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MEMORANDUM

To: Members of the Subcommittee on National Security, Emerging Threats, and International Relations

From: Kristine K. McElroy

Subject: Briefing Memorandum for the hearing, *Following Toxic Clouds: Science and Assumptions in Plume Modeling,* scheduled for Monday, June 2, 2003, at 1 p.m. in Room 2154, Rayburn House Office Building.

PURPOSE OF THE HEARING

The purpose of the hearing is to examine the strengths and weaknesses of current methodologies to model the spread of aerosolized biological, chemical or radiological agents.

HEARING ISSUES

1. **To what extent are conclusions drawn from DOD and CIA models valid and reliable regarding the dispersion of the plume and exposure to U.S. forces during the 1991 Persian Gulf War?**

2. **What are the strengths and limitations of current biological, chemical and radiological plume modeling?**

BACKGROUND

> "Modeling is the science and art of using interconnected mathematical equations to predict the activities of an actual event." **(Web Resource 1)**

Plume modeling is used to recreate or predict the release and dispersion paths of hazardous materials and their effect on the health of the general population. Plume modeling can be used prior to a event for emergency planning purposes, during an emergency to guide response, and after an event to determine the effects of a past incident.

"The methodology for modeling the release of an agent is a process that includes:

- A source characterization to describe the type and amount of agent released, and how rapidly it discharged;
- Data from global weather models to simulate global weather patterns;
- Regional weather models to simulate the weather in the vicinity of the suspected agent release, and
- Transport and dispersion models (often simply called dispersion models) to project the possible spread of the agent as a result of the simulated regional weather." **(Web Resource 2)**

Modeling Chemical Agent Releases at Khamisiyah

At the end of Operation Desert Storm in 1991, US Army units were located in southeastern Iraq in an area that encompassed Khamisiyah (also known as Tall al Lahm Ammunition Storage Area). The army's XVIII

Airborne Corps conducted two large-scale demolition operations to destroy munitions and facilities around Khamisiyah.

On March 4, 1991, soldiers destroyed 37 ammunition bunkers. Iraq later declared one of the bunkers, Bunker 73, had 2,160 chemical warfare-filled rockets. On March 10, 1991, Soldiers destroyed 40 additional ammunition bunkers and 45 warehouses. In an open-air location outside the Khamisiyah Ammunition Supply Point (ASP) (also known as "the Pit") soldiers destroyed 1,250 rockets, many of which the United Nations Special Commission on Iraq (UNSCOM) later found contained chemical nerve agents sarin and cyclosarin. UNSCOM also found an aboveground area, about 3 kilometers from the ASP that contained chemical weapons. However, according to DOD coalition forces were not at this site.

In 1996, the Central Intelligence Agency (CIA) developed computer modeling to simulate the possible releases of chemical warfare agents from several sites in Iraq. However, the CIA only used a single model approach and the results showed the strengths and weaknesses of that model. On November 2, 1996, the DOD asked the Institute for Defense Analyses (IDA) to convene an independent panel of experts to evaluate previous modeling analyses. The panel recommended using several atmospheric models instead of relying on one model.

The recommendation of the IDA panel was implemented and a modeling team was formed of scientists from the Defense Threat Reduction Agency (DTRA), the Naval Research Laboratory (NRL), the Naval Surface Warfare Center (NSWC), the National Center for Atmospheric Research (NCAR) and Science and Applications International Corporation (SAIC).

Since on-site measurements of chemical agent exposure, and local weather data were lacking, computer simulations were used to develop possible exposure areas. According to DOD the team combined the computer models, "to compensate for the bias that is inherent in each model, that is, to produce a more robust result by maximizing the strengths of each model and minimizing its weaknesses." **(Web Resource 2)**

The methodology behind Persian Gulf War modeling used local and global weather models and dispersions models. Weather models simulated the weather conditions in the area, and dispersion models simulated how chemical warfare agents may have moved in the atmosphere given the

weather conditions. The models used characteristics of the agent such as the amount of the agent, type of agent, location of release, and release rate along with local weather to predict the agent's dispersal. The CIA, and reports by the United Nations Special Commission on Iraq provided source characterization for the modeling of Khamisiyah. Since there were several weather models and dispersion models, combining each set resulted in different hazardous areas. To account for these differences, a composite of all the various models was created.

