Nuclear Forensics: A Capability at Risk (Abbreviated Version)

Committee on Nuclear Forensics; National Research Council

ISBN
978-0-309-15874-9

31 pages
8 1/2 x 11
2010

NUCLEAR FORENSICS
A CAPABILITY AT RISK
(Abbreviated Version)

Committee on Nuclear Forensics

Nuclear and Radiation Studies Board
Division on Earth and Life Studies

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. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This study was supported by contract number DE-AM01-04PI4513, DE-AT01-08NA28455.A000, TO#24 between the National Academy of Sciences and the U.S. Department of Energy. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://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. Ralph J. Cicerone 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. Charles M. Vest 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. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

Committee on Nuclear Forensics

ALBERT CARNESALE, University of California, Los Angeles, *Chair*
MARVIN L. ADAMS, Texas A&M University, College Station
R. STEPHEN BERRY, University of Chicago (retired), Illinois
SUE B. CLARK, Washington State University, Pullman
JAY C. DAVIS, Hertz Foundation, Livermore, California
JOHN A. GORDON, U.S. Air Force (retired), Alexandria, Virginia
DARLEANE C. HOFFMAN, University of California (retired), Oakland
MICHAEL O. LARSON, Lawrence Livermore National Laboratory (retired), California
MILTON LEVENSON, Bechtel International (retired), Menlo Park, California
RANDALL S. MURCH, Virginia Polytechnic Institute & State University, Alexandria
DANIEL B. PONEMAN,* The Scowcroft Group, Washington, DC
JERRY B. WILHELMY, Los Alamos National Laboratory (retired), Honolulu, Hawaii

STAFF

MICAH D. LOWENTHAL, Study Director
TONI GREENLEAF, Administrative and Financial Associate
SHAUNTEÉ WHETSTONE, Senior Program Assistant

*Daniel Poneman resigned from committee in May 2009 when he was confirmed by the U.S. Senate for the position of U.S. Deputy Secretary of Energy.

Nuclear and Radiation Studies Board

RICHARD A. MESERVE, Carnegie Institution for Science, Washington, DC, *Chair*
BARBARA J. MCNEIL, Harvard Medical School, Boston, Massachusetts, *Vice Chair*
JOONHONG AHN, University of California, Berkeley
JOHN S. APPLEGATE, Indiana University School of Law, Bloomington
MICHAEL L. CORRADINI, University of Wisconsin-Madison
PATRICIA J. CULLIGAN, Columbia University, New York City, New York
SARAH C. DARBY, Oxford University, United Kingdom
JAY C. DAVIS, Hertz Foundation, Livermore, California
ROBERT C. DYNES, University of California, San Diego
JOE GRAY, Lawrence Berkeley National Laboratory, California
DAVID G. HOEL, Medical University of South Carolina, Charleston
HEDVIG HRICAK, Memorial Sloan-Kettering Cancer Center, New York City, New York
THOMAS H. ISAACS, Stanford University, Palo Alto, California
ANNIE B. KERSTING, Lawrence Livermore National Laboratory, Livermore, California
FRED A. METTLER, JR., New Mexico VA Health Care System, Albuquerque
BORIS F. MYASOEDOV, Russian Academy of Sciences, Moscow
RICHARD J. VETTER, Mayo Clinic (retired), Rochester, Minnesota
RAYMOND G. WYMER, Oak Ridge National Laboratory (retired), Oak Ridge, Tennessee

Staff

KEVIN D. CROWLEY, Director
MICAH D. LOWENTHAL, Program Director
SARAH CASE, Program Officer
TONI GREENLEAF, Administrative and Financial Associate
LAURA D. LLANOS, Administrative and Financial Associate
SHAUNTEÉ WHETSTONE, Senior Program Assistant
ERIN WINGO, Senior Program Assistant
JAMES YATES, JR., Office Assistant

Preface to the Abbreviated Version

This is an abbreviated version of the National Academies' report on sustaining and improving the nation's nuclear forensics capabilities, entitled, *Nuclear Forensics: A Capability at Risk (U).* The full version of that report, which is classified, was issued in January 2010.

The Committee on Nuclear Forensics has been informed about progress made since that time on several matters related directly to the committee's findings and recommendations. There has been a modest increase in funding for nuclear forensics. As required by the 2010 Defense Authorization Act, the President has issued a 5-year strategic plan for work in this area. His National Security Staff has informed the committee staff that an interagency policy committee will soon be initiated to develop strategic requirements for nuclear forensics. The Joint Atomic Energy Intelligence Committee has issued guidelines on which measurements would be most valuable for post-detonation nuclear forensics. Guidance has been issued on which nuclear forensics matters may be discussed with non-U.S. citizens. The interagency apparatus has begun work on reconciling security classification guidance among the responsible agencies. The National Level Exercise 2010, held in May, for the first time incorporated attribution in a nuclear detonation exercise. A nuclear forensics personnel pipeline program is funding fellowships for graduate students and supporting professors in a few mission-relevant fields, and has created a nuclear forensics summer school. Other actions have been taken but remain beyond the bounds of this abbreviated report for national security reasons.

These all appear to be positive developments, although the committee has not had a chance to review them. Much work remains to be done on matters raised by the committee. It appears that these issues are being recognized by the responsible federal agencies and the White House, and steps are being taken to address them.

Albert Carnesale, Chair
Committee on Nuclear Forensics

Preface

Leaders of the United States for more than a decade have believed that nuclear terrorism is among the gravest threats to our nation. Beyond the terrible loss of life, which in itself is difficult to appreciate fully, the successful detonation of one or more nuclear explosives in a U.S. city and the potential for more detonations could transform our nation into a national security state, focused on common defense to the detriment of the justice, general welfare, and blessings of liberty envisioned by our nation's founders. The nation's responses to the attacks on the United States on September 11, 2001, hint at this danger. America has proven resilient, but a nuclear detonation would cause far more death and destruction than were seen on 9/11.

Our nation's ability to conduct forensic analyses of nuclear materials, nuclear explosions, and debris from radiological dispersion devices can contribute substantially to deterring, limiting, and responding to nuclear terrorism—complementing and enhancing efforts to secure nuclear materials and detect theft, diversion, and clandestine production. The capability to identify or exclude possible origins of nuclear material could, most importantly, enhance U.S. diplomatic and investigative efforts to prevent nuclear terrorism.

