

# **Critical Infrastructure Protection in the National Capital Region**

**Risk-Based Foundations for Resilience and  
Sustainability**

**Final Report, Volume 18:  
Epidemiology of Transportation Systems and  
Bioterrorism**

**September 2005**

**University Consortium for Infrastructure Protection**

Managed by the  
Critical Infrastructure Protection Program  
School of Law  
George Mason University

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## Risk-Based Foundations for Resilience and Sustainability

### Final Report, Volume 18: Epidemiology of Transportation Systems and Bioterrorism

Submitted in fulfillment of:

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September 2005

Arnauld Nicogossian, Laurie Schintler, and Danielle Mutone-Smith

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– **Notice** –

This research was conducted as part of the National Capital Region Critical Infrastructure Project, carried out by the University Consortium for Infrastructure Protection, managed by the Critical Infrastructure Protection Program, George Mason University, John A. McCarthy, Director and Principal Investigator.

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School of Public Policy  
George Mason University  
Fairfax, Virginia  
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# Epidemiology of Transportation Systems and Bioterrorism

Prepared by Arnauld Nicogossian, MD, FACPM, FACP;  
Laurie Schintler, PhD; and Danielle Mutone-Smith, MA

August 20, 2005



## ***Research Team\****

### **George Mason University**

Arnauld Nicogossian (Principle Investigator)

Ken Alibek

Zafer Boybeyi

Vikas Chandhoke

Laurie Schintler

Roger Stough

Thomas Zimmerman

### **INOVA Health Care System**

Dan Hanfling

Allan Morrison

### **Center for Food and Nutrition Safety Policy, Virginia Tech. Univ.**

Gary Weaver

### **James Madison University**

Stephen Stewart

Joshua Barnes

### **Uniformed Services University of Health Sciences**

Joshua Vayer

### **GMU School of Public Policy Graduate Research Assistants**

Stacey Brooks

Danielle Mutone-Smith

Shanae Watkins

Rosann Wise

Ting Zhang

This research was conducted as part of the National Capital Region Critical Infrastructure Protection Project, carried out by the University Consortium for Infrastructure Protection, managed by the Critical Infrastructure Protection Program, George Mason University, John A. McCarthy, Director and Principal Investigator. It was sponsored by the U.S. Department of Homeland Security's Urban Area Security Initiative grant #03-TU-03 under the direction of the Senior Policy Group of the National Capital Region. The views expressed are those of the authors, and do not necessarily reflect the views of the Department of Homeland Security or the Senior Policy Group.

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## **Office of International Medical Policy**

**The School of Public Policy (SPP) at GMU emphasizes interdisciplinary and alternative approaches to public policy. In addition to offering seven master's degrees and the largest PhD program in Public Policy in the nation, SPP offers a variety of hands-on research activities conducted through several research centers. From global issues, such as peacekeeping and electronic commerce, to regional issues, such as land use and transportation management in Northern Virginia, SPP conducts inquiry into public policy formulation and recommendation of appropriate solutions.**

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## Executive Summary

Widely available, rapid, and easily accessible transit for passengers and goods is a key ingredient for economic development and global prosperity. These same attributes, notably ease and accessibility, can facilitate the spread of infectious diseases and make it an attractive target for a terrorist attack.

Epidemiology in the title of this report recognizes the potential for economic, political, societal and infrastructure vulnerabilities resulting from the use of mass transit technology developed in the last century. The use of car/bus bombs, the events of September 11, 2001, the bombings of the Madrid commuter train on March 11, 2004 and the London subway on July 7, 2005, and the global transmission of SARS are just a few examples of emerging vulnerabilities. *Epidemiology of the Transportation System and Bioterrorism* report is the result of a review of relevant events, search of scientific and technical materials, inputs from multidisciplinary expert workshops, and modeling of the impact of a plume dispersion in the National Capital Region (NCR) area.

The research team opted to model the dispersion of a significant amount of anthrax spores on a large geographic scale. Such scenario calls for major production and stockpiling of the spores, requiring advanced technical capability, and as such can be detected and is considered difficult to accomplish. Likewise the use of anthrax spores in the amounts contained in the letters mailed in 2001, would not produce a substantial aerosol, hence little infrastructure damage or casualties. However, based on the experience from the 2001 anthrax spores delivered by mail, it is reasonable to assume that the number of “well

and worried” visitors to emergency and health care facilities might overwhelm the health care system. The problem of decontamination of a large scale area following even a small spill might also present a significant regional, societal, psychological, and economic impact.

As the modeling exercise revealed, a regional attack will negatively affect the ability of the existing medical infrastructure to cope with such an event. The significant disparity in the distribution of medical and public health facilities within the NCR area further complicates this problem. The surge capacity for the NCR health care system, with an emphasis on the Northern Virginia, specifically west of the Capital Beltway (I-495) and away from the contaminated area, deserves further evaluation, based on the results of our modeling and simulation. Contamination of the DC and Maryland areas, by anthrax spores will disrupt the ability to use the METRO or other means of transportation. Modeling designed to test realistic scenarios and provide inputs into the education and sustained training of disaster managers and responders is vital to the successful preparedness for a terrorist event.

This report identifies a set of concerns and possible solutions. Based on the availability of resources and ease of mitigation these concerns and solutions are divided into near and long term categories .

### **Near term (weeks up to 6 months):**

1. The release of a large amount of anthrax spores (*Bacillus anthracis*) will invariably impact the availability of hospital beds and consequently proper provisions must be

made to secure additional medical resources for the NCR.

2. Evaluation of threats and planning for additional deployment of countermeasures during favorable meteorological conditions, conducive to a large scale bioterrorist attack, must be a priority for our national biodefense program.
3. Proper communication protocols and systems must be developed and tested. Psychological and emotional aspects of the targeted population, beyond just scientific facts, should be part of any communication protocols. METRO should continue to work with stakeholders, including riders, to promote education and address potential threats.
4. The Federal Government, in consultation with leading experts in the field, should establish and adopt safety, isolation, and decontamination standards for weaponizable biological agents to prevent unnecessary confusion within the community and loss of public confidence.
5. A regional public health authority should be identified to organize, develop, coordinate, and implement prevention and mitigation strategies for the NCR region.
6. Further research will be necessary to develop protocols regarding the real time allocation of resources, evacuation, and treatment in mass casualty situations. These protocols should address:
  - a) The standardization of terms. The development of standardized defini-

tions of “hospital beds”\*\* and “surge capacity” for example, are necessary to effectively measure medical resources in the NCR.

- b) The standards of care in mass casualty situations (bio-chemical attacks) should be defined, with the understanding that such standards can be very different from usual disaster approach and procedures.

**Long Term (6 months to 3 years):**

1. Policies addressing protective measures, such as increased surveillance, monitoring of the environment and passenger health, deployment and periodic testing of sensors, drills and training, use of vaccination and rapid delivery of medical treatment, provisions for surge capacity of hospital beds and associated equipment and staff, requires further investigation and improvement.
2. Existing resource allocation policies and processes, including the funding of focused research and deployment of operational capabilities, are inadequate and require reassessment.
3. Additional reliable technologies for rapid and real time detection of those biological agents most likely to be used must be developed and deployed as soon as technologically feasible (1).
4. Develop means for isolating contaminated segments of the underground METRO system, including interrupting air ventilation. A

\*\*Currently an effort is in progress with in the NCR to standardize definitions of surge capacity and hospital beds.

capability for safe and rapid passenger evacuation into aboveground and uncontaminated areas (safe or cold zones) is required.

5. Medical equipment and medications must be regionally deployable on demand or stockpiled in the designated areas of greatest risk within the NCR.
6. Routine awareness programs for communities and rapid transit passengers at risk (similar to commercial aviation) must be made available. The passenger training currently offered by the METRO system should be properly funded, expanded, and made available to all commuters
7. Additional resources must be devoted for planning and training purposes for first responders and communities. This training should be based on plausible models of threat assessment, using available transportation systems. It should complement currently used models that are primarily focused on agricultural airplanes, large occasional events and public venues (university graduations, shopping malls, movie theaters etc.).

The research team concludes that the current capacity for predicting or effectively preventing a bioterrorist attack upon the NCR transit system designed for rapid and easy access is difficult if not impossible. This makes the adoption of a set of vulnerability assessment tools, the identification of strengths and weaknesses, and the implementation of threat reduction strategies to be extremely important. Additional resources should be devoted toward the development of educational materials and the training for commuters/passengers and communities, residing in

the immediate vicinity of mass transit systems. Attention should be paid to developing additional capabilities that support high tourist seasons, which are also a time for increased vulnerability. The research team strongly recommends that the modeling tool developed by the GMU research team be further researched and tested in the actual METRO setting and used in training exercises.