Initial modeling of Khamisiyah did not account for environmental degradation of the agent, however later models included this factor. The dispersion models used to model Khamisiyah were the Hazard Prediction and Assessment Capability (HPAC) run by DTRA and the Vapor, Liquid, and Solid Tracking (VLSTRACK) model maintained by the Naval Surface Warfare Center (NSWC). Even though these dispersion models use the same weather inputs and source characterization they yielded different results due to different assumptions.

The hazard projection graphics derived from the dispersion models were sent to the US Army Center for Health Promotion and Preventative Medicine (CHPPM). CHPPM used these graphics with data on US unit locations to create an exposure plot showing the areas and levels of possible exposure.

As a result of DOD modeling efforts, 100,752 veterans were identified based on the plume modeling as possibly being exposed to low levels of nerve agent. **(Web Resource 2)**

National Research Council Report

The National Research Council Board on Atmospheric Sciences and Climate recent report entitled *Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases,* examines how meteorological and dispersion models can be used by emergency managers in the event of an aerosolized chemical, biological or nuclear release.

The report found:

> atmospheric observational and modeling tools can contribute substantively to preparation and planning for possible future events, to emergency response in the minutes to hours after an event occurs, and to the post-event recovery and analysis. Existing capabilities generally are useful, but emergency responders have a number of observational modeling needs that are not well satisfied by existing services. Although it may never be possible to provide a 'perfect' atmospheric dispersions prediction for any individual hazardous release, the committee believes that with more effective application of available tools and development of new technologies and capabilities, the atmospheric science community could play a larger role in addressing this critical national security concern. **(Attachment 1, p. 1)**

Modeling WMD Events

Different dispersion modeling methodologies will be needed for the preparedness, response, and recovery stage of chemical, biological or nuclear events. During the preparedness stage, site-specific meteorological data along with probability-based dispersion model predictions and wind tunnel simulations for different scenarios will be needed.

The response stage will need short execution time dispersion models in order to provide emergency response personnel with event information. A model in the response stage of a chemical, biological or nuclear event must have input data available in real time and the model must be executed in a short period of time. During the recovery stage, data can be put into a dispersion model in order to reconstruct the plume's space/time concentration distribution. **(Attachment 1, pp. 35-36)**

According to the National Research Council report, "The accuracy of a dispersion model's output (a statistical description of concentration in space and time) will depend on the quality of model inputs, the model's analytical methodology, and inherent random nature of turbulent processes in the atmosphere." **(Attachment 1, p. 36)** However, the true area of a

specific chemical, biological, and nuclear event can only be estimated by plume modeling. **(Attachment 1, p. 36)**

Types of Models

There are hundreds of models but no single model is capable of addressing all situations and scenarios. Steps are currently being taken to identify what model (s) would be best for use in emergency situations.

Current chemical, biological and nuclear models include the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) and Computer-Aided Management of Emergency Operations/Areal Locations of Hazardous Atmospheres (CAMEO/ALOHA) from the National Oceanic and Atmospheric Administration (NOAA); the National Atmospheric Release Advisory Center (NARAC) from the Department of Energy/Lawrence Livermore Laboratory; the Hazard Prediction and Assessment Capability (HPAC) from the Defense Threat Reduction Agency (DTRA); VLSTRACK from the Navy, and MIDAS-AT from the Marines. **(Attachment 1, p. 61)**

The NOAA CAMEO/ALOHA system is used by fire departments and first responders for chemical accidents. The HPAC model and the Navy's VLSTRACK model are used for military applications. NOAA's HYSPLIT model system is used for general purposes. The nuclear industry uses NARAC (DOE), and the weather forecasting community uses HYSPLIT (NOAA). **(Attachment 1, p. 61)**

A good model has a relative mean bias of about 20 or 30 percent and a scatter (normalized root-mean-square error) of a factor of 2. The majority of air quality models predict the ensemble mean value and not the fluctuations. The HPAC model is the exception to this, since it predicts fluctuations using standard methods from literature. **(Attachment 1, p. 62)**