The crucial importance of nuclear forensics invites questions such as this: What capabilities are embodied in the current U.S. nuclear forensics program, and how might they best be sustained and improved? These basic but highly important matters are addressed in this report by the National Academies Committee on Nuclear Forensics.

Nuclear materials and weapons have, since their discovery, required special attention. The development of nuclear forensic analyses took place largely in secret at a few laboratories. The nature of the work dictates that some of it will have to remain connected to but separate from other forensic science research, development, and practice. For that reason, the nuclear forensics program must stand on its own.

The committee was aided in its efforts by knowledgeable, skilled, and accommodating members of the National Research Council staff. In particular, Micah Lowenthal, the study director, was invaluable in organizing and marshalling the effort, as well as for his substantive contributions.

He and we received considerable assistance from Toni Greenleaf and Shaunteé Whetstone on the Nuclear and Radiation Studies Board staff and from the program security staff of the National Academies. To these individuals, and to others within and outside of government who provided information, perspectives, and the benefits of their experience and wisdom, we are sincerely grateful.

Albert Carnesale, Chair
Committee on Nuclear Forensics

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 its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The content of 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 participation in the review of this report:

Donald Barr, Los Alamos National Laboratory (retired)
Linton A. Brooks, National Nuclear Security Administration (retired)
Charles Craft, Sandia National Laboratories
John Foster, GKN Aerospace Transparency Systems, Inc.
Lisa Gordon-Hagerty, LEG Consulting, Inc.
Stanley G. Prussin, University of California (emeritus)
Wayne Shotts, Lawrence Livermore National Laboratory (retired)

In addition, Carol Burns (Los Alamos National Laboratory), Nathan Wimer (Lawrence Livermore National Laboratory), and staff in the National Technical Nuclear Forensics Center each conducted fact checks on excerpts of the draft report that contained no findings or recommendations. Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Cherry Murray of Harvard University and Richard A. Meserve of the Carnegie Institution for Science. Appointed by the Report Review Committee and the Division on Earth and Life Studies, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the National Research Council.

Contents

Executive Summary

Nuclear forensics is important to our national security. Actions, including provision of appropriate funding, are needed now to sustain and improve the nation's nuclear forensics capabilities. The Department of Homeland Security (DHS), working with cooperating agencies and national laboratories, should plan and implement a sustainable, effective nuclear forensics program.

Nuclear forensics is the examination and evaluation of discovered or seized nuclear materials and devices or, in cases of nuclear explosions or radiological dispersals, of detonation signals and post-detonation debris. Nuclear forensic evidence helps law enforcement and intelligence agencies work toward preventing, mitigating, and attributing a nuclear or radiological incident. This report, requested by DHS, the National Nuclear Security Administration, and the Department of Defense, makes recommendations on how to sustain and improve U.S. nuclear forensics capabilities.

The United States has developed a nuclear forensics capability that has been demonstrated in real-world incidents of interdicted materials and in exercises of actions required after a nuclear detonation. The committee, however, has concerns about the program and finds that without strong leadership, careful planning, and additional funds, these capabilities will decline.

Major areas of concern include:

Organization. The responsibility for nuclear forensics is shared by several agencies without central authority and with no consensus on strategic requirements to guide the program. This organizational complexity hampers the program and could prove to be a major hindrance operationally.

Sustainability. The nation's current nuclear forensics capabilities are available primarily because the system of laboratories, equipment, and personnel upon which they depend was developed and funded by the nuclear weapons program. However, the weapons program's funds are declining.

Workforce and Infrastructure. Personnel skilled in nuclear forensics are too few and are spread too thinly. Some key facilities are in need of replacement because they are old, outdated, and not built to modern environmental, health, and safety standards.

Procedures and Tools. Most nuclear forensics techniques were developed to carry out Cold War missions and to satisfy a different, less restrictive set of environmental, health, and safety standards. Some of the equipment also does not reflect today's technical capabilities.

The Executive Office of the President established the National Technical Nuclear Forensics Center under the direction of the Secretary of Homeland Security, to coordinate nuclear forensics in the United States. DHS's responsibility can only be carried out with the cooperation and support of the other agencies involved.

The committee recommends the following. DHS and the other cooperating agencies should:

1. *Streamline the organizational structure, aligning authority and responsibility; and develop and issue appropriate requirements documents.*
2. *Issue a coordinated and integrated implementation plan for fulfilling the requirements and sustaining and improving the program's capabilities.* This plan would form the basis for the agencies' multi-year program budget requests.
3. *Implement a plan to build and maintain an appropriately sized and composed nuclear forensics workforce,* ensuring sufficient staffing at the national laboratories and support for university research, training programs, and collaborative relationships among the national laboratories and other organizations.
4. *Adapt nuclear forensics to the challenges of real emergency situations,* including, for example, conducting more realistic exercises that are unannounced and that challenge regulations and procedures followed in the normal work environment, and implementing lessons learned.

The national laboratories should:

5. *Optimize procedures and equipment* through R&D to meet program requirements. Modeling and simulation should play an increased role in research, development, and planning.

The nuclear forensics community should:

6. *Develop standards and procedures* for nuclear forensics that are rooted in the same underlying principles that have been recommended to guide modern forensic science.

DHS and the other cooperating agencies should:

7. *Devise and implement a plan that enables access to relevant information in databases*—including classified and proprietary databases—for nuclear forensics missions.

The Executive Office of the President and the Department of State, working with the community of nuclear forensics experts, should:

8. *Determine the classes of data and methods that are to be shared internationally* and explore mechanisms to accomplish that sharing.

Summary

When the U.S. government interdicts significant special nuclear or radioactive materials, the President of the United States wants answers to several questions: What is it? Where did it come from and whose is it? Who had it and how did they get it? Did they have help? What were they going to do with it? Is there more of it out there? What should we do about it?

If the United States were attacked with a nuclear or radiological device, the political environment would be extraordinarily intense, and the pressure for the nation to respond would be great. The president would seek answers to a similar set of immediate and urgent questions, including: What was it? How bad is the damage, and how much worse will it get? Who did it? Are there more out there? Did they have help? Where did it come from? Was it ours? And ultimately, What should we do about it?

