University Research Centers of Excellence for Homeland Security: A Summary Report of a Workshop

Alan Shaw, National Research Council

ISBN: 0-309-53272-8, 30 pages, 8 1/2 x 11, (2004)

University Research Centers of Excellence for Homeland Security

A Summary Report of a Workshop

Alan Shaw
National Research Council

Division on Engineering and Physical Sciences
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

Support for this project was provided by the Department of Homeland Security under Purchase Order Number 248836. Any views expressed in this publication are those of the workshop participants and do not necessarily reflect the views of the agency that provided support for the project.

International Standard Book Number 0-309-09236-1 (POD)
International Standard Book Number 0-309-53272-8 (PDF Full Book)

Available from the National Academies Press, Lockbox 285, Washington, DC 20055; 800-624-6242 or 202-334-3313 (in the Washington metropolitan area); www.nap.edu.

Printed in the United States of America

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Wm. A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Wm. A. Wulf are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

ORGANIZING COMMITTEE

LEWIS M. BRANSCOMB, Harvard University (Emeritus)
M. GRANGER MORGAN, Carnegie Mellon University
NEIL J. SMELSER, University of California, Berkeley

Preface

As the Department of Homeland Security (DHS) passes its 1-year anniversary, Secretary Tom Ridge often cites the essential role of science and technology (S&T) in the nation's efforts to "carry out a vigorous and ambitious slate of [homeland] security initiatives."[1] Congressional appropriations for DHS include substantial funding for S&T efforts, including research and development (R&D). Indeed, Congress acknowledged the key role science and technology would play in the nation's efforts to counter terrorism by including the S&T Directorate prominently in the organizational structure of the new department.[2]

In organizing the new S&T Directorate, DHS established two major new entities, the Office of Research and Development (ORD), which focuses on the use of federal laboratories and facilities as well as universities to advance S&T objectives, and the Homeland Security Advanced Research Projects Agency (HSARPA), which will sponsor activities primarily in industry. Key challenges for both ORD and HSARPA include striking an effective balance between applied and basic research and matching urgent R&D needs to strengthen homeland security with the institutional capabilities most suited to specific research areas.

The nation's universities constitute a formidable resource in both basic and applied research areas. The Office of University Programs within ORD is responsible for sponsoring a number of homeland security centers of excellence (HS-centers) in U.S. universities. These centers are envisaged principally as building important multidisciplinary and crosscutting capabilities in research areas where universities can contribute most effectively to the department's mission and to improvements in technology that will yield the most cost-effective benefits for the prevention, detection, and mitigation of the effects of terrorist actions. Defining and creating HS-centers such that specific research needs are matched to specific center capabilities will be an especially important task for ORD. In November 2003 DHS announced that the University of Southern California had been chosen to host the first HS-center, devoted to the study of risk analysis related to the economic consequences of terrorist threats and events. The FY 2004 congressional appropriations for DHS provide funding for additional centers to be established among the nation's universities. The department plans to establish these centers to work across a spectrum of short- and long-range research and development areas, carrying out crosscutting multidisciplinary research that brings together the nation's best experts and focuses its most talented researchers on a variety of threats that include chemical, biological, nuclear and radiological, explosive, and cyber-threats.

HS-centers will do more than study threats. They will also look at technical means for delivering weapons; sources of vulnerability and thus of targets; public responses to attack or threats of attack; and roots of terrorism and the motivations and intent of terrorists.

In December 2004, DHS issued a Broad Agency Announcement to establish two additional HS-centers focusing on agro-terrorism, and the department expects to establish additional centers over the

[1]See, for example, the testimony by Secretary Tom Ridge on the FY05 Budget before the Senate Appropriations Committee, February 10, 2004.

[2]Creating the S&T Directorate was a key recommendation of the National Research Council's report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*, National Academies Press, Washington, D.C., 2002.

next several years, with the topics for the remaining centers yet to be decided. These centers will be established within official guidelines, including legislation, that specify the following stated purposes:

- Training a cadre of new leaders in science, engineering, and related fields;
- Creating a technical and research skill base to address issues related to homeland security; and
- Producing a broad range of products for strengthening homeland security and countering terrorism.

The individual centers are intended to be valuable producers in their own right, while supporting efforts across the larger DHS S&T program.

In planning for the creation of future HS-centers, the Office of University Programs sought the help of the National Academies' National Research Council (NRC). To this end, the NRC's Division on Engineering and Physical Sciences (DEPS) convened a 1-day workshop on January 29, 2004, that brought together DHS officials with key university officials as well as other experts (many of whom were involved in preparing the NRC report *Making the Nation Safer*, noted above). Appendix A includes a statement of the scope of work and the workshop agenda. Information on the workshop participants is given in Appendix B.

Conceived and tasked as a general brainstorming session to generate a broad range of ideas from which DHS might draw in defining future centers of excellence, the workshop was intended primarily to elicit ideas through a free-wheeling discussion. To help in planning the workshop, the NRC appointed a three-member organizing committee that did not include the workshop co-chairs. As agreed by the organizers and the sponsor (DHS), the workshop agenda formed only a loose framework to stimulate a discussion in which topics emerged, re-emerged, and intertwined over the course of the day. Within the context of existing official legislative guidelines for creating the HS-centers, workshop participants discussed and assessed topical multidisciplinary and crosscutting research areas to help inform DHS as it decides areas in which universities can contribute most effectively to the DHS mission. Participants also suggested additional ideas for consideration by DHS as it sets criteria for the selection of HS-centers. Viewgraphs presented to workshop participants and summarized in this report are posted on the DEPS Web site at www7.nationalacademies.org/deps.

This report summarizes the results of the workshop and presents the major ideas that emerged from the day's discussions, assembling themes and ideas in an order based on the ideas themselves, rather than the order suggested by the agenda. This approach captures the ideas that the workshop generated but does not present the actual flow of conversation over the course of the day.

This workshop report does not make recommendations, nor does it prioritize the ideas that were generated. No priorities are implied in the order in which ideas are presented.

In accordance with procedures approved by the National Research Council's Report Review Committee, this workshop summary was reviewed in draft form by Ashton Carter, Harvard University; Ruth David, Analytic Services Inc.; Marye Anne Fox, North Carolina State University; and Charles M. Vest, Massachusetts Institute of Technology. The review was overseen by Robert A. Frosh, Harvard University. Their effort in this task is much appreciated. Final responsibility for the content of this workshop summary rests with the National Research Council and the author.

Contents

WORKSHOP SUMMARY

Introduction

At the request of the Office of University Programs within the Office of Research and Development (ORD) of the Department of Homeland Security (DHS), the National Research Council convened a one-day workshop to explore specific avenues of university research in advancing the nation's capabilities for developing new science and technology to anticipate, prevent, and mitigate the effects of catastrophic terrorist events. The workshop was tasked with identifying and discussing topical multidisciplinary and crosscutting research areas where universities can contribute most effectively to the Department of Homeland Security's mission and to improvements in technology that yield the most cost-effective benefits in detection, prevention, and mitigation of effects. The workshop participants were invited to define this task broadly. The goal of the workshop was to support the creation of a summary report that could be used by the department to help inform the selection of a number of university-based homeland security centers of excellence. This is that summary report.

The day began with an emphasis on the urgency of developing effective means for countering terrorism and terrorist attacks and a focus on the nation's universities as a major national asset to be harnessed for this effort. Workshop participants were reminded that the National Academies had responded rapidly to the September 11, 2001, attacks by bringing together a group of experts to begin to address how the science, engineering, and health communities could best contribute. The first brainstorming session was held within 10 days of the attacks, and more than 80 relevant academy reports and projects have been developed to date. This workshop is one more important step in that process.

Given the workshop's overarching theme—How can university research centers of excellence optimally contribute to the issues surrounding homeland security?—participants were urged to think expansively in terms of topics to be considered, time scales for university efforts, and other related issues. The workshop co-chairs reminded workshop participants that university centers of excellence for homeland security will help build intellectual assets, educate and train a cadre of experts, and develop a wide variety of products for use in ensuring homeland security. Key aspects will be interdisciplinary research and the ability to interface with government, industry, and other communities involved in homeland security.