## Background

Historically biological agents have been used during conflicts and warfare. Terrorist attacks either sponsored by governments, interest groups, or individuals are not new phenomena. Nature and the wild life offer an abundant source of easily harvested pathogens for intentional and malevolent use. Deliberate use of community services, such as transportation, water, and food, and since October 2001 the postal system, by hostile organizations and terrorists alike, to disseminate infectious agents and create terror has been a common occurrence in the 20<sup>th</sup> Century .

History is replete with incidents of the testing and/or dissemination of weapons of mass destruction (WMD) using different transportation modalities. In the mid to late 1930s, the Germans purportedly tested the dispersion of the *Serratia marcescens* (SM) and *Bacillus globigii* (BG) in the Paris and London Subways. During World War II the Japanese researchers experimented with many bacteria and delivery systems, including airplanes, insects and foodstuff on the Manchurian population. In the 1950s, at the height of the Cold War, the US conducted dispersion tests over entire cities and specifically in the New York subway system using SM and BG as substitutes for anthrax and tularemia (1A). The Soviet Union conducted tests using similar organisms in remote and isolated areas such as the Vozrozhdenie Island on the Aral Sea (2).

In the 1980s the Aum Shinrikyo Cult in Japan attempted to produce, store and deliver chemical and biological WMD (3, 4). The cult hired physicians and a pharmacist for this project. Efforts were made to

procure “dirty bombs” and highly infective microorganisms such as Ebola. In the early 1990 the Cult tried to use chemical and biological weapons to attack Tokyo residents and target Japanese officials. Apparently the group attempted on four occasions to deliver biological agents:

1. 1990, by means of a specially outfitted automobile to disseminate botulinum toxin;
2. Twice in 1993 using specially adapted vehicle to disseminate botulinum toxin
3. Again in 1993 by spraying anthrax from the roof of Aum owned building;
4. In 1995, the members of Aum Shinrikyo Cult, charged with the release of botulinum toxin in Tokyo subway, delivered instead a harmless agent.

These failed efforts are a testimony to poor planning, operator error, and/or difficulty in developing weapon grade agents and effective delivery means. Finally on March 20, 1995 the Aum resorted to the release of sarin in the Tokyo subway which resulted in mass casualties, 12 deaths and over 5,000 injured. In addition thousands of “well and worried” citizens flooded the medical facilities in search of reassurance and medical examinations (5).

These historic events further highlight that modern transportation, and the commercial service sector as a whole, including health care facilities, designed for rapid and convenient access by a large number of individuals can be attractive targets for resourceful terrorists. Urban, inter urban, and international transportation systems are interconnected, serving passengers and industries alike, and are capable of transmitting infections and are vulnerable to a terror-

ist attack(s) (6-13). Thus the combination of these two factors, a *vector* and a *target*, if not addressed, can result in a major medical vulnerability and should be systematically evaluated for risk reduction and protection.

Plausible health threats against different transportation grids and modalities deserve inclusion into the planning process for near or real time epidemiological monitoring and protection (26).

The objectives of this research can be summarized as:

- ◆ Study current strengths, barriers and other factors which can contribute to the vulnerability of the transportation system to bio agents;
- ◆ Simulate and understand the potential risks and health impacts of a bioterrorist attack(s) on the local and regional infrastructure and community;
- ◆ Recommend relevant policies and practices.

The research team, comprised of representatives from George Mason University, Virginia Tech, Uniformed Services University of Health Sciences, INOVA Health Care System and James Madison University. A bibliographic reference database, a vulnerability/risk assessment of the NCR area transportation system, a model(s) of the potential impact of an anthrax (primary agent) release in the D.C. metro area, including secondary effects on the local regional infrastructure, public health and medical care systems were assessed. Preliminary policies necessary to protect the health the community and the physical infrastructure were formulated.

## Methodology

The methodology used in this report can be divided into internal and external evaluations, and modeling.

1. - The *internal evaluation* was comprised of

- (1) Review of available data and information in the open literature
- (2) Development of a bibliographic data base relevant to the research project
- (3) Compilation of parameters suitable for selection of pathogens and their dissemination using different forms of urban transportation within the NCR
- (4) Modeling the interdependencies between the NCR transportation systems and select communities and/or regional enterprises, using geographic information and superimposing atmospheric dynamics and meteorological behavior.

The data and information obtained from the internal reviews were subjected to statistical analysis as appropriate in order to:

1. Create an evidence-based annotated bibliography,
2. Identify new research directions or demonstrated threats,
3. Guide discussions at the meeting(s) of investigators and experts,
4. Develop notional models as appropriate
5. Generate educational and/or training concepts and materials within the available resources,
6. Develop policies and benchmark best practices, and
7. Recommend processes to reduce vulnerability and improve recovery.

A standard approach to the data mining was agreed upon and adopted prior to the literature search. This consisted of key words or phrases to be searched and articles, books, websites, etc. to be queried. The total number of documents and materials found were either rejected as not useful or retained as relevant. Those materials identified as relevant were then categorized by topic and the findings were summarized for entry into a bibliographic database.

The information was categorized as:

- 1= Highly Relevant
- 2 = Relevant
- 3 = Minimally Relevant
- 4 = Not Relevant

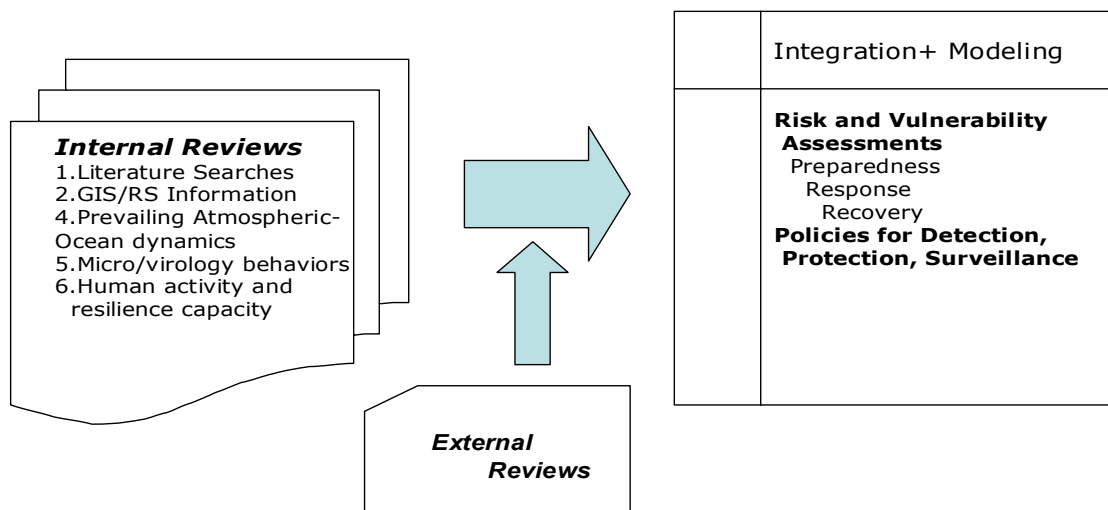
For Internet searches: Alta Vista, Google, Pub Med, government (federal and state) websites, congressional records and university web sites were que-

ried. Additional sources of information, such as books, CDs, brochures, were identified as appropriate and searched for secondary citations.

2. - **External review(s)** were provided by subject matter experts through workshops or focus group meetings. Inputs and discussions were based on the research materials developed as a result of internal reviews and presented by the research team. Findings, discussions and advice provided were evaluated for relevancy and incorporated into the final recommendations.

