Evaluation of the Health and Safety Risks of the New USAMRIID High Containment Facilities at Fort Detrick, Maryland

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Committee to Review the Health and Safety Risks of
High-Biocontainment Laboratories at Fort Detrick

Board on Life Sciences

Division on Earth and Life Studies

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Preface

There has been vocal public opposition to the expansion of the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) at Fort Detrick in Frederick, Maryland. The laboratory studies infectious agents that could cause serious and potentially lethal diseases by the inhalation route of exposure. Although work with such agents must be conducted in laboratories designed and operated to prevent release of agents into the environment, the public is skeptical that public health considerations have been adequately considered in the Army's Environmental Impact Statement (EIS), which supports the construction of the new facility. To address these concerns, Congress directed the Secretary of Defense to commission a National Research Council study of the health and safety aspects of the EIS and other relevant information regarding health risks associated with work with infectious agents (PL 110-329).

The National Research Council convened the Committee to Review the Health and Safety Risks of High-Biocontainment Laboratories at Fort Detrick, which prepared this report. The members of the committee were selected for their expertise in biosafety, infectious diseases, industrial hygiene, environmental engineering, risk assessment, epidemiology, and stakeholder participation (see Appendix A for biographic information on the members).

The committee held two public meetings to gather information to address its task. At the first meeting, held September 22, 2009, in Frederick, Maryland, the committee met with USAMRIID staff (COL Roger Martin, Deputy Commander; Shawn Boesen, Chief of Safety; and LTC James Wadding, Chief of the Medicine Division) and contractors (John Beaver, BSA Environmental) to obtain background on the EIS, learn about the plans for the new biocontainment facilities, get an overview of the procedures and regulations currently in place to reduce exposure to pathogens, and learn about the history of laboratory-acquired infections at USAMRIID. The committee also heard from representatives of the Frederick County Board of Commissioners—Jan Gardner (President), David Gray (Vice President), and Kai Hagen—and from interested members of the general public. At the second meeting, held November 5, 2009, in Washington, D.C., the committee met with COL John Skvorak, Commander of USAMRIID, to learn about the institute's biosurety plans for its facilities and personnel. Pres-

entations also were given by David Eskildsen, the Fort Detrick Fire Chief, on fire and emergency services, and by Robert VanAtta, the Fort Detrick Emergency Manager, on USAMRIID's biological mishap and incident response program. The committee also was briefed by Carol Tobias of the Barquist Army Health Clinic about the memorandums of understanding and agreement between the clinic and Frederick Memorial Hospital. The committee also had separate meetings with the medical and security staff of Frederick Memorial Hospital, officials from Frederick County's emergency management and health departments, and representatives from the community. In particular the committee wishes to thank the following individuals for their time and constructive comments: Frederick County representatives Jack Markey, Director of Emergency Management, and Dr. Barbara Brookmyer, Health Officer; Frederick Memorial Hospital staff Dr. Manuel Casiano, Chief of Staff, John Veltri, Director of Safety and Security, and Phil Guiliano, Security Manager; and community members Paul Gordon, Barry Kissin, Bob White, Beth Willis, and John Willis.

This report has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of the independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Michael S. Ascher, California Emergency Management Agency; Richard A. Berman, Manhattanville College (retired); Gerardo Chowell, Arizona State University; Margaret E. Coleman, Upstate New York Society for Risk Analysis; Robert P. Ellis, Colorado State University; Richard Frothingham, Duke University School of Medicine; Paul Langevin, Merrick Canada ULC; and Paul A. Locke, Johns Hopkins Bloomberg School of Public Health.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Michael R. Ladisch, Purdue University, and Georges C. Benjamin, American Public Health Association. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee is grateful for the assistance of National Research Council staff in preparing the report. It particularly wishes to acknowledge the support of Project Director Susan Martel, who coordinated the project and contributed to the committee's report. Other staff members who contributed to this effort are Frances Sharples, director of the Board on Life Sciences; Joyce Wondolowski,

Christine Mirzayan Fellow; Tamara Dawson, program associate; Kathi Hanna, editor; Mirsada Karalic-Loncarevic, manager of the Technical Information Center; and Radiah Rose, manager, editorial projects.

Finally, I thank all the members of the committee for their efforts throughout the development of this report.

Charles N. Haas, Ph.D., *Chair*
Committee to Review the Health and Safety
Risks of High-Biocontainment Laboratories
at Fort Detrick

Abbreviations

ABSA	American Biological Safety Association
ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ANSI	American National Standards Institute
APHA	American Public Health Association
APHIS	Animal and Plant Health Inspection Service
AR	Army Regulation
ASCE	American Society of Civil Engineers
ASM	American Society of Microbiology
AWWA	American Water Works Association
BMBL	Biosafety in Microbiological and Biomedical Laboratories
BSAT	biological select agents and toxins
BSC	biological safety cabinet
BSL	biosafety level
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
DA PAM	Department of the Army Pamphlet
DHS	U.S. Department of Homeland Security
DOD	Department of Defense
DOE	U.S. Department of Energy
DOJ	Department of Justice
DSB	Defense Science Board
DTRA	Defense Threat Reduction Agency
EIS	Environmental Impact Statement
FBI	Federal Bureau of Investigation
GAO	Government Accountability Office
GSU	Georgia State University
HEPA	high-efficiency particulate air
HHS	U.S. Department of Health and Human Services
HPAC	Hazard Prediction and Assessment Capability
IBC	Institutional Biosafety Committee
LBM	Laboratory Biosafety Manual

MCE	maximum credible event
NADC	National Animal Disease Center
NEPA	National Environmental Policy Act
NIAID	National Institute of Allergy and Infectious Diseases
NICD	National Institute for Communicable Diseases
NIH	National Institutes of Health
NRC	National Research Council
PPE	personal protective equipment
SIP	special immunization program
SOP	standard operating procedure
USAG	U.S. Army Garrison
USAMRIID	U.S. Army Medical Research Institute of Infectious Diseases
USAMRMC	U.S. Army Medical Research and Materiel Command
USDA	U.S. Department of Agriculture
UTMB	University of Texas Medical Branch
VEE	Venezuelan equine encephalitis
WEF	Water Environment Federation
WHO	World Health Organization

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Summary

The U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) is expanding and renovating its existing biocontainment facilities at Fort Detrick in Frederick, Maryland. These facilities are and will be designed to handle infectious agents (pathogens) that cause serious or potentially lethal diseases, which require that research performed on them be contained in specialized laboratory suites.

As part of the decision process for the expansion, and to comply with the National Environmental Policy Act (NEPA) of 1969 and associated regulations, the Army prepared an Environmental Impact Statement (EIS), required for Federal Government agency actions significantly affecting the quality of the human environment. The final EIS was issued in December 2006, and the Record of Decision to construct and operate the new USAMRIID facilities was issued in February 2007. However, residents of Frederick County, Maryland, have questioned whether the potential public health and safety risks, and strategies to mitigate those risks, were adequately considered in the decision to go forward with the expansion. To address these concerns, Congress directed the Secretary of Defense to commission an independent review by the National Research Council (NRC) of certain aspects of the EIS relating to risks from work with infectious agents (P.L. 110-329). The NRC assembled a multidisciplinary committee of individuals with expertise in biosafety, infectious diseases, industrial hygiene, environmental engineering, risk assessment, epidemiology, and stakeholder participation. The committee was asked to evaluate the scientific adequacy and credibility of the analyses of health and safety risks associated with exposure to pathogen research, and the proposed strategies to mitigate those risks, as presented in the final EIS. The committee also was asked to examine USAMRIID's current procedures and regulations for reducing exposure to pathogens to determine whether they are comparable to those in place at other facilities and whether they meet accepted standards established by the Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH) and by other rules and guidance. USAMRIID's records on laboratory-acquired infections were also to be considered, as well as measures being taken

for ensuring the prevention and mitigation of risks to the health and safety of laboratory workers and the public.

The committee held public meetings to gather information to address its task. It met with USAMRIID and Fort Detrick medical and safety officials, contractors involved in the development of the EIS, members of the Frederick County Board of Commissioners, and members of the general public. The committee also had separate meetings with the medical and security staff of Frederick Memorial Hospital, officials from Frederick County's emergency management and health departments, and representatives from the community.

ASSESSMENT OF THE ENVIRONMENTAL IMPACT STATEMENT

EISs are documents required under NEPA to identify probable environmental impacts (including health effects) from programs and actions of the Federal Government. They are required to provide full and fair discussion of significant potential environmental and health impacts and consider reasonable alternatives that would avoid or minimize adverse environmental impacts or enhance the quality of the human environment. However, there is no specific guidance for considering some of the unusual infectious disease risks from biocontainment facilities.

The hazard assessment included in the USAMRIID EIS explored a range of possible consequences that could result from a mishap at the new USAMRIID facilities. The maximum credible event (MCE) analyses (required in an EIS) involved simulation of biological aerosol releases from biosafety level (BSL)-3 and BSL-4 laboratories. In the scenarios, *Coxiella burnetii* (requiring BSL-3 containment) and *Ebola Zaire* virus (requiring BSL-4 containment) were released to the surrounding environment from an exhaust stack after vials in a centrifuge leaked and air filters failed to filter the pathogens. The EIS estimates that ground concentrations would be insignificant and would not pose a hazard to the nearby community. However, the committee was unable to verify this prediction, because the modeling performed in support of the scenarios was not transparent, could not be reproduced, and was incomplete. Specifically, the data and parameterizations used in the computerized simulation scenarios were not provided in the EIS and the model software (Hazard Prediction and Assessment Capability model) is a closed-source system not available for independent review. The committee attempted to verify the calculations using common alternative models. The committee's calculations indicated the potential for significantly higher doses of infectious agents following puff releases than was described in the EIS.

Other problems with the MCE scenarios were the use of inappropriate scenarios and inadequate enumeration and characterization of risks. EIS guidance specifies that hazard scenarios should be "reasonably foreseeable," but the ones used in the USAMRIID EIS required multiple failures, such as human errors (e.g., failure to use O-rings to seal the centrifuge tubes) and safety failures

(e.g., inoperable high-efficiency particulate air [HEPA] filter). Results appear to present only peak concentrations, rather than total infectious agent dose, which is the most appropriate measure of per-person risk. The EIS contained no documentation of an individual's risk of infection under the prescribed conditions or any description of the effect of population density and population size on the number of cases expected for any of the pathogens of interest. Furthermore, the scenarios only considered exposures beyond the Fort Detrick fence line, with no consideration of exposure to USAMRIID workers or other people on the base. Despite the committee's estimation that an exceptionally large aerosol release might pose a human health risk, there are no reasonably foreseeable scenarios where such a release could occur.

The EIS does not provide a systematic characterization of exposure risks and consequences associated with the scenarios. Nor does it document the effects of mitigation measures on scenarios or how risks would vary under alternative actions. For example, a systematic review would have identified arthropod escape as an exposure scenario, in addition to those characterized in the EIS of escape of an infected animal, mishaps during biological material shipments, terrorist acts, external acts (such as natural disaster or mechanical failures), spread by an infected worker, and cumulative impacts. Several biological agents likely to be studied at the new USAMRIID facility are transmitted by arthropod vectors (such as fleas, mosquitoes, and ticks), and the vectors may be used in the course of research. Consideration of such a scenario in the EIS would have shown that there are significant ecological barriers that make associated relative risks small. Another scenario that was not considered was the threat of an insider with malicious intent. Although such a situation is difficult to predict or quantify, it is clearly of concern to the citizens of Frederick County.

The EIS does not provide scenarios describing potential exposure risks involving pathogens to USAMRIID laboratory personnel, but does cite a brief history of cases of laboratory-acquired infections occurring between 1989 and 2002. Review of these cases illustrates both means of transmission and procedures in place to address identification and treatment of affected laboratory workers. Common risks to workers are needle- or sharps-stick accidents, inadvertent aerosol generation that leads to inhalation or ocular/mucosal exposure, and contact with infected laboratory animals.

The EIS explained that the new USAMRIID facility will be part of the National Interagency Biodefense Campus, which Congress directed to be located at Fort Detrick. NEPA requires consideration of all reasonable alternatives, including reasonable alternatives not within the jurisdiction of the lead agency. In this case, the Army did not analyze any geographic alternative sites. Such an exercise might have illustrated how risks differ between locations and could have provided guidance on whether changes or improvements might be needed at the mandated site.

Findings:

- The analyses in the EIS of the risks and the mitigation measures to address them were not comprehensive and there was insufficient documentation for a fully comprehensive independent assessment of the risks to the community posed by biological agents. The problem was compounded by the fact that the MCE scenarios were not reasonably foreseeable accidents.
- The epidemiologic characteristics, including transmission pathways, natural reservoirs, geographic distributions, and clinical outcomes of the pathogens, were not systematically documented.
- There was incomplete consideration of some of the possible routes through which the general public might be exposed to pathogens.
- Although the congressional mandate placing the National Interagency Biodefense Campus at Fort Detrick precludes siting the new USAMRIID facility elsewhere, it would have been appropriate for the EIS to include consideration of an alternative location, such as one in a less populated area. Such an exercise could have provided a comparison that identified advantages and disadvantages specific to each location, and guided preventive strategies and mitigation efforts if differential risks were found.
- Despite the problems identified with the EIS, the committee judged that it would not be useful to propose specific revisions to the EIS or supplementary analyses given its findings (discussed below) that USAMRIID has the appropriate regulations, operating requirements, and medical and emergency response plans in place to provide appropriate protections to its workers and the public. The Record of Decision to construct the new USAMRIID facility was issued and construction has begun on the project.

Recommendation:

- The committee recommends that the Army consider developing detailed and practical guidance for conducting hazard assessments of infectious agents for inclusion in its guidance for implementing NEPA to improve future EIS processes and products.

REGULATIONS AND OPERATING REQUIREMENTS OF THE NEW LABORATORY

The guidelines, procedures, and regulations that govern the operations of biocontainment facilities at USAMRIID were reviewed by the NRC committee. The new USAMRIID biocontaiment laboratories are required to be constructed and operated under the most current standards and guidelines for such facilities

established by CDC and NIH. Before work with BSL-3 and BSL-4 pathogens (serious and high-risk infectious agents) can be performed in these laboratories, they must be independently inspected and approved by CDC. The operations of the containment laboratories are governed by biosafety guidelines established by CDC that prescribe engineering controls, personal protective equipment, work practices, and administrative controls (such as immunizations, medical surveillance, and training). In addition, the Army has its own laboratory-specific standard operating procedures, regulations, and guidelines for USAMRIID.

The Department of Defense and the Army also developed regulations and guidance related to biosurety. Biosurety involves establishing systems and procedures to safeguard biological select agents and toxins (BSAT; select agents are agents and toxins that have the potential to pose a severe threat to public, animal, or plant health, or to animal or plant products) against theft, loss, diversion, or unauthorized access or use, and to operate the laboratory in a safe, secure, and reliable manner. Because the laboratory will be on an Army base, the level of physical security is even greater than that found at other biocontainment facilities. The new USAMRIID facilities also will be subject to announced and unannounced inspections by CDC, which will include scrutiny of the receipt, storage, use, and transfer of BSAT.

Personnel reliability is another important aspect of biosurety. It involves systems and procedures to ensure that individuals with access to BSAT meet high standards of reliability. The Army has taken the lead in establishing a robust biosecurity program, which has been fully adopted by USAMRIID. However, it is the consensus of the committee that no program can stop all threats of theft or misuse of BSAT. The solution to preventing such incidents is not in stopping all work with BSAT, but rather in identifying means to further strengthen biosecurity programs, such as by formalized training for laboratory workers on their individual and collective responsibilities and accountability and paying increased attention to behavior signals that may identify personnel as "at risk." Because insider threats are a significant concern of the citizens of Frederick County, it will be important for USAMRIID to develop a means for addressing their concerns (possible options are discussed below).

It is also noteworthy that the Army has been a leader in developing cutting-edge requirements for high- and maximum-containment facilities. For example, the institute was involved in the development of biological safety cabinets, establishing the scientific basis for packaging and shipping infectious agents, applying HEPA filtration technology, and vaccinating its workers. When these and other related developments are placed in context with the history of laboratory-acquired infections at USAMRIID, it is clear that lessons learned from past incidents have improved safety practices and significantly reduced the incidence of laboratory-acquired infections. It is expected that any future incidents will continue to guide improved safety practices.