In the course of the discussion, the participants defined and broadened the workshop topics as presented in the task statement and agenda (see Appendix A). There was general agreement among the participants—including the representatives of the Department of Homeland Security—that "specific avenues of university research" involved more than just specific topics of university research. In addition to the study topics around which centers of excellence might be organized, these "avenues" include the basic organization of a university research center, and the connection of the center to the various communities that would support it or use its products. Thus, in addition to identifying "specific topical multidisciplinary and crosscutting research areas," workshop participants also addressed and discussed these other considerations. Furthermore, the workshop took a broad view of research as encompassing more than research that leads to technology or to the development of products.

The workshop identified and considered three basic aspects of university research centers of excellence for homeland security:

1. Basic defining topic(s) around which a center could be organized;
2. Organization of the center, including how it relates to the primary sponsoring university, other university-based partners, and partners in other types of organizations, including industry, national laboratories, and government facilities; and
3. Connection to user communities, particularly the broader community beyond DHS.

According to DHS, the centers have a dual mission of (a) conducting research and developing technology and (b) educating students. To be useful, these "products"—research, technology, and educated graduates—must transition into the larger community. To perform effectively, the centers must understand the needs and cultures of user communities and be responsive to users' needs.

The workshop also considered the related questions of (1) how long a center should remain in existence (and if, indeed, it makes sense to consider "sunset provisions") and (2) the relationship of a federally sponsored university center to state and local authorities.

The participants raised, addressed, and challenged the assumption that all university centers of excellence should fit within the cultures, competencies, and communities of top-level research institutions. For example, it was suggested that one or more centers be based in consortia of community colleges, or alternatively that community colleges be included in center-based partnerships or otherwise engaged. In this regard, it was observed that first responders and local security officers are more likely to receive training at community colleges than at major research universities. Ties between research universities and federal departments and agencies are long-standing and have fostered a degree of cultural harmonization that generally does not extend to relationships with state and local law enforcement, firefighting, and emergency medical services personnel and activities.

Identifying Topics for Research Centers of Excellence

Several dozen specific topic areas for research to strengthen homeland security were raised in the workshop, some clearly redundant and others arguably so. These topics fell into three general areas:

1. Specific technologies, including (a) technologies that terrorists could use and that would have to be countered, such as primary weapons technologies (e.g., chemical, nuclear, or biological weapons), and means of delivery; (b) research on modes of attack, targets (e.g., buildings, bridges, power plants, transportation), and sources of vulnerability of specific targets and of larger arrays that include such targets; and (c) capabilities to be developed for broad or specific applications, such as technologies for sensors and networking of sensors and technologies for data mining and for providing information to first responders and other officials.
2. Broad areas of function, which could include research related to understanding terrorism, including its origins, operations, and other specifics; identifying, understanding, and taking into account the interdependency of systems, complex systems, or "systems of systems"; and integrating responses to threats and attacks or understanding the psychological and social aspects of how people respond to acts of terrorism.
3. Broad areas of application—cities, borders, transportation security, critical infrastructure security, ports, hospitals—in all their complexities.

There is clear overlap across these areas. Many individual topics could be put within two or three areas. And as discussion at the workshop made clear, the principle(s) according to which such topic areas might be organized will affect which specific research topics are addressed. The workshop participants did not favor one of these organizing principles over the others, although some participants no doubt had individual preferences. There appeared to be recognition that the final roster of university research centers of excellence for homeland security could well include a few that are organized according to one postulated central principle, and some organized along other lines.

There was also recognition that reality was likely to impose organizing principles unrelated to research topics themselves—for example, regional balance in the placement of the research centers across the nation and also in different types of universities (e.g., balance between public institutions and private ones, or between prestigious universities and emerging schools). There was also some discussion of involving community colleges along with institutions that have graduate, professional, and baccalaureate programs. One participant suggested the involvement of police and fire academies, or similar training schools for first responders, to improve researchers' understanding of what emergency personnel need to do their jobs and also to expose first responders to potential new tools and approaches.

Of the following specific topics suggested at the workshop, some were mentioned several times (by different participants) in somewhat different forms. Some received more discussion than others; some were mentioned more often than others. In keeping with the tasking, no attempt was made to develop a consensus that sorted and ordered the ideas. Instead, the topics are grouped according to logical similarities. The order carries no other significance; i.e., no prioritizing or rank ordering is implied.

All of the topics are broad. All—at either the broad or somewhat less broad levels shown—could be appropriate to organize a center around.

LIST OF RESEARCH TOPICS IDENTIFIED

- Understanding terrorism and terrorists
  - Roots of terrorism
  - Terrorist behavior
  - Terrorist motivations: reducing motivations to engage in terrorism; increasing incentives to other life paths
    - Study of and outreach to educational systems in Muslim countries particularly to introduce science education
- Assessing and countering threats to security
  - Threat anticipation
  - Toxic chemicals: detection, identification, evaluation, response
  - Pathogenic organisms: detection, identification, evaluation, response
  - Nuclear threats and response, including detection of concealed nuclear materials
  - Computer and network security breaches and attacks, to include attacks on SCADA software
  - Low-sophistication, high-consequence threats
  - High-consequence attacks (not necessarily limited to WMD attacks; high consequences are not necessarily synonymous with high immediate casualties): identification, prevention, mitigation
- System-of-systems analysis, modeling, simulation
  - Studies that integrate threats, vulnerabilities, consequences, and opportunities for defense
  - Cities as complex systems with interrelated vulnerabilities
  - Borders
  - Ports
  - Hospitals
  - Transportation security
  - Critical infrastructure security
  - Making complex systems robust against attacks (as an alternative to hardening all components)
  - Balancing security needs and other needs that are affected by security measures (e.g., airport throughput; food quality, availability, price; open access to public places and government facilities)
- Sources of information and their integration
  - Integrated sensor networks to include security and other measures to maintain (and understand) system reliability
  - Data mining
  - Decision models
  - Biometrics and other means of identification as sources of information
- Reactions and responses
  - First-responder studies: understanding how first responders operate and interoperate; developing methods to help different organizations work better together
    - Methods for integration of responses across federal, state, and local authorities; “cultural” integration
    - Applications of organizational theory, communications theory
  - Integration of responses to terrorism with preparedness for more likely, everyday emergencies

  - Public health, to include integrating responses to chemical, biological, and radiological weapons attack; exploitation of recent rapid advances in public health
  - Projecting consequences of various types of terrorist attacks (severity and extent of consequences do not necessarily scale with the severity and extent of an attack)
    - Psychological consequences of terrorist attacks, and reactions they may engender
    - Political consequences of terrorist attacks and of long-standing terrorist threats
    - Collective responses to terrorist-threat-induced uncertainties, to include media coverage and communication, civil rights issues, scapegoating
    - Broad, long-term consequences of an attack as well as immediate effects
  - Law and economics
- Robotics for homeland security applications, including intelligent robots and robotics networks; autonomous operations

These topics could easily be organized in different ways. For example, "reactions and responses" and "understanding terrorism and terrorists" are both predominantly social-science-based topics. This particular list was arrived at by noting the topics that workshop participants suggested, grouping them in a consistent manner, and observing that some of the suggested topics could be subsumed under other, broader, suggested topics, should one decide to do so.

WORKSHOP DISCUSSION LEADING TO TOPICS IDENTIFIED

The topics listed above were neither suggested nor discussed in anything approaching the order of the list—or any other order, for that matter. Rather, they emerged and re-emerged in the course of the conversation. Some surfaced only briefly, while others were discussed from the beginning of the day to the end. Discussions of individual topics were often intertwined. Often, discussions built on earlier discussions. In other instances, topics re-emerged to be discussed in different contexts. Discussions of individual topics were often intertwined with discussions of other topics, for example, structuring of centers, transitioning of products, and so on.