The overall approach to the policy formulation is represented in *Figure 1*. A schematic representation of the process used for developing the modeling capability used in this research project are shown in *Figure 2*. The aerosol and plume dispersion simulations were superimposed on the Geographic

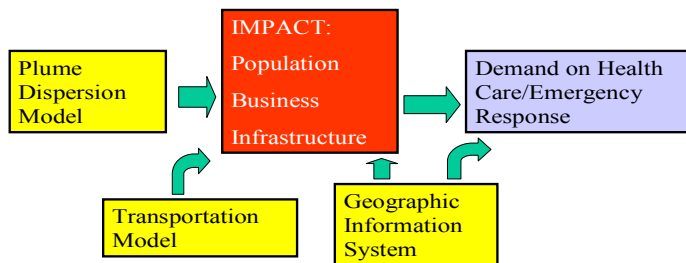
**Figure 1. Methodology and Approach**



Information System (GIS) to determine the extent of the impact on infrastructure. An aerosol is a collection of very small particles that behave similarly to a gas. The extent of contamination within the NCR area on the population (primarily rider ship on the METRO

**Figure 2**

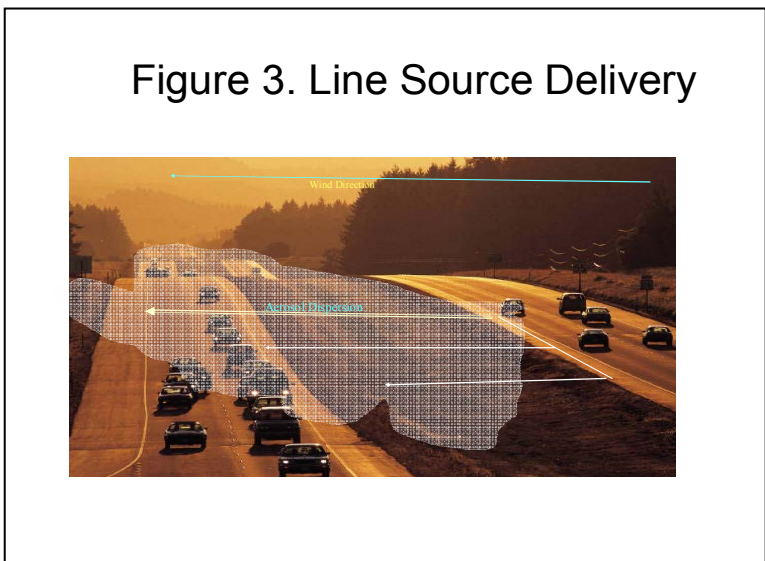
### Modeling Framework



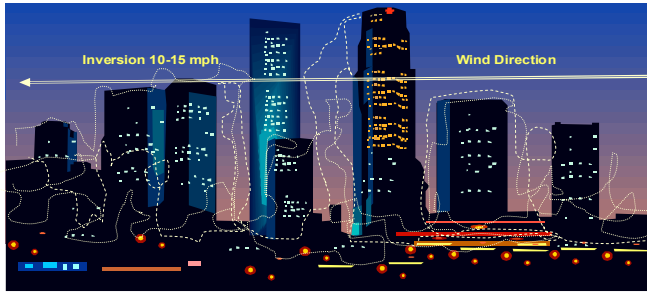
subway system), businesses, and medical care facilities were assessed. The worst case scenario, consistent with the delivery of a large amount ( 10 to 20 Kg. or greater of 1 to 10  $\mu$  size and  $10^6$  spores/mg.) of weapon grade anthrax spores either by a specially outfitted vehicle traveling on a predetermined route, such as George Washington Parkway, or the subway within Washington, DC., were evaluated for modeling. The vehicle as a delivery tool was entertained because of the ease of use, but was deemed to be limited in efficacy and was not pursued further at this time. The primary research emphasis was placed on the METRO subway system with subsequent atmospheric escape through the ventilation system(s) and exits. It was assumed that the occasional speed of the subway (reaching 80 miles/hour in some areas) would further help disseminate the spores with little breakage effect of the

aerosol. It was postulated that the contamination of the DC subway system and subsequent release into the atmosphere would follow the same patterns as those described during earlier experiments with *Bacillus globii* in the New York subway and other available scenarios in the open literature (2, 14, 15, and 19). The conceptual dispersion pattern considered or used in the modeling scenario is depicted in *Figures 3-5*.

*Figure 3* represents a hypothetical event associated with a line source delivery by a specially outfitted automobile traveling the length of a highway (in this case assumed to be the George Washington Parkway), with winds blowing towards the north east disseminating the plume toward the city. *Figure 4* depicts the dissemination and breakdown of an aerosol plume in a large city with tall buildings, which would be the case of a line source delivery. *Figure 5* represents the NCR geographical area,(11), with superimposed climatology information, selected for modeling purposes. The statistical and dilution concepts were adapted from references 16 through 18.



**Figure 4** - Plume dispersion in the city. Buildings might create micro-meteorological conditions which will affect the integrity of the aerosol.



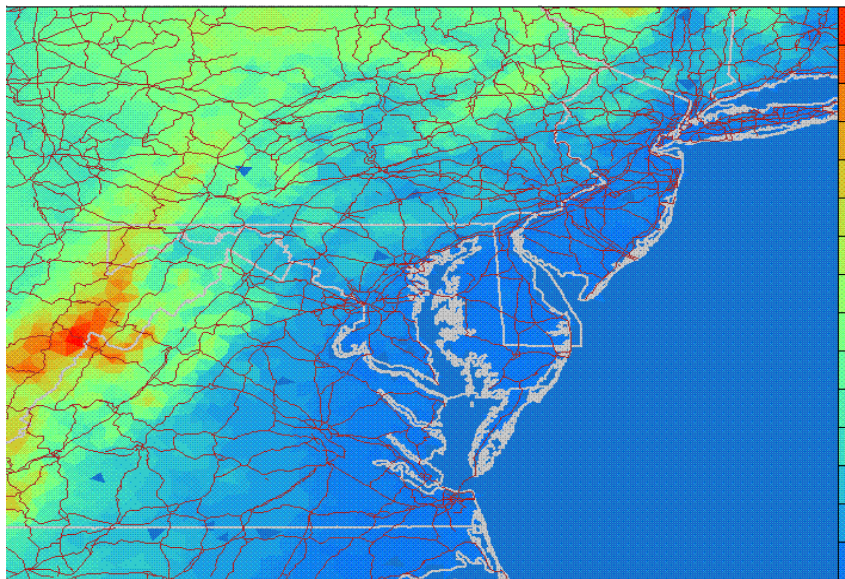
(Adapted from Reference 2 and 16)

establishments, demographics by census block group, the location and capacity of medical care facilities, transportation infrastructure (METRO, highways and arterials, industrial rail and airports). METRO rider ship and traffic volumes, and other related information, by road segment and different routes is also available.

The approach was to overlay onto the data from the plume dispersions using multiple release scenarios in the

NCR area to develop estimates of extent of impacts. These estimates yielded the number of people affected by the attack in need of medical care, the timing of an attack, the capacity of various medical care facilities to handle the number of casualties and concerned residents, and the availability of alternative transportation and health care facilities to manage overflow. Algorithms built into the GIS can also be used to extract additional information

**Figure 5:** The Baltimore-Washington, DC region is the focus of the model and research.



**Modeling**

To better illustrate and address the many uncertainties of a terrorist event, the research team used advanced modeling techniques to evaluate possible scenarios. Prior to the Olympic Games in Salt Lake City, a similar meteorological simulation was used to determine possible aerosol plume dispersion patterns. This study used a Geographic Information System (GIS) to examine how a bioterrorist attack in the Washington, D.C. region might impact its population, business activity, transportation systems, and health care sector. The GIS contains databases of the location and type of business

that may be useful in analyzing the problem.

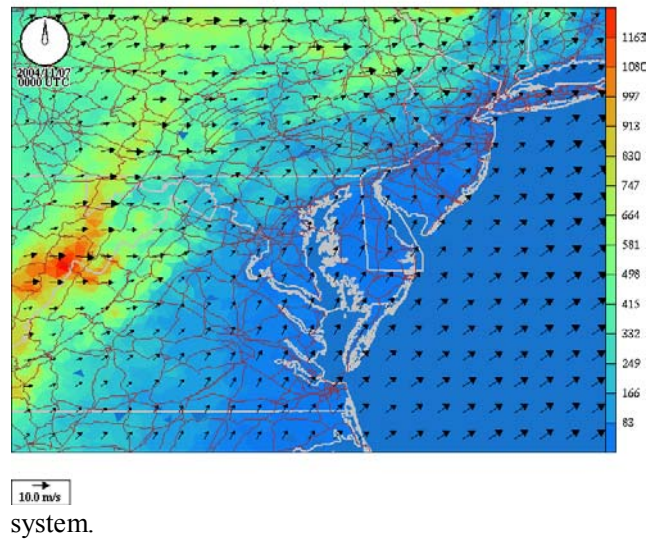
A widespread attack or one that causes great concern in the region could have a critical impact on communities and the medical systems to respond appropriately. It is vital to determine the surge capacity for the region hospital system with an emphasis on Northern Virginia outside of the 495-beltway since it is expected that an attack would cause people to evacuate south and west to avoid the contaminated areas and prevailing winds blowing towards the northeast during the summer months (Figure 6).

Based on the analysis of the weather patterns

and prevailing winds in the area the research team determined that the largest impact would occur if an agent(s) was released into the atmosphere in the early morning during the summer months. The impacts of any attack, whether inside the METRO or outside near key transit routes, could have different degrees of severity depending on the number of daily passengers, including tourists, by destination and traffic patterns.

