than sufficient, but we include the constraint to emphasize the importance of fully assessing available resources.

Trucks are assumed to return to the SNS after being unloaded at the RSS. The time required to travel between the RSS and the SNS is assumed known and includes the time required for unloading. We assume that it is extremely undesirable to make trucks wait to be unloaded at the RSS; hence, trucks are not sent to the RSS from the SNS unless it is known that the RSS will be able to receive them during the time period of their arrival. In a nondeterministic setting, where travel times and the RSS unloading capacities are not known precisely, we would relax such an assumption; but, in the deterministic model, this requirement is achievable and does not change the optimal solution.

Each truck has a fixed volume capacity, in terms of pallets, so the total volume of the inventory loaded onto each truck must not exceed this value. And, of course, inventory cannot be shipped out to the RSS until it has arrived to the SNS. The SNS has some initial supply of inventory, and additional materials arrive to the SNS from external sources over time. All inventory at the SNS is managed in terms of pallets. Note that there may be many different inventory types, and the number of units per case, the size of each case, and the number of cases per pallet may vary by type.

At the RSS, there is a limit on the number of pallets of inventory that can be received during each time period, and there is a fixed amount of usable warehouse space available for storing inventory. Inventory cannot be unloaded and stored in the warehouse unless space is available. Inventory is sent to PODs in units of cases, and there is a limit on the rate at which cases can be loaded onto trucks to be sent to PODs. Depending on the RSS organization, more inventory storage constraints may be required. For example, there may be constraints on where, within the warehouse, certain types of inventory may be stored. However, for the illustrative purposes of this model, we do not include these details.

A fixed number of trucks is available to move inventory to the PODs. These trucks travel on routes that include one or more PODs. For now we assume that each POD lies on exactly one route, but this assumption could be relaxed easily if it would be useful to allow some PODs to lie on multiple routes. The PODs along a route are always visited in the same order, so the lead time to reach each POD is known, as well as the total route time. We assume that these times include the time required to unload material at the PODs. We do not limit the rates at which inventory can be received at each POD because we assume that these values will normally be somewhat small and so the task of unloading material will not require significant time or resources at the PODs. This capacity could be restricted if necessary. However, the model will indicate how much capacity is needed and when to unload the incoming trucks.

At the PODs, the patient arrival rate may change over time, but within a single time period the rate is assumed to be constant. Similarly, the rate at which a POD can serve patients may change over time, but is constant during each individual time period. So, if we used short time periods, then we could model very detailed patient arrival patterns and changing POD service capacities.

The model recognizes that patients can be served only after they have arrived and only when the POD has available service capacity and sufficient inventory. In the model, arriving patients who cannot be served immediately wait until the POD has service capacity and inventory available to process them. Different patient types may require different types of medical supplies. The amount of inventory used for each patient may also change over time; for example, during the first days of an emergency response to an anthrax attack, when inventory might be severely limited, it may be desirable to distribute unit-of-use bottles containing only 10-day pill regimens. Once more inventory has arrived, patients would return to PODs to receive the remainder of their prescribed regimens.

3 Model Objective

To determine the optimal performance of this supply chain, we first must decide what we mean by "optimal." The most important goal of the system is to serve as many people as possible, as quickly as possible. Therefore, the model objective is to minimize the number of person-hours of delay experienced by patients who arrive to PODs seeking service. If desired, we could weight patients by type, by location, or by time period. For example, during an influenza pandemic, it may be more important to serve small children and immunocompromised individuals before the rest of the population. During an anthrax attack, there may be a larger penalty for making patients wait for antibiotics near the end of the time horizon, when patients have a higher chance of becoming symptomatic. Thus, we will assign a cost for each patient who is waiting at a POD for service at the end of each time period, and we will minimize the sum of these costs. Note that these "costs" are not monetary, but rather parameters that can be tuned to measure the effects of different strategies for serving incoming streams of patients.