The following highlights the most relevant portions of the discussions in a generally chronological order.

The question of defining consequences of terrorist attacks emerged early, during the DHS presentations that began the day. It was noted that direct consequences, while better understood than indirect consequences, are not necessarily the most significant. Deaths, injuries, and property damage can be measured. Lingering effects—for example, the effects of widespread salmonella outbreaks on the fast-food industry—economic effects, and psychological effects are less well understood. Such indirect effects could be much larger than direct effects.

In response, it was noted that system interdependencies are similarly poorly understood and potentially very significant. For example, much depends on the electric power grid, which in turn depends on supplies of fuel, such as natural gas, to it. Understanding such interdependencies is crucial to anticipating and planning for the indirect consequences of an attack.

Similarly, it was noted that a focus on acute catastrophic consequences could lead to overemphasizing the development of systems that reduce these (e.g., immediate deaths) but do not support limiting indirect consequences.

One identified approach to protecting interdependent systems was to focus on making the systems robust against attack rather than hardening them against attack. The example of

designing traffic signals to be independent of power grid failures was suggested as an alternative to insisting that the power grid be hardened against all possible attacks. In this example, traffic disruption as a consequence of an attack on the power grid could be minimized.

The subject of identifying and bridging cultural differences among institutions also emerged early and persisted as a theme throughout the workshop. Early on, one participant noted that universities and national laboratories don't usually have close working relationships with first-responder communities, e.g., police, firefighters, and emergency medical personnel. Another responded by noting the positive experience at MIT with the Institute for Soldier Nanotechnologies, where students and faculty are enthusiastic about getting into the field and working with the end users.

Somewhat later, the topics of risk assessment, threat assessment, vulnerability, and the role of the social sciences were introduced. One speaker noted that risk communication (and similar topics related to communication) requires attention. Actionable communication to the public is an important aspect of the response to an emergency.

These points led to a return to discussion of the consequences of terrorist acts. It was suggested that a string of low- to moderate-level attacks could have very severe consequences, even if the total number of deaths was low. One speaker offered that he did not know whether the United States could suffer what the Israelis currently suffer and not be profoundly changed, implying that consequences—particularly those arising from sustained attacks—could be far-reaching indeed. Another participant interjected that consequences are a function not just of the event, but also of the way that leadership responds to the event.

These observations were followed by a call for emphasis on "problem-oriented interdisciplinary research" and "system-of-systems analysis" from several participants. One emphasized that "interdisciplinary" should be taken in the most general sense, encompassing physical sciences, life sciences, engineering, and social sciences.

Turning to a more focused topic—in this case sensors—a participant noted that the work needed on sensors goes far beyond the invention and construction of different types of sensors. It is necessary—and difficult—to figure out how, for example, an array of 1,000 sensors of different types, some of which have been destroyed, some of which give false positives, and others of which give false negatives, can be made to provide a single recommendation to a mayor or a police chief. In many cases, the recommendation that would come from an array of sensors would not be sufficient and would have to be combined somehow with recommendations from other, very different sources. Not all of those sources would provide quantitative information.

Returning to the subject of first responders, one participant claimed that not much progress has been made in the last 5 years in giving first responders a real role in identifying technology they need, in coordinating the use of the technology, and in communicating with a range of first responders on technology issues. He also noted that first responders—firefighters, emergency medical services workers, police—see issues that must be dealt with every day as more pressing than preparation for a terrorist attack that might occur some day. They must handle fire, health, and policing problems on a daily basis. It was suggested that progress toward dealing with emergencies caused by terrorist attacks could be made by tying preparation for those emergencies to preparation for similar types of emergencies that have other sources.

Another participant added comments on the issue of access to intelligence information for first responders. Despite recent legislation concerning security clearances for some key people, there is a sense among first responders that much information is being kept from them. It was noted that first responders have a long history of being beleaguered, jurisdictional, and jealous of their prerogatives. During emergencies, squabbling often ensues. In response, it was noted that these same problems existed in the medical community and have been addressed.

A representative of DHS remarked that experience shows that it is often difficult to introduce new technology to first responders after they have left their training academies. It was asked: How do we introduce new technologies into training and education programs?

One participant suggested that the field of terrorist threat assessment is currently scattered among disciplines and departments within various academic institutions. In this view, threat assessment should be approached in a concentrated, integrated manner that brings together the disciplines of political science, economics, psychology, anthropology, history, and so on. A social and behavioral sciences-based program could concentrate on threat assessment, and then on post-attack consequence management, crisis management, and recovery studies.

It was then suggested that threat assessments and vulnerability assessments need to be integrated.

A related suggestion was to concentrate on reducing the incentives to engage in terrorism. Carnegie Mellon University has a center that looks into madrassa education systems, and how to extend opportunities for science and technology careers for Islamic students. Two related problems are understanding and decreasing motivations for following paths that lead to terrorism, and increasing incentives for young people to follow other paths, e.g., studies of science and engineering.

Returning to the topic of networks of sensors, participants noted that such networks must be robust, which in turn requires reasonable security. Practical networks will require, generally, that sensors be low cost. One example that was offered was networks of sensors integrated into the structure of a building. Providing security and encryption for low-cost sensors is a challenge. There are other, related challenges, such as meeting sensor (and other) requirements during construction and ensuring that sensors can operate on very low power.

One workshop participant who had had a long career in both law enforcement and research was asked to comment on the cultural harmonization issue. He likened being in law enforcement to being in a big city hospital emergency room all the time. Reactions have to be rapid; there is no time to give someone something to study and say "come back with results when you have an answer." If the academic world is to help, he said, it has to be able to interface with this culture, this lifestyle. Universities want to get a grant and come back with results when they are ready; that's not how law enforcement and first responders operate. That community operates by who it knows well that can help on a short time scale. Emergency personnel will not be interested in basic research, but in work that can lead rapidly to products. Often, those offering to help the law enforcement community have no idea how it really works. Most of the first-responder community is not used to working with people who hold advanced degrees. Medicine is the exception, as is the FBI. That's another culture gap.

The discussion then turned to biometrics and other means of identification. It was pointed out that it is not enough to identify an individual as being the same one parameterized in a database. It is also important to know something about that person. Is this person who he says he is (i.e., is the ID real or is it fake)? Does this person have hostile intent? These questions need to be addressed.

Beyond the issue of how well techniques like biometrics work is the question of what use can be made of the information that such techniques might provide. If a biometrics technique is 100 percent accurate, how can it be used, and what can be done with the information supplied? This is a system-of-systems issue. What is the use of knowing with 100 percent certainty that a person holding a particular ID card is indeed the person on the card if we know nothing else about that person?

Regarding the application of biometrics and other sophisticated identification techniques at monitored ports and border crossings, it was observed that not everyone who enters the United States does so through official entry points. Making security more robust at official entry points could increase traffic through unofficial entry points. Such outcomes need to be taken into account when deciding how much to invest in better security at official entry points—again, a system-of-systems analysis is required. This approach should also be applied to analyzing the consequences of false positives.

One workshop participant then suggested that rather than focus on technology topics like biometrics, centers might more usefully be defined by topics such as "cities," or "borders," or "transportation." Another participant expanded the list to include "ports" and "hospitals." Such research topics would incorporate many of the elements touched on in the workshop discussion. Taking an interdisciplinary approach to areas of broad function would serve a number of purposes. It would address dual-use issues, such as how to respond to emergencies other than terrorist attacks. It would also focus attention on basic questions such as how the capacity of a system or the security of a system could be rapidly raised (i.e., "surged") during an emergency, and understanding how an entire system works in detail and in the aggregate.

The discussion then returned to addressing interdependencies of infrastructures, and then back to the origins of terrorism. One participant suggested that it would be useful to consider how to deal with cultures where little children are taught to hate Americans and Jews.