The research team assumed that several intentional releases would occur on the Red, Blue and Orange lines near the METRO Center Station. The initial modeling aspects were simplified by assuming that the subway would distribute the spores throughout the confined space, with subsequent escape into the air through the ventilation system and the tunnel openings to the surface areas. Thus the multiple air releases would act as point sources and be subject to the prevailing winds. In all probability, dissemination of spores throughout the subway would also result in the contamination of those buildings which have entrances into the METRO rail

**Figure 6– Prevailing Winds in the NCR Region**



system. Table 1 represents an operational mesoscale model (Operational Multiscale Environment Model with Grid Adaptivity, OMEGA) used to link plume prediction with GIS information. A complete description of OMEGA can be found in Bacon et al. (2000) and Boybeyi et al. (2000). OMEGA is a fully non-hydrostatic, three-dimensional prognostic model. It is based on an

**Table 1. An Overview of OMEGA**

<b>Governing equations</b>	Fully non-hydrostatic
<b>Dimensionality</b>	3D
<b>Grid structure</b>	Unstructured triangular prisms
<b>Grid adaptivity</b>	Both static and dynamic grid adaptation
<b>Coordinate system</b>	Rotating Cartesian coordinates
<b>Numeric</b>	Finite volume
<b>PBL</b>	Treated separately as viscous sublayer, surface layer, and transition layer
<b>Turbulence closure</b>	1.5 order turbulent kinetic energy closure
<b>Cumulus par.</b>	Modified Kuo scheme and Kain-Fritsch scheme
<b>Microphysics</b>	Extensive bulk-water
<b>Radiation</b>	Shortwave absorption by water vapor and longwave emissivities of water vapor and carbon dioxide
<b>Lower boundary</b>	Based on Monin-Obukhov similarity theory
<b>Upper boundary</b>	Rigid, free-slip surface
<b>Lateral boundaries</b>	Radiative boundary condition, large scale nudging boundary condition
<b>Initialization</b>	Based on 4D data assimilation
<b>Transport and diffusion</b>	Embedded Eulerian and Lagrangian (Monte Carlo particle and probabilistic puff) aerosol dispersion algorithms

adaptive, unstructured triangular prism grid that is referenced to a rotating Cartesian coordinate system.

The model itself uses a finite-volume flux-based numerical advection algorithm derived from Smolarkiewicz (1984). OMEGA has a detailed physical model for the planetary boundary layer (PBL) with a 2.5 level Mellor and Yamada (1974) closure scheme. OMEGA uses a modified Kuo (Kuo, 1965; Anthes, 1977) and Kain-Fritsch schemes to parameterize cumulus effects, and an extensive bulk-water microphysics package derived from Lin et al. (1983). OMEGA models the shortwave absorption by water vapor and long wave emissions of water vapor and carbon dioxide using the computationally efficient technique of Sasamori (1972). OMEGA uses an Optimum Interpolation analysis scheme (Daley, 1991) to create initial and boundary conditions and supports piecewise four dimensional data assimilation using a previous forecast as the first guess for a new analysis. Finally, OMEGA contains both Eulerian (grid based) and Lagrangian (grid free) dispersion models embedded into the model.

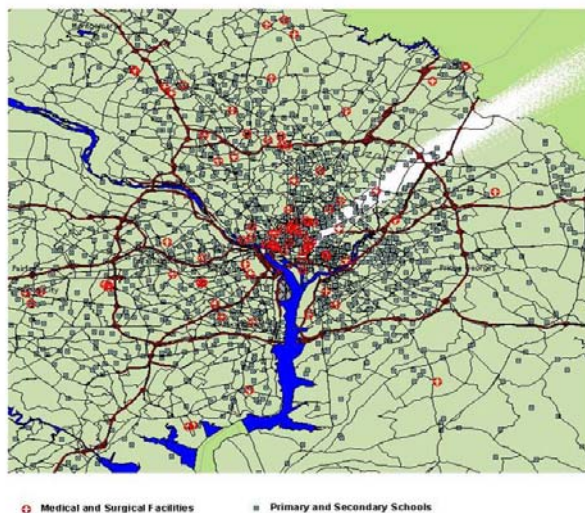
A unique feature of the OMEGA model is its unstructured grid. OMEGA is based on a triangular prism computational mesh that is unstructured in the horizontal dimension and structured in the vertical. The rationale for this mesh is that the physical reality of the atmosphere is highly variable horizontally but always stratified vertically. The flexibility of unstructured grids facilitates the gridding of arbitrary surfaces and volumes in three dimensions. In particular, unstructured grid cells in the horizontal dimension can increase local resolution to better capture topography or the important physical features of atmospheric circulation flows and cloud dynamics. The underlying mathematics and numerical

implementation of unstructured adaptive grid techniques have been evolving rapidly and in many fields of application. There is recognition that these methods are more efficient and accurate than the structured logical grid approach used in more traditional codes (Baum and Löhner, 1989; Schnack, *et al.*, 1993) (19, 20).

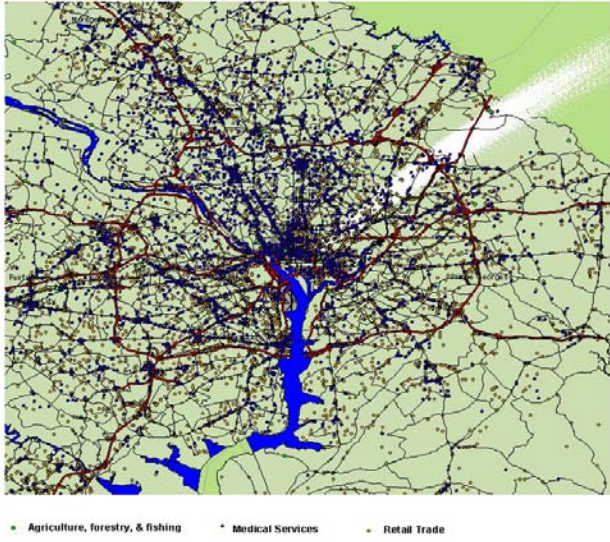
Geographic information (maps) addressing the facilities and commercial services of interest were identified. Meteorological information was then superimposed over these maps for the estimation of impacts. **Figure 7 (maps 1-6)** depicts the information available on the distribution of the transportation system, facilities, schools and university campuses, businesses, and medical and health care facilities. Campuses were selected because they can serve as areas of assembly for exposed individuals for triage and initial distribution of medical supplies.

**Figure 7 (Maps 1-6)**– Geographic information on the NCR population, transportation, medical care facilities, and location of school which can serve as back up medical and shelter facilities in the event of a bioterrorist attack.

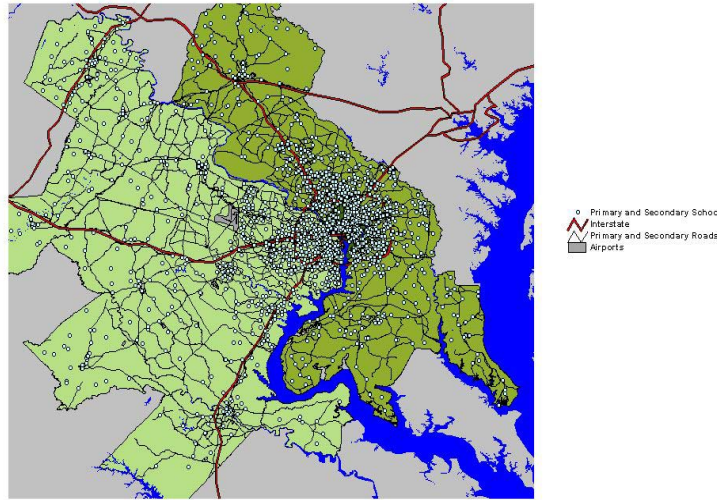
Map 1-  
Plume overlaid on map of medical/surgical facilities and



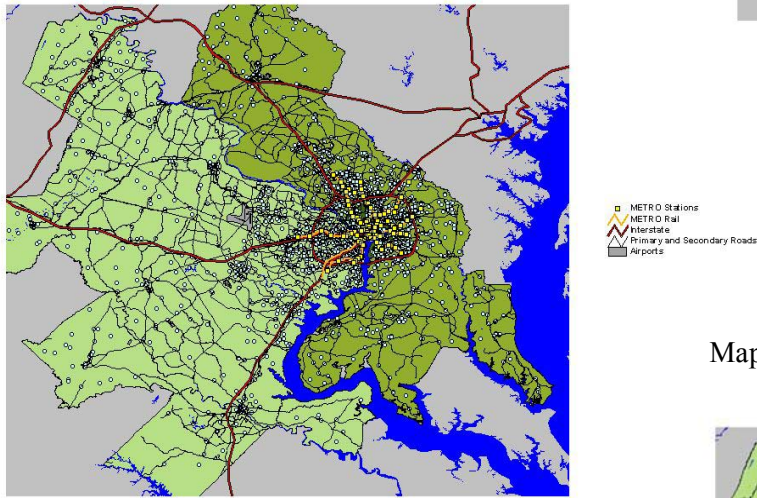
Map 2- Plume overlaid on map of agriculture, forestry, and fishing, medical services, and retail trade