The United States has technical capabilities to analyze interdicted nuclear and radiological devices and the materials that can be used to make them, analyze the signals and debris from a nuclear detonation or radiological dispersion, and simulate materials production and weapons performance. Together, these *nuclear forensics* capabilities can help answer the president's questions by learning what the materials are; how, when, and possibly where they were made; what has been done with them since they were made; and, in the case of a nuclear device, features of the device's design, construction, and performance. Each and any piece of information that nuclear forensics provides could be useful in the investigations of the incident as law enforcement and intelligence agencies work toward prevention, mitigation, and attribution. These capabilities can be made available through the Department of State to other countries, if another nation requests such assistance, as is currently done in conventional terrorist events, such as embassy bombings.

Substantial nuclear forensics capabilities exist in U.S. laboratories today. This report, requested by the Department of Homeland Security (DHS), the National Nuclear Security Administration (NNSA), and the Department of Defense (DoD), makes recommendations on how to sustain and improve those capabilities.

CURRENT CAPABILITIES

During the days of U.S. nuclear weapons testing, the national security laboratories analyzed measurements taken during and after each test, which provided insights into the phenomena that occurred during the detonation. Some measurements were analyzed quickly, but full results were provided over the course of months. The analyses of these tests led to an understanding of nuclear weapons design and performance that now enables the weapons laboratories and U.S. Strategic Command to certify the safety and reliability of the U.S. nuclear weapons stockpile without additional nuclear testing. Although this experience is valuable for nuclear forensics, it is much more challenging to work from observations of unknown materials or from detonation debris from unknown devices and analyze and interpret them accurately and quickly. The nuclear forensics task is subject to the challenge of intense time pressure because of the demand for immediate answers. Additionally, in a domestic post-detonation event, the pressure for release of preliminary or partial analyses would be enormous.

In real-world interdiction cases and in exercises, U.S. laboratories have demonstrated the ability to analyze uranium and plutonium samples and report on the composition and time since last chemical separation of the material. In the same samples they can identify other materials and characteristic features of processes and features of facilities that might have produced the material in the sample. The laboratories have extensive experience with many other radioactive materials aside from uranium and plutonium, but most of that experience is not in conducting analyses needed for nuclear forensics, such as trace-constituent analyses and time since last separation. The laboratories are taking steps to improve their practices and methods to build greater confidence in the results. The timelines for obtaining results also vary depending on the material, the type of analysis, and the resources devoted to analysis and evaluation.

In addition to the incidents and domestic exercises, the national laboratories also take part in international round robin exercises that provide opportunities to compare analytic procedures and results. These international efforts complement the U.S. exercises and build relationships among the analysts, enhance development and application of techniques.

In post-detonation exercises, nuclear forensics has provided information sequentially about the nuclear explosive, beginning almost immediately and working to completion after receipt of samples at the national laboratories. For these exercises, the national laboratories were provided with advance notice and relatively good input data.

The timeline for post-detonation analysis and evaluation is longer than is desired. Even delivering on the exercised pace will be taxing to the limited human and facility resources that are available for this operation. It is the committee's judgment that under similar conditions the time required to provide all of the information with higher confidence than can be achieved today could be reduced with improvements in procedures and techniques.

These improvements include:

- development and deployment of prompt diagnostic systems;
- simulations to better interpret data from prompt diagnostics;
- identification of useful short-lived signatures[1] and how to measure them;
- better planning for air and ground sampling;
- development of tools and procedures for sample selection;
- formalizing procedures for faster sample distribution to and receipt by fixed laboratories;
- development of faster, more reliable sample-preparation techniques;
- development of automated analytical techniques that meet modern environmental, health, and safety requirements;
- simulations to explore signatures of nuclear-material-production technologies; and
- more detailed simulations of the performance of a broad range of known and

[1] Signatures are observable features that are indicative of the composition, origin, or history of the material or device.

improvised nuclear devices in the types of environments that are the most likely targets of a nuclear attack.

Although U.S. nuclear forensics capabilities are substantial and can be improved, right now they are fragile, under resourced, and, in some respects, deteriorating. Without strong leadership, careful planning, and additional resources, these capabilities will decline.

Major areas of concern include the complex organization of nuclear forensics efforts within the federal government; the sustainability of a nuclear forensics capability that relies on base support from a shrinking nuclear weapons program for facilities, equipment, and personnel; a diminishing workforce and aging infrastructure; and reliance on procedures and tools developed during the Cold War, which may not be optimized for the nuclear forensics mission. Each of these is described in more detail below along with the committee's major findings and recommendations, which appear in bold text.

ORGANIZATION

The nuclear forensics mission is spread among multiple offices in several federal agencies and is overseen by and reports to different committees and subcommittees in Congress. The Executive Office of the President has assigned leadership for coordinating nuclear forensics to DHS. The National Technical Nuclear Forensics Center (NTNFC) in the Domestic Nuclear Detection Office of DHS was established in October 2006. The NTNFC was given the mission to coordinate the nation's nuclear forensics program. Under the direction of the Secretary of Homeland Security, NTNFC is to develop and implement a nuclear forensics program plan; ensure national-level integration of the program with relevant work performed for intelligence and arms control purposes; assess the capabilities through exercises; build support for improvement in infrastructure, personnel, research, development, testing, and evaluation; and establish standards and stewardship for the nation's nuclear forensic capabilities.

DHS and the other cooperating agencies have not yet devised or institutionalized a program that is optimized with respect to readiness, operational effectiveness, sustainment, and improvement. There is extensive and effective information sharing among several of the parties that constitute the NTNFC. Part of this success results from the sense of common purpose shared by the principals involved, and some arises from the short-term exchanges and extensive use of detailees among agencies. However, DHS does not direct resources or actions in program elements outside of the pre-detonation nuclear materials mission area, and agencies are more likely to optimize within their mission areas than across the mission areas. With this structure, it is difficult to form a coherent program with a single set of common goals and funds aligned appropriately and consistently to meet those goals. In particular, it is difficult to prioritize among missions, actions, and efforts (e.g., research, training, and operations; pre-detonation versus post-detonation capabilities; improvised nuclear devices versus radiological dispersal devices).

