

MAKING  
THE NATION  
**SAFER**

THE ROLE OF SCIENCE AND TECHNOLOGY  
IN COUNTERING TERRORISM

Committee on Science and Technology for Countering Terrorism

NATIONAL RESEARCH COUNCIL  
*OF THE NATIONAL ACADEMIES*

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## Foreword

This report reflects the commitment of the U.S. scientific, engineering, and health communities to help our country respond to the challenges made evident by September 11. It is a contribution from the National Academies—the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council—which initiated this critical effort and paid for it. But this report is also a contribution to the nation from many distinguished individuals, each of whom dedicated a great deal of time to the production of the report. In all, there were 24 members of the main committee, 94 additional individuals who served on its eight subpanels, and 46 expert reviewers who provided critical feedback on the committee’s draft report. These 164 individuals were motivated solely by a commitment to public service, and all of them made personal sacrifices to do their part on a very tight schedule.

The great enthusiasm and dedication with which the above groups approached their tasks are but one indication of the strong interest that Americans have shown in contributing to counterterrorism efforts. The vigorous science and technology community in our nation is ready, willing, and able to be called into service, and this report focuses on strategies for harnessing the vast talent and energy available.

This report is about the contributions of science and technology to countering terrorism, but we recognize that they are only one element of a broad array of important responses. These must include, for example, diplomacy, military actions, intelligence, and an understanding of how terrorism originates and is sustained.

Because of the fast-track nature of this effort, it has necessarily focused on the homeland security of the United States. But we must not forget that, with

respect to terrorism, the nations of the world share a common set of enemies. Many of the technical solutions that we develop in the United States to make our nation safer will also be useful for protecting the citizens and facilities of other nations. And the efforts of the scientists, engineers, and health professionals in many nations will be important for bringing the best of science and technology to bear on the world's counterterrorism efforts.

The National Academies have built strong relationships of trust over the years with colleagues around the world. Whether these colleagues are in the United Kingdom, Brazil, Russia, China, India, or elsewhere, we all share the same perspectives and hopes for a better world. This report therefore represents only the first step in what must become a long and continuing global effort to spread peace and prosperity to every nation.

Bruce Alberts  
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of Sciences

Wm. A. Wulf  
President  
National Academy  
of Engineering

Kenneth I. Shine  
President<sup>1</sup>  
Institute of Medicine

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<sup>1</sup>Through June 30, 2002.

# Preface

## **INTRODUCTION AND BACKGROUND**

The September 11, 2001, terrorist attacks on the United States galvanized the nation to strengthen its homeland defenses and to pursue those responsible for the terrorist acts. The United States now leads a global effort against terrorism. The aim is to eliminate worldwide terrorist networks and reduce the effectiveness of terrorist threats. Success will depend not only on the leadership, initiative, and capabilities of the United States, but also on the cooperation and capabilities of its international partners and allies.

Immediately following the events of September 11, the presidents of the National Academy of Sciences (Bruce Alberts), the National Academy of Engineering (Wm. A. Wulf), and the Institute of Medicine (Kenneth I. Shine) collectively wrote to President George W. Bush. Stating that the new war against terrorism would “demand a focus on the complex interplay between technological, sociological, and political issues,” they offered to provide the nation with the advice and counsel of the National Academies (which includes the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council).

Historically, the National Academies have long recognized the important role of science and technology in helping the nation meet its security needs. The ability to create, maintain, and draw from a reservoir of science, engineering, and medical knowledge has underpinned many of the nation’s efforts to combat adversaries. Such a reservoir was the basis for the great science, engineering, and medical contributions made during World War II. It must be recognized, however, that successful application then required dedicated financial resources, sci-

entists, engineers, and physicians who directed themselves to the tasks at hand, and organization and leadership to effectively deploy both knowledge and people in the wartime science effort. The science and engineering community responded in a similar way to the shock of Sputnik and the growing technical capability of the USSR, then our adversary, and the Cold War required a sustained effort by this community over four decades. More recently, the national and international response to AIDS by scientists and physicians has demonstrated once again that science can mobilize to respond to a threat. The response has benefited from a reservoir of knowledge accumulated through two decades of sustained biomedical science that has been well supported financially in the United States and other industrialized nations. A successful response to the threat of catastrophic terrorism will require the same type of long-term dedication and focus.