One participant suggested the following as broad topics around which to organize research centers of excellence for homeland security: (1) risk analysis and risk communication; (2) security and cities in the 21st century; (3) border security; (4) transportation security; and (5) critical infrastructure—the science and technology involved in dealing with critical infrastructure. Another noted that these were all "system-of-systems" topics, a subject evident throughout the entire day's discussions. Yet another suggested that centers based on these topics could usefully be oriented not just to dealing with terrorist threats, but also to advancing conventional civil missions. Such an approach would enhance the prospects that identified solutions would actually be implemented.

Another participant offered the following grouping of topics: (1) sensor networks, information management, and emergency decision support; (2) detection, identification, and warning of biological and chemical agents prior to clinical manifestations; (3) behavior and psychology of terrorists; and (4) systems studies of large metropolitan areas as multipoint targets.

Another proffered list was (1) cities, (2) ports, (3) borders, (4) communications, (5) transportation, (6) risk assessment and risk communications, (7) hospitals, (8) transportation security, and (9) critical infrastructure. There was some discussion of whether hospitals were really a DHS problem or a public health problem.

The group was reminded that the National Research Council study that produced *Making the Nation Safer* first structured its panels along the lines of cities and transportation, but then added specialty panels to address such areas as information technology, nuclear and radiological threats, and toxic chemical and biological threats.

One participant brought up the topic of autonomous operations, including the concept that robots, remotely operated vehicles, and so on could take on tasks that were too dangerous for first responders. Another participant returned to issues related to the collective response to terrorist threats and attacks and added as possible topics for research the news media, group conflict, scapegoating, civil rights, and political repression.

Yet another participant suggested law and economics and their potential for study in a homeland security context. Laws affect operations, developments, marketing, and so on. Laws, for example, can be made, and written, in the manner of building codes, to institutionalize elements of protection.

Toward the end of the workshop, the discussion turned to cybersecurity, a topic that had been brought up several times throughout the day. Cybersecurity is a field in which very few people are currently trained. It was noted that in the United States seven Ph.D.s are graduated per year in computer security, as compared with several thousand in microbiology. This area has suffered from sporadic funding and lack of a federal agency with responsibility for it. It was pointed out that SCADA software is often written in India or Europe. Compromising SCADA

software could not only bring down power plants, pipelines, and chemical factories but also damage and/or destroy the targeted systems and other systems that are dependent on them.[3]

Organizing and Structuring Research Centers of Excellence

Discussion of the organization and structure of research centers of excellence for homeland security followed presentations made by Fawwaz Ulaby and Granger Morgan on their thoughts on models for center organization. In the course of the discussion, other models were suggested and were discussed as well.

First, Fawwaz Ulaby discussed his ideas for a model of university centers that would consist of partnerships among universities, industry, and national laboratories (or other similar national centers). He described such partnerships as being appropriate to centers focused on technology-based R&D with a strong emphasis on producing engineered products (i.e., equipment) that would be made available to users: Universities have strengths in research and early technology development; industry has strengths in applied research, product development, and system integration; and national laboratories bring specialized instrumentation, secure facilities, and great breadth and depth of competence. Following this model, a typical center might be, for example, a consortium of four universities, two companies, and one or two national laboratories.

Granger Morgan presented two alternative organizational models based, in part, on existing engineering-based policy-oriented multidisciplinary programs at Carnegie Mellon University, MIT, Stanford University, the University of Virginia, and the University of California at Berkeley. He observed that successful evolution of these programs is a strong function of the local culture and of institutional realities. His first model (Model 1) was a center that—although managed by a university and perhaps drawing on its faculty, staff, and students—was outside the university's traditional academic departments and not integral to the core academic activities of the institution and its departments. His Model 2 was a unit integrated into the core academic activities of the institution and its departments. Morgan observed that for many host institutions, Model 1 would be faster and more feasible to establish, could more easily accommodate specific DHS-specified programmatic objectives, and could more easily deal with constraints on information dissemination. If DHS wants sustained production of graduates who will work in homeland security and the benefits of the critical interdisciplinary contributions of a wide range of leading faculty, Morgan said, then Model 2 is superior.

Both Ulaby and Morgan discussed concepts for largely technology-based centers. Each addressed somewhat different aspects of the problem of how to structure such a center. Ulaby's model took into account the numbers and types of institutions that might be members of a university-led center or consortium, and the general process for drawing on their relative strengths to conduct research, technology development, and product engineering. It focused on how universities could partner with private industry and national laboratories. Morgan's models addressed the relationship of a research center to the university with which it is associated. He highlighted the two basic missions of such a center: (1) involvement in research, development, and engineering and (2) education.

[3]Editor's note: Several weeks after this January 2004 workshop, the *Washington Post* reported that during the last years of the USSR the CIA disrupted the gas pipelines in the Soviet Union by sabotaging control software, causing destruction to the pipeline and severe damage to the Soviet economy. David E. Hoffman, "Reagan Approved Plan to Sabotage Soviets," *Washington Post*, February 27, 2004.

It was noted by workshop participants that the models described by Morgan and Ulaby could apply equally well to biology-based science and engineering and to work based on the physical sciences and associated engineering.

Other participants broadened this view to include centers with basic orientations in areas other than (or in addition to) natural sciences and engineering. The "products" of such centers might differ from those of engineering-oriented centers. For example, a center that focused on roots and causes of terrorism, or centers that sought to understand social responses to terrorist actions, would produce research results that could support strategic decisions, rather than specific equipment.

National Science Foundation Deputy Director Joseph Bordogna described aspects of currently operating NSF university centers, with the qualifying observation that NSF's and DHS's respective needs are not necessarily similar. For NSF, supporting education is a major requirement, and proposals are expected to have an explicit education component. Similarly, partners are viewed as vital components of centers. One type of NSF center is established for 10 years and is reviewed on a 3-year cycle. A center can be disestablished after a review. In any case, NSF support ceases after 10 years. If a center is closed, the university can bid to open another—in a new topic area—through the program. He noted that there are centers for which NSF provides only partial funding. The remainder comes from other federal agencies and from the private sector.

Several participants noted that a "one size fits all" approach to setting up research centers of excellence for homeland security would be unwise, considering the great variety of topics and types of centers discussed in the workshop and the different cultures of different universities. It was observed that overly constraining the form of a center that a university could propose would be a mistake. It would make more sense to issue a broadly worded announcement and to rely on the inventiveness of the proposers to come back with good ideas that could then be judged on their own merits rather than their conformity with some preconceived ideas of how a center should be structured and managed.

It was further noted that centers are more likely to attract the best researchers if they avoid overly constraining what the researchers can do—i.e., avoid specifying too closely the problems to be solved. Centers are more likely to be effective in supporting the DHS mission if they are chartered to challenge assumptions, think imaginatively, and look for effective new approaches to the task of defense against terrorism. This approach is consistent with university research operations.

One participant suggested that DHS consider adding funding to existing university centers to enable them to start working on homeland security problems that are related to the work they are already pursuing. This alternative to establishing entirely new centers would leverage other funding and the work that has already been done to establish such centers.

It was further suggested that, considering the broad range of ideas that were discussed, DHS should expect, plan for, and encourage a range of center types. For example, one or two centers might have an explicit high-technology orientation, while the others might be defined according to some of the other organizing principles discussed above.

As noted above, this discussion touched only briefly on the possible relationships between university departments and centers of excellence. This suggests possible topics for future discussions, such as how the issues that underlie the center topics might fit within existing or future educational curricula at sponsoring institutions—for example, system-of-systems analysis, or balancing security needs and throughput rates at locations such as airports.

The question of involvement of foreign students, faculty, research staff, and institutions was briefly raised, but not discussed. This might also be a useful topic for future discussions, with attention to specifics. For example, the implications of multinational participation could be very different for studies of causes of terrorism than they would be for studies of counters to specific attacks, including those that involve weapons of mass destruction.

Aside from the general observations noted above, the workshop did not delve into the question of how to map suggested topics for study onto suggested center organizations. However, as noted in the next section, some participants did comment that centers that include community colleges or training academies might be better positioned to connect to the first responder community than those based solely at research universities would be.