Findings:

- USAMRIID's current procedures and regulations for its biocontainment facilities meet or exceed the standards of NIH and CDC for such facilities and other accepted rules and guidance for handling and containing pathogens during use, inventorying, and storage; treating and safely disposing of laboratory solid waste; and handling and decontaminating wastewater.
- Measures have been taken to improve safety at USAMRIID when problems have been identified. The new facilities will be operated under even more stringent guidelines than were in place previously regarding physical security, engineering infrastructure and redundancies, biosafety, and biosecurity. Thus, the committee has a high degree of confidence that the new USAMRIID facility will have the appropriate and effective physical security, biosurety program, and biosafety operating practices and procedures in place to protect its workers and the public from exposures to pathogens, and any new pathogens, studied in its laboratories.
- USAMRIID has strived to improve safety procedures. Lessons learned from exposure and/or disease incidents have directed some of the improvements, as indicated by the decrease in laboratory-acquired infections from the 1940s to the present, so that laboratory-acquired infections are now infrequent.

Recommendations:

- USAMRIID should continue to set high standards for advancing security, operational, and biosurety measures.
- Although USAMRIID has sought to set high standards for biosurety and biosafety, recent examples of laboratory-acquired infections (glanders and tularemia) and breaches in containment (*Bacillus anthracis* spores) point to human error or deliberate misuse. The committee recommends further formalized training in responsibility and accountability at USAMRIID, similar to that required for NIH-sponsored training programs. The circumstances surrounding the laboratory-acquired infections also should be carefully evaluated to determine what lessons can be learned for preventing future cases.

MEDICAL AND EMERGENCY MANAGEMENT RESPONSE

USAMRIID has a special immunizations program (SIP) clinic that serves as the occupational health provider for laboratory personnel and an outpatient research facility for investigational vaccines. It is staffed with infectious disease specialists and laboratory staff with experience in testing for the agents under study at USAMRIID. Although the SIP clinic should be the first place to go when seeking medical care for symptoms suspected to be work-related, it is in-

cumbent on the individual worker to report laboratory incidents and to go through the appropriate channels for care.

In the event of an incident requiring medical care, a formal agreement is in place between USAMRIID and Frederick Memorial Hospital for patients to be transported and treated at the hospital. In addition, the two organizations have an understanding on providing mutual support to deal with a public health emergency or terrorist attack. The understanding calls for USAMRIID to provide quarterly training for hospital staff and for the director of safety and security at the hospital to receive annually updated material on USAMRIID's medical management of biological casualties. To facilitate care, each USAMRIID staff member is provided with a contact card identifying him or her as an employee to expedite notification by clinicians of infectious disease experts for consultation.

The Barquist Army Health Clinic at Fort Detrick also has an ongoing and good relationship with Frederick County's Health Department, such that the county has confidence that it will be informed of any reportable medical incidents of which the clinic is aware. However, there is no guarantee that USAMRIID workers will report incidents or seek medical care at the Barquist or SIP clinics. Since 2000, there have been two known cases in which USAMRIID workers failed to seek medical attention at the SIP clinic and also appeared to have failed to disclose that they were USAMRIID employees to the off-base physicians from whom they sought medical care. These failures delayed prompt diagnosis and treatment, and have raised community concerns about the potential for secondary transmission (that is, infection of others through contact).

A primary concern of the committee focuses on medical response and whether clinicians with specialized training in the clinical diagnosis and treatment of unusual infectious diseases are readily available. The committee was informed that, at present, there are only a few physicians in the community who regularly consult on infectious disease problems and none are believed to have had substantial training in dealing with diseases caused by the organisms being studied at USAMRIID. Efforts have been made by USAMRIID to provide education to some of the Frederick Memorial Hospital physicians through quarterly training. However, it is unrealistic to expect many of the physicians in the county to avail themselves of such educational efforts or to know when and whom to consult when confronted with a patient with an unknown infectious disease.

The Fort Detrick Garrison has on-base fire and emergency services equipped to deal with medical and fire emergencies at USAMRIID. Formal agreements also are in place between Fort Detrick and Frederick County's Division of Emergency Management to provide mutual aid in dealing with fire, hazardous materials problems, and other disasters, including biological incidents. The Garrison team conducts regular drills at the USAMRIID facility, including rescue drills involving BSL-3 and BSL-4 laboratories. Procedures and appropriate equipment are in place to ensure proper decontamination of a exposed person before transport to Frederick Memorial Hospital.

Findings:

- USAMRIID, Fort Detrick, and Frederick County have the resources and partnerships in place to address medical and emergency situations at the containment laboratories. There are several concerns, however, that need to be addressed.
- A primary concern is the lack of readily available clinicians with the necessary specialized training to consult on the clinical diagnosis and treatment of unusual infectious diseases.

Recommendations:

- Given the unique nature of USAMRIID's mission in dealing with special pathogens, additional measures should be taken to provide assurance that experienced medical professionals are readily available to consult on unusual infectious diseases. Serious consideration should be given to support an initiative that would provide experienced specialist physicians knowledgeable of diseases caused by organisms studied at the laboratories. This would include consultation as needed on a 24/7 schedule to see patients from the community. Such physicians should also serve to provide continuing communication and coordination between USAMRIID scientists and community physicians and public health personnel.
- For medical and emergency response mechanisms, a senior authoritative management system is needed to ensure that USAMRIID works effectively with county government agencies, the local medical community, emergency preparedness and response initiatives, and Frederick Memorial Hospital. Such a system would include a clear chain of command with designated personnel to work directly with partners in the county and community. The Army should consider the use of permanent civilian staff for these positions to ensure continuity of relationships. Because USAMRIID will be part of the National Interagency Biodefense Campus, which will include biocontainment facilities of two other agencies, consideration should be given to delineating and coordinating emergency and medical response plans and resources for all facilities on the campus.

COMMUNICATION AND COOPERATION WITH THE PUBLIC

A variety of views have been expressed by the Frederick community about the planned expansion of USAMRIID. Some citizens hold views that no research that requires containment should be performed there at all, while others are fully supportive of USAMRIID's expansion. Views that fall between those extremes include the belief that biocontainment facilities should be built in remote locations or that if the work must be done in populated areas, assurances that the work will be done in a safe manner and that plans are in place to deal

with any potential exposure are needed. The underlying theme of these concerns has to do with *trust* that USAMRIID will act promptly and openly regarding any safety breaches. To date, USAMRIID's interactions with the community have been perceived by some to be perfunctory and not performed in a way that merits public trust. Community leaders have stated that information presented by the Army to this committee during its public meetings is the type of information that would help them better understand the potential public health risks. Such information involved discussions about USAMRIID's operations, regulations and guidelines, training, history of laboratory exposures and illnesses, and details about the institute's agreements with Frederick County and Frederick Memorial Hospital on emergency response and health incidents. To date, such information had not been adequately shared with the public.

While the committee does not believe that improved communication with the public in these areas will eliminate all opposition to USAMRIID's expansion, a more proactive communication program could build trust, alleviate concerns about community safety, and provide an opportunity for community involvement. USAMRIID should go beyond demonstrating that it is following the rules and procedures that govern its operations and more directly answer the specific concerns raised by its critics. This would involve a public dialogue between citizens and Army officials with authority at USAMRIID, and not just press releases and announcements.

Findings:

- A segment of the local population around Fort Detrick is not satisfied that the Army is doing everything it can to protect them from infection by pathogens being studied at USAMRIID.
- Communication between USAMRIID and the Frederick community has not been adequate to address community concerns. The community has not been made aware of the details of the many safeguards already in place at USAMRIID, the requirements governing the operation of biocontainment facilities, and the Army's ongoing commitment to improving safety and security.

Recommendations:

- USAMRIID should expand its two-way communications with the public. Examples of possible communication efforts are:
  - Promptly disclosing laboratory incidents to the public,
  - Providing fact sheets about pathogens being studied, to include information on their natural reservoirs and how they are transmitted, and
  - Holding an open house prior to activation of the new USAMRIID facility or opening a visitors' center.

- USAMRIID should consider strategies that have been used by other containment laboratories to enhance community understanding and facilitate integration into the community. If possible, such communication strategies could be coordinated with the two other laboratories of the National Interagency Biodefense Campus.
- USAMRIID should involve the Frederick community in ongoing activities related to improving safety at the laboratory. For example, it might be useful to include community members on the Institutional Biosafety Committee (which reviews research involving biohazardous risks) or other relevant committees.
- USAMRIID should create a community advisory board, with a broad representation of community views. This board should meet regularly to learn about successes, problems, and improvements in policies and practices; encourage public suggestions for improvements; and help shape the laboratory's public communications and activities—including the development of guidelines for reporting incidents to the public.

In summary, although the EIS hazard assessment failed to provide adequate and credible technical analyses, current procedures, regulations, physical security, and biosurety guidelines at USAMRIID meet or exceed accepted standards and practices. Furthermore, the Army and Frederick County have the resources and the partnerships in place to address medical and emergency situations at the containment laboratories. Thus, the committee has a high degree of confidence that policies and procedures are in place to provide appropriate protections for workers and the public. Nonetheless, no program can fully stop all threats resulting from human error (for example, laboratory-acquired infections), or from theft or misuse of select agents. In going forward, the Army and USAMRIID should review their methods and procedures for preparing EIS hazard assessments, more actively train personnel regarding accountability and responsibility, and more proactively reach out to the local community to inform it of its safety and security policies and procedures and to constructively design approaches for communicating timely information should an adverse incident occur.

1

Introduction

The U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) is expanding and renovating existing research facilities in Frederick, Maryland. These facilities are and will be designed to handle infectious agents that are considered Category A and Category B under the Centers for Disease Control and Prevention (CDC) schedules, and that require safety precautions to the extent of biosafety level (BSL)-3 and BSL-4 (see Chapter 2). The new USAMRIID will be part of the National Interagency Biodefense Campus, which includes the Department of Homeland Security's National Biodefense Analysis and Countermeasures Center and the National Institute of Allergy and Infectious Diseases' Integrated Research Facility. These two other facilities also will house BSL-3 and BSL-4 laboratories.

As part of the decision process for the USAMRIID expansion, the Army prepared an Environmental Impact Statement (EIS). The Record of Decision to construct and operate new USAMRIID facilities was issued in February 2007. However, residents of Frederick County have questioned whether the potential public health and safety risks and strategies to mitigate those risks were adequately considered in the decision to go forward with the expansion. To address these concerns, Congress directed the Secretary of Defense to commission an independent review by the National Research Council of certain aspects of the EIS relating to risks from work with infectious agents (P.L. 110-329). The specific scope of the study is delineated below:

> The National Research Council will convene a committee of experts to evaluate the scientific adequacy and credibility of the analyses of health and safety risks associated with exposure to pathogen research in the proposed new USAMRIID high-containment labs as presented in the *Final Environmental Impact Statement, Construction and Operation of New USAMRIID Facilities and Decommissioning and Demolition or Re-use of Existing USAMRIID Facilities at Fort Detrick, Maryland*. The committee will also evaluate the proposed strategies to mitigate those risks as they are presented

in the EIS. In addition, the committee will examine the current procedures and regulations in use by USAMRIID to reduce exposure to pathogens and evaluate whether these procedures and regulations are comparable to those in place at other similar facilities and whether they meet accepted standards under the National Institutes of Health (NIH), CDC, and other rules and guidance. These procedures will include measures for handling/containing pathogens during use, storage and inventorying of pathogens, procedures laboratory workers follow for treating and disposing of laboratory solid waste within USAMRIID, and handling contaminated waste water. The focus of the study is on the safety of both the general public and the laboratory workers, and for this reason USAMRIID's records on laboratory acquired infections will also be considered, as will the measures being taken for ensuring the prevention and mitigation of risks to the health and safety of workers and the public.

This committee was formed to develop findings with respect to the charge. The committee comprised individuals with expertise in biosafety, infectious diseases, industrial hygiene, environmental engineering, risk assessment, epidemiology, and stakeholder participation. This report presents the consensus findings of the committee.

CONTEXT

It is clear that the impetus for this project was the Frederick County residents, who are concerned about risks to their health from the research that will be conducted at the new USAMRIID facility. The only readily available documentation regarding potential health risks has been the EIS. EISs are documents required under the National Environmental Policy Act (NEPA) of 1969 to identify probable environmental impacts from programs and actions of the Federal Government. They are required to provide full and fair discussion of significant environmental impacts and consider reasonable alternatives that would avoid or otherwise minimize adverse environmental impacts or enhance the quality of the human environment. The categories of impacts are mainly determined by federal statutes, such as those governing air quality and water quality, which require that a particular environmental impact be considered.

NEPA grew from public concern that federally funded projects were causing significant harm and destruction to the environment and human health without any regulation. The language of the Act (Section 101 [42 U.S. Code § 4331]) definitively states that its purpose includes the need:

- "[to] assure for all Americans safe, **healthful**, productive, and aesthetically and culturally pleasing surroundings" (emphasis added)

- "[to] attain the widest range of beneficial uses of the environment without degradation, **risk to health or safety**, or other undesirable and unintended consequences" (emphasis added).

NEPA (Section 1508.14) requires that EISs are developed to support major federal actions that significantly affect the quality of the human environment, with "human environment" to include "the natural and physical environment and the relationship of people with that environment." However, NEPA has no specific provisions for how EISs should consider human health effects, especially how to consider impacts that are not governed by strong regulations. This is due largely to the breadth of projects that must undergo the EIS process before beginning. Thus, consideration of direct impacts on human health in EISs has been fairly sparse (Steinemann 2000; Cole et al. 2004; Bhatia and Wernham 2008). Federal agencies have their own sets of requirements and guidelines for preparing these statements, and the level of detail and topics in these guidelines varies greatly from agency to agency.

The U.S. Army NEPA Regulations handbook (32 Code of Federal Regulations [CFR] 651), describes NEPA's background, details the actions requiring analysis, and provides guidelines for formatting the EIS and obtaining public involvement. The handbook contains little specific information regarding the actual content of the EIS reports. Appendix E of the handbook covers "Content of the Environmental Impact Statement," but there is no explicit mention of human health impacts.

In contrast, the U.S. Department of Energy's (DOE) recommendations for the preparation of EISs contain some of the most detailed explanations and guidelines for discussing human health impacts in an EIS. Although DOE's recommendations for analyzing human health effects are limited to exposure to radiation and chemicals, they also are relevant to pathogen exposures. Excerpts of DOE's recommendations are provided in Box 1-1. An important theme of the DOE guidance is that the EIS's consideration of human health effects should involve "realistic scenarios," "realistic exposure conditions," and "reasonably foreseeable accidents."

COMMITTEE'S APPROACH

The committee held two public meetings to gather information to address its task. At the first meeting, held September 22, 2009, in Frederick, Maryland, the committee met with USAMRIID staff and contractors to obtain background on the EIS, learn about the plans for the new biocontainment facilities, get an overview of the procedures and regulations currently in place to reduce exposure to pathogens, and learn about the history of laboratory-acquired infections at USAMRIID. The committee also heard from representatives of the Frederick County Board of Commissioners and from interested members of the general

BOX 1-1 Excerpts from DOE (2004) Recommendations for Analyzing Human Health Impacts in EISs

- Analyses generally should be based on realistic exposure conditions. Where conservative assumptions (i.e., those that tend to overstate the impact) are made, describe the degree of conservatism, and characterize the "average" or "probable" exposure conditions if possible.
- Consider all potential routes of exposure, not just the most obvious route. Example: Where the proposed activities might result in the air suspension of contaminated soils, consider the downwind exposure of the public to suspended particles.
- Aim to provide estimates of potential health effects from chemical or radiological exposure for three subsets of populations and maximally exposed individuals in those populations: (1) involved workers (participants at the location of the action), (2) noninvolved workers (workers that would be on the site of the alternative but not involved in the action), and (3) members of the general public.
- Provide the basis for health effects calculations, as it may be misleading to present only the resulting estimates. As appropriate, present the dose, or dose-to-risk (health effects) conversion factor, potential health effects calculated for the year of maximum dose and for the total period of estimated exposure, and any other germane information.
- An accident is an unplanned event or sequence of events that results in undesirable consequences. Accidents may be caused by equipment malfunction, human error, phenomena. NEPA documents should inform the decision maker and the public about chances that reasonably foreseeable accidents associated with proposed actions alternatives could occur, and about their potential adverse consequences.
- It may be appropriate in certain cases to address potential environmental impacts that could result from intentional destructive acts. Analysis of such acts, which are not accidents, poses a challenge because the potential number of scenarios is limitless and the likelihood of attack is unknowable. Consequences of destructive acts, however, may be compared to consequences of severe accidents, because the forces resulting in releases of hazardous or radioactive materials could be similar.
- Develop realistic scenarios that represent the spectrum of reasonably foreseeable accidents. Analyze maximum reasonably foreseeable accidents for a given alternative to represent potential accidents at the high consequence end of the spectrum. Also analyze other accidents in the "spectrum" if they may contribute importantly to, or even dominate, accident risks. Explanation: A maximum reasonably foreseeable accident is an accident with the most severe consequences that can be reasonably expected to occur for a given proposal. It is not the same as a worst-case accident. A worst-case accident is one whose probability is so remote or speculative as to render it not reasonably foreseeable and therefore not helpful to the decision maker. Analysis of worst-case accidents is not required under NEPA.
- Because one purpose of NEPA analysis is to inform the public, consider analyzing an accident scenario in which the public has expressed a keen interest, even when the scenario is not reasonably foreseeable. Do not, however, analyze physically impossible accidents or scenarios that are based on pure conjecture (consistent with 40 CFR 1502.22). Always explain why a scenario of interest to the public was excluded from analysis.

public. At the second meeting, held November 5, 2009, in Washington, D.C., the committee met with the Commander of USAMRIID to learn about the institute's biosurety plans for its facilities and personnel, and with the Fort Detrick Fire Chief and Emergency Manager to be briefed on emergency response coordination with Frederick County. The committee also was briefed on the agreements between the Barquist Army Health Clinic and Frederick Memorial Hospital. In addition, the committee met with the medical and security staff of Frederick Memorial Hospital, officials from Frederick County's emergency management and health departments, and representatives from the community.