The objective we have described is an efficacy-based goal. Another possible objective would be to consider balancing efficacy and efficiency, by calculating the operating expenses of the system as well as the penalties for patient delays. In such a case, we could assign monetary costs to the SNS and RSS trucks used, to the inventory stored at the SNS, RSS, and PODs, and to the capacity at each location over time. These costs could be calculated using a spreadsheet tool such as RASCAL [3]. The goal of the model would then be to minimize the sum of all of these costs in addition to the penalty costs for patient delays. Alternatively, we could consider a model in which prescribed service constraints must be met, and our objective would be to achieve the desired level of service with the lowest possible cost. To implement such a model, we would again assign monetary costs to each type of capacity and then minimize the total cost. That is, the level of desired efficacy would be given, and the model would have an efficiency-based objective. Such a model could be implemented in a manner similar to the one discussed below.

4 Linear Programming Model

The problem that we have described above can be written as a linear program [2]. That is, we can define a linear objective function and linear constraints which enforce the conditions described in earlier sections. We now define in detail the variables, parameters, and constraints described above. The values of the variables will be determined by the linear program, but all of the parameter values must be calculated or estimated by the POD designers.

4.1 Definition of Variables

Sets

Note that the elements of set $\mathcal{N}$ are indexed by n, the elements of $\mathcal{T}$ are indexed by t, and so forth. We let

$\mathcal{N} =$ the set of PODs;

$\mathcal{T} =$ the set of time periods;

$\mathcal{K} =$ the set of inventory types; (These might include such items as unit-of-use bottles of doxycycline and ciprofloxacin in response to an anthrax attack. In an influenza pandemic, we may be concerned with antivirals, masks, and N-95 respirators.)

$\mathcal{R} =$ the set of truck routes; and (Each route consists of an ordered sequence of PODs from the set $\mathcal{N}$.)

$\mathcal{P} =$ the set of patient types. (Patient types might include such categories as children, mobility-impaired adults, or symptomatic individuals. Different patient types may require different resources and arrive at different rates over time.)

Decision Variables

We let

$s_{npt} =$ number of patients of type p at POD n who are served during time period t;

$q^p_{kt} =$ number of pallets of inventory type k sent to the RSS during time period t;

$q^c_{knt} =$ number of cases of inventory type k sent to POD n during time period t;

$u^S_t =$ number of trucks dispatched from the SNS to the RSS during time period t;

$u_{rt} =$ number of trucks dispatched from the RSS to PODS on route r during time period t;

$v_{kt} =$ number of pallets of inventory type k loaded at the SNS in time period t; and

$w_t =$ number of trucks that are loaded at the SNS in time period t.

State Variables

We let

$I^S_{kt} =$ inventory of type k on-hand at the SNS at the beginning of time period t;

$I^R_{kt} =$ inventory of type k on-hand at the RSS at the beginning of time period t;

$I^P_{knt} =$ inventory of type k on-hand at POD n at the beginning of time period t;

$U^S_t =$ number of trucks available to be used at the SNS at the beginning of time period t;

$U^R_t =$ number of trucks available to be used at the RSS at the beginning of time period t;

$P_{npt} =$ number of patients of type p at POD n waiting to be served at the beginning of time period t;

$V_t =$ number of pallets already loaded and ready to send out from the SNS at the beginning of time period t; and

$W_t =$ number of trucks already loaded and ready to send out from the SNS at the beginning of time period t.

Model Parameters

We let

$D_{npt} =$ number of patients of type p who arrive to POD n for service in time period t;

$Q_{kt} =$ number of pallets of inventory type k that arrive to the SNS in time period t;

$\Delta^S_t =$ number of trucks that are removed from or added to service at the SNS in time period t;

$\Delta^R_t =$ number of trucks that are removed from or added to service at the RSS in time period t;