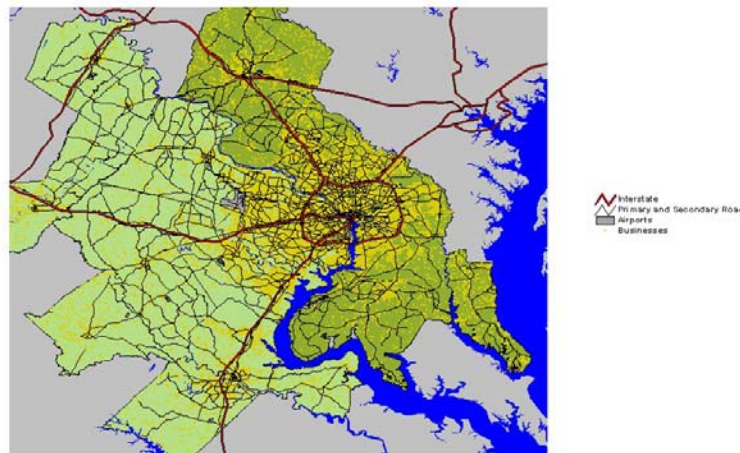
Map 5- Schools, interstates, roads and airports



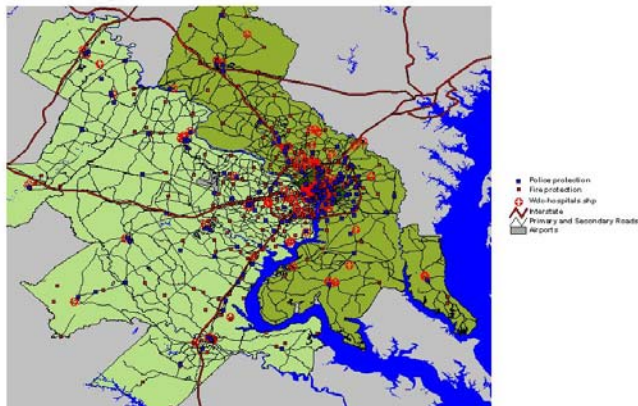
Map 3- METRO system, interstates, roads, and airports



Map 6- Interstates, roads, airports and businesses



Map 4- Police and fire stations, hospitals, interstates, and airports



## External Reviews

Three one-day workshops were held on June 11, 2004, October 16, 2004 and April 1, 2005 respectively. The lists of participants and the agenda for all three workshops are contained in *Appendices 1 through 3*.

The research team presented to the experts its findings, parameters to be included in the simulation efforts, potential impacts on the NCR selected critical infrastructure, vulnerabilities, risks and proposed remedial actions. The participants were asked to discuss the materials and provide advice on the best approach and practices to determine potential outcomes following the dispersion of the bacteria (bioagent) in the transportation system. Three types of bioagents were considered: anthrax, smallpox and plague. All three can or have been weaponized. The primary route of their dissemination is through aerosols, with only anthrax spores able to be delivered in the form of dry powder.

*Considering the time and resource constraints for this research effort, it was determined that anthrax should be the primary agent of study.* Weaponized anthrax was selected because it cannot be transmitted from person to person, the aerosol of anthrax dry spores will be dispersed over wide areas, and will also contaminate the physical facilities. In addition, anthrax was already disseminated through letters, giving additional experience to the research team in its handling within the NCR area.

The workshop participants assessed the feasibility of the use of several transportation modes in order to identify subsequent response(s). The research team together with the experts identified and agreed upon the preliminary parameters to be modeled, soft-

ware and hardware needs, and identified “real life” lessons learned as inputs into the modeling, health policy formulation and recommendations.

The following parameters were identified and incorporated into the subsequent modeling effort:

- Release time of day and month (best meteorological conditions)
- Number of daily passengers by destination
- Medical facilities and surge capacity in the NCR
- Dispersion and spread and dilution factors for anthrax spores
- Interconnectivity between the different transportation modalities and facilities served
- Agricultural and food production and distribution facilities (not included in the current effort)
- Environmental and climatologic parameters conducive to large area dispersion
- 2-3 days delay before the attack is suspected and confirmed
- Number of transit passengers affected
- Number of individuals with severe pulmonary manifestations requiring hospitalization
- Number of health care related facilities and hospital beds (including surge capacity) available for patient care.
- Due to constrained resources the following were not included in our modeling efforts:
  - ◆ Availability and distribution of medications as proposed in postal service delivery assuming shelter in place
  - ◆ Utilities and other logistics: food, expendable surge/med supplies, fuel, etc.
  - ◆ Evacuation routes and means
  - ◆ Based on the availability of out of state

and nationwide resources, it was assumed that EMS availability will be adequate

The modeling was focused on the METRO system. The METRO events had two types of possible releases: small with no plume and large dispersion with plume. The George Washington Parkway was not modeled because of its limited effect. For the modeling purposes we assumed that the population at risk is the average daily ridership of the METRO. This in turn determined the facilities and people affected above ground by type (plume-worse case scenario only).

Future modeling efforts should included the number of monitored care and critical care beds available, the diagnostic and treatment capacity (i.e. ventilators/monitoring equipment), the secondary and tertiary contamination of buildings, buses, cars, and facilities, and the number of such facilities and systems that will need to be closed.

The current scenario assumed the delivery of the anthrax spores early in the morning, dry weather conditions and during the summer months.

## Results

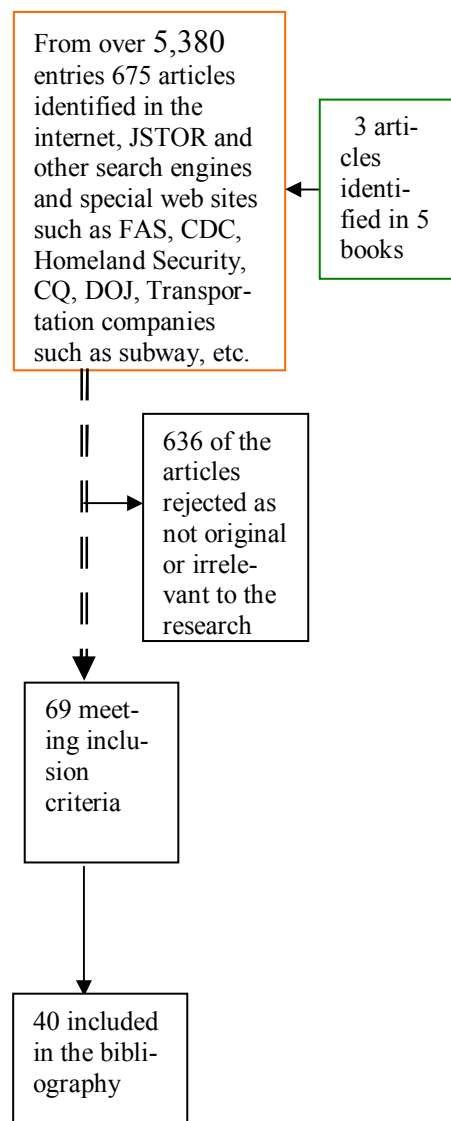
### *Literature Reviews*

For Internet searches Alta Vista, Google, Pub Med, government (federal and state) websites, congressional records and university web sites were queried. Additional sources of information, such as books, CDs, brochures, were identified as appropriate and searched for secondary citations.

By the end of January 2005, a total of 5,380 articles, web sites and 5 books were identified. From this initial search 675 articles and other materials were selected as potentially relevant to this research.

After additional reviews 69 were identified as containing material of interest to the research topic. From these 69 articles, 14 were judged to be very relevant, 7 as relevant, 19 as minimally relevant and 29 as not relevant. Only 40 articles and other printed material were included in the bibliographic database (Table 2).