Subcommittee Investigations

The Subcommittee held a series of hearings on the "Status of Efforts To Identify Persian Gulf War Syndrome." During a Subcommittee hearing on September 19, 1996, James J. Tuite, III, International Security Consultant and Director, Gulf War Research Foundation, testified, "U.S. soldiers were exposed to detectable levels of chemical warfare agent fallout from the aerial

bombings of Iraqi chemical warfare agent research, production, and storage facilities by Coalition forces." According to Mr. Tuite, "Archived meteorological data, including visible and infrared satellite imagery illustrates that the heat and smoke, and therefore the toxic debris, from these facilities traveled directly towards U.S. military personnel."[1]

The Subcommittee in collaboration with Senator Robert C. Byrd recently requested the General Accounting Office study the soundness and limitation of the computer models used by Department of Defense to determine the extent of chemical exposures associated with Operation Dessert Storm for both U.S. and United Kingdom servicemembers. The hearing today will address the findings of this work.

DISCUSSION OF HEARING ISSUES

1. To what extent are conclusions drawn from DOD and CIA models valid and reliable regarding the dispersion of the plume and exposure to U.S. forces during the 1991 Persian Gulf War?

The Department of Defense (DOD) claims the composite model used for Khamisiyah, "provides the most credible array of potential agent vapor hazard areas for determining where military units might have been exposed." **(Web Resource 2)** However DOD notes, "Weather models represent our best attempts to approximate actual atmospheric conditions. They do not replicate reality with absolute certainty, but modern modeling techniques enable us to generate reasonably close approximations." **(Web Resource 2)**

DOD further states, "the modeling process is based on computer simulations and not empirical data. Results, although based on best science, are predictions and should be evaluated carefully." **(Web Resource 2)**

According to DOD, it is difficult to determine the concentration of an agent within a hazard, "Since the atmosphere is inherently turbulent in nature, the actual concentration of an agent within the hazard area might not be the same throughout the projected area. As a result, modeling predicts

[1] See Subcommittee files.

that the concentration of chemical warfare agent is at the exposure threshold throughout the hazard area, even though the agent may not necessarily be everywhere in the area." **(Web Resource 2)**

According to DOD, the CIA overstated the size of the chemical agent release at Khamisiyah in order to, "minimize [the] risk of failing to identify all of the agent that might have been released." **(Web Resource 2)** Since DOD prefers, "to identify a veteran incorrectly as possibly exposed rather than fail to recognize a veteran who was exposed." **(Web Resource 2)**

The General Accounting Office (GAO) will testify DOD and CIA modeling underestimated the extent of U.S. troop exposure since the modeling was not accurate enough to draw conclusions. GAO will explain the models were not fully developed and validated. Inputs were not accurate, and the plume height was underestimated. GAO will further state there is a great difference among the various models DOD selected with regard to the size and path of the plume.

A sound meteorological analysis of the transport and diffusion of the Khamisiyah plume is dependent upon the availability of meteorological data. However, according to GAO, DOD did not have accurate weather data to model Khamisiyah. This lack of data made it difficult to determine the speed and direction of the plume

Due to uncertainties in the source term used in plume modeling at Khamisiyah, DOD and the CIA made assumptions about the source term used. However, GAO will testify the assumptions made by DOD and the CIA were based on incomplete information. GAO will conclude that DOD models cannot make a definitive conclusion regarding troop exposure since the models were flawed. Therefore, epidemiological studies using DOD modeling results to classify troop exposures are invalid.

2. What are the strengths and limitations of current biological, chemical and radiological plume modeling?

There are various atmospheric transport model systems used by different agencies. However, it has not yet been determined what model (s) would be best to use in the event of an aerosolized biological, chemical or

radiological event. According to the National Research Council report, the variations in models presents a problem for emergency managers who may not know which agency to turn to or which model to use during an emergency.