The program managers also do not have clear direction from senior decision makers, law enforcement, and the intelligence community on the operational requirements for nuclear forensics and information deliverables. Technical practitioners learn only anecdotally what senior decision makers expect and want most from nuclear forensics. A clearer statement of national-level requirements would provide a basis for interagency coordination and prioritization. To put together a program plan, DHS must work with senior decision makers, law enforcement experts, and members of the intelligence community, as well as the nuclear forensics practitioners, to define more clearly and build greater acceptance of the program's requirements and goals. This might be begun by convening a workshop composed of experts within these communities with the specific objective of refining and agreeing on a proposed set of requirements and goals to guide the program. Such a workshop could draw upon this and other studies of nuclear forensics functions in the United States, and lessons learned from exercises and real-world cases. Such a workshop is a starting point, but it might not resolve actual disagreements between and among agencies. For such situations, DHS and possibly the Executive Office of the President will need to adjudicate disagreements.

Clarifying the goals for the program is an essential step in developing and refining objectives and guidelines from which to build the capability and performance metrics. Clarifying requirements and other guidance would also inform and support a more realistic assessment of needs and acquisition of resources for near-, mid-, and far-term investments. At each site the committee visited, there were important questions about program needs that the scientists and managers could not answer specifically because they did not have a requirements document. The committee has been told that the last draft requirements document failed to achieve concurrence from two agencies, and that there have been renewed efforts to address the concerns raised and put something in place to assist the program. It makes sense for this to be done in time for an implementation plan that flows from the requirements to affect the next budget cycle.

The organizational complexity of nuclear forensics responsibilities and authority in the U.S. government hampers the program and could prove to be a major hindrance operationally. To address this problem, the committee considered recommending consolidating authority and responsibility for nuclear forensics in a particular agency. Ultimately, the committee did not do so because (l) the committee was not asked to tell the government how to reorganize itself for this mission; (2) the committee could not evaluate the implications, advantages, and disadvantages of doing so; and (3) a presidential directive was issued in 2007 establishing the agencies' responsibilities. However, in the committee's view, the organizational complexity remains a serious problem that must be addressed.

Recommendation 1: If the nuclear forensics mission is to succeed, then: (a) the organizational structure must be streamlined with the agency in charge possessing both the requisite authority and responsibility; and (b) DHS, the cooperating agencies, and the President's National Security Staff must develop and issue the appropriate requirements documents.

SUSTAINABILITY

The existing nuclear forensics capabilities are highly leveraged off of the nuclear weapons program and other related programs. The system of laboratories, equipment, and personnel upon which they depend was developed and funded by the nuclear weapons program and others. The weapons program's funds have been declining and NNSA is focusing remaining resources more narrowly to eliminate redundancies and maintain stockpile-mission-critical competencies at fewer sites. In these circumstances, the nuclear weapons program may not provide the resources necessary to sustain the nuclear forensics mission, and as a result the laboratory system's effectiveness and responsiveness for nuclear forensics missions become less certain. Historically, most nuclear-forensics functions have been paid for at the marginal cost, relying on other programs to establish the infrastructure and facilities and to pay for most of the training and the balance of the salary for the workforce, as well as some of the equipment. Because of that reliance, even level funding for nuclear forensics will result in a decline in the nuclear forensics capabilities as the underlying nuclear weapons program shrinks.

Recommendation 2: DHS and the cooperating agencies should issue an implementation plan for fulfilling the requirements and sustaining and improving the nuclear forensics program's capabilities. This plan would represent a coordinated, integrated program view, including prioritized needs for operations, infrastructure, research and development. The plan should specify what entity is responsible for each action or program element. The plan would form the basis for the multi-year budget requests essential to support the program and its plan.

If the implementation plan is reasonable and Congress agrees that nuclear forensics is an important element of our national security, then Congress should fund and support this mission.

To maintain appropriate facilities and equipment, the nuclear forensics program needs:

- Multiple programmatic uses of the facilities and equipment relevant to nuclear forensics so that they are functioning, calibrated, and ready when they are needed. This would result in facilities and equipment whose costs are shared.
- A quality management program, including standards, validated techniques, and regular calibration.
- An on-going effort to modernize and accelerate methods for analysis and evaluation based on R&D.

WORKFORCE AND INFRASTRUCTURE

At present, personnel skilled in nuclear forensics at the national laboratories are too few and are spread too thinly. Furthermore, a substantial fraction of the experienced personnel are retired, now eligible for retirement, or nearing retirement age. The university pipeline produces too few people in needed specialties and universities will not produce them without stable funding for relevant R&D.

Most nuclear forensics work is not continuous, so the majority of current practitioners must be occupied with other work for much of their time. Personnel in nuclear forensics participate in exercises, which are necessary to maintain competence, but exercises alone are not sufficient to occupy these personnel. It would be desirable if the other work in which personnel were engaged were complementary to nuclear forensics work. Fields such as environmental remediation, advanced fuel-cycle research, and nuclear medicine development and production are examples of relevant related work for radiochemists. Weapons designers mainly work on stockpile stewardship and on R&D to support that program. But for weapon designers there is still relevant nuclear forensics work outside of exercises, such as analyzing the predicted performance of unconventional improvised-nuclear-device designs, foreign weapons, underperforming known designs, and nuclear explosives detonated in urban environments.

To improve the personnel base for nuclear forensics, the committee suggests increased and sustained funding for nuclear forensics exercises, building and sustaining better connections with universities, and engaging workers from academia and industry with crossover skills on a reserve basis. The NTNFC has established the National Nuclear Forensics Expertise

Development Program to address some of these issues. This program needs to be sustained to have an impact on the nuclear forensics capabilities.

Recommendation 3: DHS and the cooperating agencies should implement a plan to build and maintain an appropriately sized and composed workforce.

To do this, the nuclear forensics program needs:

- synergistic professional work to engage program personnel when they are not working on nuclear forensics exercises and events;
- an R&D program focused on useful, challenging, and interesting goals;
- an exercise, evaluation, training, and learning program;
- collaborative relationships among the laboratories and an external community of experts and organizations to review and contribute to the program, to supply new personnel, and to assist the national laboratories in case of an event; and
- stable and sustainable funding.