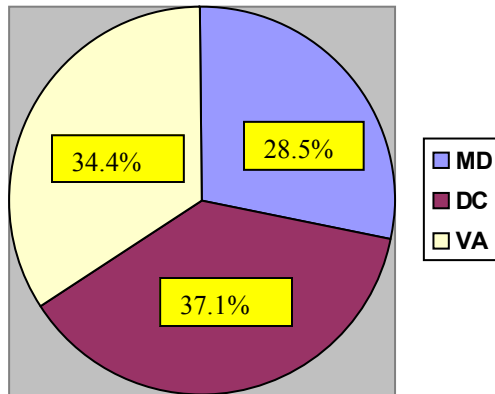
**Table 2– Results of Literature Survey**



The research team found that there is a significant disparity in the distribution of medical and

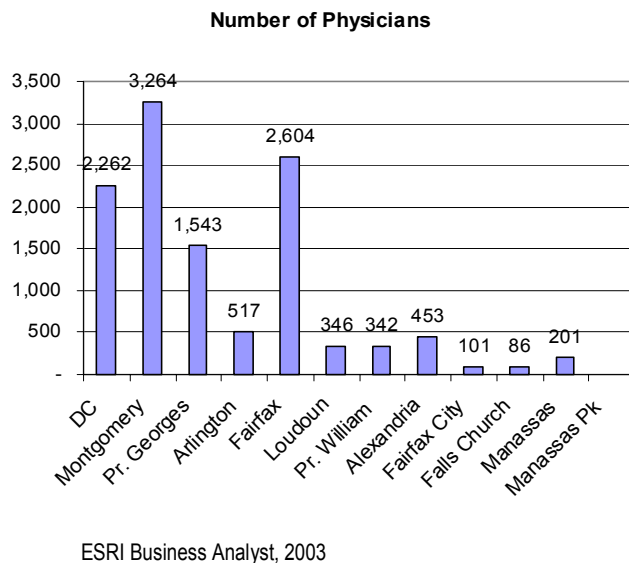
public health facilities and services within the NCR especially when taking into consideration the population growth rate in different NCR jurisdictions. Figures 8-10 depict the distribution of health care resources for the NCR including the planned 36% surge capacity for medical beds..

**Figure 8**

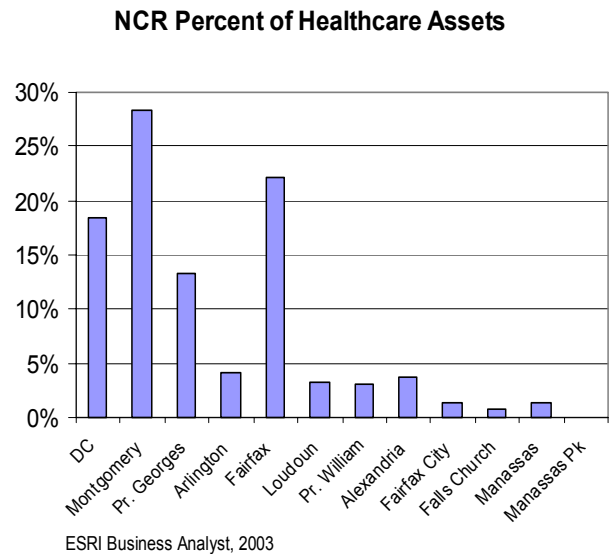


**Assumption:** 36% surge capacity additional beds required for 4.2 million residents and visitors

**Figure 9**



**Figure 10**



For the modeling purpose it was assumed that the population at risk is the average daily ridership of the METRO. This number combined with the estimated exposure of the air release plume would effect approximately 172,376 NCR residents living in an area of about 19.5 square miles. This suggests that the medical capacity of the region will be exceeded and overwhelmed within 48 to 72 hours after the diagnosis of the first cases of anthrax. Table 3 represents the number of selected facilities that could be affected by the plume dispersion within 120 minutes. Though the number of facilities affected will not exceed 1 to 5% of the total NCR capacity, the actual regional economic and daily life disruption routines might be significant. For example there is no clear agreement on what constitute the minimum acceptable exposure risk and facility contamination levels (21, 22). The impact and cost of closing the beltway, highways, roads and condemning the affected buildings can be staggering. The decontamination of the subway system might take years and might not be fully possible.

**Table 3– Impact of the Plume on select facilities after 120 minutes of exposure (definitions of facilities in Appendix 3)**

<b>Facilities</b>	<b>Actual Number</b>	<b>Percent of NCR</b>
Health Care Services	789	3.33
-Medical and Surgical	2	1.43
Schools	101	5.28
Agriculture, Forestry & Fishing	4	1.91
Total retail	1366	3.69

### **Discussion**

The area under consideration is the Washington, DC Metro area, with a focus on the Subway of the METRO System. A METRO rail-based attack could result in significant impacts on the transportation, critical facilities and have serious health consequences. The line release along a major highway will have limited affect on the transportation infrastructure, but can cause significant disruption to traffic and contribute to the psychological and health consequences.

The research team finds that current capacity for predicting or effectively preventing a bioterrorist attack upon a transit system designed for rapid and easy access is difficult if not impossible. Nevertheless, it is important to adopt a set of vulnerability as-

essment tools, identify strengths and weaknesses, and implement risk reduction strategies.

In order to be prepared to respond to bioterrorist attacks, which in all probability will be of limited scope, it is important to focus on the worst case risk scenarios. There will most likely be a two to three day delay before the bio attack is confirmed. Because of this delay, projecting the number of transit passengers affected and where they will seek medical care is difficult. Available information suggests that at least 658,000 riders use the subway daily. Some of the passengers board the stations, especially around the METRO Center several times a day (23, 24). It is likely that METRO personnel and the daily frequent METRO station users will be exposed to a higher secondary spore loads than the occasional or the one time riders. Scientific and evidence based individual variability and repeated exposure to anthrax spores and subsequent severity of disease is not readily available and requires further research. The number of individuals with severe pulmonary involvement requiring hospitalization will determine the ability of medical systems to cope with the logistics for providing uninterrupted care to the community. In the case of *anthrax* there will be a need for continuous re-evaluation of the availability and distribution of hospital beds (including surge capacity), antibiotics, and intensive care respiratory and cardiovascular equipment, protective gear, such as high efficiency particulate air (HEPA) filter respiratory masks, support services, including utilities, postal and FedEx delivery systems, and other logistics (i.e., food, water, expendable surgical and medical supplies, fuel, etc.).

Another major unknown is the number of possible reporting and available medical and Emer-

gency Medical Service (EMS) personnel. Will there be adequate out-of-state or out-of-region help forthcoming? This information should be part of the planning process, including access to the affected area, evacuation means and routes, designated “shelter in place” facilities, and their conditions and locations. The latter will present a significant psychosocial and logistics problem, especially if a large number of schools, churches, shopping malls, armories, unused prison facilities, stadiums and other facilities are contaminated.

Terrorism is meant to be psychologically devastating. Risk identification and mitigation are part of the response capacity. The psychological consequences of terrorism include emotional, behavioral, and cognitive reactions. The sustained threat of terrorism or the occurrence of an actual terrorist event will have adverse psychological impacts on many people. Our national public health, medical, and emergency response systems are not presently well prepared to meet the large scale psychological needs. Intervention strategies for pre-event, event, and post-event phases of preparedness and response to a terrorist attack are lacking. To further evaluate the impact of this issue, the research team is conducting a literature search regarding anxiety and panic disorders associated with pre- and post-event terrorist attack which is included in the report entitled “Critical Role of Citizens in Biodefense and Early Warning”.

Within the D.C. metro area, there is a distinct relationship between the transit system and access to medical facilities and services. Patients and medical staff in Washington, D.C. rely on METRO bus and rail to reach D.C. healthcare facilities. If the METRO closes, other means of transportation or emergency

response systems such as 911 may be quickly overwhelmed. Surface transportation will be adversely impacted if METRO is unavailable. Fear-caused voluntary evacuation will place a tremendous strain on surface transportation. The George Washington Hospital medical emergency preparedness team has investigated several scenarios (25). Some health care facilities plan to remain open even if surrounding areas are contaminated.

Anthrax spores release in the METRO rail will likely disperse throughout the system rapidly and within hours. However, disease symptoms resulting in visits to health care providers will most likely be spread over the first several days with early peak of serious illness and a rising demand for prophylactic treatment. In addition, passengers returning home will produce an increased burden on local health care. The information on the distribution of the NCR population, medical facilities, transportation system, and schools as a potential planning tool for medical and emergency care, using the geographic information is presented in Figures 8 through 10. Combining the geographic and meteorological information provides a useful modeling tool to identify the distribution and behavior of the anthrax spore aerosol plume. Affected physical facilities and communities can be easily identified with proper response and solutions exercised.

These types of simulations and exercises can help formulate proper messages and allow timely communications with the public/medical communities to prevent confusion and loss of confidence by the public. Two plume dispersion models were studied to provide insight on the weather pattern changes

from the 2004 fall hurricane. While the prevailing wind direction in the NCR is predominantly in the north easterly direction, during the hurricane period a shift to the south-southwest direction was observed. This analysis indicates the need for flexible planning and surveillance in specific areas during certain times and climatology events.

