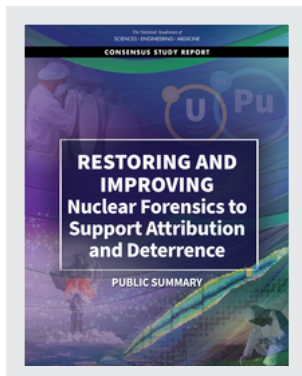


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## Restoring and Improving Nuclear Forensics to Support Attribution and Deterrence: Public Summary (2021)

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# **RESTORING AND IMPROVING Nuclear Forensics to Support Attribution and Deterrence**

## **PUBLIC SUMMARY**

Committee on Enhancing U.S. Nuclear Forensics and Attribution Support  
Capabilities

Committee on International Security and Arms Control

Policy and Global Affairs

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*The National Academies of*  
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## ACKNOWLEDGMENT OF REVIEWERS

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, 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 thank the following individuals for their review of this report:

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Alton Romig, executive officer of the National Academy of Engineering. He was 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 Academies.





## Preface

It has been the committee members' collective experience that studies of this kind are fairly straightforward: the object of study is well defined and the charge tasks can be readily executed. However, this has not been our experience in executing this charge.

Early in our fact-gathering stage, we discerned that the actual organization of the federal nuclear forensics program did not correspond to what the available documentation had led us to expect. It became evident that the nuclear forensics program was undergoing a significant unplanned reorganization because leaders of some components of the previous nuclear forensics organizational structure had disengaged their agencies from active participation and funding, and that an effort to put in place a new organizational structure for the national nuclear forensics program was under way. While this study report was in review, a new National Security Presidential Memorandum on nuclear forensics (NSPM-35) was signed by the President on January 19, 2021. The committee is gratified to see that many of the steps that the committee recommends in the study report are included in the NSPM and its Implementation Plan. Some of the committee's findings and recommendations focus on addressing those issues, and are included to warn against the lapses that led to the observed need for remediation. Furthermore, the committee makes many recommendations that are not in the federal reports or plans.

Chapter 1 of the 2010 National Academies assessment of U.S. nuclear forensics capability, to which this study compared the current state of affairs, begins by proposing a hypothetical scenario (NAS, 2010, p. 14):

The sleepy morning haze in Dallas, or Atlanta, or Chicago, or New York, or Los Angeles is ripped apart by the blinding flash, the sudden shockwave, and the expanding fireball from a nuclear explosion in the heart of the city. Minutes later, the President of the United States, entrusted with the responsibility to protect and defend the nation, is seeking answers to several questions. What was it? How bad is the damage, and how much worse will it get? Who did it? Did they have help? Where did it come from? Was it ours? Are there more? And finally, what should we do about it?

The discipline of nuclear forensics plays a key role in answering these questions. This study's findings and recommendations detail ways to improve U.S. nuclear forensics capabilities that help deter a nuclear device from being used against the United States or its allies and determine who is responsible if one is found or used. They outline a national strategy to ensure that nuclear forensics capability is given high priority and that improvements are sustained over the long term.

For the national strategy to be successful, the President and leaders charged with nuclear forensics must take action. There is no substitute for top-level leadership and for ensuring that departments and agencies fulfill their designated and even legislated responsibilities. With leadership that fosters initiative and invention to meet challenges and fulfill the mission, the program will not only make better progress toward its goals, but it will also provide the excitement that we see in active successful programs, rather than only a concern about how to preserve minimum functionality. Failure to stop an unclaimed nuclear attack or prevent additional attacks would cause

unprecedented harm to the United States. The nation deserves and needs a stronger deterrent against such attacks and the ability to attribute an attack in the event that deterrence fails. The nation deserves and needs stronger and more dedicated support for nuclear forensics.