The committee reviewed numerous documents and testimony, which included the final EIS, supporting information provided by USAMRIID and its contractors, comments from members of the public (including a DVD of the proceedings of open hearings held by the Frederick County Commissioners), and the scientific literature. The committee focused its assessment on material relevant to assessing potential human health risks and available strategies for preventing or mitigating accidental exposures to pathogens. Such materials included Army regulations, USAMRIID operating procedures, operating guidelines from CDC and NIH, guidelines from the Department of Defense and other agencies regarding biological safety and security, and information on laboratory-acquired infections at USAMRIID and other biosafety laboratories. The information was evaluated in the context of whether appropriate and credible consideration was given to human health risks and whether strategies are in place to prevent and mitigate potential exposures from pathogen research and the spread of disease in the event that an exposure or illness occurs.

ORGANIZATION OF THE REPORT

The committee decided to organize its evaluation by first providing some context for its review of the EIS. Chapter 2 provides an overview of the guidelines, procedures, and regulations that govern the operations of USAMRIID to see if they meet acceptable standards under guidance from NIH, CDC, and other relevant agencies. Chapter 3 summarizes plans for medical and emergency management response to address any incidents that could occur at USAMRIID, possibly involving partnerships with Frederick County and Frederick Memorial Hospital. A review of the EIS is provided in Chapter 4, with a focus on the scientific adequacy and credibility of the analyses of health and safety risks associated with pathogen research. Finally, Chapter 5 considers the community concerns about the planned expansion of USAMRIID and measures that might be taken to address them.

2

Comparative Evaluation of Procedures and Regulations for Biocontainment Facilities

This chapter reviews the guidelines, procedures, and regulations that govern the operations of biocontainment facilities at the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) and other facilities. It is intended to provide context for the history of operations at USAMRIID and for the operations of the planned facility. The review included information presented in the Environmental Impact Statement (EIS), materials provide by USAMRIID (Army regulations, polices, standard operating procedures [SOPs], and suite-specific safety manuals), and discussions with USAMRIID personnel.

In this chapter and elsewhere in this report, the term "biosurety" refers collectively to systems and procedures used to safeguard biological select agents and toxins (BSAT) against theft, loss, diversion, or unauthorized access or use and to ensure that operations are conducted in a safe, secure, and reliable manner. There are several aspects of biosurety discussed in this chapter—biocontainment, biosafety, and biosecurity. Figure 2-1 provides USAMRIID's illustration of how these aspects provide the foundation for its biosurety program.

BIOCONTAINMENT

Biocontainment laboratories are designed to prevent the accidental release of pathogenic organisms during scientific research. There are four biosafety levels (BSLs) of containment: BSL-1, BSL-2, BSL-3, and BSL-4. These levels indicate increasing levels of containment and are inclusive, so all safety features found at BSL-1 are found at BSL-2. BSL-3 builds on BSL-2. BSL-4—the highest level of biosafety—includes all of the features required at lower levels, plus additional engineering controls such as filtration of all exhaust air through two

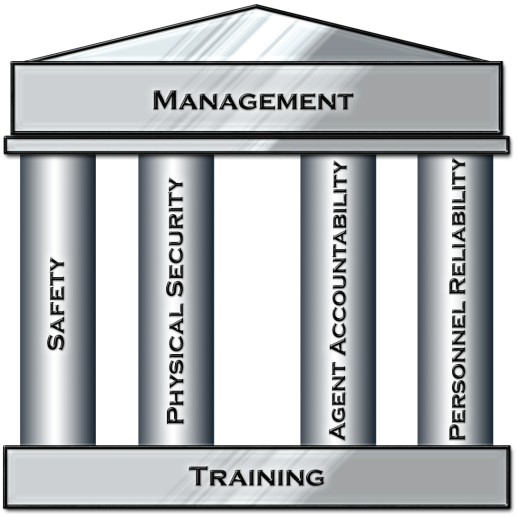

FIGURE 2-1 USAMRIID's Biosurety Program. The program includes systems and procedures to properly safeguard BSAT against theft, loss, diversion, or unauthorized access or use, and to ensure that operations are conducted in a safe, secure, and reliable manner. Source: Skvorak 2009.

HEPA (high-efficiency particulate air) filters in series, personal protective equipment (PPE; such as the one-piece encapsulated suit), SOPs (such as special decontamination processes), and administrative controls (for example, training requirements and medical surveillance enhancements). The proposed new USAMRIID facility will include BSL-3 and BSL-4 laboratories.

The Army has been a leader in developing cutting-edge requirements for high- and maximum-containment laboratories. As new containment laboratories have proliferated across the country in recent years, there has been a steady development of better facilities, increasingly robust biosafety practices and procedures, and a continuing cross-fertilization of new technologies. With this development has come a significant reduction in laboratory-acquired infections at USAMRIID and at other biocontainment facilities (Rusnak et al. 2004a).

Efforts to codify guidelines for improved biosafety began in the 1970s (Centers for Disease Control and Prevention [CDC] 1974; London School of Tropical Medicine 1974; 41 Fed. Reg. 27902 [July 7, 1974]; National Research Council [NRC] 1974). These guidelines primarily addressed the interrelationships among engineering aspects, secondary containment systems, and biosafety principles (practices and procedures). The guidelines detailed the four levels of biosafety for work with microbial agents in the laboratory and in parallel animal facilities. The focus was to protect laboratory workers and the surrounding community by creating a safe work environment that kept the microbes inside the clinical or research facility. By the late 1990s there was recognition that more attention was needed for securing particularly hazardous pathogens (BSAT) from potential acquisition by persons who did not have legitimate need to possess them (CDC/National Institutes of Health [NIH] 1999). Following the anthrax mailing events in fall 2001, significant attention was focused on who should have access to these agents (42 CFR 73 Select Agent Rule 2003, 2005).

As more laboratory facilities aiming to conduct research with these agents were constructed, more attention was paid to the process of commissioning the buildings before they were put into operation. Commissioning is the process whereby detailed scrutiny is given to individual and component operational systems (e.g., air supply, exhaust fans, dampers, and ducts) to assure the owner that the facility has been built as specified by the approved architectural plans. Lessons learned from the commissioning of one facility become the new baseline for the next. After the commissioning step comes the approval that the new facility in fact meets all of the requirements as specified for the intended biocontainment level.

In the United States, the "gold standard" for biosafety is the CDC/NIH (2007) guideline *Biosafety in Microbiological and Biomedical Laboratories* (BMBL). This guideline, currently in its fifth edition, is the basis for assessing all biosafety programs and is used by the CDC Division of Select Agents and Toxins to implement oversight and grant permits for all work with select agents and toxins. In addition to BMBL guidelines, USAMRIID is subject to Army regulations (AR 385-69), Department of the Army guidelines (DA PAM 385-69), NIH Guidelines for Research Involving Recombinant DNA Molecules (NIH 2009), and CDC oversight for Select Agents and Toxins (42 CFR 73).

The EIS for the new USAMRIID facility was published in December 2006. At that time, the BMBL was in its fourth edition (CDC/NIH 1999), so the EIS does not specifically address any changes that might be reflected in the 2007 edition. For example, there has been one very significant change in engineering controls specified for BSL-3 labs (CDC/NIH 2007, p. 55):

> A ducted air ventilation system is required. This system must provide sustained directional airflow by drawing air into the laboratory from "clean" areas toward "potentially contaminated" areas. The laboratory shall be designed such that under failure conditions the airflow will not be reversed.

This is one example of the continuous improvements that have been made in the design, construction, and operation of containment facilities. Although this requirement was not in place in 2006, the new USAMRIID facility will be designed to adhere to these and other guidelines set forth in the most current BMBL. The BMBL also provides guidance on the performance of risk assessments and the selection of appropriate safeguards with experience, changes in research protocols, or the use of new agents.

The new USAMRIID building(s) will be designed, constructed, verified, and operated according to all the design and engineering standards specified by CDC/NIH (2007) and the applicable requirements of the Biological Defense Safety Program set forth in AR 385-69 and DA PAM 385-69. The facility will be credentialed according to the specifications of the CDC Division of Select Agents and Toxins and/or the counterpart regulations of the U.S. Department of Agriculture (USDA) and Animal and Plant Health Inspection Service (APHIS) that apply to BSAT. USAMRIID reports that none of the research to be performed at the new facility will be classified, nor will there be projects using dry aerosols, such as powdered *Bacillus anthracis* (U.S. Army Medical Research and Materiel Command/U.S. Army Garrison [USAMRMC/USAG] 2006).

Another aspect of containment is the handling of wastes resulting from biological research. The committee reviewed current practices at USAMRIID, as well as the plans for the new facility as presented in the EIS. The wastewater collection, conveyance, and treatment systems at Fort Detrick are segregated into two separate systems: one that serves to contain and treat what is for the most part domestic wastewater generated on the base, and the other, which collects and treats all wastewaters associated with BSAT research, including its animal research operations. While not explicitly stated in the EIS, wastewater associated with BSAT research is autoclaved and/or infused with potent oxidizing chemicals (e.g., hypochlorite) and surfactants (e.g., quaternary amines) according to BMBL practices, prior to underground transmission through a recently rehabilitated, corrosion-resistant collection system. This process serves to disinfect the water by killing the organisms and deactivating the toxins. Chemically treated BSAT wastewaters are then stored above ground in large holding tanks prior to high-energy thermal treatment using batch steam injection. The thermally treated BSAT wastewater is then decanted into the existing Fort Detrick sanitary sewer, prior to permitted discharge under the National Pollutant Discharge Elimination System into the Monocacy River.

The wastewater volumes generated by the existing and proposed facilities are formidable (between 10^7 and 10^8 gallons per year). The EIS states that future USAMRIID facilities will use a limited amount of existing infrastructure (about 20 percent of subsurface collection system), but that on-site thermal treatment processes will be redesigned and decentralized. Stage 1 and 2 construction call for satellite steam-injection facilities in or immediately adjacent to buildings housing BSL-3 and BSL-4 laboratories. This is a significant departure from past USAMRIID operations, and will substantially reduce the hazard potential associated with the handling of relatively large wastewater volumes. Independent of

satellite thermal treatment, current BMBL physical/chemical laboratory disinfection practices will continue to be applied to all liquid wastes and wastewater generated by the proposed USAMRIID facilities.

Like its wastewater counterpart, there are distinctly separate systems to contain, convey, and treat solid wastes generated at USAMRIID. Solid wastes generated by BSAT research are categorized and specially sequestered at the laboratory of origin; they are contained, tracked, and destroyed on site, so they remain separate from the otherwise conventional solid waste generated on the base. BMBL practices require the careful segregation of all solid materials containing or contacting microbes, their culture media, and any vessel involved in their assay (no matter how dilute). Well-marked secondary and tertiary containments (such as barrels, drums, and mylar biohazard bags ["red bags"]) are used to identify and hold solid materials, the potentially infectious fraction of which are autoclaved in bulk prior to transport from the laboratory of origin. Each solid waste load containing potentially infectious material is traced by a chemical marker that verifies its exposure to accepted inactivation conditions during an autoclave cycle. Non-infectious solid materials are then subject to oxidative incineration at a central facility, and the residuals disposed at landfills according to licensed civil engineering practices (such as those of the American Society of Civil Engineers [ASCE 1996]). According to the USAMRIID EIS, there are no planned significant departures from past solid waste management practices, which the committee finds safe and appropriate when executed in accordance with existing SOPs and BMBL practices.

BIOSAFETY AT USAMRIID RELATIVE TO NIH AND CDC RULES AND GUIDELINES

Biosafety is defined by the World Health Organization as "… containment principles, technologies and practices which are implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release" (WHO 2004, p. 47). Biosafety utilizes a number of control methodologies to include engineering controls, PPE, work practices (such as SOPs), and administrative controls (such as immunizations, medical surveillance, and training) to address the variety of hazards anticipated in the laboratory. These methodologies work synergistically to protect laboratory workers (and people they may come in contact with, such as co-workers and family members) as well as the environment. These control methodologies begin with basic principles and increase in scope and intensity as the nature of the hazards increase. The BMBL describes the requirements for the four levels of increasing biosafety (BSL-1 through BSL-4). As noted in the previous section, USAMRIID is subject to the BMBL guidelines (CDC/NIH 2007), as well as Army standards AR 385-69 and DA PAM 385-69, NIH Guidelines for Research Involving Recombinant DNA Molecules (NIH 2009), and CDC oversight for Select Agents and Toxins (42 CFR 73).

DA PAM 385-69: Safety Standards for Microbiological and Biomedical Laboratories (2009) prescribes the technical safety requirements for the use, handling, transportation, transfer, storage, and disposal of infectious agents and toxins rated at BSL-2, -3, or -4. The standards mandate the use of the most recent edition of the BMBL.

USAMRIID provided the committee with 15 SOPs detailing various aspects of handling and inventorying BSAT materials, processing laboratory waste, decontaminating workspaces, and certifying waste-treatment equipment (autoclaves). These SOPs meet or exceed all requirements of the BMBL as well as the requirements of the Select Agent Program (42 CFR 73) promulgated by the U.S. Department of Health and Human Services (HHS) and USDA. For example, relative to certifying containment equipment, the USAMRIID SOP entitled *Biological Safety Cabinet, Chemical Fume Hood, Class I Safety Enclosures, and HEPA Filtered Clean Benches Certification Program* requires that any of these devices used in BSL-3 or BSL-4 laboratories be certified semi-annually. This schedule exceeds the National Sanitation Foundation Standard 49 for Class II BSC Certification as well as the BMBL requirement that these devices should be certified on an annual basis.

USAMRIID also provided examples of current safety program regulations and examples of suite-specific safety manuals. These materials meet or exceed guidelines and recommendations from CDC/NIH (2007), the Occupational Safety and Health Administration (CFR 1910.1030), and the Select Agent Program (42 CFR 73), and the Army, in fact, turned these recommendations into USAMRIID regulations. Notable in one suite-specific manual (Safety Manual for the BSL-2 Lab) is a section devoted to safety communications. The following statement indicates a commitment to ongoing attention to safety with emphasis on continuous improvement by incorporating "lessons learned" into current practice: "Accounts of laboratory mishaps, along with the lessons to be learned from them are discussed during the quarterly Safety Committee meeting and are available at the Safety Office" (p. 10). However, human error will continue to result in occasional exposures to infectious agents (see discussion of the glanders and tularemia cases later in this chapter).

The documents provided by USAMRIID are dated recently, most within the past 12 months. However, the revision history noted on the documents indicates these SOPs/regulations have been in place for long periods and are subject to regular review and revision as dictated by changes in external requirements or internal changes in risk assessment or from lessons learned. Also notable is Policy Letter 08-18, Commander's Safety Policy, which clearly states the Commander's commitment to safety and reminds all staff member of their rights and responsibilities for maintaining a safe environment for employees of the organization as well as the community at large.