Several of the facilities used for nuclear forensics are old and outdated, were not built to modern environmental, health, and safety (EH&S) standards, and are in need of replacement. The cost of constructing new facilities for handling special nuclear material[2] and highly radioactive material is large, so careful investment or replacement decisions are required, particularly if necessary redundant analytical capabilities are to be maintained. Funding for these investments is difficult to obtain today in part because a coordinated and integrated program plan has not yet been created.

Post-detonation nuclear forensics capabilities have been demonstrated in test and training exercises, but their operational readiness has not been tested in some realistic scenarios or no-notice events. With more realistic exercises (e.g., no notice, samples that are realistic outliers, real-time distribution of samples to the laboratories), managers will gain greater confidence in assessments and exercise participants will identify strengths, gaps, and deficiencies. This will enable DHS and its partner agencies to improve performance.

Pressure for increasingly stringent interpretation of EH&S goals has made it increasingly challenging to work with materials and equipment that emit radiation or are otherwise hazardous. This problem is particularly acute at DOE and NNSA facilities where concerns about health and safety can, in some cases, add a substantial time and cost burden to, or even preclude, the performance of tasks that are essential to national security. The full implications of these burdens for nuclear forensics are not known. Dealing with exigencies that might arise in such cases takes time that would be better spent on analysis, so it makes sense to work through predictable obstacles (EH&S restrictions among them) in advance.

Recommendation 4: DHS and the cooperating agencies should adapt nuclear forensics to the challenges of real emergency situations, including, for example, conducting more realistic exercises that are unannounced and that challenge regulations and procedures

[2] Special nuclear material is defined in the Atomic Energy Act of 1954, as amended (P.L. 83-703), as "(1) plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other materials which the [Nuclear Regulatory] Commission, pursuant to the provisions of section 51, determines to be special nuclear material but does not include source material; or (2) any material artificially enriched by any of the foregoing, but does not include source material."

followed in the normal work environment, and these agencies should implement corrective actions from lessons learned[3]

PROCEDURES AND TOOLS

In post-detonation exercises, national laboratories have demonstrated that they can characterize nuclear debris and other forensic data and infer key design features of a variety of nuclear explosive devices. However, many of these characterization techniques are based on legacy procedures developed for analyzing U.S. and foreign nuclear weapons tests. Some of the techniques used in the past yielded results quickly but cannot be employed today because they would not meet contemporary EH&S requirements.

There are numerous opportunities for the United States to improve its technical nuclear forensics capabilities and performance. The top priorities are to increase analytic and operational capabilities in ways that reduce timelines and uncertainties in findings. The committee judges that marked reductions in timelines and uncertainties are achievable with reasonable efforts in R&D and operational improvements. In light of the cost-benefit tradeoffs inherent in the selection of a timeline, this selection has to be made by policymakers with input from the technical community.

The committee favors the development of an R&D effort that pursues both evolutionary improvements in the existing nuclear forensics methods and techniques as well as entirely new methods and techniques having far greater capabilities than those currently available.

In addition to building the expert personnel base, the program needs:

- *Improved sampling procedures,* especially for urban environments, informed by simulations of a variety of detonation scenarios;
- *Improved laboratory techniques,* including increased automation, improved techniques for sample preparation and laboratory analysis that extract more useful information from a spectrum of sample types and matrices, and techniques that more readily comply with EH&S requirements;
- *Proper and defensible validation protocols* for analytical methods;
- *A better understanding of measurements* that have been and could be made on nuclear materials production facilities and nuclear detonations;
- *Improved techniques to assess uncertainties* in sampling, laboratory analysis, and data evaluation;
- *Validated and more complete databases of nuclear materials, facilities, and devices,* including advanced querying techniques to extract information from incomplete and/or noisy data and find signatures and correlations among entries; and possibly
- *New or newly deployed equipment for prompt diagnostics.*

Modeling and simulation are used in modern scientific and engineering programs to guide experiments and examine the possible outcomes of events that cannot or will not be tested physically. The nuclear forensics program would benefit from increased use of modeling and

[3] Implementing corrective actions from lessons learned is important and difficult and requires resources. DoD has a formal process for lessons learned, but few other agencies do. The committee was told that funding was not available to implement corrective actions from lessons learned. Since that time, NTNFC has created corrective action teams for this purpose. The committee did not have an opportunity to evaluate their performance.

simulation for informing decisions about how to allocate resources, what experiments to perform, and where and how to sample in a post-detonation scenario. The needed work includes

- development and deployment of prompt diagnostic systems;
- simulations to better interpret prompt diagnostic measurements;
- identification of useful short-lived signatures and how to measure them;
- better planning for ground and air sampling, including simulations of debris fields and investigation of preexisting objects which, in the presence of an attack, can record signatures;
- development of tools and procedures for better sample selection;
- formalizing procedures for rapid sample distribution to and receipt by fixed laboratories;
- development of faster, more reliable sample preparation techniques;
- development of automated analytical techniques that meet modern EH&S requirements;
- simulations to explore signatures of nuclear-material-production technologies; and
- simulations of explosions of various postulated nuclear explosive devices, their effects, and resulting debris fields in the types of environments that are the most likely targets of a nuclear attack.

Recommendation 5: The laboratories involved in nuclear forensics should conduct research and development aimed at optimizing procedures and equipment to meet evolving program requirements. Modeling and simulation should play an increased role in several parts of the program, both for planning and for conducting analyses. This work should be funded at a level consistent with the overall implementation plan.

Nuclear forensics is a specialized subset of forensic science, a field that has developed over several decades and that continues to pursue properly validated standards and procedures. Forensic science today is moving to build an even stronger scientific base. There is an apparent tension between the requirements for forensic science that have evolved to support prosecution in a court of law, which is the usual context in which forensic science is employed, and what may be desired from forensic science to support decision making in a policy context. For example, the chain of custody of evidence is an established critical requirement in forensic science to support criminal prosecution, which may be difficult to sustain in a nuclear event. The chain of custody for a post-detonation sample may never meet the rigors required for a courtroom. However, this tension can be overstated. Several underlying principles have been recommended to guide forensic science.[4] Those principles that are focused on ensuring a robust, reliable, scientifically sound analysis that provides well-characterized results, including uncertainties, apply equally to nuclear forensics and other branches of forensic science. While nuclear forensics procedures and standards will be developed for emergency or near-emergency situations, it makes sense for them to be rooted in the same underlying principles that are intended to guide modern forensic science. Many nuclear forensics techniques already have a strong scientific basis and so would fit well into a scientifically based forensic science framework.