Connecting Research Centers of Excellence with User Communities and Transitioning Products to Users

The Department of Homeland Security can be expected to serve a wide variety of constituents both directly and indirectly. These include DHS agencies, other federal departments and agencies, state and local authorities, industry, the academic community, and the public. The products of the research centers of excellence will be, generally, (1) science, technology, and technology-based products; (2) knowledge and understanding to support decisions; and (3) trained people. This broad mandate raises issues of interaction with the user community, and of the transition of products to user communities.

The process by which federal departments and agencies develop products for internal use is well developed and well understood. Coordination across federal agencies is also reasonably well developed. These processes cannot generally be applied directly when the users are outside the federal sphere.

Much discussion at the workshop was concerned with inventing and developing products for use by first responders, private companies (particularly those that own important elements of the critical infrastructure), and the public. There are cultural gaps that need to be bridged.

First responders—firefighters and rescue workers and law enforcement personnel—were the focus of a large part of the discussion. Issues include how to harmonize what DHS might develop with what the first responders would use. Funding is an issue, as is setting priorities (e.g., a police department may see a greater need for something like a new patrol car that will be used frequently, rather than equipment to respond to a highly unlikely event like a terrorist nuclear attack). Acceptance is a related issue. Local authorities would not necessarily accept a federal agency judgment regarding what equipment they should have, and they might be reluctant to devote scarce training time to learning how to use it.

Several observed that the federal government does not have a good record of understanding the culture of first responders and working with them accordingly, which has led to ineffective interactions. However, the federal government has much to offer to first responders (as illustrated by the workshop discussion as summarized earlier in this report); closer interaction would help first responders to understand what the federal agencies can offer them and how to have access. It was suggested that programs like the Department of Defense's Advanced Concept Technology Demonstrations provide a useful model to follow, giving potential users an opportunity to "buy into" a technology concept early in a program, and then participate in field trials and prototype deployments.

The market for rescue and law enforcement equipment, while theoretically large, has yet to be demonstrated. This raises the question of how companies might be motivated to invest the funds to engineer, produce, and market such equipment. What inducements could be generated to help transition the output of engineering-oriented centers of excellence into the marketplace? One idea suggested at the workshop was to concentrate on products that are dual-benefit, i.e., that have applications in both homeland security and in other areas that first responders are likely to give more attention to. Emergency medicine was cited as an example. A second idea was to look for opportunities to generate a market, i.e., ways to make a product valuable. Possible approaches might involve some combination of regulation and market-driven incentives, such as those that

created markets for automobile seatbelts and home smoke detectors, both of which have major implications for insurability.

Similar considerations were discussed as applying to education and training. Students enter fields of study—undergraduate and graduate/professional—partly on the basis of career expectations. How positive expectations can be generated for the value of careers related to homeland security needs to be addressed. Skills attendant to firefighting, rescue work, emergency medicine, and law enforcement are increasingly taught at community colleges and other community-based institutions. Some workshop participants suggested that university centers of excellence for homeland security should include partners at this level. The idea of a center run by a consortium of community colleges was suggested. Some participants thought that community colleges lacked the necessary depth and breadth to manage a research center but might be good candidates to participate.

It was also pointed out that first responders are not the only community with which connections should be made by those engaged in homeland security-related research. Much of the nation's critical infrastructure belongs to private companies and to local governments and authorities. Positive and productive interactions with these communities are necessary if a university center's work is to be solidly grounded in reality. Good relationships with private and local authorities would also enhance the transfer of the products of the university centers to the people, organizations, and places where they can be of most use.

University centers would be a good place to study how to balance security requirements and other responsibilities of companies and local agencies. One example is balancing security checks and throughput rates for transportation elements such as airports, bridges, and tunnels.

Several workshop participants raised an issue related to government-industry-academia collaborations. Universities prefer to work in an environment of open access to information. Governments and companies often control information: government through the classification of national security information and other restrictions on dissemination, and companies through the general wish to keep proprietary any information that they deem to be competition-sensitive. These are not new issues, but they will likely have to be addressed to achieve effective partnerships for strengthening homeland security.

APPENDIXES

Appendix A
Scope of Work and Workshop Agenda

STATEMENT OF TASK

The National Research Council (NRC) will convene a one-day workshop formed under the auspices of the Division on Engineering and Physical Sciences (DEPS) in consultation with other NRC divisions to explore specific avenues of university research in advancing the nation's capabilities for developing new science and technology to anticipate, prevent, and mitigate the effects of catastrophic terrorist events. The workshop will identify specific topical multidisciplinary and crosscutting research areas where universities can contribute most effectively to the Department of Homeland Security's mission and to improvements in technology that yield the most cost-effective benefits in detection, prevention, and mitigation of effects. The areas of inquiry identified in this workshop will be used by the Department to help inform the selection of a number of university-based homeland security centers of excellence.

WORKSHOP AGENDA

8-10 a.m. **Introductory Session**

Welcome

Peter D. Blair, Executive Director, Division on Engineering and Physical Sciences, National Research Council

Introductory Comments: Workshop Co-Chairs

Charles M. Vest, President, Massachusetts Institute of Technology

Marye Anne Fox, Chancellor, North Carolina State University

DHS Overview—Programs, Portfolios, and Expectations for the Workshop

Maureen McCarthy, Director, Office of Research and Development, Department of Homeland Security

Mel Bernstein, Director, Office of University Programs, Department of Homeland Security

Other DHS Representatives

Relevant Context from the National Research Council Report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*

Lewis Branscomb, Professor, John F. Kennedy School of Government, Harvard University

10-10:15 Break

10:15-12 noon **Session I: Cross-cutting perspectives. Suggestions for multidisciplinary areas that cut across multiple portfolios and other areas of interest**

12-1 p.m. Lunch and informal discussions

1-2:30	**Session II: Overarching perspectives. Suggestions for areas that encompass DHS needs and goals (including potential future needs and goals) but are not necessarily defined directly by the portfolios**
2:30-2:45	Break
2:45-4	**Session III: Examination of results of first two sessions in terms of what makes sense for a multidisciplinary university center** *Fawwaz Ulaby,* Vice President for Research, University of Michigan Special needs, features, and limitations of multidisciplinary university research programs. *Granger Morgan*, Head, Department of Engineering and Public Policy, Carnegie Mellon University Special features of university research that supports public policy
4-5 p.m.	Summary comments and discussion

Appendix B
Workshop Participants and Biographies

LIST OF PARTICIPANTS

Charles M. Vest, President, Massachusetts Institute of Technology, *Workshop Co-Chair*
Marye Anne Fox, Chancellor, North Carolina State University, *Workshop Co-Chair*
Thurman J. Allard, Director of Homeland Security, Sandia National Laboratories
Melvin Bernstein, Director of University Programs, Science and Technology Directorate, Department of Homeland Security
Thomas Blau, Professor, School for National Security Executive Education, National Defense University
Joseph Bordogna, Deputy Director, National Science Foundation
Lewis M. Branscomb, Professor Emeritus, Public Policy, and Corporate Management, John F. Kennedy School of Government, Harvard University
W. Seth Carus, Deputy Director, Center for Counterproliferation Research, National Defense University
Elizabeth L. Grossman, Professional Staff, Committee on Science, U.S. House of Representatives
William Happer, Professor, Department of Physics, Princeton University
Maureen I. McCarthy, Director of Research and Development, Science and Technology Directorate, Department of Homeland Security
M. Granger Morgan, Professor and Head, Department of Engineering and Public Policy, Carnegie Mellon University
Randall S. Murch, Science and Technology Division, Institute for Defense Analyses
Kenneth I. Shine, Executive Vice Chancellor for Health Affairs, The University of Texas System
Neil J. Smelser, University Professor of Sociology, Emeritus, University of California, Berkeley
Gary W. Strong, Manager, Behavioral and Biometrics Programs, Science and Technology Directorate, Department of Homeland Security
Lydia W. Thomas, President and CEO, Mitretek Systems
Fawwaz T. Ulaby, Vice President for Research, University of Michigan
Vincent Vitto, President and CEO, The Charles Stark Draper Laboratory, Inc.
William A. Wulf, President, National Academy of Engineering