There are two related "markers" that are indicative of the effectiveness of biological safety programs associated with laboratories that work with infectious pathogens: 1) Have laboratorians become infected with the agents in use? or 2)

Have there been any illnesses in the surrounding community attributable to the release of infectious materials from the laboratory? In the first instance, activities in the laboratory are considered to be the cause of the infection (for example, inappropriate protective equipment, accidents, animal bites). An infected laboratory worker might serve as the means for spreading the pathogen to family members or other community members. Alternatively, failures of the engineering controls that maintain containment in the facility have the potential for releasing infectious materials into the community.

Table 2-1 contains a list of laboratory-acquired infections that have occurred at USAMRIID since the 1940s; notable are the diminishing numbers over the decades since research first began. These reduced numbers clearly reflect the positive changes in biosafety practices, procedures, use of equipment, and better engineering controls. None of the reported laboratory-acquired infections were related to engineering systems failures. Rather, the reported infections resulted from human activities. Perhaps more important, no community infections related to work done at USAMRIID have been reported.

The pathogens recently studied at USAMRIID and anticipated to be studied in the near future are listed in Box 2-1. These agents are variously transmitted through physical contact, mucous membrane exposure, ingestion, bite from an arthropod vector, or inoculation. Others are spread by the aerosol route. The majority of these agents are not spread from human to human. These agents are carefully contained inside biological safety cabinets using BSL-3 practices and procedures. Risk assessments on specific agents, or any new agents, determine whether work is done in BSL-2, BSL-3, or BSL-4 laboratories.

USAMRIID currently has a robust biosafety program that consistently updates training, SOPs, and other written policies and manuals. In addition, USAMRIID has constituted and registered an Institutional Biosafety Committee (IBC) in compliance with the NIH Guidelines for Research Involving Recombinant DNA Molecules (NIH 2009; p. 2-32, part 2.3.4).

There are several select toxins that may be studied at the new USAMRIID. They are non-reproducing biochemicals that pose some risk to the user, and are studied in high-containment laboratories because of the added security associated with such facilities.

The nature of recombinant DNA research at USAMRIID is similar to that conducted in many federal, private, and university laboratories across the country. The protocols are closely monitored by the IBC and by NIH, which oversees such work through the Recombinant DNA Advisory Committee and its guidelines. The IBC membership includes knowledgeable USAMRIID scientists, a representative from the Barquist Army Health Clinic, and a virologist not affiliated with USAMRIID.

TABLE 2-1 Timeline of Significant Advances in Biocontainment, Biosafety, Biosurety, and Biosecurity and Listing (by Decade) of Laboratory-Acquired Infections at USAMRIID

Decade	Laboratory-Acquired Infections at USAMRIID (route of exposure if known)[a]	Significant Biosafety-Related Army Events[b]	Other Significant Biosafety-Related Events
1940s	27 anthrax (cutaneous) 43 tularemia 51 brucellosis (inhalation) 7 glanders (1 cutaneous, 6 inhalation)	• Offensive biowarfare efforts underway (1942) • A.G. Wedum initiates scientific evaluation of laboratory-acquired infections, accident investigation, and testing of laboratory procedures for safety • Development of Class I and III biological safety cabinets (BSCs) • Establishment of scientific basis for packaging and shipping infectious agents • Introduction of BSCs (1949)	
1950s	4 anthrax (1 inhalation, 3 cutaneous) 107 tularemia (primarily inhalation) 43 brucellosis (inhalation) 32 Q fever (primarily inhalation) 18 Venezuelan equine encephalitis (VEE; primarily inhalation) 1 plague	• Application of HEPA filtration technology to biology laboratories • Development of Class II BSCs • Anthrax vaccine provided for researchers • Tularemia vaccine available (1959) • Ultraviolet technologies applied to microbiology laboratories • Air sampling conducted for aerosolized agents • Identification of hazards associated with laboratory activities	• Plum Island Animal Disease Center opens with BSL-3 for large animal research on foreign animal diseases (1954) • Biological Safety Conferences begin (Fort Detrick, Plum Island, CDC, National Animal Disease Center [NADC])

(Continued)

TABLE 2-1 Continued

Decade	Laboratory-Acquired Infections at USAMRIID (route of exposure if known)[a]	Significant Biosafety-Related Army Events[b]	Other Significant Biosafety-Related Events
1960s	11 tularemia (inhalation, cutaneous) 1 brucellosis (inhalation) 23 Q fever (primarily inhalation) 7 VEE (primarily inhalation)	• Shut down of offensive biowarfare program • Continued development of investigational new drug vaccines for military • Q fever vaccine available (1965) • VEE vaccine available (1963) • USAMRIID containment laboratories constructed	• World Health Organization (WHO) issues statement regarding Small Pox laboratory design • Foot and Mouth Disease virus release at Pirbright, England • CDC issues *Classification of Agents on the Basis of Hazards* (1969)
1970s	9 Rocky Mountain Spotted Fever (inhalation) 1 tularemia 1 VEE	• Applied research continues	• London School of Tropical Medicine publishes *Report of the Committee of Inquiry into the Small Pox Outbreak in London in March and April 1973,* which recommends BSCs for aerosol production activities • CDC biosafety office established after Rocky Mountain Spotted Fever deaths • Asilomar Conference focuses scientific community on potential biosafety hazards related to recombinant DNA (1975) • NIH publishes *Guidelines for Research Involving Recombinant DNA Molecules* (1976) • "Biosafety officers" appointed, institutional biosafety committees (IBCs) established

		• 1st BSL-4 lab at CDC (both glove box and suit lab) • Small pox eradicated; BSL-4 requirements; consolidation of small pox viral stocks at CDC in the US and at Vector in Russia • WHO publishes guidelines on physical containment, strict control of entry, biowaste decontamination, BSCs, double-ended autoclaves for laboratories handling dangerous pathogens • Draft *Biosafety in Microbiological and Biomedical Laboratories* (BMBL) published • BSCs are added to biological research laboratories • Federal regulations published; CDC issues permits for importation of infectious agents
1980s	1 tularemia 1 dengue fever 1 Q fever	• BMBL I is published (1983); compliance is a requirement for NIH-funded research laboratories • American Biological Safety Association (ABSA) formed (1981) • Occupational Safety and Health Administration's Blood Borne Pathogen Standard published • BSL-4 laboratories constructed in San Antonio (glove box), Gelong (animals), CDC (suit lab, building 15) • BMBL II published (specific information about HIV added) (1984)

(Continued)

TABLE 2-1 Continued

Decade	Laboratory-Acquired Infections at USAMRIID (route of exposure if known)[a]	Significant Biosafety-Related Army Events[b]	Other Significant Biosafety-Related Events
1990s	1 chikungunya (needle stick) 1 vaccinia (cutaneous) 1 plague 3 staphylococcal entertoxin B		• BMBL III published (1988) • WHO *Laboratory Biosafety Manual* (LBM 2) (1993) published (multiple languages) • Initiation of CDC Biosafety Symposia (biannual) (1992) • Growing number of architectural and engineering firms involved in designing containment labs • Larry Wayne Harris *Y. pestis* incident → Select Agent Rule • CDC funds construction of BSL-3 laboratories in state public health laboratories • Canadian maximum containment laboratories are constructed; first laboratory at University of Texas Medical Branch (UTMB) completed; Georgia State University (GSU) I glove box laboratory built • BMBL IV published (1999) (Appendix F – biosecurity) (translated into 7 languages, online) • ABSA begins publishing *Anthology of Biosafety* series (1999)

2000s	1 glanders 1 VEE 1 tularemia Possible anthrax diversion	• *B. anthracis* spores found outside laboratory (2002) • EIS for National Institute of Allergy and Infectious Diseases (NIAID) facility released (2003) • EIS for National Biodefense Analysis and Countermeasures Center facility released (2004) • Experimental Marburg vaccine developed (2006) • Renovation of one BSL-4 suite (2007) • Fort Detrick Community Liaison Council formed (2008) • Overage of biological select agents and toxins (BSAT) reported, stand down, and resulting inventory certification (2009) • Ground breaking for new USAMRIID laboratory (2009) • AR50-X and AR50-1 – Army Biological Surety Program • DoD Instruction 5210.88 – Safeguarding BSAT • Army IGM Oct 08 – Interim Guidelines for the Shipment of BSAT • Army IGM Jan 09 – Interim Guidance for Biological Mishap Notification, Investigation, and Reporting • Army IGM May 09 – Interim Guidance for BSAT Inventory and Accountability • Army IGM May 09 – Personnel Reliability Program and Personnel Security Investigation Interim Guidance	• 9/11/01 – 10/4/01 → Division of Select Agents and Toxins formed at CDC • 42 CFR 73 – Select Agent Rule effective (2003/05) • WHO LBM 2nd edition published (2004) • BMBL V published online (2007) • Construction of containment laboratories: UTMB II, NIAID, National Emerging Infectious Diseases Laboratories, National Biodefense Analysis and Countermeasures Center, USAMRIID, NIAID Rocky Mountain Laboratory, NADC, GSU II, CDC II • FMDV released in England as a result of aging facilities

[a]Oster et al. 1977; Rusnak et al. 2004a, 2004c; Wadding 2009.
[b]Rusnak et al. 2004a; Skvorak 2009.

BOX 2-1 Pathogenic Agents Recently Studied or Potentially Studied in the Near Future at USAMRIID[a]

Bacillus anthracis
Brucella species
Burkholderia mallei
Burkholderia pseudomallei
Clostridium botulinum
Coxiella burnetii
Crimean-Congo hemorrhagic fever virus
Dengue virus
Ebola virus
Eastern equine encephalitis
Francisella tularensis
Guanarito virus
Hantaviruses
Influenza viruses
Japanese encephalitis virus
Junin virus
Lassa fever virus
Machupo virus
Marburg virus
Non-*Variola* pox viruses
Rift Valley fever virus
Staphylococcus enterotoxin B
Venezuelan equine encephalitis
Vibrio species
West Nile virus
Western equine encephalitis
Yellow fever virus
Yersinia enterocolitica
Yersinia pestis

[a]The list is subject to change over time and with USAMRIID's mission. Source: Personal communication with COL P. Skvorak, Commander, USAMRIID, December 2, 2009.

The Department of Defense's (DOD's) biological safety and security program was reviewed by a Defense Science Board (DSB) task force in 2009. The review involved a comparison of DOD biological laboratories with similar facilities in academia, industry, and the Federal Government. Twenty-two laboratories were considered, including USAMRIID. The task force found that the safety and security of the DOD facilities was as good or better than that found in comparably sized facilities. It also made the observation that several BSL laboratories are more modern than the DOD laboratories. It further stated that "if USAMRIID is to stay in the forefront and address evolving threats, investment in new infrastructure must be sufficient" (DSB 2009, p. 39).

BIOSURETY

Biosurety programs involve systems and procedures to properly safeguard BSAT against theft, loss, diversion, or unauthorized access or use. The EIS states USAMRIID will undergo CDC inspection and approval prior to beginning work. As laws, regulatory requirements, and guidelines change and are adopted by CDC, USAMRIID would have to be compliant to pass inspection and be operational. This would include new requirements such as *The Possession, Use, and Transfer of Select Agents and Toxins* (42 CFR Part 73 [2005]), which was promulgated by HHS and USDA and forms the basis of current programmatic and operational biosecurity requirements in the United States (the BMBL)

(CDC/NIH 2007). Registered select agent facilities also are subject to announced and unannounced inspections by CDC, USDA, or both, depending on the agents studied at the facility. These inspections include detailed scrutiny of the receipt, storage, use, and transfer of BSAT.

CFR 42 Parts 72 and 73 establish specific requirements for institutes that possess, use, store, and transfer BSAT. In accordance with AR 385-69, USAMRIID must develop a program compliant with the regulations that in summary require:

- registration of facilities/entities (application and inspection) with CDC/USDA APHIS,
- assignment of a responsible official to manage the biosecurity program,
- investigation and adjudication by the Department of Justice (DOJ) of personnel with access to BSAT,
- restricted access to BSAT,
- development and implementation of a security plan (physical and IT security, inventory control), biosafety plan, and incident response plan,
- provision of documented biosafety and biosecurity/security training to personnel,
- maintenance of records,
- inspections, and
- notification of CDC or APHIS of theft, loss, or release of materials.

The biosurety program at USAMRIID focuses on accountability of both personnel and materials. Taken together these criteria complement each other and are more stringent than the existing requirements set forth by DOJ and HHS/USDA.

Personnel reliability is another aspect of biosurety, which involves systems and procedures to ensure that individuals with access to BSAT meet high standards of reliability. The issue of personnel reliability goes beyond the investigation and adjudication by the DOJ that is required of all personnel having access to BSAT. The Army has taken the lead in establishing a robust biosurety program, which has been fully adopted by USAMRIID (see Table 2-1). The Biological Personnel Reliability Program was initiated in 2003, and every new employee undergoes a 10-week process of personal interviews with questions on drug and alcohol use, mental health, financial issues, and any interactions with law enforcement. Personnel records are reviewed. A medical evaluation is performed that includes physical, emotional, and psychological assessments. After enrollment in the program, personnel are monitored carefully for disqualifying attributes including inappropriate attitude, conduct, or behavior. This Biological Personnel Reliability Program is considered to be a model by other institutions.

While this program is robust at screening and potentially deterring and detecting insider threats, it is the consensus of the committee that no program can stop all threats of theft (or misuse) of BSAT posed by those who have been granted access to BSAT and who are determined to take action. Risk in any ac-

tivity cannot be reduced to zero. The committee also recognizes that there are very few reports in the literature regarding employee theft or misuse of biological agents at USAMRIID or in the United States despite the large number of personnel working with these agents and the number of years research has been conducted. Preventing further incidents is an ongoing challenge that will need to balance strengthened biosecurity measures against the placement of undue additional stress on laboratory personnel. The current program will be strengthened by further training laboratory personnel on their individual and collective biosecurity responsibilities, reinforcing ethical norms of safe and responsible scientific conduct, and paying increased attention to behavioral signals that may identify personnel as "at risk" of becoming potential threats to their coworkers and the program. A recent NRC report, *Responsible Research with Biological Select Agents and Toxins* (NRC 2009), recommends training in scientific ethics and dual-use research, and that the training be designed to foster community responsibility. Research enterprises in academic, corporate, and military settings have been slow to respond to increasing calls for training of life scientists in ethical aspects of their work (Dando 2009). It would appear that USAMRIID has some difficulty assigning priority to training in ethics and responsibility in research, but this is not unique to military installations.

Before 2001 there was no requirement for a centralized BSAT database for inventory accountability. Since then there has been a dynamic inventory of agents in frequent usage, which includes review of research notebooks and physical inventory audits. BSAT transfers between laboratories require oversight by two persons. BSAT transfers outside of USAMRIID follow CDC/APHIS tracking requirements, packaging specifications of the Department of Transportation, and are moved through commercial "white glove" service.

In November 2008, USAMRIID undertook a 100-percent BSAT inventory verification to double-check the accuracy of its automated inventory management system. A significant overage of vials (9,079, including 141 BSAT vials) was discovered and reported in January 2009, and a "stand-down" was ordered until the individual laboratories were recertified as being compliant. Additional inventory controls have since been established and implemented (Skvorak 2009).

BIOSECURITY

Physical security at Fort Detrick is commensurate with the maximum level of fortification typical of high-value domestic military bases. The entire facility is surrounded by fencing, and there are security check points at all entrances. Vehicle and personnel checks are performed for all who enter the fort. There are additional security check points at the entrance to the laboratory buildings, as will be the case for the new USAMRIID facility. Incoming packages are subject to X-ray and/or physical inspection. Access to the individual laboratory suites requires use of swipe cards, key pads, and/or biometric readers, depending on

the nature of the laboratory. There are exterior and interior closed-circuit television systems. Access to BSAT requires further security access. As indicated above, all persons having access to BSAT must undergo FBI verification and adjudication, then extensive further scrutiny through the Biological Personnel Reliability Program process.

CASE STUDIES OF RECENT EVENTS AT USAMRIID

There are four fairly recent events at USAMRIID that can be used as case studies for identifying weaknesses in the institute's programs and procedures. They include two cases of laboratory-acquired infections (tularemia and glanders), the discovery that the material in the "anthrax letters" mailed in 2001 originated from a source in a USAMRIID laboratory, and the discovery that the institute's BSAT inventory was inaccurate.

