Written Testimony of
Dr. Donald L. Ermak
Program Leader
National Atmospheric Release Advisory Center (NARAC)
Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, California 94550-9234

to the

Subcommittee on National Security, Emerging Threats,
and International Security
Committee on Government Reform
House of Representatives
Congress of the United States

Hearing Entitled:
Following Toxic Clouds: Science and Assumptions in
Plume Modeling

Monday, June 2, 2003
1:00 p.m. in Room 2154
Rayburn House Office Building
Washington, DC

Dr. Donald L. Ermak
Program Leader
National Atmospheric Release Advisory Center (NARAC)
Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, California 94550-9234

Mr. Chairman and members of the committee, thank you for the opportunity to appear before you today. I lead the National Atmospheric Release Advisory Center (NARAC) programs at the Lawrence Livermore National Laboratory (LLNL). However, the opinions that I present today represent my views and not necessarily those of the Laboratory, the Department of Energy (DOE) or the Department of Homeland Security (DHS). Today I would like to focus on plume prediction of hazardous atmospheric releases and the science and technology development in plume modeling that is needed to address challenges posed by current threats to national and homeland security.

NARAC Calculations for the Khamisiyah Incident

NARAC is the DOE and DHS operational support and resource center for plume modeling. Its mission is to provide timely and credible assessment advisories to emergency managers for hazardous releases to the atmosphere in order to help minimize the exposure of the population at risk. For over two decades NARAC has provided the DOE and other federal agencies with real-time assessments, planning support, and detailed studies of incidents involving a wide range of hazards, including chemical, biological, and radiological releases to the atmosphere.

Before I address more current issues, I will briefly review NARAC's simulations of the 1991 Gulf War Khamisiyah event. In October 1996, the Central Intelligence Agency requested NARAC to calculate the atmospheric dispersion of sarin resulting from U.S. demolition activities in March 1991 at the Khamisiyah munitions storage facility in Iraq. Three hypothetical release scenarios were specified. NARAC was requested to complete the calculations in less than one day, and we fulfilled that requirement.

In November 1996, the Office of the Secretary of Defense requested NARAC to present the results to the Institute for Defense Analysis (IDA) Panel on Low-Level Exposure to Chemical Agents. On November 20, Dr. Michael Bradley presented the NARAC calculations for three scenarios out to 24 hours. At that meeting, we were asked to do additional simulations for 21 new case scenarios, to extend the duration of the calculations to 72 hours, and to present the results at a meeting at IDA in February 1997, which we did. NARAC was not asked to participate in further studies following the February meeting.

At that time, we were not convinced that all paths to understanding the 1991 Khamisiyah event had been exhausted. However, since then, several other attempts using other models have been made to simulate the weather and plume dispersion for the Khamisiyah event. Unfortunately, both the weather observations and the sarin source data appear to be inadequate for any model to provide a single, definitive simulation of sarin dispersion from Khamisiyah, and it is not clear that further analyses are warranted.

A more complete report is included in the written testimony.

Terrorism Presents Unique Challenges for Plume Prediction

Recent terrorist events, particularly September 11th, 2001, have heightened national concern over urban terrorism and the release of airborne nuclear, biological, and chemical (NBC) agents in the urban environment. Terrorist releases of hazardous airborne material present unique threats. Potential targets are numerous and are located throughout the world in urban areas and at critical infrastructure sites. The source of the released hazardous material may be unknown or poorly known. And the hazardous area can extend from the local release location to surrounding cities and beyond.

Preparation for such an event requires appropriate emergency planning, hazard assessment, and response training at the local city and county level. During an NBC release, emergency managers and responders (fire, police, hazmat, etc.) need accurate information on the extent and effects of the airborne material to guide decisions regarding protective actions to be taken (evacuation, sheltering in place, etc.), critical facilities that may be at risk (hospitals, schools, etc.) and safe locations for incident command post siting. In addition, response teams from multiple jurisdictions (local, state, and federal) need to effectively share information regarding the areas and populations at risk.