5

$\xi^S =$ initial number of trucks available to ship between the SNS and RSS;
$\xi^R =$ initial number of trucks available to ship from the RSS to the PODs;
$\zeta_k^S =$ initial inventory of type k at the SNS;
$\zeta_k^R =$ initial inventory of type k at the RSS;
$\zeta_{kn} =$ initial inventory of type k at POD n;
$\gamma^R =$ volume of storage space available at the RSS;
$\gamma_n^P =$ volume of storage space available at POD n;
$\tau^S =$ travel time from the SNS to the RSS;
$\tau_n =$ lead time to reach POD n from the RSS;
$\tau_r^R =$ total time to travel route r;
$\sigma_t^S =$ maximum number of pallets that can be loaded onto trucks in time period t at the SNS;
$\sigma_t^{RA} =$ maximum number of pallets that can be unloaded from arriving SNS delivery trucks in time period t at the RSS;
$\sigma_t^{RD} =$ maximum number of cases that can be loaded onto departing POD delivery trucks in time period t at the RSS;
$\eta_k^p =$ units of inventory type k in a pallet;
$\eta_k^c =$ units of inventory type k in a case;
$\beta_k^v =$ volume of a unit of inventory type k;
$\rho^{vS} =$ volume capacity of a truck that ships inventory from the SNS to the RSS;
$\rho^{vR} =$ volume capacity of a truck that ships inventory from the RSS to the PODs;
$\alpha_{nt} =$ total POD service capacity available;
$\phi_{kpt} =$ units of resource type k needed to treat a patient of type p in time period t; and
$c_{npt} =$ penalty for making one patient of type p wait at POD n during time period t.

4.2 Constraints

Using the notation defined above, we will now define the mathematical constraints corresponding to the model described in section 2.

1. Inventory at the SNS in period $t+1$ is equal to the inventory from the previous time period plus inventory received, minus inventory loaded onto trucks to go to the RSS:

$$I_{k,t+1}^S = I_{kt}^S + \eta_k^p (Q_{kt} - v_{kt}).$$

2. The number of pallets of inventory already loaded onto trucks at the SNS in period $t+1$ is equal to the number of pallets already loaded in the previous time period, plus the newly loaded pallets from the current time period, minus the pallets sent to the RSS:

$$V_{k,t+1} = V_{kt} + v_{kt} - q_{kt}^p.$$

3. The number of loaded trucks at the SNS in period $t+1$ is equal to the number of trucks already loaded in the previous time period, plus the newly loaded trucks from the current time period, minus the trucks sent to the RSS:

$$W_{t+1} = W_t + w_t - u_t^S.$$

4. The number of trucks available at the SNS in period $t+1$ is equal to the number available during the previous time period, minus those that were sent to the RSS, plus those that returned from previous trips to the RSS, plus the change in the total number of available trucks:

$$U_{t+1}^S = U_t^S - u_t^S + \Delta_t^S \quad \text{for all } t = 1, ..., 2\tau^S, \text{ and}$$
$$U_{t+1}^S = U_t^S - u_t^S + u_{t-2\tau^S} + \Delta_t^S \quad \text{for all } t = 2\tau^S + 1, ..., T-1.$$

5. The maximum number of pallets that can be loaded during each time period from the SNS is limited by a known capacity:

$$\sum_{k \in \mathcal{K}} v_{kt} \le \sigma_t^S.$$

6. Pallets of inventory can only be loaded onto trucks at the SNS if there is inventory available:

$$\eta_k^p v_{kt} \le I_{kt}^S.$$

7. Trucks can only be loaded at the SNS if there are trucks available:

$$w_t \le U_t^S.$$

8. The trucks can only hold a limited amount of volume:

$$\sum_{k \in \mathcal{K}} \beta_k^v \eta_k^p v_{kt} \le \rho^{vS} w_t.$$

$$\sum_{k \in \mathcal{K}} \beta_k^v \eta_k^p q_{kt}^p \le \rho^{vS} u_t.$$

9. Trucks from the SNS are not sent to the RSS until the RSS has available unloading capacity:

$$u_t^S \le \sigma_t^{RA}.$$

10. Inventory at the RSS in period $t+1$ is equal to the inventory from the previous time period plus inventory received, minus inventory sent to the PODs:

$$I_{k,t+1}^R = I_{kt}^R - \sum_{n \in \mathcal{N}} \eta_k^c q_{knt}^c \quad \text{for all } t = 1, ..., \tau^S, \text{ and}$$

$$I_{k,t+1}^R = I_{kt}^R - \sum_{n \in \mathcal{N}} \eta_k^c q_{knt}^c + \eta_k^p q_{k,t-\tau^S}^p \quad \text{for all } t = \tau^S + 1, ..., T-1.$$