National Research Council Staff

Peter D. Blair, Executive Director, Division on Engineering and Physical Sciences
Alan Shaw, Division on Engineering and Physical Sciences

BIOGRAPHIES OF PARTICIPANTS

Charles M. Vest, *Workshop Co-chair,* has been president of MIT since 1990. During this time he has placed special emphasis on enhancing undergraduate education, exploring new organizational forms to meet emerging directions in research and education, building a stronger international dimension into education and research programs, developing stronger relations with industry, and enhancing racial and cultural diversity at MIT. He also has devoted considerable energy to bringing issues concerning education and research to broader public attention and to strengthening national policy on science, engineering, and education. Dr. Vest chaired the President's Advisory Committee on the Redesign of the Space Station and has served as a member of the President's Committee of Advisors on Science and Technology (PCAST), the Massachusetts Governor's Council on Economic Growth and Technology, and the National Research Council's Board on Engineering Education. He chairs the U.S. Department of Energy Task Force on the Future of Science Programs and is vice chair of the Council on Competitiveness and immediate past chair of the Association of American Universities (AAU). He sits on the board of directors of both IBM and E.I. du Pont de Nemours and Co. As a member of the mechanical engineering faculty at MIT, Vest has research interests in the thermal sciences and the engineering applications of lasers and coherent optics. He earned his B.S. degree in mechanical engineering from West Virginia University in 1963 and both his M.S. and Ph.D. degrees from the University of Michigan in 1964 and 1967, respectively.

Marye Anne Fox, *Workshop Co-chair*, is the twelfth chancellor of North Carolina State University. Before her appointment at NC State, Dr. Fox was the M. June and J. Virgil Waggoner Regents Chair in Chemistry and vice president for research at the University of Texas at Austin, where she was responsible for administrative support for research both on and off the campus at Austin. In 1996-1997, this research enterprise included $246 million in sponsored research which extended over a broad range of university departments and interdisciplinary units. Dr. Fox is a frequent lecturer on science education reform and is currently president of the Association for Women in Science. She has served as co-chair of a National Science Foundation/National Science Board taskforce on graduate education and has served on state and National Research Council advisory panels. She now chairs the National Research Council's Committee on Undergraduate Science Education and serves on the Committee on Science, Engineering, and Public Policy. She is president of Sigma Xi. Dr. Fox was elected co-chair of the National Academy of Sciences' Council of Government-University-Industry Research Roundtable. She currently serves on the boards of W.R. Grace, Inc. and the Stanford Research Institute, and on scientific advisory boards for the Welch, Dreyfus, and Packard Foundations. From 1994 to 1996 she served as vice chairman of the National Science Board and chaired its Committee on Programs and Plans from 1991 to 1994. She serves on a large number of state, national, and professional society boards and has published extensively in organic photochemistry and electrochemistry. Her work has clear application in materials science, solar energy conversion, and environmental chemistry. She has been elected to membership in the National Academy of Sciences and the American Philosophical Society and is a fellow of both the American Academy of Arts and Sciences and the American Association for the Advancement of Science. She has received numerous professional awards. Dr. Fox received her B.S. from Notre Dame College and a Ph.D. degree from Dartmouth College, both in chemistry. After a postdoctoral appointment at the University of Maryland, she joined the University of Texas at Austin in 1976.

Thurman John (T.J.) Allard leads Sandia National Laboratories' Homeland Security Office. He is responsible for guiding and overseeing all of its terrorism-combating activities and is also Sandia's point of contact for the Department of Homeland Security. Prior to his current

assignment, he led Sandia's Executive Staff, whose responsibilities include corporate strategic planning, acting as Sandia's primary interface to Congress, and supporting Sandia's president and executive vice-president in the strategic and tactical operations of the laboratories.

Melvin Bernstein has directed the Office of University Programs, Office of Research and Development, in the Science and Technology Directorate of the Department of Homeland Security (DHS) since June 1, 2003. Dr. Bernstein came to DHS from Tufts University, where he is a research professor in the Department of Mechanical Engineering. Previously, he served as professor and head of the Department of Metallurgy and Materials Science at Carnegie Mellon University; provost and then chancellor at the Illinois Institute of Technology; academic vice president and dean of the faculties at Tufts University; and most recently, provost and senior vice president for academic affairs at Brandeis University. Other relevant experience includes liaison scientist at the London office of the Office of Naval Research; member of the National Materials Advisory Board of the National Research Council; and panel chair of the National Research Council study *Materials Science and Engineering for the 1990s.*

Thomas Blau is a professor of national security decision making, National Defense University, School for National Security Executive Education (SNSEE). At SNSEE, he creates and manages new courses and programs on homeland security and homeland defense, defense transformation, decision making, and counterterrorism. These programs serve U.S. executive and legislative branch professionals, foreign military officers, and specialized agencies including the General Accounting Office. He is also a research professor of public policy, George Mason University, where he teaches courses on national security and on strategic management. He has been an international aerospace business consultant, on staff in the U.S. Senate and in the Department of Energy, and a consultant to the U.S. government, with a focus on strategic defense, technology security, energy security, nuclear proliferation, and nuclear forces. He has lectured in Europe and South America on U.S. security policy. He holds a Ph.D. from the University of Chicago, where he studied political science and economics. His publications on security and business matters have appeared in the Asian Wall Street Journal, the Journal of Commerce, NATO's 16 Nations, Military Technology, Aviation Week & Space Technology, Sea Power, Defense & Security Review (London), various edited volumes, and numerous proprietary studies.

Joseph Bordogna is deputy director and chief operating officer of the National Science Foundation, and he served previously as head of NSF's Directorate for Engineering. Complementing his NSF duties, he is a member of the President's Management Council; has chaired committees on manufacturing, environmental technologies, and automotive technologies within the President's National Science and Technology Council; and was a member of the U.S.-Japan Joint Optoelectronics Project. Prior to his appointment at NSF, he served at the University of Pennsylvania as Alfred Fitler Moore Professor of Engineering, director of the Moore School of Electrical Engineering, dean of the School of Engineering and Applied Science, and faculty master of Stouffer College House. Dr. Bordogna is a fellow of the American Association for the Advancement of Science (AAAS), the American Society for Engineering Education (ASEE), and the International Engineering Consortium and a fellow and former president of the Institute of Electrical and Electronics Engineers (IEEE). He has made contributions to the engineering profession in a variety of areas, including early laser communications systems, electro-optic recording materials, holographic television playback systems, and early space capsule recovery. He received the B.S.E.E. and Ph.D. degrees from the University of Pennsylvania and the S.M. degree from the Massachusetts Institute of Technology.

Lewis M. Branscomb is the emeritus Aetna Professor of Public Policy and Corporate Management and emeritus director of the Science, Technology, and Public Policy Program in the

Center for Science and International Affairs at Harvard University's Kennedy School of Government. Dr. Branscomb, a member of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, has a background in physics and public policy. He was a research physicist at the National Bureau of Standards (now the National Institute of Standards and Technology) and also served as its director. He was the founder and first director of the Joint Institute for Laboratory Astrophysics at the University of Colorado and an at-large director of the Associated Universities for Research in Astronomy. He served on the President's Science Advisory Committee (PSAC), where he chaired the PSAC committee on space science and technology during Project Apollo. Dr. Branscomb served as vice president and chief scientist of IBM Corporation until his retirement in 1986. Dr. Branscomb is a former president of the American Physical Society and of Sigma Xi, the Scientific Research Society.