The security threat the nation now faces affects every phase of domestic life and demands that technical solutions that might be deployed relatively quickly be readily accessible to local and state entities, as well as to the federal government. The challenge is to identify the threats (and the nation's vulnerabilities), to identify responses to those threats, and to organize properly the nation's immense science and engineering capabilities to meet both short- and long-term needs.

The scientific enterprise is enormously complex—consisting of universities, industry, government, professional societies, and such. Although capable of meeting the research and development challenges posed by the threat of terrorism, it is highly fragmented. The institutional, managerial, and public policy problems that must be solved are daunting. They include (1) defining criteria for setting the nation's research priorities, (2) identifying those research priorities, and (3) proposing new institutional arrangements and entities that will enable a stronger interaction between the nation's science and technical enterprise and its security apparatus.

From its vantage point as an adviser to the nation on science, engineering, and medicine, the National Academies have been working diligently since September 11 to marshal a substantial number of the most knowledgeable experts to address how the scientific and technological capabilities of the United States can best be harnessed for the many challenges ahead.

## TERMS OF REFERENCE

In December 2001, the National Academies, using institutional funds, initiated this project. The aim was to help the federal government—and, more specifically, the Executive Office of the President—to enlist the nation's and the world's scientific and technical community in a timely response to the threat of catastrophic terrorism. A committee of distinguished scientists and engineers was established to help the government develop an integrated science and technology program plan and a research strategy for combating terrorism.

The terms of reference called for the following three tasks to be completed within 6 months: (1) prepare a carefully delineated framework for the application of science and technology for countering terrorism, (2) prepare research agendas in nine key areas, and (3) examine a series of crosscutting issues. More specifically,

- The framework should characterize the range of threats to the nation's security (in terms of targets, weapons, and delivery systems, and the possible points of intervention).
- Research agendas should be developed in areas of vulnerability related to biological sciences; chemical sciences; nuclear and radiological sciences; information technology and telecommunications; transportation; energy facilities; cities and fixed infrastructure; behavioral, social, and institutional issues; and systems analysis and systems engineering. For each area, the research agenda should identify highly leveraged opportunities for using science and technology in countering terrorism.
- Multidisciplinary research topics that cut across the above domains and the threats that arise from the interdependence of these areas should be considered in developing the final program plan and research strategy.

The objective of this study has been to strengthen the government's ability to use science and technology for combating terrorism. Critical questions also exist about how a comprehensive national counterterrorism effort involving research, development, and deployment can be planned and executed. Many of these questions remain to be addressed, but this study did define a number of the important issues in this area.

### THE COMMITTEE'S APPROACH

A committee of 24 of the nation's leading scientific, engineering, medical, and policy experts conducted the study described in this report. The range of expertise on the committee reflected the broad array of scientific and technical topics to be covered under its charge. The committee also included members with the expertise necessary to address issues related to the context in which the research priorities would be set and implemented (e.g., experts in science and technology policy, national security, and public health). Finally, many of the committee's experts were or are active advisers to federal agencies, and they brought to this project an awareness of ongoing governmental counterterrorism efforts. Biographies of the committee are provided in Appendix A.

To supplement the committee's own expertise, eight panels were separately appointed and asked to provide input on the specific topical areas identified in the committee's charge. The panels were (1) Biological Sciences, (2) Chemical Issues, (3) Nuclear and Radiological Issues, (4) Information Technology, (5)

Transportation, (6) Energy Facilities, Cities, and Fixed Infrastructure, (7) Behavioral, Social, and Institutional Issues, and (8) Systems Analysis and Systems Engineering. Each panel was chaired by a member of the committee. The panels brought the expertise and experience of approximately 90 additional scientists, engineers, and medical professionals (supported by approximately 15 NRC senior staff) to the study. These study participants are listed in Appendix B.