Robert Rosner, *Chair*  
Committee on Enhancing U.S. Nuclear Forensics  
and Attribution Support Capabilities

## Acknowledgments

This report could not have been completed without the cooperation of the many present and former federal agency staff members who have played central roles in building and maintaining U.S. nuclear forensics capabilities, as well as the staff members of the Air Force Technical Applications Center, the Federal Bureau of Investigation, and the Department of Energy national laboratories charged with executing the operations and research and development at the heart of the U.S. nuclear forensics program. Randy Weidman, the National Nuclear Security Administration's point of contact for the project, was especially helpful.

While we were fortunate that our committee's investigation and interviews were largely complete by February 2020, the severe restrictions on travel and facility access due to the COVID-19 pandemic did substantially delay our ability to finish the study. Simply put, this report could not have been completed were it not for the hard work, dedication, and expertise of this committee's National Academies staff, Benjamin Rusek, Jennifer Heimberg, Micah Lowenthal, Marie Kirkegaard, and Hope Hare, who persevered despite these difficulties.



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## Executive Summary

The National Defense Authorization Act of 2019 directed the Secretary of Energy, in consultation with the Secretary of Defense and the Secretary of Homeland Security, to commission a study from the National Academies of Sciences, Engineering, and Medicine (the National Academies) of the U.S. government's nuclear forensics capabilities. Nuclear forensics is the analysis of nuclear materials, devices, emissions, and signals to determine the origin and history of those nuclear materials and devices. The mandate revisits a 2010 National Academies report, *Nuclear Forensics: A Capability at Risk*, which characterized the precarious state of the national technical nuclear forensics (NTNF) program at that time: NTNF relied almost entirely on staff dedicated to and residual funding from other related programs. The current study committee found evidence that the agencies responsible for NTNF acted on many of the 2010 report's recommendations, and although the program never reached the strong, sustainable state sought by the National Academies and the agencies in 2010, it did improve substantially until the end of 2016.

In 2017 and 2018, based in part on changing Presidential and agency leadership priorities, the Department of Homeland Security and the Defense Threat Reduction Agency within the Department of Defense reduced NTNF funding. In response, NTNF personnel sought ways to maintain capabilities and chart a path toward a stronger program.

The study committee developed findings and recommendations to provide a road map for improvement through strategic planning, assessments, gap analysis, priority setting, and appropriate funding; a subset of the findings and recommendations are highlighted below (numbered to match their numbering in the report). The U.S. government is already taking some of these steps. If all of these steps are implemented, the committee believes that the NTNF program will be on the right path.

*FINDING A.1: A robust U.S. NTNF capability is an important element of deterring, preventing, and responding to an unclaimed nuclear attack or smuggling incident, much as the nuclear weapons enterprise deters overt nuclear attacks and offers response options if deterrence fails.*

*FINDING A.3: U.S. NTNF capabilities have advanced since 2010 and received increased funding until 2016. Without sufficient and consistent leadership, support, and priority by the White House, NTNF agencies, and Congress, U.S. NTNF capabilities will atrophy.*

*RECOMMENDATION A.2: To support nuclear deterrence through a robust attribution capability, the NTNF program must be sustainable. The Executive Office of the President should issue a policy memorandum or policy directive elevating the importance of NTNF within the national security enterprise, stating that the mission of the program is both national and global, driving the need to detect, analyze, and support the attribution of nuclear events domestically and worldwide. Following the issuance, the National Security Council should direct, coordinate, and oversee actions to demonstrate commitment commensurate to that importance.*



The guidance offered by National Security Presidential Memorandum 35, “National Technical Nuclear Forensics” (NSPM-35), is a good start, and if leaders agree that a robust NTNF program is an important element of deterrence and prevention of nuclear incidents, then more must be done to support, sustain, and advance the program. The committee does not have a specific estimate for the appropriate size of the program—that should come from the process that is recommended below and detailed in the summary of the report that follows—but it is certainly larger than it is now.