W. Seth Carus is a Distinguished Research Professor at the National Defense University (NDU) and the deputy director of the university's Center for Counterproliferation Research. He has been at NDU since 1997. His research focuses on homeland security, biodefense and biological warfare threat, consequence management, and the role of the Department of Defense in responding to chemical and biological terrorism. He also is researching allegations of biological agent use by terrorists and criminals and has published a working paper, "Bioterrorism and Biocrimes: The Illicit Use of Biological Agents in the 20th Century," and several articles on that subject. From 2001 to 2003, Dr. Carus was the senior advisor to the vice president for biodefense. Prior to that he was on the staff of the National Preparedness Review and then worked with the Office of Homeland Security while it was being established. Before joining NDU, Dr. Carus was on the staff of the Center for Naval Analyses. From 1991 to 1994, he was a member of the policy planning staff of the undersecretary of defense for policy, Office of the Secretary of Defense. Before joining the government, he was a research fellow at the Washington Institute for Near East Policy. He has a Ph.D. from the Johns Hopkins University.

Elizabeth L. Grossman is a professional staff member at the Science Committee of the U.S. House of Representatives. She is responsible for issues in homeland security, nanotechnology, and cybersecurity and also for general issues affecting the conduct of research. Before joining the Science Committee in January 2003, she spent 6 years at the National Academy of Sciences, where she worked on a variety of studies on science, technology, and public policy, including the National Research Council report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism.* She holds a B.A. in physics and mathematics from Swarthmore College and a Ph.D. in computational physics from the University of Chicago.

William Happer, a professor in the Department of Physics at Princeton University, is a specialist in modern optics, optical and radio-frequency spectroscopy of atoms and molecules, and spin-polarized atoms and nuclei. Dr. Happer began his academic career in 1964 at the Physics Department of Columbia University, rising to the rank of full professor. While serving as a professor of physics he also served as co-director of the Columbia Radiation Laboratory from 1971 to 1976, and director from 1976 to 1979. In l980 he joined the faculty at Princeton University. He was named the Class of 1909 Professor of Physics in 1988. On August 5, 1991, Dr. Happer was appointed director of energy research in the Department of Energy by President George Bush, where he oversaw a basic research budget of some $3 billion, which included much of the federal funding for high energy and nuclear physics, materials science, magnetic confinement fusion, environmental science, the human genome project, and other areas. After leaving DOE on May 31, 1993, he was reappointed professor of physics at Princeton University on June 1, 1993, and named Eugene Higgens Professor of Physics and chair of the University Research Board in 1995. In 2003 he was named to the Cyrus Fogg Brackett Chair of Physics. Dr. Happer has served as a consultant to numerous firms, charitable foundations, and government

agencies. From 1987 to 1990 he served as chairman of the Steering Committee of JASON, a group of scientists and engineers who advise agencies of the federal government on matters of defense, intelligence, energy policy, and other technical problems. He is a trustee of the MITRE Corporation, the Richard Lounsbery Foundation, and the Marshall Institute. He was a co-founder in 1994 of Magnetic Imaging Technologies Incorporated (MITI), a small company specializing in the use of laser polarized noble gases for magnetic resonance imaging. Dr. Happer is a fellow of the American Physical Society and the American Association for the Advancement of Science and a member of the American Academy of Arts and Sciences, the National Academy of Sciences, and the American Philosophical Society. He was awarded an Alfred P. Sloan Fellowship in 1966, an Alexander von Humboldt Award in 1976, the 1997 Broida Prize and the 1999 Davisson-Germer Prize of the American Physical Society, and the Thomas Alva Edison Patent Award in 2000. He received a B.S. degree in physics from the University of North Carolina in l960 and the Ph.D. degree in physics from Princeton University in l964.

Maureen I. McCarthy is the director, Research and Development, Science and Technology Directorate, Department of Homeland Security. She is responsible for management of programs and facilities at DHS federal and national laboratories, strategic partnerships with other federal agencies, university fellowships and centers of excellence, international cooperation, and technical support to incident management. From August 2002 to March 2003, Dr. McCarthy was the senior representative from the Department of Energy to the Homeland Security Transition Planning Office, and deputy team captain, Science and Technology. From March 2000 to March 2003 she served as chief scientist, National Nuclear Security Administration, Department of Energy, and from March 1999 to March 2000 she was senior advisor for national security and nuclear energy to the secretary of energy and senior science advisor to the assistant secretary for nonproliferation and national security, Department of Energy. Before coming to DOE, Dr. McCarthy was an American Association for the Advancement of Science (AAAS) Defense Policy Fellow to the Office of the Secretary of Defense, at which she specialized in arms control implementation and compliance matters. From 1991 to 1997 she was a senior staff scientist at the Pacific Northwest National Laboratory, where she directed the interface physics group. She holds a B.Sc. in chemistry from Boston College (1983) and a Ph.D. in chemical physics from the University of Colorado (1988). She is the recipient of several professional awards, including the NNSA Administrators Silver Medal for Outstanding Service, and the Lady Davis Postdoctoral Fellowship at the Hebrew University of Jerusalem (1988-1991).

M. Granger Morgan is a professor and head of the Department of Engineering and Public Policy, Lord Chair Professor in Engineering, a professor in the Department of Electrical and Computer Engineering, and a professor in the H. John Heinz III School of Public Policy and Management at Carnegie Mellon University. He is interested in a wide range of problems in science, technology, and public policy. These include integrated assessment and uncertainty in policy analysis; risk analysis, management, and communication; and technology and R&D policy. Much of his work has involved the development and demonstration of methods to characterize and analyze uncertainty. With colleagues in the Center for the Integrated Study of the Human Dimensions of Global Change he has addressed issues in the integrated assessment of climate change impacts and policy. With colleagues in the Electricity Industry Center he is exploring problems such as distributed resources, carbon management, and basic technology research to support clean energy. He has worked extensively in risk analysis, communication, and ranking. He is an active participant in the Center for the Study and Improvement of Regulation. Professor Morgan holds the following degrees: B.A. (physics) 1963, Harvard College; M.S. (astronomy and space science) 1965, Cornell University; and Ph.D. (applied physics and information science) 1968, University of California, San Diego. He has participated in several major Academies'

activities, some of which he has chaired. He is currently a member of the Committee on the Human Dimensions of Global Change.

Randall S. Murch is the director, Technology Discovery and Insertion Group, Institute for Defense Analyses, Alexandria, Virginia, which designs and performs studies and analyses on topics involving science and technology and their application to solving difficult challenges for intelligence, homeland security, and counterterrorism. From January 1980 to November 2002, he was a special agent with the Federal Bureau of Investigation; his activities included performing counterterrorism and counterintelligence investigations; serving as a forensic biologist and research scientist in the FBI Laboratory; and serving as a planning officer for complex technical national security projects, Intelligence Division, FBI Headquarters. His career has included leading R&D efforts and managing detailed technical support to investigations. From 1995 to 1999, Dr. Murch was a section chief (department head) responsible for the core forensic units of the FBI Laboratory, and then as deputy director, FBI Laboratory, he had responsibility for all forensic, research, and counterterrorism response (including WMD) programs of the laboratory. From late 1999 to mid 2001, he was detailed to the Defense Threat Reduction Agency as director, Advanced Systems and Concepts Office. He completed his career with the FBI as the deputy director, Investigative Technology Division Quantico. He holds a B.S. degree from the University of Puget Sound (biology, 1974), an M.S. degree from the University of Hawaii (botanical sciences, 1976), and a Ph.D. from the University of Illinois (plant pathology, 1979). He has briefed and served on Defense Science Board and National Academy of Sciences studies and is currently a member of the Board on Life Sciences, National Research Council.