Recent Laboratory-Acquired Infections

In late November 2009, a laboratory worker at USAMRIID contracted tularemia pneumonia as a result of her research with the causative agent *Francisella tularensis*. She began to exhibit symptoms of illness (fever, chills, myalgia, and headache) several days after having worked with the agent. Vaccination for tularemia is available to all BSAT workers. This researcher had not been vaccinated against *F. tularensis* because she had a non-laboratory related clinical case of tularemia in 1992, and had positive hemagglutinin titers suggesting that she retained immunity to the bacteria. Because her children were ill, she attributed her symptoms to catching their illness. Thus, she sought medical attention from the usual military channels for non-occupational illnesses about a week after symptoms began.

However, after her fever and symptoms persisted she sought care from USAMRIID's special immunization program (SIP) clinic, the occupational health provider for USAMRIID. The SIP clinic confirmed a diagnosis of tularemia. The Frederick County Public Health Officer was informed by the on-base Barquist Army Health Clinic once a presumptive diagnosis was made, and was periodically updated. No other cases of tularemia occurred.

Based on these observations and comments on the case from USAMRIID, the Frederick County Health Officer, and the public, a number of lessons may be learned. First, even though there were circumstantial reasons for the worker to suspect her illness was unrelated to work in the laboratory, this case suggests that workers with fevers should be required to report to the SIP clinic before seeking care elsewhere because it has the specialized clinical staff and resources to identify diseases related to USAMRIID's laboratory research. Second, it is important to maintain communications among USAMRIID, the Barquist Army Health Clinic, and the Frederick County Health Department to ensure timely reporting of cases to the State. In particular, because there is routine and frequent turnover of medical

staff at the military facilities, it is important that procedures are in place to ensure that communications are maintained. This incident should be carefully reviewed by USAMRIID for other lessons to be learned. Questions to consider include: 1) Were work practices appropriate? 2) Was respiratory protection appropriate, what level of protection would be appropriate, and was it employed? 3) Were practices in the laboratory regularly audited? 4) Are vaccination practices appropriate? 5) Was the worker aware of the procedures for reporting incidents and was she comfortable that incidents can be reported without fear of reprisal? 6) Are changes in current practices, PPE, engineering controls, or administrative controls for work with *F. tularensis* necessary?

In 2000, another incident also highlights that human actions are probably the weakest link in biosafety. The case involved occupational exposure to *Burkholderia mallei*, the causative agent of glanders. This was the first known case of human glanders in the United States since 1945. *B. mallei* typically infects equids (horses, mules, and donkeys). The infected USAMRIID worker sought medical attention outside the military system, but did not disclose the type of work with which he was involved, which contributed to the delayed diagnosis of his illness. No other cases occurred. The scientist admitted to not wearing gloves while working with the agent, so the route of exposure was assumed to be percutaneous. This case illustrates a breach of biosafety procedures for working safely with BSL-3 agents, as well as a violation of the laboratory's requirement that illnesses be reported promptly. As noted earlier in this chapter, special training and SOPs are in place to prevent such events, but it remains the responsibility of an individual to adhere to ethical norms for safe and responsible scientific conduct.

In response to the circumstances of this case, USAMRIID conducted safety "stand-down" training with all employees and conducted laboratory environmental sampling, which found no evidence of surface or air contamination. In addition, the employee involved was provided additional training and was required to demonstrate competency before being allowed to work independently (Wadding 2009).

2001 Anthrax Attacks

In 2001, letters tainted with *B. anthracis* spores were mailed to lawmakers on Capitol Hill and members of the news media. The mailings were linked to 22 cases of anthrax, five of which were fatal. The spores are believed to have originated from the laboratories at USAMRIID because the strain of *B. anthracis* used in the attacks appeared to be the same as one used at the institute for research. The laboratory worker was suspected by the FBI because he had ready access to the specific *B. anthracis* strain and because aspects of his personality and work habits were considered suspicious. (The FBI's public findings came after the publication of the EIS.) The incident reinforced existing serious concerns about biosurety. There has been rigorous federal attention paid to the vet-

ting of individuals who have access to these agents (42 CFR 73 Select Agent Rule 2003, 2005), inventory and accountability, and the development of a Biological Personnel Reliability Program (see earlier discussion in the section on *Biosurety*).

Inaccurate Inventory of BSAT

In early 2009, a USAMRIID researcher found four vials of BSAT material that were not included in the institute's inventory database. USAMRIID undertook a complete BSAT inventory to double-check the accuracy of the automated inventory management system in accordance with new Army and DOD requirements that the inventory system account for 100 percent of BSAT material in its possession. A "stand-down" was ordered until every freezer and refrigerator was inventoried and all BSAT materials were identified and accounted for. A significant overage of vials (over 9,000 vials) was discovered and reported. Many of these "newly found" vials contained small volumes of working stocks left behind in freezers by departing scientists. Since this incident, additional inventory controls have been established and implemented. For example, SOPs for BSAT inventory shipping, receiving, and transfers were revised; BSAT inventory audits will now be performed annually; and consideration is being given to creating a centralized BSAT storage facility within USAMRIID (Skvorak 2009).

FINDINGS

- USAMRIID's current procedures and regulations for its biocontainment facilities meet or exceed the standards of NIH and CDC for such facilities and other accepted rules and guidance for handling and containing pathogens during use, inventorying, and storage; treating and safely disposing of laboratory solid waste; and handling and decontaminating wastewater.
- Measures have been taken to improve safety at USAMRIID when problems have been identified. The new facilities will be operated under even more stringent guidelines than were in place previously regarding physical security, engineering infrastructure and redundancies, biosafety, and biosecurity. Thus, the committee has a high degree of confidence that the new USAMRIID facility will have the appropriate and effective physical security, biosurety program, and biosafety operating practices and procedures in place to protect its workers and the public from exposures to pathogens and any new pathogens studied in its laboratories. However, the recent tularemia case shows that risk cannot be reduced to zero.
- USAMRIID has strived to improve safety procedures. Lessons learned from exposure and/or disease incidents have directed some of the improvements, as indicated by the decrease in laboratory-acquired infections from the 1940s to the present, so that laboratory-acquired infections are now infrequent.

RECOMMENDATIONS

- USAMRIID should continue to set high standards for advancing security, operational, and biosurety measures.
- Although USAMRIID has sought to set high standards for biosurety and biosafety, recent examples of laboratory-acquired infections (glanders, tularemia) and breaches in containment (*B. anthracis* spores) point to human error or deliberate misuse. The committee recommends further formalized training in responsibility and accountability at USAMRIID, similar to that required for NIH-sponsored training programs. The widely used text for this training (*On Being a Scientist: Responsible Conduct in Research* [National Academy of Sciences 1995]) includes modules for aspects such as error and negligence in science and conflicts of interest, but can be supplemented with case studies and discussions of relevant issues, such as whistle-blowing, whistle-blower protection, and dual use awareness. The circumstances surrounding the laboratory-acquired infections also should be carefully evaluated to determine what lessons can be learned for preventing future cases.

3

Medical and Emergency Management Response

MEDICAL AND PUBLIC HEALTH SERVICES

The availability of medical and emergency response resources is of special importance to assure the Frederick County citizens that plans are in place to address any disease incidents that might occur from exposure to pathogen research at the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID). Frederick County residents are understandably concerned about risks posed by the various biological agents that are already under study at USAMRIID or may be used in research at the new facility. The concerns are reflected in numerous letters and communications; in the transcripts of two community-wide meetings; and in meetings with community members. The laboratory's research roster of existing or prospective organisms spans a wide array and includes a number that potentially could be deployed as biological weapons by governments or individuals with hostile intent. The research is designed to better define the character of these organisms in the interests of prevention, diagnosis, and treatment. Considerable efforts have been made to assure the community that the plans for the new laboratory call for it to be equipped with the most modern and sophisticated systems to handle these agents safely and in a secure manner. Nevertheless, there are some in the community who remain concerned as to whether the medical and emergency resources and response systems are fully prepared to diagnose and treat a rare illness caused by one of these agents and to prevent its further spread in the community.

The population of the county surrounding Fort Detrick is about 220,000, of which 950 individuals are expected to be employed at USAMRIID. The county's one full-service hospital is Frederick Memorial Hospital, a modern 260-bed facility. It includes a 50-bed emergency suite that opened in 2004 and six special isolation rooms to house individuals with contagious communicable infections. (These isolation rooms have engineering controls to maintain nega-

tive air pressure to prevent infectious agents from being spread outside of the rooms. They also have anterooms where medical personnel put on personal protective equipment [PPE] before entering the room and are decontaminated before leaving the room.) Some 400 physicians are said to be resident in the county, about 250 of whom are currently in practice and providing care to county residents. There are few infectious disease specialists.

USAMRIID has a special immunizations program (SIP) clinic, which is an outpatient research facility and health care provider for USAMRIID employees involved in biocontainment laboratory work. The clinic provides both licensed and investigational vaccines, if available, to staff who are at risk of exposure to biohazard agents. The vaccines augment protection provided by PPE and engineering controls for working with biohazard agents. Personnel with work-related injuries or symptoms of illness (especially fevers) are expected per standard operating procedures to report to the SIP clinic. Five physicians are dedicated to the SIP clinic, with an additional four who participate in after hours on-call and a medical-monitor physician, who serves as a patient advocate for subjects enrolled in studies of investigational new drug products. Five of the physicians, including the medical monitor, are board certified infectious disease specialists. The clinic has a clinical laboratory and a research serology laboratory. The research laboratory has the ability to perform serological testing for the types of pathogens under study at USAMRIID. The SIP clinic also has a biosafety level (BSL)-3/4 observation/isolation suite on site.

General medical care for USAMRIID staff is provided by the Barquist Army Health Clinic, except for those handling infectious agents under the SIP with illnesses that might be caused by agents under study. Should there be an incident requiring further medical care, a Memorandum of Agreement (Commander, USAMRIID; Commander, U.S. Army Garrison; Commander, Barquist Army Health Clinic; and Vice-President for Medical Affairs, Frederick Memorial Hospital, March 27, 2009) provides for USAMRIID patients to be received and treated at the Frederick Memorial Hospital. Further medical care for military staff is provided by Walter Reed Army Medical Center. A Memorandum of Understanding (Commander, Barquist Army Health Clinic, and Vice-President for Medical Affairs, Frederick Memorial Hospital, June 4, 2009) provides for mutual support between USAMRIID and Frederick Memorial Hospital staff to deal with a public health emergency or terrorist attack. It calls for USAMRIID physicians to provide quarterly training for hospital staff and for the Director of Safety and Security at the hospital to receive annually updated material on USAMRIID's medical management of biological casualties. To facilitate care, each USAMRIID staff member is provided a contact card identifying him/her as an employee so as to expedite access to subject matter experts for consultation. The Barquist Army Health Clinic has an ongoing and good relationship with Frederick County's Health Department, such that the county has confidence that it will be informed of any reportable medical incidents of which the clinic is aware. Notwithstanding the above resources and guidelines, there are case incidents where individual workers have not reported illnesses in accordance with

the rules and guidelines (see Chapter 2 for case examples and recommendations for addressing such breaches in procedures). Thus, the patient did not receive needed and timely medical care and there was an unacceptable delay in instituting appropriate preventive measures at USAMRIID and in the community.

The committee was informed that, at present, there are only a few physicians in the community who regularly consult on infectious disease problems and none are believed to have had substantial training in dealing with diseases caused by the organisms being studied or that may be studied at USAMRIID. The problem posed by this shortage can be illustrated by the hypothetical example of a late night arrival at the emergency room of a delirious, febrile patient with a strange rash of uncertain diagnosis and whose employment is uncertain. Expertise in the community is limited and a contact with an emergency desk at USAMRIID would be of little help if this was not an employee. But, even if the patient were an employee of USAMRIID, would the requisite medical consultation be immediately available if the person does not provide a contact card or disclose that he/she works at USAMRIID?

Efforts have been made by USAMRIID to provide education to some of the hospital physicians through quarterly training and for the hospital's Director for Safety and Security to receive annually updated materials on the medical management of biological casualties. However, it is unrealistic to expect many of the more than 200 physicians in the county to avail themselves of such educational efforts or to know who to call when confronted with a patient with an unknown serious infectious disease. In a meeting the committee had with staff at Frederick Memorial Hospital and the Frederick County Public Health Officer, the possibility of having knowledgeable infectious disease physicians available 24/7 was provisionally explored. All parties welcomed the possible assignment of physicians with dual responsibilities at USAMRIID and Frederick Memorial Hospital to bridge the gap in understanding and cooperation between the community and USAMRIID. The committee suggested that such physicians could have joint appointments at the hospital and at USAMRIID, with provision for them to spend some time with laboratory scientists to keep abreast of work and the diseases of concern. If based at the hospital, their contact with local physicians and the local community would be facilitated. They could, as well, work with the hospital, the county health department, and the local medical society in arranging appropriate continuing education programs.

EMERGENCY MANAGEMENT RESPONSE

Should a significant emergency situation occur, a Memorandum of Agreement for Mutual Assistance (Commander, Fort Detrick, and the Frederick County Board of Commissioners, January 1, 2009) commits the Fort Detrick Fire and Emergency Staff to join with personnel of the Frederick County Division of Emergency Management in providing mutual aid in dealing with fire, hazardous materials problems, and other disasters, including biological defense. The com-

mittee was briefed by the Chief of the Fort Detrick Garrison Fire and Emergency Services on its preparedness for medical and fire emergencies at the USAMRIID facility. It is an actively engaged unit. In 2008, it recorded 723 total responses; 499 on post, 224 off post. None of these responses involved the USAMRIID facility. The Chief described a fully staffed department with a total of 31 personnel, all Maryland certified EMT-B as well as all being nationally certified Hazmat technicians. He cited a close working relationship with the local first responder network both at the committee and County Safety Council levels. He also noted that the Garrison team trains regularly with the county-wide volunteer first responders and each serves as backup to the other.

The Garrison team has regularly scheduled drills at the USAMRIID facility, including rescue drills involving BSL-3 and BSL-4 laboratories. These drills occur, at a minimum, on a semiannual basis and more often as allowed by access to the facility when laboratory activity permits. These drills involve entering the laboratory in Level A protective gear (to be selected when the greatest level of skin, respiratory, and eye protection is required) and extracting a victim to an airlock where the victim and the rescuer are decontaminated. Following decontamination, transport to Frederick Memorial Hospital is done in the Garrison's recently acquired ambulance. The ambulance is equipped with a patient transport isolation system should it be required.

In discussions with the Director of the County Emergency Management program, the Hospital Emergency Preparedness Director, and the County Health Officer, who is responsible for medical preparedness and response, it was apparent that there are close working relationships among the leadership and that regular preparedness exercises are being conducted. The hospital itself, in addition to having the 50-bed emergency unit and the six isolation suites, is generously stocked with portable isolation units, reserve quantities of PPE, and N95 face masks (which filter at least 95 percent of airborne particles). Should an event with large numbers of casualties occur, several geographically more distant buildings (used now for out-patient surgery and ambulatory care) could be quickly converted to provide care. A cadre of health personnel has been identified in the community to be called up as needed. Emergency operations centers have been established at Frederick Memorial Hospital and at the County Preparedness Office. These are interconnected and have direct contacts to USAMRIID and the Fort Detrick Emergency Center as well as with State facilities. Special drills and exercises are regularly conducted.

FINDINGS

- USAMRIID, Fort Detrick, and Frederick County have the resources and partnerships in place to address medical and emergency situations at the containment laboratories. There are several concerns, however, that need to be addressed.

- A primary concern is the lack of readily available clinicians with the necessary specialized training to consult on the clinical diagnosis and treatment of unusual infectious diseases. Offering continuing medical education courses on such topics is not adequate to address this concern.