11. The number of trucks available at the RSS in period $t+1$ is equal to the number available during the previous time period, minus those that were sent to the PODs, plus those that returned from previous trips to the PODs:

$$U_{t+1}^R = U_t^R + \sum_{r \in \mathcal{R}: \tau_r < t} (u_{r,t-\tau_r} - u_{rt}) + \Delta_t^R.$$

12. Inventory can only be received if there is space (volume) available at the RSS:

$$\sum_{k \in \mathcal{K}} \beta_k^v (\eta_k^p q_{k,t-\tau^S}^p + I_{kt}^R) \le \gamma^R.$$

13. Inventory can only be sent out to the PODs if there is inventory available at the RSS:

$$\eta_k^c \sum_{n \in \mathcal{N}} q_{knt}^c \le I_{kt}^R.$$

14. Trucks can only be sent out to the PODs if there are trucks available at the RSS:

$$\sum_{r \in \mathcal{R}} u_{rt} \le U_t^R.$$

15. There is a limit on the number of cases that can be loaded onto trucks headed to PODs during each time period:

$$\sum_{k \in \mathcal{K}} \sum_{n \in \mathcal{N}} q_{knt}^c \le \sigma_t^{RD}.$$

7

16. The trucks that transport inventory from the RSS to the PODs can only hold a limited amount of volume:
$$\sum_{k\in\mathcal{K}}\sum_{n\in r}\beta_k^v\eta_k^c q_{knt}^c \leq \rho^{vR}u_{rt}.$$

17. Inventory at POD n in period $t+1$ is equal to the inventory from the previous time period plus inventory received, minus inventory given out to patients:
$$I_{kn,t+1} = I_{knt} + \eta_k^c q_{nk,t-\tau_n}^c - \sum_{p\in\mathcal{P}}\phi_{kpt}s_{npt}.$$

18. The number of patients of type p waiting to be served at POD n in period $t+1$ is equal to the number of patients waiting at the beginning of the previous time period plus those that arrived during the previous time period, minus those that were served:
$$P_{np,t+1} = P_{npt} + D_{npt} - s_{npt}.$$

19. Inventory can only be received at the POD if there is capacity to store it:
$$\sum_{k\in\mathcal{K}}\beta_k^v(\eta_k^c q_{kn,t-\tau_n}^c + I_{knt}) \leq \gamma_n^P.$$

20. Patients can only be served is there is available inventory, people, and service capacity:
$$s_{npt} \leq D_{npt} + P_{npt},$$
$$\sum_{p\in\mathcal{P}}\phi_{kpt}s_{npt} \leq I_{nkt}, \text{ and}$$
$$\sum_{p\in\mathcal{P}}s_{npt} \leq \alpha_{nt}.$$

21. The state variables must be initialized in the first time period:
$$U_1^S = \xi^S,$$
$$U_1^R = \xi^R,$$
$$I_{k1}^S = \zeta_k^S,$$
$$I_{k1}^R = \zeta_k^R,$$
$$I_{kn1} = \zeta_{kn}, \text{ and}$$
$$P_{pn1} = 0,$$
$$W_1 = 0, \text{ and}$$
$$V_{k1} = 0.$$

22. All state and decision variables must be nonnegative.

4.3 Objective Function

As discussed previously, our objective is to minimize the total patient delay over the time horizon. Thus, our objective function is given by:
$$\min\sum_{t\in\mathcal{T}}\sum_{n\in\mathcal{N}}\sum_{p\in\mathcal{P}}c_{npt}(P_{npt} + D_{npt} - s_{npt}).$$

References

[1] K. Aaby, R.L. Abbey, J.W. Herrmann, M. Treadwell, C.S. Jordan, and K. Wood. Embracing computer modeling to address pandemic influenza in the 21st century. *Journal of Public Health Management Practices*, 12(4):365–372, 2006.