Kenneth I. Shine is past president of the Institute of Medicine, National Academies, and professor of medicine emeritus at the University of California, Los Angeles (UCLA) School of Medicine. He is UCLA School of Medicine's immediate past dean and provost for medical sciences. Currently he is a clinical professor of medicine at the Georgetown University School of Medicine. A cardiologist and physiologist, Dr. Shine received his A.B. from Harvard College in 1957 and his M.D. from Harvard Medical School in 1961. Most of his advanced training was at Massachusetts General Hospital (MGH), where he became chief resident in medicine in 1968. Following his postgraduate training at MGH, he held an appointment as assistant professor of medicine at Harvard Medical School. He moved in 1971 to the UCLA School of Medicine and became director of the Coronary Care Unit, chief of the Cardiology Division, and subsequently, chair of the Department of Medicine. As dean at UCLA, Dr. Shine stimulated major initiatives in ambulatory education, community service for medical students and faculty, mathematics and science education in the public schools, and the construction of new research facilities funded entirely by the private sector. Dr. Shine is a member of many honorific and academic societies, including Phi Beta Kappa and Omega Alpha; is a fellow of the American Academy of Arts and Sciences, the American College of Cardiology, and the American College of Physicians; and was elected to the Institute of Medicine in 1988. He served as chair of the Council of Deans of the Association of American Medical Colleges from 1991 to 1992 and was president of the American Heart Association from 1985 to 1986. Dr. Shine's research interests include metabolic events in the heart muscle, the relation of behavior to heart disease, and emergency medicine. He participated in efforts to prove the value of cardiopulmonary resuscitation following a heart attack, and in establishing the 911 emergency telephone number in the multi-jurisdictional Los Angeles area. Dr. Shine is the author of numerous articles and scientific papers in the area of heart physiology and clinical research.

Neil J. Smelser served as the director of the Center for Advanced Study in the Behavioral Sciences, Stanford, California, from 1994 to August 2001. His research interests are sociological theory, economic sociology, collective behavior, sociology of education, social change, and

comparative methods. From 1958 to 1994 he was on the faculty of the Sociology Department of the University of California, Berkeley, serving as university professor since 1971. He is a member of the American Academy of Arts and Sciences, the American Philosophical Society, and the National Academy of Sciences.

Gary W. Strong is the director, Behavioral Research and Biometrics, in the Science and Technology Directorate of the Department of Homeland Security. He is currently on detail from the National Science Foundation, where he assisted with interagency coordination of national security and homeland security related programs, managed the computer science cluster of biology-related research programs, and managed a large cross-agency information technology research program. Prior to this, Dr. Strong was on detail to the Defense Advanced Research Projects Agency to manage the Translingual Information Detection, Extraction and Summarization Program and co-manage the Bio:Info:Micro Program. Dr. Strong is currently co-chair of two National Science and Technology Council groups: the NSTC Biometrics Working Group and the Social, Behavioral, and Economics Research Subcommittee. Previously, Dr. Strong was a member or the chair of several interagency working groups on information technology research and development. He led the development of a research initiative for every-citizen access to the National Information Infrastructure, commissioning a study by the National Research Council (Computer Science and Telecommunications Board, *More Than Screen Deep*, National Academy Press, Washington, D.C., 1997) that continues to serve as a reference standard for efforts to bridge the digital divide. Dr. Strong's international efforts have resulted in the NSF-European Commission multilingual research program, a cooperative science program that involved coordinated peer review on both sides. From 1982 to 1994, Dr. Strong was a faculty member at Drexel University, where he established a new undergraduate degree program in information systems. From 1967 to 1974, he worked at Bell Telephone Laboratories, in the Data Communications Laboratory. He received his B.S. in electrical engineering from the University of Michigan in 1967, his M.S. in electrical engineering from Columbia University in 1969, and his Ph.D. jointly in computer and communication sciences and in anthropology from the University of Michigan in 1981.

Lydia W. Thomas is president and CEO of Mitretek Systems, Inc., where she served previously as senior vice president and general manager responsible for strategic planning and leadership of Mitretek's Center for Environment, Resources and Space. Dr. Thomas was with the MITRE Corporation from 1973 to 1996, where she held a series of technical and management positions, spanning the areas of energy, environment, health, and space systems. Dr. Thomas is a member of the President's Homeland Security Advisory Council and the Virginia Governor's Higher Education Summit Steering Committee. She serves on the board of directors of the Cabot Corporation, the United States Energy Association, and the Northern Virginia Technology Council (NVTC). She is a trustee of George Washington University and a corporate member of the Charles Stark Draper Laboratory, Inc. Dr. Thomas has held several advisory positions for the Department of Defense. She is the recipient of many prestigious professional awards and is a member of the Council on Foreign Relations, American Society of Toxicology, American Defense Preparedness Association/National Defense Industrial Association, American Institute of Aeronautics and Astronautics, and the Teratology Society. She holds a Ph.D. in cytology from Howard University, an M.S. in microbiology from American University, and a B.S. in zoology from Howard University.

Fawwaz T. Ulaby is the vice president for research and the R. Jamison and Betty Williams Professor of Electrical Engineering and Computer Science at the University of Michigan. He is a member of the National Academy of Engineering and serves on several national scientific boards and commissions. Since joining the University of Michigan faculty in 1984, he has been

directing large, interdisciplinary projects, and he was the founding director of a NASA-funded center for space terahertz technology. Dr. Ulaby has authored eight books, contributed chapters to several others, and published over 600 scientific papers and reports. His undergraduate textbook, *Applied Electromagnetics*, published by Prentice Hall in January 1997, has been adopted by some 80 universities across the United States. He is the recipient of numerous awards, including the Eta Kappa Nu Association C. Holmes MacDonald Award for "An Outstanding Electrical Engineering Professor in the Untied States of America for 1975," the IEEE Centennial Medal (1984), the American Society of Photogrammetry's Presidential Citation for Meritorious Service (1984), the Kuwait Prize in applied science (1986), the NASA Group Achievement Award (1990), the University of Michigan's Distinguished Faculty Achievement Award (1991), the University of Michigan Regents Medal for Meritorious Service (1996), the IEEE Millennium Medal for Outstanding Achievements and Contributions (2000), and the 2001 IEEE Electromagnetics Award. In January 2001 he assumed the position of editor in chief of the IEEE Proceedings. Jointly with Michigan State University, Wayne State University, and the Van Andel Institute, the University of Michigan developed and submitted a proposal to the State of Michigan in FY2000 for establishing a core technology alliance (CTA) composed of five cores focused on genomics, proteomics, structural biology, bioinformatics, and animal models; Dr. Ulaby served as vice president, overall principal investigator, and chair of the CTA executive committee. He holds a B.S. in physics from the American University of Beirut (1964), an M.S. in electrical engineering from the University of Texas, Austin (1966), and a Ph.D. in electrical engineering from the University of Texas, Austin (1968).

Vincent Vitto is the president and CEO of Charles Stark Draper Laboratory, Inc., which specializes in guidance, navigation and control, and autonomy and microelectronics. His areas of expertise are communications and surveillance technologies. As assistant director of the Lincoln Laboratory of the Massachusetts Institute of Technology (MIT), he was responsible for programs in surface surveillance and communications. Prior to holding that position, Mr. Vitto was head of the Communications Division, which included work on technology and system concept development of military satellite communications systems. Mr. Vitto has been a member of many government advisory boards and panels; he currently is vice chair of the Defense Science Board and chair of the NRC's Naval Studies Board.

William A. Wulf was elected president of the National Academy of Engineering (NAE) in 1997. The NAE and the National Academy of Sciences operate under a congressional charter to provide advice to government on issues of science and engineering. Dr. Wulf is on leave from the University of Virginia, where he is a university professor. His research spans computer architecture, computer security, programming languages, and optimizing compilers. From 1988 to 1990 Dr. Wulf was also on leave to be assistant director of the National Science Foundation. Prior to joining the University of Virginia, he founded a software company, Tartan Laboratories, based on research he did while on the faculty at Carnegie Mellon University. Dr. Wulf is a member of the National Academy of Engineering, a fellow of the American Academy of Arts and Sciences, a corresponding member of the Academia Espanola De Ingeniera, and a foreign member of the Russian Academy of Sciences. He is also a fellow of four professional societies: the ACM, the IEEE, the AAAS, and AWIS. He is the author of over 100 papers and technical reports, has written three books, holds two U.S. patents, and has supervised over 25 Ph.D.s in computer science.