*RECOMMENDATION A.3: In its annual report to Congress, the NTNF program should provide a description of the steps needed to make the program more effective and sustainable.*

## WAYS TO IMPROVE NTNF AND A VISION FOR ITS FUTURE

To be effective, the NTNF program needs a clearly articulated mission that flows through the program, guiding decisions and funding, with regular assessments to identify improvements needed to fulfill the mission. A mission-driven approach that sustains coordination, cooperation, focus, and commitment is especially important for NTNF because no single department can accomplish the NTNF mission alone. The Executive Office of the President, federal agencies, namely the National Nuclear Security Administration within the Department of Energy, the departments of Homeland Security, Defense, Justice, and State, and the Office of the Director of National Intelligence and the intelligence community, and Congress should take the steps listed in the following recommendations (elaborated in the body of the public summary report) on interagency functionality, vision and goals, assessment, implementation, and operational capability:

- *Interagency functionality (RECOMMENDATION B.1):* Coordinate development of the goals, assessments, implementation, and capabilities, and promote interagency cooperation and functionality at all levels within the relevant organizations. An effective interagency function will have clear lines of responsibility and authority and will hold entities accountable for those responsibilities. The program should persistently seek improvement and synergies with other programs.
- *Vision and goals (RECOMMENDATION C.1):* Issue a coordinated, consistent high-level requirements document for the NTNF program covering the elements of a capable, reliable, sustainable, and improving program, taking into account its interfaces with the attribution process and the other programs that feed into it. The requirements should derive from both minimum needs and goals for the capabilities of the program, agreed to at the highest level of the interagency structure.
- *Biennial assessment (RECOMMENDATION D.1):* Conduct realistic evaluations of the capabilities, gaps, and opportunities for improvement of the program not less frequently than every two years, resulting in an assessment letter or letters from the heads of the implementing organizations to leadership in the agencies responsible and accountable for the mission, to the Executive Office of the President, and to Congress to drive an iterative process of revision for improvement. In years when full assessments are not provided, a brief update on changes in the program should be included in the annual report to Congress.

- *Implementation (RECOMMENDATION E.1)*: Based on the requirements and the biennial assessments, issue an interagency implementation plan. For their own organizations, the agencies should also issue plans that are consistent with and support the interagency plan. These plans should all derive from the same goals, requirements, and assessments; be consistent with each other; and be updated as necessary based on the results of the biennial assessments.
- *Operational capability (RECOMMENDATION F.1)*: Strengthen an operational NTNF capability based on clear requirements, including the requirement to improve. This requires improved data sharing, mission-driven routine work, exercises and evaluation, sampling, research and development, quality assurance and control and uncertainty characterization, as well as more sustainable human resources and infrastructure. Improvements in these areas, guided by the organization, assessment, and implementation processes detailed above, will reduce timelines, improve accuracy, and ensure that the U.S. NTNF program can respond when needed.

The following summary report addresses the current state of U.S. NTNF capabilities relative to the National Academies evaluation in 2010 and recommends ways to improve the NTNF program through improvements in policy, operations, and research and development efforts, and provides a vision for NTNF's future. A more unified vision, more reliable support, and a more effective and coordinated NTNF program must be restored and improved to serve this critical deterrent and attribution-support mission.



# 1

## Introduction

### 1.a STATEMENT OF TASK AND CONGRESSIONAL MANDATE

The United States maintains and seeks to improve programs to determine the origin and history of nuclear material and devices, and in the case of a nuclear explosion, the design of the device. The acquisition of the data and the performance of the analyses to support this mission are called nuclear forensics (see Box 1-1). The results are an important element of attribution—determining who is responsible—and may help to determine the history of the material or device and identify characteristics that would aid the search for additional material and/or devices.