The focus of the committee's work was on *making the nation safer* from emerging terrorist threats that would seek to inflict catastrophic damage on the nation's people, its infrastructure, or its economy. The committee's approach was to identify current threats to the nation, understand the most likely vulnerabilities in the face of these threats, and identify highly leveraged opportunities for science and technology contributions to counterterrorism in both the near term and the long term. Such contributions—including intelligence and surveillance, prevention, protection, interdiction, response and recovery, attribution, and analysis—can be made at any point along a time line that extends from before a terrorist act to its aftermath. The committee organized its approach by considering the issues in nine areas: nuclear and radiological threats; human and agricultural health systems; toxic chemicals and explosive materials; information technology; energy systems; transportation systems; cities and fixed infrastructure; the response of people to terrorism; and complex and interdependent systems. Within each of these areas, the relevant panel was tasked with the following:

- Outline current capabilities for countering terrorist threats and describe priorities and time frames for developing additional capabilities. Develop, for each domain, a research strategy that identifies highly leveraged opportunities for science and technology to contribute to counterterrorism. Identify the areas within the framework of terrorist acts and responses to which the panel's technical domain is relevant, evaluate the current state of knowledge and capacity for dealing with the most significant threats, and identify significant barriers to the use of technology, as well as areas in which knowledge may be available but underutilized.
- Consider policies or activities that might be required to reduce any new technologies to practice and facilitate their deployment. Where possible, simultaneously address domain-specific issues and identify needs that either cut across domain lines or are not readily described within the traditional domains.
- Focus on science and technology applications that are relevant to the most pressing issues and/or that would yield the most generic solutions. Identify short-term opportunities and pay special attention to ideas, admittedly some with uncertain outcomes, that might arise from new scientific discoveries and new inventions, even if they might not emerge for 5 years or more. Take note of any opportunities that were identified in earlier studies or that are currently planned or under way at federal agencies.
- Consider how the proposed research agendas could be implemented.

Accordingly, each panel developed a set of recommendations that ranged from long-term research and development to immediate- or near-term deployment of existing technologies or application of available knowledge. The motivation for these recommendations was to illustrate how knowledge gained, capabilities developed, and actions taken could mitigate specific problems. These recommendations do not answer many critical questions for the federal government, to which the majority are addressed. Nor do they provide a single prioritized list of threats, vulnerabilities, or solutions. Neither the panels nor the committee knew of a clear methodology to create such lists, especially since the committee did not access classified intelligence information about the capabilities and intentions of terrorists.

During the course of this fast-track project the committee met four times:

- December 19-20, 2001, Washington, D.C. At this organizational meeting the committee received its charge from the presidents of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. It then developed a preliminary outline of the report, devised a plan for completing its work, and reviewed the membership rosters of the panels and the committee's charge.
- January 31-February 1, 2002, Washington, D.C. The committee reviewed the initial work of the panels on threats, vulnerabilities, and responses and provided feedback to the panel chairs.
- April 8-9, 2002, Washington, D.C. The committee reviewed the work of the panels and discussed issues in the specific areas covered by the panels, as well as the overarching themes for the report.
- May 13-14, 2002, Washington, D.C. At its final meeting the committee reviewed the draft report and finalized its agreement on the findings, conclusions, and recommendations.

The committee also held a number of teleconferences over the course of the study period to review the work status and findings of the panels. Most of the panels met three times between January and March 2002, and they received scores of briefings from federal officials and other experts in the field to inform their judgment and contribute to the base of information (see Appendix C). Written panel inputs were submitted to the committee on March 31, 2002.

The work of the panels informed the committee and provided the basis for Chapters 2 through 11 of the report. The committee also used the work of the panels to motivate the discussions and recommendations on general issues related to the implementation of science and technology for countering terrorism (see Chapters 12 and 13).

Overall, the committee believes that it has identified scientific and technological means by which the nation may reduce—but not eliminate—the vulnerabilities of its society to catastrophic terrorist acts and mitigate the consequences of such acts when they occur. It outlines some research and development priori-

ties that will be needed to make the nation safer and improve its ability to succeed in the war on terrorism. But most importantly, the committee outlines a national strategy by which the strengths of U.S. science and engineering can most effectively be brought to bear on the defense of our nation on a continuing basis.