RECOMMENDATIONS

- Given the unique nature of USAMRIID's mission in dealing with special pathogens, additional measures should be taken to provide assurance that experienced medical professionals are readily available to consult on unusual infectious diseases. Serious consideration should be given to support an initiative that would provide experienced specialist physicians knowledgeable of diseases caused by organisms studied at the laboratories. This would include consultation as needed on a 24/7 schedule to see patients from the community. Such physicians should also serve to provide continuing communication and coordination between USAMRIID scientists and community physicians and public health personnel.
- For medical and emergency response mechanisms, a senior authoritative management system is needed to ensure that USAMRIID works effectively with county government agencies, the local medical community, emergency preparedness and response initiatives, and Frederick Memorial Hospital. Such a system would include a clear chain of command with designated personnel to work directly with partners in the county and community. The Army should consider the use of permanent civilian staff for these positions to ensure continuity of relationships. Because USAMRIID will be part of the National Interagency Biodefense Campus, which will include biocontainment facilities of two other agencies, consideration should be given to delineating and coordinating emergency and medical response plans and resources for all facilities on the campus.

4

Review of the USAMRIID Environmental Impact Statement

The committee was charged with evaluating the Environmental Impact Statement (EIS) supporting the construction and operation of a new U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) facility in terms of the scientific adequacy and credibility of the analyses of health and safety risks associated with pathogen research. Most of the information on health and safety risks is contained in Appendix I (Hazard Assessment) of the EIS; other supporting information is distributed throughout the document. The EIS considers seven scenarios whereby pathogenic agents might escape from the containment laboratory. They include analyses of 1) biological aerosol releases from biosafety level (BSL)-3 and BSL-4 laboratories, 2) an escape of an infected animal, 3) biological material shipment, 4) terrorist acts, 5) external acts (such as natural disaster or mechanical failures), 6) exposure from a worker, and 7) cumulative impacts.

POTENTIAL SCENARIOS IN THE CONTEXT OF MAXIMUM CREDIBLE EVENTS AND RISKS TO THE COMMUNITY

The EIS estimates that under maximum credible event (MCE) scenarios community exposure to laboratory pathogens would be insignificant. In the sections below, the committee evaluates whether the scenarios are reasonably foreseeable and considers realistic exposure conditions, and whether the exposure estimations are justified.

Routes for Infectious Agent Release

There is a remote possibility that etiologic agents studied in the proposed USAMRIID facilities could exceed their intended containment by any one of a number of routes previously described. Except for animal escape, managed

transport, or terrorist acts, agents must move with indoor aerosols, wastewater, or solid waste streams before they potentially impact internal occupational receptors and/or progress to the outdoor environment at large. Following media transport paradigms commonly employed by industrial hygienists and environmental engineers, each route—airborne, wastewater, and solids—is isolated and analyzed by the EIS, from a routine, but limited facilities design perspective.

With respect to protecting biological indoor air quality as well as the immediate outdoor air quality, the committee finds the following key design parameters and mechanical heat, ventilation, and air conditioning redundancies in accordance with or exceeding guidelines of the Centers for Disease Control and Prevention (CDC), the National Institutes of Health (NIH), the American National Standards Institute and the American Industrial Hygiene Association (ANSI/AIHA 2003), and the American Conference of Governmental Industrial Hygienists (ACGIH 1999, 2001) developed expressly for such high-exposure environments, specifically regarding: air exchange rates, vestive flow regimes, differential pressure systems, staged filtration, and protected heat transfer equipment. While special indoor air quality engineering features were presented in this context, the performance, reliability, and security concerning the operations and maintenance of indoor air quality systems were not addressed in the EIS or its associated hazard assessment. Such an analysis would include, but would not be limited to: special contextual confirmation of mixing and flow regimes using widely accepted tracer tests under multi-season heating/cooling scenarios; the confirmation of filter blow-by under both clean and ripe conditions (in addition to smoke testing); and periodic stress challenges of critical pressure-sensitive infrastructure (in addition to Magnehelic calibration).

Unlike the maintenance of indoor air quality, reliable inactivation of the capricious wastewater flows that contain potentially high concentrations of pathogenic agents relies on satellite *in-situ* laboratory pre-treatment prior to its transport and treatment in the building-centralized systems proposed under the USAMRIID expansion. With respect to treating comingled wastewater flows from the facility (apart from *in-situ* chemical pre-treatment), the committee finds key containment, transport, and design parameters in accordance with or exceeding the standards of the American Society of Microbiology (ASM 2007), CDC/NIH (2007), the American Public Health Association (APHA), the American Society of Civil Engineers (ASCE), the American Water Works Association (AWWA), and the Water Environment Federation (WEF) (APHA/AWWA/WEF 2005; ASCE/WEF 1992; WEF 1990, 1992, 1997), and guidelines written expressly for handling and treating combined wastewater flows containing discarded culture media and the biological fluids and sanitary sewage generated by USAMRIID's animal testing. While special engineering features were presented in this context, the performance, reliability, and security concerning the operations and maintenance of USAMRIID's wastewater treatment and conveyance systems were not addressed in the EIS.

Like its wastewater counterpart, reliable inactivation of pathogenic agents entrained in or on solid materials leaving the USAMRIID laboratories (exclud-

ing feces) relies on satellite *in-situ* treatment (autoclaves) prior to its transport and treatment in a centralized incineration system. With respect to treating comingled solid wastes from the facilities (apart from autoclave), the committee finds key containment, transport, and design parameters in accordance with, or exceeding the standards of the ASCE, ASM, and CDC/NIH, and guidelines written expressly for the handling and treatment of combined solid waste streams consisting predominantly of discarded culturing/assay supplies, sharps, plastics, and glassware, as well as selected animal parts. With exception of the extensive autoclave infrastructure built into the BSL-2, -3, and -4 suites, the performance of post-autoclave solid waste treatment systems or its reliability and security were not addressed in the EIS or its associated hazard assessment.

Scenarios

The EIS for the new USAMRIID facilities uses the MCE methodology to identify examples of events that may provide upper bounds on the risk posed to the public. The main MCE analysis in the EIS involved simulation of large aerosol releases from BSL-3 and BSL-4 laboratories as a result of centrifuge mishaps. Other events described include escapes of laboratory animals, an airplane flown into the laboratory, accidents during pathogen transport to the laboratory, and exposure through an infected laboratory worker. There is limited discussion of actions taken by a laboratory employee that may circumvent biosecurity measures and maliciously expose members of the community to infectious agents.

Transparency and Verification of Modeling

The EIS documents its approach to risk analysis but is not transparent. An analysis is transparent when sufficient data are provided so that an independent observer with expert knowledge can replicate the results. The information and documentation provided in the EIS are insufficient for an independent assessment of the risks to the community posed by biological agents (see discussion below). Transparency of the EIS is an issue not just for this committee, but also for the public. One role played by the EIS has been to inform the public about the risks associated with the proposed project and how those risks are mitigated now and in the future. The committee believes that much greater elaboration would be necessary on the part of the EIS to adequately fulfill this informational role on behalf of the general public. For further discussion of the role of communications, see Chapter 5.

The calculations of risk from the release scenarios appear to be incomplete and potentially incorrect. No attempts were made to systematically account for the biological characteristics of the organisms, and the analyses did not assess the potential for a local epidemic within the community or the efficacy of mitigation plans for minimizing the effects of such an epidemic. Other scenarios lacked rigorous accounting and were supported with minimal data. The EIS does

not exhaustively consider the various possible routes through which members of the general public may be exposed to pathogens studied at USAMRIID. One possible route of exposure not considered in the EIS is the potential establishment of an infectious agent within a local animal or vector reservoir, and the subsequent low-level/long-term risks this may pose to the public.

Risk of an Aerosol Release to the Community

The MCE analyses in the EIS involved simulation of large aerosol releases from BSL-3 and BSL-4 laboratories as a result of centrifuge mishaps. In the scenarios, *Coxiella burnetii* (requiring BSL-3) and *Ebola Zaire* virus (requiring BSL-4) were released to the surrounding environment from an exhaust stack after vials in a centrifuge leaked and air filters failed to filter the pathogens. For these MCE scenarios, multiple mishaps must occur. First, a laboratory worker fails to use rubber O-ring gaskets to seal all six centrifuge tubes, so the safety caps leak during centrifugation. Second, the agent is leaked into the rotor compartment, which is not sealed, and it is aerosolized into the laboratory. Third, the HEPA filter is inoperable (or one of two filters is inoperable in the BSL-4 scenario), which allows the agents to be released from the exhaust stack.

The committee does not consider these MCE scenarios to be "reasonably foreseeable" accidents. They require simultaneous disregard of procedures, multilevel engineering systems failures, and lack of administrative controls. Although there are reports documenting single-point failures—such as lapses in following proper procedures or administrative controls, engineering sub-system failure, and problems associated with personal protective equipment (PPE) and primary barriers—there are no documented reports in the literature of numerous simultaneous combined failures occurring in laboratories in the United States. Biosafety measures (outlined in Chapter 2) are designed to minimize the risk of such events. Laboratory workers are trained to use rubber O-ring gaskets to seal centrifuge tubes to prevent leakage of safety caps during centrifugation. Centrifuges used in containment laboratories are themselves sealed to prevent such possible leakage. Rendering high-efficiency particulate air (HEPA) filters ineffective in this context would mean they had not been properly installed and/or had been physically compromised without detection. Such compromise would cause pressure differences that would easily be recognized by building instrumentation and alarm systems (and the laboratory would not be used until necessary repairs were made).

The EIS used Gaussian plume calculations to estimate the maximum credible risk posed to the general public by the aerosol releases described above. The plume calculations were performed using the Hazard Prediction and Assessment Capability (HPAC) software package developed by the Defense Threat Reduction Agency (DTRA). Gaussian plume calculations are a standard method for estimating risks from the atmospheric release of pollutants. In this EIS, plume calculations were used to estimate infectious doses after the accidental

release of a pathogen from BSL-3 and BSL-4 laboratories from the new USAMRIID facilities.

The analysis of risk from an aerosolized pathogen release depends on local weather conditions affecting dispersal, environmental inactivation rates of pathogen after release, the geospatial density of susceptible human and animal hosts, and the biological characteristics of the pathogen itself. Future weather conditions for each month of the year were inferred based on meteorological records from the nearby Hagerstown Airport. Simulations were conducted under the conservative assumption that there was no environmental decay of the pathogen. There is no documentation on whether susceptible host concentrations were incorporated into the analysis of risk. The choice of *C. burnetii* and *Ebola* virus is puzzling. *C. burnetii*, a rickettsial agent that causes Q fever, is found in livestock reservoirs around the world, and is very capable of aerosol dispersal. In the United States, 169 cases of Q fever were reported in 2006 (CDC 2008). It can be isolated from pastureland in Maryland used for rearing sheep. Person-to-person transmission has not been documented. Thus, there is a low pre-existing risk from *C. burnetii* to all Maryland residents; the described release may not significantly enhance this risk. For *Ebola* virus, the only documented transmission route from human-to-human is through direct contact with body fluids (Pourrut et al. 2007).

Using the HPAC software package, puff-releases of aerosolized pathogen following large reportable accidents in the laboratory were simulated and the concentrations of pathogen, measured in human infectious doses, were calculated. Considering a range of common meteorological conditions over the course of a year, it was determined that pathogen concentrations were insignificant at ground level beyond 300 meters from the points of release in all scenarios, the shortest distance to the Fort Detrick fence line. These results were considered conservative because of the large puff size and an infinite environmental half-life of selected pathogens, which ignores natural decay and environmental factors that can significantly affect viability and infectious potential. The EIS concludes that there is no significant risk to the public from such an event based on these low concentrations.

This analysis of aerosol dispersal risk is incomplete, and was not reproducible. The committee's attempts to independently verify the calculations of doses of infectious agents delivered off site following puff releases found significantly higher concentrations than described in the report. However, the EIS's published results are difficult to verify directly because specific data and parameterizations of the simulation scenarios are not provided and the HPAC software is a closed-source system not available for independent review. In addition, the presentation of the risk analysis was incomplete. The most appropriate measure of per-person risk would be total infectious agent dose, which is calculated by the integration of concentration over time, with appropriate physiological parameters. The EIS presents no documentation of an individual's risk of infection (e.g., based on dose-response parameters) under the prescribed conditions or any description of the effect of population density and population size on the number

of cases expected. For most BSAT and other pathogens, human infectious dose-response relationships are poorly characterized. Despite the criticisms presented here, the aerosol release scenario is significantly more transparent than the other scenarios discussed in the EIS. Because of the issues raised here, the committee does not have a high degree of confidence in the conclusions of the Hazard Assessment about this or the other MCE analyses.

Risk of Secondary Transmission to the Community

In addition to the shortfalls above, no modeling was performed on transmission of disease from an infected laboratory worker to family or community members. A review by the committee of the agents to be handled at the new USAMRIID facility indicates that very few are easily transmitted among humans. But members of the Frederick County community have identified laboratory-acquired infections as a concern, both because of the risk to facility employees but also because they believe that employees could spread unusual and difficult-to-treat diseases to their families and the community at large.

The EIS does not undertake any quantitative estimation of the risks and consequences of secondary infections that may occur subsequent to index cases. The primary reason for this appears to be that human-to-human transmission of most agents under study is rare. It is further noted that rapid detection of a biosafety failure and the quick diagnosis of index cases will minimize further risk to the general public. Impacts from secondary infections following an initial infection will not vary among the three alternatives under consideration, as their spread in the community will not depend on the construction of the new USARMIID facility. However, secondary transmission risks are important components in the totaling of the consequences of individual biosafety failures.

In cases involving communicable agents, a single index case of infection can have disproportionately large adverse public health consequences if effective control measures are not in place. Two laboratory-acquired infections from the past decade have demonstrated that laboratory personnel can mediate significant public exposure (see Chapter 2). When accounting for risks posed by laboratory-acquired infections or the aerosol release of a pathogen, it is crucial to account not just for index cases of infection caused by direct exposure to pathogen release, but also secondary cases of infection that may result from the transmission of infection from an index case to members of the general public. An established set of tools exists within the academic literature on infectious diseases to assess such risks. Kermack-McKendrick and Reed-Frost models can be specified with relatively limited data in terms of basic reproductive numbers and serial intervals. They can be used to assess worst-case scenarios for the likelihood of an epidemic occurring, predict speeds of epidemic spread within a community, and estimate the total number of people infected. Alternatively, large agent-based simulation models can incorporate detailed geospatial, demographic, and socio-economic data to provide fine-grained projections about

transmission risks and the efficacies of mitigation strategies. These methods have been used in other contexts, including the MIDAS project's pandemic preparedness efforts (NIGMS 2010) and the Government Accountability Office (GAO 2009) evaluation of risks of relocating research on foot and mouth disease at Plum Island Animal Disease Center to the mainland.

Evaluation of mitigation strategies in all infectious disease models will require detailed knowledge of the ecology and lifecycles of the pathogen. To identify an appropriate MCE, a detailed enumeration of all laboratory pathogens and their characteristics would be needed. This is probably not possible for many pathogens because of incomplete scientific knowledge. Many of the characteristics are widely available, although some remain unknown. For example, a complete enumeration of all characteristics is not even known for influenza, a virus that has been studied for decades.

A list of pathogens under study at USARMIID is provided by the EIS, but the epidemiologic characteristics, including transmission pathways, natural reservoirs, geographic distributions, and clinical outcomes of the pathogens, are not systematically documented. While the pathogen characteristics are crucial components of the risk assessment, the EIS does not appear to systematically stratify the risks of different pathogens to the general public. For instance, diseases that rely on arthropod vectors for transmission can be studied without significant risk of secondary transmissions so long as they are incompatible with the native arthropod populations. Such analyses would identify maximum credible risks, and would also provide guidance for the on-going mitigation of risk as emerging pathogens are added to the list of research candidates.

Other Community Risks

The EIS Hazard Assessment addresses the risks posed by laboratory rodents, rabbits, and primates to the public. The EIS summarizes design features and practices that make the escape of a laboratory rodent or rabbit very unlikely. A similar summary indicates that primate escapes are also highly unlikely under best practices. No calculations or comparative analyses are provided, but histories of BSL-3 and BSL-4 laboratory incidents are consistent with these conclusions (DHS 2008).

If a small mammal infected with a biological agent did escape from the laboratory, the EIS states that there is only a small chance the agent would be transmitted to a compatible human host or animal reservoir. No data, analysis, or calculations are provided to support this conclusion. Events subsequent to the escape of a non-human primate are not addressed, as primate escape is considered significantly less likely and easier to mitigate.

The hazard analysis does not address risks from arthropod escape. Several biological agents that may be studied at the new USAMRIID facility are transmitted by arthropod vectors (fleas, mosquitoes, and ticks), and the vectors may be employed in the course of research. The EIS should have addressed potential

concerns that an arthropod escape leading to the establishment of pathogen in a native animal or vector reservoir could result in long-term elevation in disease risk to the general public.