[4] National Research Council. 2009. *Strengthening Forensic Science in the United States: A Path Forward.* The National Academies Press. Washington, DC.

Demands from the White House and Congress for immediate (even if preliminary) information in a post-detonation situation would be intense. In particular, there would be pressure to provide information that bears on attribution. At every stage of nuclear forensics, communicated results should be accompanied by an assessment of the confidence in the results and the implications for uncertainties arising from their use.

Recommendation 6: The nuclear forensics community should develop and adhere to standards and procedures that are rooted in the applicable underlying principles that have been recommended for modern forensic science, including calibration using reference standards; cross comparison with other methods; inter-laboratory comparisons; and identification, propagation, and characterization of uncertainties.

Even a casual observer of forensic science understands that databases are important tools for determining the possible origins and history of a material or an object: analysts compare the sample under scrutiny to a set of known samples. All nuclear material has history and it is a task of nuclear forensics to uncover that history to the extent possible.

Several U.S. agencies maintain databases populated with information that could be relevant to nuclear forensics and forensic analysis of nuclear incidents and events. Some agencies do not share their databases, or their databases are not readily accessible, which can be detrimental to performance of the program. The Nuclear Materials Information Program (NMIP) was created as the clearinghouse for information on nuclear materials inventories and characteristics. NMIP is now expected to link most but not all of the relevant databases.

Recommendation 7: DHS and the cooperating agencies should devise and implement a plan that will permit, under appropriate conditions, access to the relevant information in all databases—including classified and proprietary databases—for nuclear forensics missions. This means that, when queried, the responses to the queries will be timely, reliable, and validated, and will provide sufficient relevant data and metadata[5] to enable analysts to use them.

International collaboration and data sharing are important. Many scenarios for nuclear forensics involve non-U.S. material, so data on non-U.S. material (including foreign military material) would be of great value. An international database of special nuclear and other radioactive material properties from sources all around the world would be a valuable resource and therefore is a worthy objective, but there are many challenges to achieving a reliable, comprehensive international database. The three greatest challenges are: (l) source bias (skewing of the data resulting from who is willing to participate and what data they are willing to share because of security concerns, political considerations, or proprietary restrictions); (2) unreliability due to intentional and/or inadvertent misinformation; and (3) the potential for inconsistencies between international and domestic databases that could make it more, rather than less, difficult for the United States to convince other countries of a U.S. conclusion.

The United States is encouraging countries to develop their own databases, but not necessarily to link them. This approach encourages other countries to focus on nuclear security and nuclear forensics, to include sensitive information in the databases they develop, to have the

[5] Metadata refers to information associated with the collection of the data, such as sampling approach, the technique used for analysis, and known biases associated with the equipment or facility (such as known contamination).

ability to access that information in case of an incident, and to create entities with which the United States can communicate on these matters in case of an incident.

Recommendation 8: As the U.S. government organizes and enhances its databases and nuclear forensics methods, the Executive Office of the President and the Department of State, working with the community of nuclear forensics experts, should develop policies on classes of data and methods to be shared internationally and explore mechanisms to accomplish that sharing.

The United States should decide whether to share analytical methods to foster development of a broader international scientific base for conducting nuclear forensics. The United States should also conclude whether it would be useful to share its own analytical results to build international support for action following an event. These decisions should be made as soon as is practical, before the capabilities are needed to respond to an event.

CONCLUSION

For a decade, the U.S. government has considered a nuclear terrorist attack on the United States to be the most catastrophic threat the nation faces. Nuclear forensics is an important part of our response to that threat and important to our national security. It is not intended to provide all of the answers that decision makers desire, but to appreciate its value, one need only imagine the circumstances if the nation did not have a nuclear forensics capability in place when an interdiction or a detonation event occurred.

An impromptu nuclear forensics effort would be initiated. Such an effort would likely provide inferior and possibly misleading results on a longer timeline and with lower confidence levels. Key information might never be discovered. The intelligence and law enforcement communities would be asked to carry out their investigations without timely, reliable information about the nuclear materials or device design. Analysts would have no benchmarks by which to judge the quality of the information upon which decisions and actions are taken. This would make it more difficult to identify the perpetrators, especially their supporters or sponsors, and to inform the president of which countries may have been involved and which ones likely were not involved. Furthermore, even if intelligence and law enforcement were to successfully identify culprits associated with smuggling or detonating a weapon or material, they would have to provide supporting evidence for their conclusions, not just in a prosecutorial context but even in a national security context, domestically and internationally. Allies and adversaries alike must be persuaded, and that task would be made easier with physical forensic evidence provided by a robust program.

Important as nuclear forensics capabilities are, they are at risk and actions are needed now to sustain and improve them.

Brief Biographies of Committee Members

Albert Carnesale is University of California, Los Angeles (UCLA) chancellor emeritus and holds professorial appointments in UCLA's School of Public Affairs and Henry Samueli School of Engineering and Applied Science. His research currently focuses on issues in international affairs and security and in higher education. Dr. Carnesale served as chancellor of UCLA from July 1, 1997 to June 30, 2006. He is the author or co-author of six books and more than 100 scholarly articles on a wide range of subjects, including the control of nuclear weapons and other weapons of mass destruction, international energy issues, the effects of technological change on foreign and defense policy, and challenges and opportunities facing higher education. Prior to assuming the chancellorship of UCLA in 1997, Dr. Carnesale was at Harvard University for 23 years, serving as provost of the university and academic dean and dean of Harvard's John F. Kennedy School of Government, where he also held the Lucius N. Littauer Professorship of Public Policy and Administration. His earlier career included positions in the private sector and in government. Dr. Carnesale has represented the United States government in high-level negotiations on defense and energy issues (including the Strategic Arms Limitation Talks, SALT I). He holds bachelor's and master's degrees in mechanical engineering and a Ph.D. degree in nuclear engineering, has been awarded three honorary doctorate degrees, and is a fellow of the American Academy of Arts and Sciences and a member of the Council on Foreign Relations.