#### BOX 1-1

##### Nuclear Forensic Analysis and Attribution

Nuclear forensic analysis of physical evidence is used to determine the origin and history of nuclear materials or devices. By nuclear material, the committee generally means fissionable material, but as used here the term may also include non-fissionable radioactive material and other material relevant to nuclear explosives. The committee made a distinction between pre-detonation nuclear forensics, which is analysis of found or interdicted nuclear material out of regulatory control or of found or captured nuclear devices; and post-detonation nuclear forensics, which is analysis of the signals and debris from a nuclear explosion. For post-detonation nuclear forensics, observations and measurements of the electromagnetic and acoustic signals from the detonation can be made using prompt diagnostics to complement the analysis of debris collected from the environment at and downwind from the detonation site. These measurements may be used as inputs for modeling and simulation to infer nuclear material composition, critical design features of a device, or methods of production. Traditional forensics, such as fingerprint collection, takes place in close coordination with the nuclear forensics data collection.

In the U.S. government, results of pre-detonation and post-detonation nuclear forensic technical analyses are provided to the Attribution Assessment Group, which evaluates the origins of materials or a device based on all available information, including information from intelligence and law enforcement sources. The attribution assessment is provided to the national security leadership to inform their policy decisions.

Note that nuclear forensics is sometimes referred to as technical nuclear forensics to distinguish it explicitly from related investigation and attribution. There is no difference between nuclear forensics and technical nuclear forensics, but for consistency, the committee generally uses the term nuclear forensics to describe the activities related to technical analyses and national technical nuclear forensics (NTNF) to describe the overall federal program.

Section 3132 of the John S. McCain National Defense Authorization Act (NDAA) of Fiscal Year 2019 directs the Secretary of Energy, in consultation with the Secretary of Defense and the Secretary of Homeland Security, to commission a study from the National Academies of Sciences, Engineering, and Medicine (the National Academies) to evaluate and make recommendations for improving U.S. nuclear forensics capabilities (see Box 1-2 for the full statement of task). The request came at a time when the Defense Threat Reduction Agency (DTRA) within the Department

of Defense (DoD) was already in the process of requesting a study from the National Academies on this topic and the National Nuclear Security Administration (NNSA) within the Department of Energy was considering joining that request. This interest came approximately 10 years after the initiation of an earlier study of the same topic (NAS, 2010).<sup>1</sup> In 2018, DTRA and NNSA felt that progress had been made since 2010, and both Congress and the agencies decided it was time to have an independent reexamination of the program.

### BOX 1-2

#### Enhancing U.S. Nuclear Forensics and Attribution Support Capabilities

##### Statement of Task:

An ad hoc committee will provide an expert, independent, and peer-reviewed assessment of nuclear forensics and attribution resources that would be executed by the federal government in response to both a nuclear detonation and an interdiction of nuclear material/device.

Specifically, the study will address the following needs:

1. Assess U.S. nuclear forensics operations and technical analysis with respect to validity, quality, value, cost effectiveness, gaps, and timeliness. This will include the scientific rigor of the programs' methodologies, a cross section of use cases,<sup>a</sup> and comparison to the Academies' nuclear forensics study published in 2010.
2. Recommend how analytical, practical, and operational aspects of post-interdiction and post-detonation response can be improved. This will include technical analysis and attribution, the ability and effectiveness of interagency communication, lessons learned, and best practices.
3. Make research and development recommendations, including an integrated evaluation of current and desired future capabilities, technology maturation and operation transfer, and cost/benefit prioritization, to enhance the programs' utility for attribution and to meet the needs of national leadership.

The study will result in a restricted report and a public summary.

<sup>a</sup> The committee interpreted the term "use case" in its statement of task to refer to the various missions related to NTNF: interdicted (pre-detonation) nuclear materials out of regulatory control, interdicted (pre-detonation) nuclear devices (radiological dispersal devices or improvised nuclear devices), and nuclear devices post-detonation.