### Conclusions

The above information and discussions with the experts have resulted in the following findings and recommendations.

#### **FINDINGS:**

1. Historical assessments indicate the NCR rapid transit system can be an attractive target, already identified as such by the intelligence and law enforcement officials, as vulnerable to bioterrorism.
2. Our literature search suggest that certain information available on the internet pertaining to de-

tailed transit plans, building plans, etc. (23) may aid terrorists in planning an attack and as such should be carefully screened for information and made available as demanded for legitimate and/or limited use. Due to freedom of expression and information issues, this is an area that needs further consideration and policy refinement.

3. Under the current scenario, an attack using anthrax spores will put the subway passengers at risk of exposure and re-exposures until the event is discovered. The population under the plume will be at risk of exposure as well. This might result in a significant number of cases requiring hospitalization and a major public health burden for tracking individuals requiring diagnostic procedures and /or prophylactic treatment with antibiotics. In addition, the decontamination process for the area and the subway system will be a major undertaking, considering the resources re-

Assessment Target	Metro	Riders/ Residents	Interconnecting Facilities	Medical Services	Regional Economy
<b>Risk</b>	<b>Low</b> <i>Would require sizeable amounts of spores to produce significant dispersion</i>	<b>Medium</b> <i>An attack on a few riders is more realistic than on the whole system</i>	<b>Low</b> <i>Would require sizeable weaponized spore load to produce significant dispersion in interconnecting facilities</i>	<b>Low</b> <i>Has not been a demonstrated target for terrorist attack. outside of Iraq Can be a secondary target.</i>	<b>Medium</b> <i>Localized attack Local event. Might require relocation of the NCR resources and Government</i>
<b>Vulnerability</b>	<b>High</b> <i>Easy Access. Open system.</i>	<b>High</b> <i>Low levels of health literacy and lack of communities training</i>	<b>High</b> <i>Extensive accessibility</i>	<b>High</b> <i>Easy access. Open system Hazardous materials</i>	<b>Low</b> <i>Significant redundancy exists</i>
<b>Protective Measure</b>	<b>Inadequate</b> <i>Lack of funding, technological and decontamination capacity.</i>	<b>Inadequate</b> <i>Need for increased citizen training in response and prevention</i>	<b>Inadequate</b> <i>No standards for decontamination procedures.</i>	<b>Medium</b> <i>Not fully integrated and deployed.</i>	<b>Low</b> <i>Additional planning and training required</i>

quired. The D.C. METRO service deploys significant resources to protect the passengers from chemical, radiological, explosive, and biological harms. Since the METRO is closed at night, detection of suspicious activity can be enhanced and access denied.

4. Based on these findings, the threat matrix (on the previous page) is a compilation of the team's findings. The horizontal categories represent important infrastructure targets and the vertical column illuminates the various threats within the framework of risks, vulnerabilities and protective measures for a potential hypothetical attacks.

### **Recommendations**

#### **Near term (weeks up to 6 months):**

1. The release of a large amount of anthrax spores (*Bacillus anthracis*) will invariably impact the availability of hospital beds and consequently proper provisions must be made to secure additional medical resources for the NCR.
2. Evaluation of threats and planning for additional deployment of countermeasures during specific meteorological conditions, which may present windows of opportunity (specific and different for each region) for a terrorist attack(s), must be a priority for our national biodefense program.
3. Proper communication protocols and systems must be developed and tested. Psychological and emotional aspects of the targeted population, beyond just scientific facts, should be part of any communication protocols.

METRO should continue to work with stakeholders, including riders, to promote education and address potential threats.

4. The Federal Government, in consultation with leading experts in the field, should establish and adopt safety, isolation, and decontamination standards for weaponizable biological agents to prevent unnecessary confusion within the community and loss of public confidence.
5. A regional public health authority should be identified to develop, coordinate, and implement prevention and mitigation strategies to be used in case of emergency for the NCR region.
6. Further research will be necessary to develop protocols regarding the allocation of resources, evacuation, and treatment in mass casualty situations. These protocols should address:
  - a) The standardization of terms. The development of standardized definitions of "hospital beds" and "surge capacity" for example, are necessary to effectively measure medical resources in the NCR.
  - b) The standards of care in mass casualty situations should be defined, with the understanding that such standards can be very different from usual disaster approach and procedures.

#### **Long Term (6 months to 3 years):**

1. Policies addressing protective measures, such

as increased surveillance, monitoring of the environment and passenger health, deployment and periodic testing of sensors, drills and training, use of vaccination and rapid delivery of medical treatment, provisions for surge capacity of hospital beds and associated equipment and staff, requires further investigation and improvement.

2. Existing resource allocation policies and processes, including the funding of focused research and deployment of operational capabilities, are inadequate and require reassessment.
3. Additional reliable technologies for rapid and real time detection of those biological agents most likely to be used must be developed and deployed as soon as technologically feasible (1).
4. Developed means for isolating contaminated segments of the underground METRO system, including interrupting air ventilation. A capability for safe and rapid passenger evacuation into aboveground and uncontaminated areas (safe or cold zones) is required.
5. Medical equipment and medications must be regionally deployable on demand or stockpiled in the designated areas of greatest risk within the NCR.
6. Routine awareness programs for communities and rapid transit passengers at risk (similar to commercial aviation) must be made available. The passenger training currently offered by the METRO system should be properly funded, expanded, and made available to all commuters

7. Additional resources must be devoted for planning and training purposes for first responders and communities. This training should be based on plausible models of threat assessment, using available transportation systems. It should complement currently used models that are primarily focused on agricultural airplanes, large occasional events and public venues (university graduations, shopping malls, movie theaters etc.).

The research team concludes that the current capacity for predicting or effectively preventing a bioterrorist attack upon the NCR transit system designed for rapid and easy access is difficult if not impossible. This makes the adoption of a set of vulnerability assessment tools, the identification of strength and weaknesses, and the implementation of threat reduction strategies to be extremely important. Additional resources should be devoted toward the development of educational materials and the training for commuters/passengers and communities, residing in the immediate vicinity of mass transit systems. Attention should be paid to developing additional capabilities that support high tourist seasons, which are also a time for increased vulnerability. The research team strongly recommends that the modeling tool developed by the GMU research team be further researched and tested in the actual METRO setting and used in training exercises.

## **Appendix 1**

### **PARTICIPANTS June 11, 2004 Workshop**

**George Baker, PhD**

Associate Director  
Institute for Infrastructure and Information  
Assurance  
James Madison University

**Joshua Barnes**

Research Assistant  
Network Sec Risk Assess Model  
James Madison University

**Zafer Boybeyi, PhD**

Associate Professor  
School of Computational Sciences  
George Mason University

**Stacey Brooks, MPA**

Research Assistant  
George Mason University

**Vikas Chandhoke, PhD**

Associate Dean, Research  
College of Arts and Sciences  
George Mason University

**Wing T. Chan, PhD**

Distinguished Research Professor, GMU  
Senior Public Health Officer, NASA

**Michael L. Deaton, PhD**

Integ. Science and Technology  
James Madison University

**Bonnie Dodson Dearborn, MS, MBA**

Graduate Student  
Environmental Science and Policy  
George Mason University

**Robert Matthews, MD, FACP, FACC**

Senior Cardiologist  
INOVA Fairfax Hospital

**James P. McManus**

Network Sec Risk Assess Model  
James Madison University

**Jessica Milloy, MS.Ed**

National Capital Region Project Coordinator  
James Madison University

**Arnauld Nicogossian, MD, FACPM,  
FACP**

Distinguished Research Professor  
Director Office of International Medical  
Policy  
School of Public Policy  
George Mason University

**Jean Paelinck, PhD**

Distinguished Research Professor  
Visiting Research Scholar  
George Mason University  
4400 University Drive, MS 3C6

**Susan W. Palocsay**

Professor, Information Technology and  
Management Science Program  
James Madison University

**Laurie Schintler, PhD**

Assistant Professor  
Transportation Policy, Operations and  
Logistics Center  
School of Public Policy  
George Mason University

**Stephen H. Stewart, DrPH**

Director of Strategic Alliances & Special  
Projects  
College of Integrated Science and  
Technology  
James Madison University

**Shanea Watkins, MA**  
Research Assistant  
George Mason University

**Gary A. Weaver, DVM, PhD, Esq**  
Adjunct Research Professor  
Senior Fellow, Center for Food and  
Nutrition Policy  
Virginia Tech