POTENTIAL SCENARIOS IN THE CONTEXT OF MAXIMUM CREDIBLE EVENTS AND RISKS TO PERSONNEL

The EIS does not provide scenarios describing potential exposure risks involving pathogens to USAMRIID laboratory personnel, but does cite a brief history of laboratory-acquired infections between 1989 and 2002. Review of these cases illustrates both means of transmission and procedures in place to address identification and treatment of affected laboratory workers (Section 2.3.4.3 of the EIS). Common risks to workers are needle- or sharps-stick accidents, inadvertent aerosol generation that leads to inhalation or ocular/mucosal exposure, and contact with infected laboratory animals. In the latter case, animal caretakers or laboratory workers may be exposed to zoonotic agents, such as Herpes B virus, from contact with laboratory animals; infectious aerosols shed in urine, blood, and other body secretions; or pathogens from bites and scratches (either from caged or escaped animals).

When assessing risks to laboratory workers, reasonable scenarios can be developed using two simple and direct methodologies. One is to consider case studies of past events. The EIS does this in its discussion of a case of glanders acquired in 2000 (discussed in Chapter 2). The other methodology would be to consider the most credible exposure routes for laboratory workers. These should include needle sticks and aerosol events. Standard operating procedures are key in understanding, assessing, and mitigating the risks from credible events.

Laboratory-acquired infections happen but are rare when compared to the thousands of person-years worked and number of laboratory-acquired infections resulting from exposure to pathogens. Based on a review of 234 recognized potential exposures and illnesses over a 14-year period (Rusnak et al. 2004b,c), the EIS cites only five recognized infections. All illnesses were caused by agents requiring BSL-3 containment. No infections have been reported for workers in U.S. laboratories under BSL-4 conditions. Exposures in BSL-3 laboratories that result in infection are infrequent. The EIS (Section 2.3.4.3) describes programs (i.e., training, special immunizations and medical monitoring, and reporting requirements) and regulations to identify and report potential exposures. Such reports initiate a monitoring process appropriate for the exposure circumstances and the infectious agent involved. One of the cited laboratory-acquired infections involved a worker who in 2000 became infected with *Burkholderia mallei*, the causative agent of glanders. This case illustrates a failure at the user level. The individual did not follow standard operating procedures requiring glove use (resulting in inadequate personal protective equipment [PPE]) and requiring the prompt reporting of illness to USAMRIID's Special Immunization Program clinic.

EISs recently developed for two other BSL-3/BSL-4 laboratories, the National Bio- and Agro-Defense Facility (DHS 2008) and Rocky Mountain Laboratories (NIH 2004) provide insights to laboratory-acquired infections based on person-hours worked in USAMRIID, CDC's Special Pathogens Branch, and the National Institute for Communicable Diseases (NICD), a branch of the South Africa National Health Laboratory Service. Tables 4-1 and 4-2 point to the extremely low occurrence of laboratory-acquired infections based on personnel hours worked in BSL-3 and BSL-4 in three different institutes (DHS 2008).

TABLE 4-1 Personnel Hours Worked and Outcomes of Accidental Exposures to Infectious Agents: Intramural National Institute of Allergy and Infectious Diseases 1982-2003

	Hours at Risk		
	Bench	Animal	Total
BSL-3	553,000	81,500	634,500
BSL-2/3 P[a]	2,235,500	360,200	2,555,200
Total	2,788,500	441,700	3,189,700
	Outcomes of Accidental Exposures		
	Clinical Infections	Silent Infections	Other Exposures, No Infections
BSL-3	1	2	9
BSL-2/3 P[a]	0	2	15
Total	1	4	24

[a]P refers to partial, which was used in past practices preceding *Biosafety in Microbiological and Biomedical Laboratories* requirements. Partial laboratory status refers to the absence of single-pass directional air flow through a HEPA filter within the laboratory; however, all bench work was conducted within a biosafety cabinet (BSC), which incorporated HEPA filtration within the BSC before air was exhausted from the BSC to the facility heating, ventilation, and air conditioning system. Source: DHS 2008.

TABLE 4-2 Personnel Hours Worked and Outcomes of Accidental Exposures to BSL-4 Agents 1972-2003

	Hours at Risk	Incidents	Infections
USAMRIID	343,980	2	0
CDC Special Pathogens	120,560	2	0
NICD	40,000	2	0
Total	504,540	6	0

Source: DHS 2008.

Aerosol exposure is frequently associated with laboratory-acquired infections, often because only a small proportion of such infections are associated with a recognized accident (Pike1979). There are, however, ample examples of laboratory-acquired infections transmission via the aerosol route, such as events involving *Brucella* (Olle-Goig and Canela-Soler 1987; Staszkiewicz et al. 1991), *C. burnetii* (Meiklejohn et al. 1981), and Venezuelan equine encephalitis (VEE) virus (AVMA 2006). Additional examples are also provided in Chapter 2, Table 2-1.

A reasonable and credible scenario for an aerosol exposure in a BSL-3 laboratory might involve a laboratorian ignoring proper practice and creating a respirable aerosol while working at a biological safety cabinet. Assuming that the laboratorian was not wearing respiratory protection at the time (respirators are not universally required for work in BSL-3 labs) an unrecognized exposure and subsequent infection could occur. Depending on the agent (*C. burnetii*, for example) the subject would experience the sudden onset of characteristic symptoms. A properly trained employee should recognize these symptoms and report to medical authorities. As noted above, this patient would pose no threat to the community because this agent is not transmitted from person to person.

For the MCE in a BSL-4 setting, the EIS considered an unrealistic centrifuge failure scenario similar to the one for the BSL-3 scenario, with *Ebola* virus as the infectious agent. Except for the Reston *Ebola* virus, which primarily infects non-human primates, *Ebola* is spread by direct contact with infectious blood or other bodily secretions and is not known to be transmissible by the aerosol route (Pourrut et al. 2007). A large aerosol release in a BSL-4 setting would have little effect on laboratory workers unless there was a simultaneous break in the one-piece, positive pressure suit. If the face piece of a suit is damaged, the positive pressure within the suit would limit exposure to aerosols, and the incident would be reportable and an aerosol exposure would be considered in the hazard assessment that would follow. A more likely event would be exposure by a needle stick, animal bite, or broken glass. Unlike aerosol exposures, sharps injuries in a laboratory are obvious and elicit a quick response on the part of the injured laboratorian. USAMRIID has adopted the requirements of the Occupational Safety and Health Administration (CFR 1910/1030; also in *Biosafety in Microbiological and Biomedical Laboratories* [CDC/NIH 2007]) for preventing sharps injuries in its suite-specific safety manuals. Such injuries must be reported and evaluated by a medical panel to assess the risk of exposure. Thus, while a sharps injury in a laboratory at USAMRIID is possible, it is unlikely to result in a risk to the community. The risk to the individual may be high, but recognition of the event limits the unwitting exposure to the community because of procedures and policies in place to evaluate such injuries and promptly institute medical care or isolation as required.

As documented in Chapter 2, USAMRIID has a rigorous biosafety program to prevent or reduce exposure risk for its personnel. The EIS (Section 2.3.4.3) discusses the occupational risks posed by pathogens. A discussion in the EIS regarding PPE, available immunizations, and post-exposure medical evalua-

tion and treatment of workers is needed to provide a comprehensive and balanced assessment of exposure and risk mitigation associated with exposure scenarios and to demonstrate the high level of rigor of the existing biosafety program at USAMRIID. A better scenario would focus not only on the deficiencies and breaches of containment to the environment, but also on the risk posed to the workers in the room and individuals in adjacent work spaces (that is, rooms sharing a common entry corridor).

Reduction in exposures of laboratory personnel to pathogens, and mitigating laboratory-acquired infections through improved biosafety techniques and technology is achievable and can be demonstrated by comparing the frequency of laboratory-acquired infections from the 1950s through 2000 (Sulkin and Pike1951; Sewell 1995; Harding and Byers 2000). Today biological safety is based on a series of controls to include engineering controls, administrative controls, primary barriers, PPE, and workplace practices to achieve safety for the worker and the environment. These controls work in concert and each is designed to reinforce the others. If one control is weak (such as old facilities with aging engineering controls) additional PPE and enhanced work practices and perhaps additional training can be utilized to negate potential deficiencies in the weaker control. (See Chapter 2 for a review of operational procedures and history of laboratory-acquired infections at USAMRIID.)

While not part of the EIS's Hazard Assessment, Section 2.3.4 describes measures to be used to protect both laboratory staff (and by extension, their families and community contacts) and the environment. These measures, based on the controls enumerated above and in Chapter 2, come from the CDC/NIH (2007) and are codified as Army Regulation 385-69 and the Department of the Army Pamphlet 385-69. Governing regulations incorporate by reference a host of federal and state regulations pertaining to laboratory and general safety. The practical application of the broader regulations is detailed in suite-specific safety manuals that are developed for each laboratory unit as required by 42 CFR 73 (2007) (Possession, Use, and Transfer of Select Agents and Toxins).

CONSIDERATION OF ALTERNATIVE CONSTRUCTION SITES

The EIS provided an ample and compelling rationale for why personnel in the new facility would not be able to effectively perform their mission—which is in part dependent on leveraging complementary capabilities of the National Biodefense Analysis and Countermeasures Center and the National Institute of Allergy and Infectious Diseases' Integrated Research Facility—if sited remotely from its current location. However, the National Environmental Policy Act requires consideration of all reasonable alternatives, including reasonable alternatives not within the jurisdiction of the lead agency. In this case, the Army did not analyze any geographic alternative sites. Such an exercise would have allowed for a comparison of the advantages and disadvantages specific to each

location, and help guide strategies and mitigation efforts if differential risks are found. Furthermore, it would have distinguished risks and factors that are dependent on siting location (for example, the potential for disease transmission to livestock and wildlife in rural settings that could result in zoonotic outbreaks, or the availability of medical and emergency response personnel) and those that are independent of site (for example, risks of a malicious insider).

FINDINGS

- The EIS posed several problems:
  - The analyses of the risks and the mitigation measures to address them were not comprehensive and there was insufficient documentation for an independent assessment of the risks to the community posed by biological agents. The problem was compounded by the fact that the MCE scenarios were not reasonably foreseeable accidents.
  - The epidemiologic characteristics, including transmission pathways, natural reservoirs, geographic distributions, and clinical outcomes of the pathogens, were not systematically documented.
  - There was incomplete consideration of some of the possible routes through which the general public might be exposed to pathogens.
  - Although the congressional mandate placing the National Interagency Biodefense Campus at Fort Detrick precludes siting the new USAMRIID facility elsewhere, it would have been appropriate for the EIS to include consideration of an alternative location, such as one in a less populated area. Such an exercise could have provided a comparison that identified advantages and disadvantages specific to each location, and guided preventive strategies and mitigation efforts if differential risks were found.
- Although the EIS hazard assessment failed to provide adequate and credible technical analyses, it was determined in Chapter 2 that current procedures, regulations, physical security, and biosurety guidelines at USAMRIID meet or exceed accepted standards and practices. Thus, the committee has a high degree of confidence that polices and procedures are in place to provide appropriate protections for workers and the public. Furthermore, the review in Chapter 3 indicates that the Army and Frederick County have the resources and the partnerships in place to address medical and emergency situations at the containment laboratories.
- Despite the problems identified with the EIS, the committee judged that it would not be useful to propose specific revisions to the EIS or supplementary analyses. The Record of Decision to construct the new USAMRIID was issued and construction has begun on the project.

RECOMMENDATION

The committee recommends that the Army consider developing detailed and practical guidance for conducting hazard assessments of infectious agents for inclusion in the Army's guidance for implementing the National Environmental Policy Act to improve future EIS processes and products.

5

Communications and Cooperation with the Public

From its own meetings with the public, as well as its review of past public hearings, the committee has identified widespread—but not universal—concern in the Frederick community about the planned expansion of the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID), as well as its continuing operations. A more proactive community relations strategy could not only alleviate some of those concerns, but also could provide a channel through which community members could provide commentary on the ongoing improvement of laboratory policies and practices.

ROOTS OF PUBLIC CONCERN

It is not difficult to understand why many members of the public are seriously concerned about research on biological select agents in their backyard. USAMRIID and other biocontainment facilities were created to study these pathogens because such agents represent a significant threat of deadly epidemics were they to be released into the general population. In fact, at least in the hands of foreign governments or terrorist organizations, many of the pathogens handled at USAMRIID are considered weapons of mass destruction. The entire U.S. biodefense program is predicated on low-probability, high-consequence risk of an attack, so it is easy to see why many Frederick area residents view the risk of an accidental release or intentional diversion from USAMRIID laboratories in the same manner, that is, low probability, but high consequence.

Although some members of the public are concerned about biosafety laboratories sponsored by any organization, many appear particularly wary of USAMRIID, based on Fort Detrick's pre-1969 history as home to the U.S. offensive biological weapons program. Ironically, most are unaware of USAMRIID's contribution to the science of biosafety which grew out of the old offensive programs. Some critics view the biodefense program as biowarfare by another name.

They believe that USAMRIID is collecting or even creating biological agents that could be developed into an offensive weapons capability, despite the defensive focus of the program.

Some community members appear to have been comfortable with the level of biodefense research conducted at Fort Detrick prior to 2001, but as they have become aware of the expansion of select agent laboratories both at USAMRIID and elsewhere in the United States, they fear that the rapid growth will lead to a weakening of security and safety practices.

USAMRIID is subject to federal law, but not necessarily to local laws and regulations. In displaying confidence that it is working hard to prevent incidents and accidents, USAMRIID leadership is perceived as arrogant by many of its critics. Thus, some in the community feel that the Army, in approving its own construction proposals and National Environmental Policy Act (NEPA) documentation, has not been responsive to their concerns.

As elsewhere, past incidents and infections have heightened public concern. The Federal Bureau of Investigation's (FBI) conclusion, several years after the "anthrax letters," that a USAMRIID insider was responsible for the incidents, demonstrated that a risk the Army was previously unwilling or unable to quantify was indeed real. (Note that the FBI's public findings on the anthrax mailings came after the publication of the USAMRIID EIS.)

Finally, issues not directly related to USAMRIID's performance amplify the concerns of many in the community. Neighbors of Fort Detrick, particularly those near its Area B (recently added to the U.S. Environmental Protection Agency's National Priorities List), mistrust the base leadership because Army pollution has contaminated private wells. They say that Fort Detrick's slow response demonstrates that the Army does not care about their health. Neighbors also are concerned about other environmental impacts, such as traffic, that are far beyond the scope of this report.

PUBLIC CONCERNS ABOUT THE RELEASE OF PATHOGENS

There is concern in the greater Frederick community that USAMRIID, along with other laboratories at Fort Detrick, poses a serious threat to public health and safety. In fact, this is why Congress commissioned this review by the National Research Council (NRC). The committee recognizes that USAMRIID and its proposed expansion enjoy the support of many members of the community beyond its staff, contractors, and retirees, but, at the same time, there is vocal opposition. This has been expressed by elected officials, the editorial staff of the daily newspaper, and by the dozens of citizens who have appeared at a series of public hearings on the subject. It was beyond the scope of the committee's task to poll the community.

Opponents of laboratory expansion have argued that they would be safer if USAMRIID were to site all or some of its operations in an unpopulated area, but a comparison study is also beyond the committee's charge. People are concerned

that pathogens from the laboratory will be transmitted to the local community. They relate reports of laboratory-acquired infections, laboratory accidents, inadequate tracking of biological materials, and the deliberate removal of agents from the laboratories.

The committee finds that USAMRIID has a robust, continuously improving program for protecting both its workers and the public (see Chapter 2), but it recognizes that even with the best policies and practices there is no way to ensure that no infectious organisms will ever escape to infect individuals in the local community.

Though the committee finds that USAMRIID's safety program meets or exceeds applicable standards, it also finds that USAMRIID has done an inadequate job of communicating and cooperating with the public, particularly in developing the EIS. While *zero* risk may be unattainable, the committee believes that USAMRIID can do more to improve community confidence that it is acting conscientiously to prevent the spread of laboratory-caused disease.