### **FINAL NOTES**

Although this study is based on the extensive work of the panels and the input that they provided in their domains of expertise, the authorship responsibility for this report rests solely with the committee.

While traditional procedures for an independent NRC study, including review of the report by independent experts, were followed, it is important to note that trade-offs were made in order to accommodate the rapid schedule. For example, the report does not provide extensive references to the scientific literature nor does it marshal detailed evidence to support its findings. Rather, it largely presents the consensus scientific views and judgments of the committee members, based on the knowledge that these individuals have accumulated through their own scholarly efforts and professional experience, through formal and informal interactions with the nation's science, engineering, and medical communities, and through the efforts of the supporting panels.

The committee was deeply aware of the difficulty of writing a report that was sufficiently specific about terrorist threats to explain how science and engineering might be helpful, without providing information that might aid terrorists in determining new means of attack. In many cases, quite specific information that was available to the committee is presented in the report in a more generic form. In the area of nuclear and radiological threats, the relevant panel accessed classified information in the course of this study and has produced a classified annex to this report. An unclassified discussion of the issues related to nuclear and radiological threats is provided in Chapter 2 of this report.

## Acknowledgments

The Committee on Science and Technology for Countering Terrorism witnessed firsthand the scientific, engineering, and medical community's unstinting commitment to join with the rest of the civilized international community in the global effort against terrorism. Without hesitation the members of the eight panels supporting this study, the individuals asked to brief the panels, those who spoke informally with committee and panel members, and the National Research Council staff supporting the study shared their expertise and insights and offered their best ideas on short notice to inform the committee, the technical community, and the federal government. The committee extends its sincerest gratitude to the many individuals who provided valuable information and support during the course of this study.

The panel members are listed in Appendix B. Their work provided much of the intellectual base for the study. The panels in turn received inputs from many briefers on a wide array of topics related to counterterrorism activities across a number of disciplines and infrastructures; these inputs to the panels are acknowledged in Appendix C, "Panel Activities."

Ronald D. Taylor, study director, and Elizabeth L. Grossman, program officer, both of the National Research Council, managed this study and contributed significantly to the ideas and their expression in this report. Without their leadership and dedication, it would not have been possible for this project to achieve its objectives on an exceptionally tight schedule with an unusually broad scope of technical and policy content. The committee is immensely grateful to both of them. The committee also appreciates the support it received from the project staff, Susan G. Campbell, Mary G. Gordon, and Ian M. Cameron, over the course of this fast-track study.

The committee is also grateful to have been able to draw on resources from across the National Academies. Individual program staff members from five divisions<sup>1</sup> played a vital role in supporting the work of the panels, as listed with the panels in Appendix B. Thanks are also due to Douglas C. Bauer for undertaking research and gathering background information on some of the issues related to the structure of the federal government as well as the government's interaction with industry. His tireless work in support of the committee is greatly appreciated.

The committee was fortunate to engage the services of a highly professional and experienced editorial staff, including Steven J. Marcus (a nationally known technical editor) and Elizabeth Fikre and Susan Maurizi, both of the National Research Council staff.

The National Academies gratefully acknowledge David and Katherine Bradley for their financial support of the dissemination of this publication.

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<sup>1</sup>Program staff from the Division on Engineering and Physical Sciences, Division on Earth and Life Studies, Division of Behavioral and Social Sciences and Education, Institute of Medicine, and Transportation Research Board participated in this study.

## Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals 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 this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for 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:

John F. Ahearne, Sigma Xi, The Scientific Research Society,  
Alfred V. Aho, Lucent Technologies,  
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Alvin W. Trivelpiece, Oak Ridge National Laboratory (retired), and  
Harold E. Varmus, Memorial Sloan-Kettering Cancer Center.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by R. Stephen Berry, University of Chicago (emeritus), and Gerald P. Dinneen, Honeywell, Inc. (retired). 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 solely with the authoring committee and the institution.

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