#### 1.a.i Low-Probability, High-Consequence Events

The United States today faces many different kinds of low-probability, high-consequence threats, including those arising from nature (e.g., impacts from asteroids or comets, supervolcano eruptions, high-magnitude earthquakes, pandemics), from accidents involving engineered systems (e.g., dam failures, satellite collisions, nuclear power plant accidents), and from malevolent human actors (e.g., use of a weapon of mass destruction). Policy and decision makers face difficult choices in weighing efforts to counter these infrequent and uncertain threats versus more familiar threats like seasonal flu, car crashes, or even mass shootings. As we have seen with the COVID-19 pandemic, low-probability or infrequent high-consequence events do happen (in the case of

<sup>1</sup> Most of the advisory functions of the institution now operate under the name the National Academies of Sciences, Engineering, and Medicine (the National Academies).

COVID-19, causing more than 550,000 U.S. deaths from February 2020 through April 2021 and enormous psychological, social, and economic harm). These risks cannot be fully eliminated, so decision makers seek to manage them, which is to say that they try to reduce the likelihood and mitigate potential consequences. Part of risk management is evaluating the actions that can be taken and the value that those actions provide (NSPM-35, 2021).

Assessing the value and cost effectiveness of U.S. nuclear forensics operations and technical analyses is difficult. With natural and engineered systems, event probabilities can sometimes be quantified to inform decisions about which prevention and mitigation measures are worth pursuing. In cases involving malevolent human actors, it is not possible to assign reliable probabilities to all possible attack scenarios. Some analysts have estimated the value of programs to prevent nuclear terrorism by estimating the cost of the consequences, response, and recovery from the detonation of a nuclear weapon or radiological dispersion device in a city, but the possibility that a nuclear device or devices will be detonated in the United States or an allied country is difficult to quantify. Because some people impute accuracy to a prediction that is characterized by numbers, attempts to quantify risks can create a false impression that risks are known accurately, which can lead to counter-productive behaviors or even a false sense of security.

There are other parallels to the monitoring, detection, and verification challenges of nuclear explosive materials and devices (NASEM, 2021). Reducing the likelihood of plausible attacks is accomplished via International Atomic Energy Agency safeguards and other material control, accounting, and regulatory programs; security systems around nuclear weapons and nuclear materials; portal monitors and other radiation detection technologies and practices; and deterrence.

Nuclear forensics programs are a critical component of deterrence against trafficking nuclear materials and unclaimed nuclear attacks.<sup>2</sup> A declared and credible nuclear forensics capability helps ensure that the perpetrators of any unclaimed attack or attempt will be discovered and subject to reprisal. The U.S. government's attribution ability, combined with the global reach and power of the U.S. military, helps deter attacks. Nuclear forensics may also help uncover planned attacks (including subsequent attacks) before they occur, and possibly enable law enforcement or other capabilities to prevent such attacks.

Nuclear forensics may help to reduce the consequences of an attack by informing post-attack emergency response and management. Nuclear forensics might also prevent erroneous attribution of material or an attack, which could otherwise lead to actions up to and including war against the wrong party.

The deterrence provided by a robust nuclear forensics program is not readily quantified because it is impossible to know exactly what actions or events were deterred. Nevertheless, the committee agrees with policy makers that a capable nuclear forensics program contributes to deterrence and risk reduction by its visible existence.

### **1.a.ii The Committee's Approach to Addressing Its Charge**

The committee conducted a broad examination of technical nuclear forensics capabilities within and available to the U.S. government. These capabilities exist primarily at the U.S. national security laboratories but also within the DoD, the Department of Justice Federal Bureau of

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<sup>2</sup> The 2019 Nuclear Defense Research and Development Roadmap states: "technical nuclear forensics capabilities and timely, high-confidence attribution contribute to deterring adversaries from contemplating covert nuclear attacks or enabling would-be nuclear terrorists or other non-state actors." (NDRD, 2019, p. 14).

Investigation, the intelligence community, academia, and private industry. The committee visited relevant national laboratories, military bases, and government assets, toured their laboratories, and met with their technical staff and leaders. Committee members observed several exercises relevant to the statement of task, and interviewed and were briefed by federal leaders and managers, both current and retired, who direct or have directed aspects of nuclear forensics operations and technical analysis.