**Ting Zhang, MA**  
Research Assistant  
George Mason University

**Tom Zimmerman, Ph.D.**  
Visual Learning Systems, LLC  
Fairfax, VA

## **PARTICIPANTS October 22, 2004 Workshop**

### **Joshua Barnes**

Research Assistant  
James Madison University

### **Stacey Brooks, MPA**

Research Assistant  
George Mason University

### **Bonnie Dodson Dearborn, MS, MBA**

Graduate Student  
Environmental Science and Policy  
George Mason University

### **Michael Manyak, MD**

Professor of Urology  
Professor of Microbiology and Tropical  
Medicine  
Chairman, Department of Urology  
George Washington University

### **Arnauld Nicogossian, MD, FACPM, FACP**

Distinguished Research Professor  
Director Office of International Medical  
Policy  
School of Public Policy  
George Mason University

### **Richard Niska, MD, MPH**

Captain US Public Health Service  
Senior Epidemiologist CDC

### **Christine Pommerening, PhD**

Research Assistant Professor  
School of Public Policy  
George Mason University

### **Laurie Schintler, PhD**

Assistant Professor  
Transportation Policy, Operations and  
Logistics Center  
School of Public Policy  
George Mason University

### **Gary A. Weaver, DVM, PhD, Esq**

Adjunct Research Professor, Northern  
Virginia Operations  
Senior Fellow, Center for Food and  
Nutrition Policy  
Virginia Tech

### **Ting Zhang, MA**

Research Assistant  
George Mason University

### **Tom Zimmerman, PhD**

Visual Learning Systems, LLC  
Fairfax, VA

## **PARTICIPANTS April 1, 2005 Workshop**

### **Denise Baken**

Ph.D. Student  
School of Public Policy

### **Joshua Barnes**

Research Assistant  
James Madison University

### **Zafer Boybeyi, PhD**

Associate Professor  
School of Computational Sciences  
George Mason University

### **Mary Francis Butler**

Director  
Holy Cross Hospital  
Department of Laboratory Services  
Silver Spring, MD

### **Lucy Caldwell**

Public Information Officer  
Virginia Department of Health  
NOVA Region

### **Allan Morrison, MD, MSc, FACP, FIDSA**

Hospital Epidemiologist  
Inova Health System  
Assistant Clinical Professor of Medicine  
Georgetown University School of Medicine

### **Danielle Mutone-Smith, M.A.**

Research Assistant  
School of Public Policy  
George Mason University

### **Richard Niska, MD, MPH**

Captain US Public Health Service  
Senior Medical Epidemiologist  
CDC National Center for Health Services  
Ambulatory Care Statistics Branch  
Rockville, MD

### **Arnauld Nicogossian, MD, FACPM, FACP**

Distinguished Research Professor  
Director Office of International Medical Policy  
School of Public Policy  
George Mason University

### **Serguei Popov**

Professor  
George Mason University

### **Nancy G. Rea**

Manager  
Health, Mental Health and Substance Abuse  
Metropolitan Washington Council of Governments

### **Laurie Schintler, PhD**

Assistant Professor  
Transportation Policy, Operations and Logistics Center  
School of Public Policy  
George Mason University

### **Suzanne Simmons**

Manager, Citizen Corps, State of VA  
Virginia Department of Emergency Management

### **Stephen H. Stewart, Dr. Ph, CHES, FAAHE**

Director of Strategic Alliances and Special Projects  
Professor of Health Sciences  
College of Integrated Science and Technology  
James Madison University

### **Sheryl Stuckey**

Manager for Microbiology Services  
Department of Laboratory Services  
Holy Cross Hospital

**Marion Warwick, MD, MPH**  
Sector Coordinator-Public Health and  
Healthcare  
US Dept of Homeland Security

**Gary A. Weaver, DVM , PhD, Esq**  
Research Professor, National Capital Region  
Senior Fellow, Center for Food and  
Nutrition Policy  
Virginia Tech

**Rosann Wise, MA**  
Research Assistant  
School of Public Policy  
George Mason University

**Thomas Zimmerman, PhD**  
Senior Research Associate  
School of Public Policy  
George Mason University

## Appendix 2

*Epidemiology of the Transportation Systems and Bioterrorism*

**Friday, June 11, 2004  
Large Conference Room, Finley Building  
George Mason University, Fairfax Campus**

09:30	<b>Welcome</b>	Arnauld Nicogossian
	<b>Orientation to School of Public Policy</b>	
10:00	Introductions Review of the Agenda Objectives of the Meeting	Roger Stough Vikas Chandhoke Arnauld Nicogossian
10:15	NCR/CIVA Overview	Dr. Tom Zimmerman JMU Representative(s)
10:40	Research Project: Deliverables and Schedules, Relevant Background Information, Proposed Parameters to be Researched, Simulated and Modeled	Arnauld Nicogossian
11:15	General Discussions	All Participants
11:45	Discussions of GMU and JMU GIS and Atmospheric Dynamics Modeling Capabilities <i>(lunch served at 12:30)</i>	Dr. Laurie Schintler Dr. Zafer Boybeyi Others from GMU and JMU (TBD)
14:20	Afternoon Break	
14:30	Summary of the findings, software/hardware needs/data mining/ Roles and responsibilities for the modeling and deliverables, schedules	<b>JMU Representative(s)</b>
15:00	Adjourn	

## AGENDA

### *Epidemiology of the Transportation Systems and Bioterrorism*

**Friday, October 22, 2004**  
**Large Conference Room, Finley Building**  
**George Mason University, Fairfax Campus**

08:30	Breakfast	
09:00	Background & Overview of the Project	Arnauld Nicogossian
09:30	<i>Update on Activities</i>	
	Definition of Scenarios	Arnauld Nicogossian
10:15	Transportation and GIS Modeling	Laurie Schintler
Noon	Working Lunch	All Participants
13:00	Discussions	All Participants
13:30	Findings and recommendations	Schintler/ Nicogossian
14:00	Next Steps	All Participants
14:20	Adjourn	

## Agenda

### *Epidemiology of the Transportation Systems and Bioterrorism*

**Friday, April 1, 2005**  
**Large Conference Room, Finley Building**  
**George Mason University, Fairfax Campus**

10:00 am	Welcome and Introductions	Arnauld Nicogossian
10:10 am	Comments and Discussions of the Draft Report	Thomas Zimmerman
11: 15 am	Review of the Model and Tools for Vulnerability Assessment	Laurie Schintler
12:30 pm	Working Lunch	
13:00 pm	Testing and Discussions of the Model and Tools	Laurie Schintler
14:15 pm	Policies and Recommendations / Meeting Summation	Steven Stewart
14:45 pm	Meeting Survey Review and Completion	Danielle Mutone-Smith and Rosann Wise
15:00 pm	Adjourn	

## Appendix 3

### Facilities Classifications

<b>Health Care Services</b>	<b>Education Services</b>	<b>Agriculture, forestry, and fishing</b>	<b>Retail</b>
<ul style="list-style-type: none"> <li>◆ Offices &amp; clinics</li> <li>◆ Physicians' offices</li> <li>◆ Osteopathic</li> <li>◆ Dental</li> <li>◆ Nursing and personal care facilities</li> <li>◆ Hospitals</li> <li>◆ Miscellaneous health and related services</li> </ul>	<ul style="list-style-type: none"> <li>◆ Elementary and secondary schools</li> <li>◆ Colleges and universities</li> <li>◆ Professional schools</li> <li>◆ Junior colleges</li> <li>◆ Libraries</li> <li>◆ Vocational schools</li> <li>◆ Other private and commercial education services</li> </ul>	<ul style="list-style-type: none"> <li>◆ Agricultural production- crops, livestock</li> <li>◆ Agricultural services, including soil preparation, crops, farm, labor, management services, landscape and horticulture</li> <li>◆ Animal specialties services including veterinary services, livestock boarding</li> </ul>	<ul style="list-style-type: none"> <li>◆ Sale of merchandise, commodities, and services of nondurable goods (usually to households)</li> </ul>

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in: Washington, District of Columbia; Atlanta, Buffalo, Baltimore, Dallas, Los Angeles, San Francisco, Montreal, Toronto, the Seattle Bus Tunnel, and in rail transit systems around the world. The SES provides tunnel designers with the tools to: properly size and locate ventilation shafts, evaluate tunnel geometry and fan size, optimize temperature, and model the effects of heat and smoke resulting from fires and other sources. The most recent enhancement is the validation of the subroutine which describes the behavior of smoke in emergency conditions.

URL: [http://www.fta.dot.gov/2426\\_7294\\_ENG\\_HTML.htm](http://www.fta.dot.gov/2426_7294_ENG_HTML.htm) (Added: 5-Aug-2000)

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