Science and Technology Development is Needed

Effective preparation for, and response to, the release of toxic materials into the atmosphere hinges on the accurate prediction of the dispersion pathway, local concentration, and ultimate fate of the hazardous agent. Of particular concern is the threat to civilian populations within major urban areas, which are likely targets for potential attacks. Both new capabilities, and the expansion and effective application of existing capabilities are needed to address this critical national security concern.

Enhanced Meteorological Data Networks

Atmospheric dispersion models are powerful tools that can provide realistic assessments of nuclear, chemical, and biological events. However, in order to accurately predict the location of toxic clouds and to assess their effects on human health, *all* dispersion models require high-quality, three-dimensional weather observations (wind direction, wind speed, etc.). To some extent, high-resolution weather models can help "fill in the gaps" in sparse data areas, but this capability is limited by the nature of larger-scale weather systems and other factors.

Weather observations are required not only near the ground, but also in layers of the atmosphere above the ground. Ground-level and upper-air weather observations are collected routinely at airports. Additional ground-level observational data are collected by local, state, and federal agencies. However, even more weather observation locations are needed for models to accurately predict plumes in urban areas. Of particular note is the need for above-ground weather observations in urban areas.

Integrated Urban Dispersion Modeling

Accurate and timely prediction of the atmospheric dispersion of hazardous materials in densely populated urban areas is a critical homeland and national security need. High-fidelity, computationally-efficient, building-to-urban-to-regional scale dispersion simulations are essential for vulnerability studies, risk assessments, critical infrastructure protection, attribution and signature analyses, and intelligence applications. In addition to predicting concentration levels of hazardous materials, such dispersion simulations can answer questions concerning building infiltration through HVAC (heating, ventilation, and air conditioning) intakes, exits and vents, guide command post siting decisions, and aid in determining optimal evacuation routes for emergency response.

Atmospheric Transitions and the Coastal Environment

Many metropolitan areas are within 20 miles of an ocean or a large body of water such as the Great Lakes. In these coastal regions, *land-sea breezes* change the direction and speed of the winds throughout the course of a day, especially during the transitions between day and night. In fact, these transitions can completely reverse the wind direction within an hour or so. Currently available weather observation locations are too far apart to accurately characterize the three-dimensional structure of land-sea breezes, and weather prediction models often do not adequately represent their spatial structure or timing. Additional meteorological observations and improved fine-scale weather prediction models are needed to provide accurate and reliable predictions in the coastal environment.

Model Evaluation and Testing

Plume models can be evaluated in a number of ways. We see the following key components.

- Analytic comparison with known mathematical solutions to test the numerical accuracy of the model.
- Field experiment comparison to test the model in real-world situations.
- Operational testing to evaluate the usability, efficiency, consistency and robustness of the models under operational conditions.
- Open literature publication and public availability of the model to allow for scrutiny by the scientific and user communities.

Model evaluation is an ongoing activity at NARAC. While it is not practical to verify the models under all conditions, we strongly support continued field programs focused on the issues discussed above.

Systems Approach

An effective response capability must be an integrated, end-to-end system. In addition to data assimilation, weather prediction and plume dispersion models, an effective response capability needs to include dependable voice and data communications with emergency managers and first responders; rapid, high-volume atmospheric data collection and archiving; and extensive databases of terrain elevation, maps, population density, and health effects.

Of critical importance are situation awareness tools that provide emergency managers with a clear picture of the extent of the hazard and anticipated impacts so that they can make informed decisions. In this regard, event reconstruction capabilities that seamlessly integrate observational data with prediction models are needed to provide the best possible estimates of unknown sources, as well as optimal and timely situation analyses that are consistent with both models and data.

At NARAC, we believe the core of our response capability is the highly trained and experienced staff of interdisciplinary professionals. For the capability to be robust, all these elements must be available on a 24/7 basis, be able to respond to multiple simultaneous events, and have built-in redundancies. Training for end users, periodic exercises, and established procedures are also essential features.