[2] D. Bertsimas and J.N. Tsitsiklis. *Introduction to Linear Programming*. Athena Scientific, Belmont, MA, 1997.

[3] C. Caggiano and J. Muckstadt. *Regional Antibiotic Storage Cost Analysis and Locator (RASCAL)*. Cornell Unviersty College of Engineering, 2009.

[4] M. Castorena, C. Hawkins, N. Hupert, K. King, C. Lee, J. Muckstadt, and W. Xiong. Uncertainty and operational considerations in mass prophylaxis workforce planning. *Disaster Medicine and Public Health Preparedness*, To appear.

[5] E.K. Lee, J. Mason, and W. Glisson. Large-scale dispensing for emergency response to bioterrorism and infectious disease outbreak. *Interfaces*, 36(6):591–607, 2006.

Appendix: AMPL Model

There are a number of ways in which this model can be implemented. One of the most efficient and convenient is to describe the model in AMPL, a mathematical programming modeling language. We can then use CPLEX, or another linear programming solver, to read and solve the AMPL model, given a data set also described in AMPL. Below we show an implementation of the model described above.

```
### System parameters:
param N >= 1;
param T >= 1;

### Sets
set PODS := 1..N;
set TIME := 1..T;
set PATTYPES;
set INVTYPES;
set LOCS := 0..N; #0 is nowhere
#routes can have at most 5 stops, not including the RSS
#(assume first and last stops are the RSS):
set ROUTES in {LOCS,LOCS,LOCS,LOCS,LOCS};

### System Parameters
param PODdemand {PODS, PATTYPES, TIME} >= 0;
param SNSDeliveries {INVTYPES, TIME} >= 0;
param PODinitpats {PODS, PATTYPES} >= 0;
param RSStoPODtime {PODS} >= 1;
param SNStoRSStime >= 1;
param RSSroutetime {ROUTES} >= 1;
param RSStruckvolcap >= 0;
param SNStrucks >= 1;
param SNStruckvolcap >= 0;

param invvol {INVTYPES} >= 0;
param unitspercase {INVTYPES} >= 0;
param unitsperpallet {INVTYPES} >= 0;
param unitsperpat {INVTYPES, PATTYPES, TIME};
param PODservicecap {PODS, TIME} >= 0;
```

```
param RSSloadingcap {TIME} >= 0;
param RSSunloadingcap {TIME} >= 0;
param PODstoragecap {PODS} >= 0;
param PODinitinv {INVTYPES, PODS} >=0;
param SNSinitinv {INVTYPES} >= 0;
param RSStrucks >= 1;
param RSSstoragecap >= 1;
param RSSinitinv {INVTYPES} >= 0;
param SNSloadingcap {TIME} >= 0;
param RSStrucksadded {TIME};
param SNStrucksadded {TIME};

### Cost parameters
param HoldingCost {PODS} >= 0;
param BackorderCost {PODS} >= 0;

### Decision Variables
var shippedtorss {INVTYPES, TIME} >= 0;
var shippedtopod {INVTYPES, PODS, TIME} >= 0;
var served {PODS, PATTYPES, TIME} >= 0;
var truckssenttorss {TIME} >= 0;
var truckssenttopod {ROUTES, TIME} >= 0;
var palletsloaded {INVTYPES, TIME} >= 0;
var trucksloaded {TIME} >= 0;

### State Variables
var snstrucksavail {TIME} >=0;
var rsstrucksavail {TIME} >=0;
var snsinventory {INVTYPES, TIME} >= 0;
var rssinventory {INVTYPES, TIME} >= 0;
var inventory {INVTYPES, PODS, TIME} >= 0;
var waitingpats {PODS, PATTYPES, TIME} >= 0;
var readypallets {INVTYPES, TIME} >= 0;
var readytrucks {TIME} >= 0;
var podcost{PODS,PATTYPES,TIME} >= 0;


### Objective Function minimize TotalCost:
  sum{n in PODS, p in PATTYPES, t in TIME} podcost[n,p,t];


### Constraints subject to

#0
CostIncurred{n in PODS, p in PATTYPES, t in TIME}:
  podcost[n,p,t] = BackorderCost[n]*(waitingpats[n,p,t] + PODdemand[n,p,t] - served[n,p,t]);

#1
SNSUpdateInventory{k in INVTYPES, t in 1..T-1}:
  snsinventory[k,t+1] = snsinventory[k,t] + unitsperpallet[k]*(SNSDeliveries[k,t]
  - shippedtorss[k,t]);

#2
SNSUpdateReadyPallets{k in INVTYPES, t in 1..T-1}:
```