For example, at the November 19, 2007, public meeting convened by the Frederick County Board of Commissioners (DVD submitted by Jan Gardner, President, Frederick County Commissioners), a member of the public compared the brief description of the 2000 glanders case in the EIS with the detailed descriptions of this case in journal articles (Srinivasan et al. 2001; Rusnak et al. 2004c). With USAMRIID deliberately minimizing the seriousness of the accident, the speaker questioned how the public could have confidence in statements about the true health risks inherent in the proposed expansion.

Ironically, the journal article cited by the commenter, as well as others produced by USAMRIID staff, demonstrates the facility's ongoing and systematic approach to reducing laboratory-acquired infections. The EIS and its associated Hazard Assessment would have better served the Army if it had provided more detail on the history of laboratory-acquired infections at the facility as well as USAMRIID's efforts to learn from past exposures.

Similarly, USAMRIID has published lists of pathogens to be handled at the expanded laboratory. The public, however, is unaware that most of the pathogens under study have limited capacity for being transmitted from human to human. This and other concerns about the nature of organisms and the research program have not been well addressed either in the EIS or in other public documents. Nor does it appear that the public is aware that none of USAMRIID's research is classified (USAMRMC/USAG 2006).

THE IMPORTANCE OF TRUST

Establishing trust is key to successful public interactions in evaluating and responding to risk. Slovic, for example, suggested that more public participation in both risk assessment and risk decision making would "make the decision process more democratic, improve the relevance and quality of technical analysis, and increase the legitimacy and public acceptance of the resulting decisions"

(Slovic 1999, p. 689). The NRC (1996) proposed a model in which the formal risk assessment step is preceded and accompanied by a broad interaction with stakeholders. Renn (1999) has outlined several strategies for this process, including its use in the context of facility siting decisions or other matters of environmental controversy. In retrospect, it may be that the judicious use of such approaches at the outset of the decision planning process might have reduced the degree of contentiousness associated with the decision or even led to a more widely accepted decision.

Developing and sustaining public trust is essential to the effective long-term operations of USAMRIID. Reviewing the community relations program at the Canadian Science Centre for Human and Animal Health in Winnipeg, Keith and Wagener (2004, p. 194) wrote:

> Having a strong community relations program is important not only because of what opposition may mean for a facility but also because of the potential impact on the facility's ongoing reputation. The impact of an incident within an environment lacking in trust can extend far beyond the easily identified direct harm and can include long-term costs often not considered in cost-benefit analyses. Damage to the reputation of one facility may even have a ripple effect than can impact other facilities of the same nature.
>
> A good reputation within the community can mean potential partnerships, more accommodating politicians, and greater interest from prospective employees. It can also minimize public alienation during difficult times. If the facility has shown itself to be trustworthy, people will be more likely to support it in times of difficulty.

Trust does not necessarily mean agreement. That is, community members may still question the laboratory's mission or the magnitude of the Nation's biodefense program. But they may come to recognize that given that mission, USAMRIID is committed to operating safely and to protect its employees, its neighbors, and the entire Nation.

Race (2008, p. 45) summarized research findings on community trust:

> While accurate, detailed message content is necessary, it is likewise important to recognize that trust, transparency, competence, and avoiding secrecy are essential for effective risk communication. If the public is distrustful of officials because of credibility problems, past history, or social alienation, even the best-designed risk communication efforts may be unsuccessful, or impeded. Overall, communication must be a proactive dialogue that addresses the needs of diverse audiences and stakeholders, starts from the earliest planning stages of a project, and continues through project operations.

There are three key elements to the development of public trust. One is to perform in a way that merits public trust. In this case, that means maintaining and continuously improving practices that protect the public from infectious disease. A second element is communicating those practices to the public in an open, transparent fashion. The third element is listening to public concerns and addressing them when appropriate.

A NEW APPROACH TO COMMUNICATIONS AND COOPERATION WITH THE PUBLIC

Although the committee does not believe that improved communication will eliminate all opposition to USAMRIID's operation or expansion, a proactive community relations strategy can build trust, alleviate concerns about community safety, and provide an opportunity for community members to participate in the continuous improvement of laboratory practices. The Army should go beyond demonstrating that it is following the rules and procedures that govern its operations and more directly answer the specific concerns raised by its critics. Furthermore, as Race (2008, p. 45) found, "Ongoing communications involving true public dialogue and engagement—not just press releases and announcements—must be part of the lifetime of these facilities."

First, environmental studies and hazard assessments should report the type of laboratory incidents and laboratory-acquired infections described in USAMRIID's scientific literature, as well as actions taken to prevent them. Safety and security failures, along with their countermeasures, should be reported promptly to the public. The tendency to minimize such rare accidents has created mistrust among the local population.

Second, USAMRIID should consider holding an "open house," which might include displays showcasing its approach to safety, before the new laboratory begins operations. The December 1996 open house at the Winnipeg Canadian Science Centre provides a successful model (Redekop 1996). It is likely that members of the Frederick community are unaware of the engineering controls and security procedures designed to minimize the risk of accidental infections. With careful planning, such an event could be conducted without risking the security of the facility. Such an open house also would provide concerned community members an opportunity to suggest improvements in safety and security.

Third, USAMRIID, perhaps in cooperation with other laboratories at the National Interagency Biodefense Campus, should consider creating a visitors' center containing inactive—that is, without agents—models of laboratory operations to provide continuing opportunities for the public to understand its operations. While such a center might be located within the gate of Fort Detrick, the Army's Chemical Demilitarization programs have found it productive to establish outreach offices in the host communities.

Fourth, USAMRIID and other laboratories handling pathogens could provide fact sheets to describe the pathogens that they are researching. Public testimony suggests that the undifferentiated knowledge of select agents compounds people's fears.

Fifth, and most important, the committee believes that two-way communications between USAMRIID and the public at large, including its critics and opponents as well as its supporters, would best be served by the creation of a community advisory board that meets regularly. At such meetings, led by USAMRIID personnel with administrative, not just public relations, responsibility, the Army should report regularly on problems, successes, and improvements in policies and practices. It should take suggestions from the public and work with public representatives to prepare fact sheets and other educational materials. By meeting regularly, the advisory group would create a group of lay participants with above-average understanding of the laboratory's work, establish a mutual problem-solving mentality, and if successful, build trust. While the proposed board would be advisory, with no formal decision-making authority, USAMRIID should obligate itself to respond to all suggestions and comments offered by members of the proposed board.

Fort Detrick's Garrison already operates a Community Liaison Council, which is said to be convened quarterly and attended by local community and political leaders. Its stated intent is to provide a platform for the Garrison Commander to provide information and updates about Fort Detrick programs, construction, and environmental issues and to get feedback from community leadership. Fort Detrick's Installation Restoration (clean-up) Program also sponsors a Restoration Advisory Board. While similar in structure to the proposed USAMRIID advisory board, these two bodies fulfill different functions.

Sixth, USAMRIID should work with public representatives on the proposed board to develop guidelines for reporting incidents, accidents, and laboratory-acquired infections to the public—that is, who should be notified and when. Some events may merit immediate notification of public officials or the public at large, while for others periodic summaries may prove sufficient.

Seventh, a non-governmental member of the advisory board, as well as a representative of local government, should be invited to serve on the Institutional Biosafety Committee.

Finally, members of the Frederick community have expressed the need for the various laboratories that make up the National Interagency Biodefense Campus to coordinate and streamline their communications with the public.

This committee has not reviewed the community relations activities and plans of the other laboratories on the National Interagency Biodefense Campus. Indeed, it is beyond its scope. Nevertheless, the committee urges USAMRIID to consider whether it might strengthen and/or simplify its community relations strategy by combining or coordinating the above suggested activities with the other agencies on the campus.

FINDINGS

- A segment of the local population around Fort Detrick is not satisfied that the Army is doing everything it can to protect them from infection by pathogens being studied at USAMRIID.
- Communication between USAMRIID and the Frederick community has not been adequate to address community concerns. The community has not been made aware of the details of the many safeguards already in place at USAMRIID, the requirements governing the operation of biocontainment facilities, and the Army's ongoing commitment to improving safety and security.

RECOMMENDATIONS

- USAMRIID should expand its two-way communications with the public. Examples of possible communication efforts are:
  - Promptly disclosing laboratory incidents to the public,
  - Providing fact sheets about pathogens being studied, to include information on their natural reservoirs and how they are transmitted, and
  - Holding an open house prior to activation of the new USAMRIID facility or opening a visitors' center.
- USAMRIID should consider strategies that have been used by other containment laboratories (e.g, the laboratory in Winnipeg) to enhance community understanding and facilitate integration into the community. If possible, such communication strategies could be coordinated with the two other laboratories of the National Interagency Biodefense Campus.
- USAMRIID should involve the Frederick community in ongoing activities related to improving safety at the laboratory. For example, it might be useful to include community members on the Institutional Biosafety Committee or other relevant committees.
- USAMRIID should create a community advisory board, with a broad representation of community views. This board should meet regularly to learn about successes, problems, and improvements in policies and practices; encourage public suggestions for improvements; and help shape the laboratory's public communications strategy and activities—including the development of guidelines for reporting incidents to the public. It would be helpful to create such an advisory board as soon as possible so that it can be engaged with the ongoing activities associated with the construction of the new facility.

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Appendix

Biographical Information on the Committee to Review the Health and Safety Risks of High-Biocontainment Laboratories at Fort Detrick

CHARLES N. HAAS (*Chair*) is the L.D. Betz Chair Professor of Environmental Engineering and Head of the Department of Civil, Architectural, and Environmental Engineering at Drexel University. His broad research interests are in drinking water treatment, bioterrorism, and risk assessment. Specific research activities include assessment of risks from exposures to deliberately released agents; engineering analysis and optimization of chemical decontamination schemes; microbiological risks associated with pathogens in drinking water, biosolids, and foods; novel kinetic models for disinfection processes and process control; and use of computational fluid dynamics for process modeling. Dr. Haas is co-director of the Center for Advancing Microbial Risk Assessment that is jointly funded by the U.S. Department of Homeland Security and the U.S. Environmental Protection Agency. He received his M.S. from the Illinois Institute of Technology and his Ph.D. in environmental engineering from the University of Illinois. He is currently a member of the National Research Council's (NRC's) Water Science and Technology Board.

NANCY D. CONNELL is professor of infectious disease in the Department of Medicine at the University of Medicine and Dentistry of New Jersey (UMDNJ), New Jersey Medical School. Her major research focus is the interaction between *Mycobacterium tuberculosis* and the macrophage. She directs the UMDNJ Center for Biodefense, which does research into detection and diagnosis of biowarfare agents and in development of biodefense preparedness training programs. She chairs the Recombinant DNA Subcommittee of the Institutional Biosafety Committee, and directs the Biosafety Level 3 Facility of UMDNJ's Center for the Study of Emerging and Re-emerging Pathogens. Dr. Connell was a member

of the NRC Committee on Testing and Evaluation of Biological Standoff Detection Systems and the Institute of Medicine (IOM) Committee on Advances in Technology and the Prevention of their Application to Next Generation Biowarfare Agents. She received her Ph.D. in microbiology from Harvard University.

DONALD A. HENDERSON is a resident scholar at the Center for Biosecurity at the University of Pittsburgh Medical Center. He was the first Director of the Office of Public Health Emergency Preparedness, and continues to serve as the senior science advisor to the Secretary of the Department of Health and Human Services. Dr. Henderson is a Johns Hopkins University distinguished service professor and dean emeritus of the Bloomberg School of Public Health, with appointments in the Departments of Epidemiology and International Health. He is also professor of medicine and public health at the University of Pittsburgh School of Medicine. Dr. Henderson directed the World Health Organization's global smallpox eradication campaign, and was instrumental in initiating the organization's global program of immunization. He received his M.D. from the University of Rochester School of Medicine and his M.P.H. from the Johns Hopkins University School of Hygiene and Public Health. He was elected to the National Academy of Sciences and the IOM in 1978.

MARK T. HERNANDEZ is a professor in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado at Boulder. His research interests lie at the cusp of molecular biology and civil engineering, including biological air pollution, sustainable industrial green chemistry, and biogenic acid production. Recent work has focused on tracking bioaerosols in the quarantined Katrina flood zone and in observing seasonal variation in biogenic aerosols in the urban Northeast and Mountain West United States. He attained his professional engineering registration after receiving all of his degrees and serving a post-doctoral tenure at the University of California's Engineering College on the Berkeley campus. Dr. Hernandez currently serves as an editor of the Journal of Aerosol Science and Technology, and is the director of the Colorado Diversity Initiative.

BARBARA JOHNSON has over 15 years of experience in the U.S. Government in the area of biosafety, biocontainment, and biosecurity, and is president of the consulting company Barbara Johnson & Associates, LLC. She has managed the design, construction, and commissioning of a BSL-3 Aerosol Pathogen Test Facility, and launched the U.S. Government's first chemical and biological counterterrorism training facility. Research areas include biological risk assessment and mitigation, testing the efficiency of respiratory protective devices, and testing novel decontamination methods against biological threat agents. In the private sector she pioneered the development of the first joint biosafety and biosecurity programs between the United States and institutes in the former Soviet Union. She has served as president of the American Biological Safety Association, and is co-editor of the journal Applied Biosafety. Dr. Johnson currently

serves on the NRC committee providing continuing assistance to the National Institutes of Health (NIH) on preparation of additional risk assessments for the Boston University National Emerging Infectious Diseases Laboratory. She received a Ph.D. in microbiology and is a registered biosafety professional.

HENRY M. MATHEWS is a consultant in biosafety and biocontainment. He also holds an appointment as an adjunct associate professor in the Rollins School of Public Health at Emory University, and is a course instructor in the Emory University Science and Safety Program, an internationally recognized, behavior-based biosafety training program for BSL-3 and BSL-4 laboratories. For 30 years, Dr. Mathews worked at the Centers for Disease Control and Prevention (CDC), where he held several senior positions, including Chief of the Safety Operations Section of the Office of Health and Safety. He was also an adviser to the Associate Director for Laboratory Science on Facility, Safety and Security issues. He participated as a technical expert in the design of the Emerging Infectious Diseases Laboratory, including BSL-2, BLS-3, and BSL-4 laboratories. He also authored operations manuals for laboratories and vivarium facilities. Dr. Mathews also represented CDC in review of laboratories at Dugway Proving Ground (BSL-3), the Southwest Foundation for Biomedical Research (BSL-4), the Canadian National Microbiology Laboratory, the Swedish Institute for Infectious Disease Control, NIH, and Georgia State University. He received his M.S. and Ph.D. in biology from Emory University.

TIMOTHY C. RELUGA is assistant professor of mathematics at Pennsylvania State University. His research interests concern the description, understanding, and prediction of the dynamics of biological systems. Population biology is his core research interest, but his work encompasses topics in evolutionary biology, immunology, epidemiology, and computer science. His most recent work has focused on incorporating social and behavioral factors into theories of infectious disease dynamics and management. Dr. Reluga received his Ph.D. in applied mathematics from the University of Washington.

JONATHAN Y. RICHMOND is CEO of Jonathan Richmond and Associates, a biosafety consulting firm with a global clientele. Prior to starting his own firm, Dr. Richmond was the director of CDC's Office of Health and Safety in Atlanta, Georgia. He is an international authority on biosafety and laboratory containment design. Dr. Richmond was trained as a geneticist, worked for 10 years as a research virologist, and has been involved in the field of biosafety for the past 32 years. He has authored many scientific publications in microbiology, chaired many national symposia, edited numerous books, and is an international consultant to ministries of health on laboratory safety and training. He served as president of the American Biological Safety Association. Dr. Richmond received his M.S. in genetics from the University of Connecticut and his Ph.D. in genetics from Hahnemann University.

LEONARD M. SIEGEL is director of the Center for Public Environmental Oversight (CPEO), a project of the Pacific Studies Center that facilitates public participation in the oversight of military environmental programs, federal facilities cleanup, and brownfield revitalization. He is one of the environmental movement's leading experts on military facility contamination, community oversight of cleanup, and the vapor intrusion pathway. For his organization he runs two Internet newsgroups: the Military Environmental Forum and the Brownfields Internet Forum. He is a member of the Interstate Technology and Regulatory Council's Permeable Reactive Barrier Work Team, the Department of Toxic Substances Control (California) External Advisory Group, and the Moffett Field (formerly Moffett Naval Air Station) Restoration Advisory Board. He has also served on several NRC committees, most recently as a member of the Committee on Review of Secondary Waste Disposal and Regulatory Requirements for the Assembled Chemical Weapons Alternatives Program. Mr. Siegel studied physics at Stanford University.