Marvin Adams is professor of Nuclear Engineering, associate vice president for research, and director, Institute for National Security Education and Research, at Texas A&M University. He worked at Sequoyah Nuclear Plant (a TVA power plant) and its support office for approximately 2.5 years before entering graduate school at the University of Michigan. There he began working on computational methods, focusing on problems involving particle transport. This effort continued through 5.5 years as a code developer in the secondary-design division at Lawrence Livermore National Laboratory, and it has continued and broadened during 15 years on the faculty at Texas A&M University. In recent years he has focused on efficient large-scale coupled-physics simulations and on assessing the predictive capability of such simulations. Dr. Adams has served on panels and committees that have reviewed and advised the NNSA labs and DOE on matters including Stockpile Stewardship and the role of Advanced Scientific Computing in the weapons program. He is a fellow of the American Nuclear Society. Dr. Adams received a B.S. degree from Mississippi State University, and M.S.E. and Ph.D. degrees from the University of Michigan, all in nuclear engineering.

R. Stephen Berry is the James Franck Distinguished Service Professor Emeritus of Chemistry at the University of Chicago and holds appointments in the college, the James Franck Institute, and the Department of Chemistry. He has also held an appointment in the School of Public Policy Studies at the university. He has held a number of positions including visiting professor at the University of Copenhagen, the Université de Paris-Sud, and Oxford University, where he was the Newton-Abraham Professor in 1986. He spent 1994 at the Freie Universität Berlin as an awardee of the Humboldt Prize. In 1983 he was awarded a MacArthur Fellowship. He is a member of the National Academy of Sciences. In 1997, he received the Heyrovsky Medal of the Czech Academy of Sciences. One aspect of his scientific research has been theoretical, in areas of finite-time thermodynamics, atomic collisions, atomic and molecular clusters and chaos, topographies and dynamics of complex potential surfaces, clusters and proteins. Another facet has been experimental, involving studies of negative ions, chemical reactions, detection of transient molecular species, photoionization and other laser-matter interactions. He has also worked in matters of scientific ethics and of some aspects of national security. His current scientific interests include the dynamics of atomic and molecular clusters, the basis of "guided" protein folding and other "structure-seeking" processes, and the thermodynamics of time-constrained processes and the efficient use of energy. He attended Harvard University where he received his A.B., A.M., and Ph.D. degrees in chemistry.

Sue B. Clark is professor and chair of the Chemistry Department at Washington State University (WSU). Her current research focuses on the environmental chemistry of plutonium and other actinides, and development of radioanalytical methods to measure actinide elements in environmental samples. Prior to joining WSU in 1996, she was an assistant research ecologist at the University of Georgia's Savannah River Ecology Laboratory, and senior scientist at Westinghouse Savannah River Company's Savannah River Technology Center (1989-1992). Dr. Clark has served as a consultant to the Nuclear Energy Agency of France, the Korean Atomic Energy Research Institute, and the Battelle Memorial Institute and several committees of the National Research Council. Dr. Clark has received several awards, including the Westinghouse Professorship (2000 to present), Ford Lecturer at Minnesota State University, the Edward R. Meyer Distinguished Professor of Chemistry, the Young Faculty Achievement Award in the College of Sciences at WSU. She is a member of the American Chemical Society, the American Association for the Advancement of Science, and Sigma Xi, the Scientific Research Society. Dr. Clark received her Ph.D. degree in inorganic and radiochemistry from Florida State University. She has served on several National Research Council committees, and she currently serves on its Nuclear and Radiation Studies Board.

Jay C. Davis is president of the Fannie and John Hertz Foundation. Previously, Dr. Davis was a scientist at Lawrence Livermore National Laboratory where he served as the first national security fellow at the Center for Global Security Research. He previously served as the founding director of the Defense Threat Reduction Agency (DTRA) of the United States Department of Defense (DOD). His current interests are homeland defense, nuclear and biological forensics, applications of accelerator technologies to multi-disciplinary research, counterforce technologies, and strategic planning and management of change in organizations. Dr. Davis has over 80 publications on research in nuclear physics, nuclear instrumentation, plasma physics, accelerator design and technology, nuclear analytical techniques and analytical methods, and treaty verification technologies. He also holds patents on spectrometer technologies and methods for low-level dosimetry of carcinogens and mutagens and for the study of metabolic processes. He has been a scientific advisor to the UN Secretariat and has served on advisory committees for the

Lawrence Berkeley National Laboratory, the Australian Nuclear Science and Technology Organization, the Institute for Nuclear and Geologic Sciences of New Zealand, the National Nuclear Security Administration, the Central Intelligence Agency, and the University of Chicago board of governors for Argonne National Laboratory. He is currently on program review committees for the Lawrence Livermore and Los Alamos National Laboratories, and he currently chairs the executive advisory board for Sandia's Microscale Immune Studies Laboratory project. He also serves on the board of directors of the Fannie and John Hertz Foundation, the board of distinguished advisors for the American Committees on Foreign Relations and the Nuclear and Radiation Studies Board of the National Research Council. For his contributions to national security during his tenure at DTRA, he was twice awarded the Distinguished Public Service Medal, DoD's highest civilian award. Dr. Davis received his B.A. and M.A. degrees in physics from the University of Texas and his Ph.D. degree in physics from the University of Wisconsin.

John A. Gordon is a private consultant and serves on the boards of several corporations and non-profit organizations. He served in the White House as the President's Homeland Security Advisor from June 2003 until June 2004 and as the deputy national security advisor for counter terrorism and the national director for counter terrorism from June 2002 to June 2003. Prior to joining the White House team, General Gordon was the first administrator of the National Nuclear Security Administration and undersecretary of energy, responsible for the entirety of the nation's nuclear weapons program, serving from June 2000 until June 2002. As an Air Force four-star general, he was the deputy director of central intelligence from October 1997 until June 2000. General Gordon's thirty-two year Air Force career included significant concentration on R&D, strategic planning, missile and space operations, inter-governmental operations, and international negotiations. He currently serves as a member on the Earth and Life Studies Division Committee of the National Research Council. General Gordon received his B.S. degree with honors in physics from the University of Missouri and received his M.S. degree from the Naval Postgraduate School. He also received an M.A. degree in business administration from the New Mexico Highlands University.