Local Integration of NARAC with Cities (LINC)

The development of such a capability is being explored by the DOE/DHS Local Integration of NARAC with Cities (LINC) program. The objective of this program is to demonstrate the capability for providing local government agencies with NARAC atmospheric plume prediction capabilities in a manner that can be seamlessly integrated with appropriate state and federal agency support for homeland security. We are currently working with the City of Seattle, which we supported during the recent TOPOFF2 exercise, and New York City, which we supported during the Staten Island fuel fire in February of this year. Expansion to four additional cities is planned for this summer.

Commitment to National Security

In closing, let me assure you that we at the National Atmospheric Release Advisory Center are dedicated to state-of-the-science plume prediction and emergency response support in the event of an atmospheric release of hazardous material. Over the past several years, our concerns have expanded to include the atmospheric release of WMD agents and other hazardous material from terrorist activity. We have built on our historical nuclear weapons mission and developed unique expertise, capabilities and technologies to meet these emerging threats, including the threat of a biological or chemical agent release. We are committed to using our world-class scientific and technological resources – people, equipment, and facilities – to meet the nation's security needs today and in the future.

The ARAC[1] Khamisiyah Calculations

Michael M. Bradley[2], Principal Investigator
National Atmospheric Release Advisory Center (NARAC[3])
Lawrence Livermore National Laboratory (LLNL)

Initial Calculations, October 1996

Our initial calculations for the Khamisiyah incident were done on very short notice. On October 16, 1996, ARAC (the Atmospheric Release Advisory Capability at LLNL) was requested by associates in Q-Division, NAI[4] Directorate, LLNL (on behalf of the Central Intelligence Agency) to prepare model runs concerning the destruction of chemical munitions in occupied Iraq following the Gulf War. ARAC was requested to complete these calculations in less than one day. The information for the assessment was received by ARAC from Q-Division shortly before noon local time on 16 October, 1996, and the products needed to be in Washington DC by 9:00 am eastern time the following day, 17 October 1996. All information provided to ARAC concerning the assessment in regards to the source term, time and duration of release, exposure contours, and meteorological data was identical to that used by SAIC for their assessment. ARAC was provided with three release scenarios based on the number of possible chemical munitions in the ammunition dump when destroyed, and how the chemical munitions might behave at the time of destruction. We were also provided with two different meteorological records. The first was upper-air data for a large region of the Far East in text format on 3.5" disks. The second was hardcopy tracings of wind speed and direction at hourly intervals beginning at 0000 UTC on 09 March 1991 and extending to 0000 UTC 13 March 1991. The latter required manual, visual interpolation by ARAC assessors to determine the actual hourly direction and speeds. We completed the calculations and faxed copies of our plots to the CIA in less than 24 hours.

November 1996 Presentation

We were asked by the Office of the Secretary of Defense to present our results to the IDA (Institute for Defense Analysis) Panel on Low-Level Exposure to Chemical Agents on November 20, 1996. The meeting was hosted by IDA and chaired by General Welch, retired Air Force Chief of Staff, and the Director of IDA. We presented a full set of calculations for three scenarios out to 24 hours. For this set of calculations we used essentially the same meteorological data that we used for our October simulations.

---

[1] Atmospheric Release Advisory Capability

[2] Coordinator for National Security Projects, National Atmospheric Release Advisory Center
L-103, P.O. Box 808, Lawrence Livermore National Laboratory, Livermore, CA 94551.

[3] At the time when the Khamisiyah calculations were accomplished, the name of the organization was ARAC. Approximately three years ago, due to an expanded mission, the organization was renamed NARAC. The DOE-sponsored ARAC Program continues to be NARAC's primary mission.

[4] Nonproliferation, Arms Control, and International Security

February 1997 Presentation

We were asked to simulate 21 case scenarios, to extend the duration of our calculations to cover a 72-hour period, and to present our results at a meeting at IDA in February 1997. The scenarios consisted of cases for 550, 325, and 100 rockets, and for instantaneous, evaporative, and a combination of 50% instantaneous and 50% evaporative releases of sarin. In each case with evaporation, the evaporation was allowed to occur over 12-hour, 36-hour, and 60-hour periods.