10

```
  readypallets[k,t+1] = readypallets[k,t] + palletsloaded[k,t] - shippedtorss[k,t];

#3
SNSUpdateReadyTrucks{t in 1..T-1}:
  readytrucks[t+1] = readytrucks[t] + trucksloaded[t] - truckssenttorss[t];

#4
SNSUpdateTrucksA{t in 1..2*SNStoRSStime}:
  snstrucksavail[t+1] = snstrucksavail[t] - truckssenttorss[t] + SNStrucksadded[t];

SNSUpdateTrucksB{t in 2*SNStoRSStime+1..T-1}:
  snstrucksavail[t+1] = snstrucksavail[t] - truckssenttorss[t]
  + truckssenttorss[t-2*SNStoRSStime] + SNStrucksadded[t];

#5
SNSPalletLimit{t in TIME}:
  sum{k in INVTYPES} palletsloaded[k,t] <= SNSloadingcap[t];

#6
SNSInventoryLimit{k in INVTYPES, t in TIME}:
  unitsperpallet[k]*palletsloaded[k,t] <= snsinventory[k,t];

#7
SNSTrucksLimit{t in TIME}:
  trucksloaded[t] <= snstrucksavail[t];

#8a
SNSTruckLoadedVol{t in TIME}:
  sum{k in INVTYPES} unitsperpallet[k]*invvol[k]*palletsloaded[k,t]
  <= SNStruckvolcap*truckssenttorss[t];

#8b
SNSTruckSentVol{t in TIME}:
  sum{k in INVTYPES} unitsperpallet[k]*invvol[k]*shippedtorss[k,t]
  <= SNStruckvolcap*truckssenttorss[t];

#9
RSSUnloadingLimit{t in TIME}:
  truckssenttorss[t] <= RSSunloadingcap[t];

#10
RSSUpdateInventoryA{k in INVTYPES, t in 1..SNStoRSStime}:
  rssinventory[k,t+1] = rssinventory[k,t]
  - sum{n in PODS} unitspercase[k]*shippedtopod[k,n,t];

RSSUpdateInventoryB{k in INVTYPES, t in SNStoRSStime+1..T-1}:
  rssinventory[k,t+1] = rssinventory[k,t] + unitsperpallet[k]
  *shippedtorss[k,t-SNStoRSStime] - sum{n in PODS} unitspercase[k]*shippedtopod[k,n,t];

#11
RSSUpdateTrucks{t in 1..T-1}:
  rsstrucksavail[t+1] = rsstrucksavail[t]
  - sum{(a,b,c,d,e) in ROUTES} truckssenttopod[a,b,c,d,e,t]
  + sum{(a,b,c,d,e) in ROUTES:RSSroutetime[a,b,c,d,e]<t}
```