Darleane C. Hoffman is professor of the graduate school in the Department of Chemistry, University of California, Berkeley (UCB) and faculty senior scientist, Nuclear Science Division, Lawrence Berkeley National Laboratory (LBNL). Her research interests include rapid chemical separation of short-lived fission products; separations chemistry of lanthanide, actinide and transactinide elements; search for heavy elements in nature; studies of radionuclide migration in geologic media; studies of the spontaneous fission process; heavy ion reactions and production of new neutron-rich heavy element isotopes; atom-at-a-time studies of chemical and nuclear properties of heaviest elements and has published more than 270 journal papers. Dr. Hoffman received B. S. and Ph. D. degrees from Iowa State University, Ames, Iowa. She served as a chemist at Oak Ridge National Laboratory and Los Alamos Scientific Laboratory, spending years as a fellow or visiting scientist in Norway and LBNL. She returned to Los Alamos National Laboratory (LANL) to be Division Leader of the Chemistry-Nuclear Chemistry and Isotope and Nuclear Chemistry Divisions. In 1984, Dr. Hoffman joined the Department of Chemistry at UCB and leader of the Heavy Element Nuclear & Radiochemistry Group at LBNL. She helped found the Seaborg Institute for Transactinium Science at Lawrence Livermore National Laboratory (LNLL), serving as its first director. She is a fellow of the Norwegian Academy of Science and Letters, the American Association for the Advancement of Science, the

American Institute of Chemists, the American Physical Society, and the American Academy of Arts and Sciences, and was inducted into the Women in Technology International Hall of Fame. She has received honorary doctorates from Clark University and Bern University. She received American Chemical Society Awards for Nuclear Chemistry, Garvan-Olin Medal, and the Priestley Medal. She was awarded the U. S. National Medal of Science in 1997, the Sigma Xi Proctor Prize for Scientific Achievement in 2003 and the 2007 J. V. Atasanoff Search & Discovery Award from Iowa State University.

Michael O. Larson retired in June 2007 from the Lawrence Livermore National Laboratory (LLNL) where he had worked for 33 years in the area of nuclear design. During this time he was principal investigator on 20 hydrodynamic experiments and 7 underground nuclear tests. He served as LLNL tactical navy military requirements officer and was project manager for the development of an Army nuclear weapons system. For the past 19 years Dr. Larson has worked with the Nuclear Emergency Support Team/Joint Technical Operations Team (NEST/JTOT) as the LLNL technical integration program manager in developing tools and techniques for deployment teams including support for the development of advance systems for detection and identification of nuclear materials. He has twice received Distinguished Service Awards from the NNSA. Dr. Larson received his B.A. and Ph.D. degrees in physics from the University of Utah and was an assistant research professor for 7 years in the Physics Department at the University of Utah.

Milton Levenson is an independent consultant. He is a chemical engineer with 65 years of experience in nuclear energy and related fields. His technical experience includes work related to nuclear safety, fuel cycle, water reactors, advanced reactors, and remote control. His professional experience includes research and operations positions at the Oak Ridge National Laboratory, the Argonne National Laboratory, the Electric Power Research Institute, and Bechtel. He was elected to the National Academy of Engineering in 1976. Mr. Levenson is a fellow and past president of the American Nuclear Society, a fellow of the American Institute of Chemical Engineers, and recipient of the American Institute of Chemical Engineers' Robert E. Wilson Award in Nuclear Chemical Engineering. He is the author of more than 150 publications and presentations and holds three U.S. patents. Mr. Levenson has served as chairman or committee member for several National Academies studies. He received his B.Ch.E degree from the University of Minnesota.

Randall S. Murch is the associate director for research program development in the Research Division of Virginia Polytechnic Institute of the National Capital Region. He also holds adjunct professorships in the School of Public and International Affairs, College of Architecture and Urban Studies, and the Department of Plant Pathology. He is also a visiting professor in the Department of War Studies, King’s College London, UK. From 2002 to 2004, Dr. Murch was on the research staff of the Institute for Defense Analyses (IDA) where he led and participated in studies for the defense, intelligence, and homeland security communities. He is still an adjunct staff member at IDA. Prior to working at IDA, Dr. Murch served for 23 years as a special agent with the Federal Bureau of Investigation (FBI). During his FBI career, he was assigned to the Indianapolis, Los Angeles, and New York field divisions, and to the national security, (forensic) laboratory and investigative technology (engineering) divisions at FBI Headquarters and Quantico, Virginia. He served as a department head and deputy division head in the FBI

Laboratory, as well as a deputy division head of the FBI's electronic surveillance division (investigative technology). He has extensive experience in counterintelligence, counterterrorism, forensic science, electronic surveillance, weapons of mass destruction (WMD) threat reduction, and outreach to those communities. He created the FBI's WMD forensic investigation/S&T response program in 1996, and served as the FBI's science advisor to the 1996 Olympics. From 1999 to 2001, he was detailed to the Defense Threat Reduction Agency (DTRA) as director of DTRA's advanced systems and concepts office. He has participated in National Research Council, Defense Science Board, and DTRA Threat Reduction Advisory Committee studies and panels and other senior review panels. Dr. Murch received a B.S. degree in biology from the University of Puget Sound, an M.S. degree in botanical sciences from the University of Hawaii, and a Ph.D. degree in plant pathology from the University of Illinois.

Jerry Wilhelmy has been a retired fellow of the Los Alamos National Laboratory since 2002. Dr. Wilhelmy is active in research and his interests have been centered on experimental nuclear science including work on nuclear fission, heavy ion reactions, superheavy elements, neutron induced reactions, supercritical atomic fields, laser driven fusion, national security applications, and weak interaction physics. He served as a group leader of the nuclear research group in the Chemical Science and Technology Division. He also served on the Transplutonium Advisory Committee for the National Research Council and the Transplutonium Assessment Panel of Lawrence Livermore National Laboratory's Technical Review Committee. Dr. Wilhelmy was a visiting scientist at the Weizmann Institute for Science and a research scientist at the Max Planck Institut für Kernphysik, and a post doctoral fellow at the Lawrence Berkeley Laboratory. He is the author or coauthor of over 100 publications on methods and phenomena in nuclear chemistry and nuclear physics. Dr. Wilhelmy received a B.S. degree in chemical engineering from the University of Arizona and a Ph.D. degree in chemistry from the University of California at Berkeley.