For this final set of calculations we used the meteorological data from the same observational sources as for the November presentation, extended out to 72 hours after the release, plus data from five additional surface stations and eight additional upper air stations that we obtained from AFCCC (Air Force Combat Climate Center). In addition, we obtained a diskette from SAIC containing surface wind data, and noted that the data for three of the stations were slightly different from what we had obtained from the hardcopy plots. We replaced the previous data with the new data on the diskette.

The results of our simulations indicated that the 72-hour exposure due to the instantaneous release of sarin from 550 rockets covered an area extending south-southeast from the release point to the Persian Gulf, then turning eastward at the Gulf coast, and then turning northeast over the Gulf and extending northeastward across central Iran. Time-integrated concentrations in excess of 0.5 mg-min/m^3 ("minimal effects level") covered a 2,255 square kilometer area extending approximately 130 km south-southeast from the release point. Dosages in excess of .05 mg-min/m^3 ("occupational limit") were predicted over a 114,468 square kilometer area, including Kuwait City, an approximately 200 km-wide swath across the Persian Gulf, and the higher elevations of the Zagos mountain range in Iran. The time-integrated concentrations from the 325- and 100-rocket scenarios covered the same area but were proportionately reduced in magnitude.

Due to changes in the wind direction over time, the totally evaporative releases resulted in simulated initial exposures to the south-southeast of Khamisiyah (as in the instantaneous release scenario), and later exposures to the northwest of Khamisiyah (even for the relatively short 12-hour evaporation scenario). In the 36-hour and 60-hour evaporation scenarios, the main exposures were to the northwest of the Khamisiyah, in a path almost centered along a straight line between Khamisiyah and Baghdad. Small areas in the higher Zagos mountain range were also exposed.

The largest simulated areal coverage (304,400 square kilometers) of time-integrated concentrations exceeding .01 mg-min/m^3, (the "general population limit") occurred for the 550-rocket scenario with 50% instantaneous release, 50% evaporative release over 36 hours.

In contrast to our simulations, calculations by the Navy Research Laboratory (NRL), using the COAMPS forecast model (and apparently later by SAIC, using the OMEGA forecast model) to predict (in a forensic sense) the wind fields, showed the plume from an instantaneous release moving first southerly, and then turning to the west-southwest. During the panel discussion at the February, 1997 IDA meeting, Dr. Kerry Emanuel, Director of the Center for Meteorology and Physical Oceanography at MIT, commented on these differences, noting that the modeled wind exhibited a line of diffluence in the general vicinity of Khamisiyah, and that the precise location of this line was critical to which way the material would be transported by the wind. He stated that an ensemble study of the problem would likely produce a bimodal distribution of results, with half the simulations showing a plume similar to ours, and other half showing a plume similar to NRL's.

Final Comments

After February 1997, we were not asked to participate in further studies of the Gulf War Syndrome. At that time, we were not convinced that all paths to understanding the 1991 Khamisiyah event had been exhausted. However, since then, several other mesoscale atmospheric models and atmospheric dispersion models have been used in attempts to simulate the weather and to calculate the transport, diffusion, and resulting sarin exposure for the event. It is not clear that further analyses are warranted.

Analyzing the Khamisiyah event is a very difficult problem, due to sparse weather data and great uncertainly regarding the amount, and nature of release, of the sarin. Although NARAC's atmospheric dispersion simulation capability is world-class, the accuracy of our simulations is limited (just as for all dispersion models) by the adequacy and accuracy of the three-dimensional atmospheric data (wind direction, wind speed, boundary layer depth, etc.) used by our models. This limitation holds not only for dispersion simulations based on observed weather conditions, but also for those based on modeled weather conditions, because the modeled weather is still ultimately based on weather observations. To some extent, mesoscale models can help "fill in the gaps" in historical observational weather data, but this capability is limited by the nature of larger-scale weather systems and other factors.

In the case of the Khamisiyah event, both the observational weather data and the sarin source data appear to be inadequate for any model to provide a single, definitive simulation of the sarin dispersion with the desired accuracy and confidence level. Given those constraints, an ensemble modeling methodology probably is the most appropriate approach for attempting to analyze the event. Perhaps enough simulations already have been accomplished to support that type of analysis.