Should a terrorist release a biological, chemical or radiological agent it may be difficult to acquire the information necessary to establish the exact source location. **(Attachment 1, p. 9)** According to the National Research Council report, "The most appropriate model for any given scenario may depend on the quantity, toxicity, and persistence of the hazardous agent; thus, it is critical that source identification be as rapid as possible." **(Attachment 1, p. 4)**

Due to the large uncertainty in model predictions, there are questions in the modeling community how best to inform emergency responders of the uncertainties. **(Attachment 1, p. 62)** Emergency managers need to know how dispersion model predictions may vary, and the uncertainties involved in dispersion model predictions. The National Research Council report states, "Dispersion models used for emergency planning and response should provide confidence estimates that prescribed concentrations will not be exceeded outside of predicted hazard zones. This requires that models provide some measure of the possible variability in a given situation." **(Attachment 1, p. 4)**

In the TOPOFF2 exercise in Seattle, Washington, a mock explosion of a radioactive "dirty bomb" occurred. The Mayor of Seattle faced various difficulties in trying to figure how to translate the mathematical model of a radiation plume. The model did not give an indication as to what it meant to be inside the plume or outside the plume. It took authorities over one hour, to figure out that 4,000 people lived or worked in the area where radiation would have been most intense. **(Attachment 2, p. 1)** According to Marianne Bichsel, the Mayor's spokeswoman, "It's one thing to have the plume model, but you need to be able to interpret it very quickly: What does that mean in terms of where the greatest risk is and which areas people ought to shelter in place and so on." **(Attachment 3, p. 2)**

The National Research Council report found, "Simple plume models are not sufficient for tracking dispersion in a dense urban area. Buildings and other characteristics of an urban environment can affect flow and dispersion patterns." **(Attachment 1, p. 74)** It was recommended new

dispersion modeling be further examined and possibly adapted for use in urban settings.

The National Research Council report on dispersion modeling systems concluded, "no one system had all the features that the committee deemed critical: confidence estimates for the predicted dosages, accommodation of urban and complex topography, short execution time urban models for the response phase, and accurate though slower models for the preparedness and recovery phases. Better integration between existing and future modeling systems could supply all of these critical features." **(Attachment 1, pp. 4-5)**

The National Research Council report recommends existing and future dispersions modeling systems be evaluated against field and laboratory measurements for potential chemical, biological, and nuclear event scenarios. **(Attachment 1, p. 5)**

Mr. Keith Rhodes, Chief General Accounting Office Technologist will testify about GAO findings regarding the Department of Defense and Central Intelligence Agency plume modeling for the Persian Gulf War.

Dr. Anna Johnson-Wineger, Deputy Assistant to the Secretary of Defense for Chemical/Biological Defense Programs will testify about how possible chemical warfare agent releases in the Persian Gulf War were modeled, and how modeling has since improved.

Dr. Donald L. Ermak, Program Leader, National Atmospheric Release Advisory Center (NARAC), at Lawrence Livermore Laboratory will testify about how NARAC has worked to build up modeling techniques to provide real-time assessment of nuclear, chemical, and biological incidents and the findings of the Lawrence Livermore Laboratory modeling of the chemical warfare releases at Khamisiyah during the 1991 Persian Gulf War.

Mr. Bruce B. Hicks, Director of the Air Resources Laboratory, at the National Oceanic and Atmospheric Administration (NOAA) will testify about how NOAA is working to improve dispersion computations in cities and the strengths/weaknesses of models used to determine the potential exposures in the 1991 Persian Gulf War.

Dr. Eric Barron, Chair, Board on Atmospheric Sciences and Climate, National Research Council will testify on the findings and recommendations of the National Research Council Report entitled *Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases: Implications for Homeland Security.*

Dr. Steven R. Hanna, Adjunct Associate Professor, from the Harvard School of Public Health will testify about the types of models and the strengths and weaknesses of the models, and how chemical warfare agent releases were modeled to determine potential exposures in the 1991 Persian Gulf War.

ATTACHMENTS

1. National Research Council report, "Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases: Implications for Homeland Security." (2003)

2. KOMO Staff & News Services, "Topoff 2 Terror Drill Gets High Marks." (May 15, 2003)

3. United Press International, "Massive U.S. anti-terror drill winds down." (May 16, 2003)

WEB RESOURCES

1. Department of Defense and Central Intelligence Agency report, "Modeling the Chemical Warfare Agent Release at the Khamisiyah Pit." (September 4, 1997) http://www.cia.gov/cia/publications/gulfwar/555/425055597.html

2. Case Narrative: US Demolition Operations at Khamisiyah Final Report (April 16, 2002) http://www.gulflink.osd.mil/khamisiyah_iii/