11

```
  truckssenttopod[a,b,c,d,e,t-RSSroutetime[a,b,c,d,e]]  + RSStrucksadded[t];

#12
RSSStorageA{t in 1..SNStoRSStime}:
  sum{k in INVTYPES} invvol[k]*rssinventory[k,t] <= RSSstoragecap;

RSSStorageB{t in SNStoRSStime+1..T}:
  sum{k in INVTYPES} invvol[k]*(unitsperpallet[k]*shippedtorss[k,t-SNStoRSStime]
  + rssinventory[k,t]) <= RSSstoragecap;

#13
ConserveInventory {k in INVTYPES, t in TIME}:
  unitspercase[k]* sum{n in PODS} shippedtopod[k,n,t] <= rssinventory[k,t];

#14
RSSTrucksLimit{t in TIME}:
  sum{(a,b,c,d,e) in ROUTES} truckssenttopod[a,b,c,d,e,t] <= rsstrucksavail[t];

#15
RSSLoadingLimit{t in TIME}:
  sum{k in INVTYPES, n in PODS} shippedtopod[k,n,t] <= RSSloadingcap[t];

#16
RSSTruckVol{t in TIME, (a,b,c,d,e) in ROUTES}:
  sum{k in INVTYPES, n in PODS: n=a or n=b or n=c or n=d or n=e} unitspercase[k]
  *invvol[k]*shippedtopod[k,n,t] <= RSStruckvolcap*truckssenttopod[a,b,c,d,e,t];

#17
UpdateInventory{k in INVTYPES, n in PODS, t in 1..T-1}:
  inventory[k,n,t+1] = inventory[k,n,t] + unitspercase[k]*shippedtopod[k,n,t]
  - sum{p in PATTYPES} unitsperpat[k,p,t]*served[n,p,t];

#18
UpdatePats{n in PODS, p in PATTYPES, t in 1..T-1}:
  waitingpats[n,p,t+1] = waitingpats[n,p,t] + PODdemand[n,p,t] - served[n,p,t];

#19
PODStorage{n in PODS, t in SNStoRSStime+1..T}:
  sum{k in INVTYPES} invvol[k]*(unitspercase[k]*shippedtopod[k,n,t-SNStoRSStime]
  + inventory[k,n,t]) <= PODstoragecap[n];

#20a
PatientsLimit {n in PODS, p in PATTYPES, t in TIME}:
  served[n,p,t] <= waitingpats[n,p,t] + PODdemand[n,p,t];

#20b
InventoryLimit {k in INVTYPES, n in PODS, t in TIME}:
  sum{p in PATTYPES} unitsperpat[k,p,t]*served[n,p,t] <= inventory[k,n,t];

#20c
ServiceCapacity {n in PODS, t in TIME}:
  sum{p in PATTYPES} served[n,p,t] <= PODservicecap[n,t];

#21
```

12

```
InitSNSTrucks:
  snstrucksavail[1] = SNStrucks;

InitRSSTrucks:
  rsstrucksavail[1] = RSStrucks;

InitSNSInv{k in INVTYPES}:
  snsinventory[k,1] = SNSinitinv[k];

InitRSSInv{k in INVTYPES}:
  rssinventory[k,1] = RSSinitinv[k];

InitPODInv{k in INVTYPES, n in PODS}:
  inventory[k,n,1] = PODinitinv[k,n];

InitPats{n in PODS, p in PATTYPES}:
  waitingpats[n,p,1] = PODinitpats[n,p];

InitLoadedTrucks:
  trucksloaded[1] = 0;

InitLoadedPallets{k in INVTYPES}:
  palletsloaded[k,1] = 0;
```

Appendix G

List of Acronyms

ADS	Associate Director for Science
BSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
CHEMPACK	Forward placement of nerve agent antidotes
COTPER	Coordinating Office of Terrorism Preparedness and Emergency Response
CRI	Cities Readiness Initiative
DSNS	Division of Strategic National Stockpile
HHS	Department of Health and Human Services
HSEEP	Homeland Security Exercise and Evaluation Program
HSPD	Homeland Security Presidential Directive
ICS	Incident Command System
MI	Managed Inventory
MSA	Metropolitan Statistical Area
OPHPR	Office of Public Health Preparedness and Response
PHEMCE	Public Health Emergency Medical Countermeasures Enterprise
PHEP	Public Health Emergency Preparedness Cooperative Agreement
POD	Point of Dispensing
PREP Act	Public Readiness and Emergency Preparedness Act
RDS	Regional Distribution Site
RSS	Receive, Store, and Stage
SIMAN	Stockpile in Motion Across the Nation
SNS	Strategic National Stockpile
TAR	Technical Assistance Reviews
TARU	Technical Advisory Response Unit
USPS	U.S. Postal Service
Y2K	Year 2000