Pursuant to the statement of task, the committee focused its efforts on the technical aspects of nuclear forensics that support attribution. The committee did not examine or make recommendations for improving law enforcement investigatory capabilities or all-source intelligence collection and evaluation capabilities, elements of attribution that may be of equal or greater importance to determining who is responsible if nuclear material or a device were interdicted or a weapon detonated. The second item in the statement of task directs the committee to provide recommendations on how to improve, among other activities, technical analysis and attribution support. The committee understood this to mean how and which technical processes and analyses might support and improve attribution.

### **1.a.iii Reviewing a Program That Is Undergoing Major Change**

As is described in the Preface, the NTNF program was in the process of a reorganization during this study. The major change was the shift from the priorities of the Obama administration to those of the Trump administration. The Obama administration prioritized reducing the risk of non-state nuclear terrorism, and therefore expanded NTNF capabilities and led the global effort to secure, within four years, all nuclear materials, both foreign and domestic, that could be used by terrorists. The Trump administration shifted the government's national security focus to peer and near-peer competition and major power conflicts of all kinds (economic, cyber, military, etc.).<sup>3</sup> This change has caused a marked reduction in the priority afforded to nuclear forensics across multiple departments and agencies. In addition, the Department of Homeland Security (DHS) reorganized its chemical, biological, radiological, and nuclear missions into a new office: Countering Weapons of Mass Destruction (CWMD). Despite the fact that both an executive order and a statute designated DHS's Domestic Nuclear Detection Office (DNDO, which was integrated into CWMD in the DHS reorganization) as the host of the National Technical Nuclear Forensics Center (NTNFC) and as the lead interagency coordinator,<sup>4</sup> DHS leadership effectively abdicated DNDO's NTNFC responsibilities by prioritizing other missions. Staff of the NTNFC, some of whom were detailees from other agencies, returned to their home agencies, and DHS reassigned other employees. It was largely left up to the Nuclear Forensics Executive Council (NFEC), an interagency entity comprising assistant secretary level personnel, to devise a reorganization plan that was not worked out until 2020.

As understood by the committee as of the writing of this report, the NTNF reorganization plan that has since emerged assigns NNSA the lead coordinating role. This transition requires changes to three separate components:

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<sup>3</sup> The distinction between nuclear terrorism by non-state actors and peer competition and major power conflicts is not always clear as non-state actors of concern can be—and have been—sponsored by nation states.

<sup>4</sup> Public Law 111-140 (2010) “establish[ed], within the Domestic Nuclear Detection Office, the National Technical Nuclear Forensics Center to provide centralized stewardship, planning, assessment, gap analysis, exercises, improvement, and integration for all Federal nuclear forensics and attributions activities.”

1. *Legislation.* Changes to Public Law 111-140 to transfer DHS's NTNFC coordination role to NNSA were not made in the fiscal year (FY) 2021 NDAA; the administration plans to ask Congress again to make the change in the FY 2022 NDAA.
2. *Presidential policy.* A new National Security Presidential Memorandum, NSPM-35 (NSPM-35, 2021), updating the federal NTNF roles and responsibilities was signed on January 19, 2021, replacing the guidance from Presidential Policy Directive-42 (PPD-42) Annex C.<sup>5</sup>
3. *NNSA intra-agency transition.* NNSA told the committee that it plans to consolidate its nuclear forensics activities (research and development [R&D] and operations) into one office; the FY 2021 and FY 2022 budget proposals include substantially increased funding for the NTNF mission at NNSA.

The reorganization may be beneficial in the long term, but even if it is implemented at the planned pace, in close coordination between DHS and NNSA, there has been a period when DHS was not fully carrying out its role as steward and coordinator for the nuclear forensics mission and NNSA has not yet been legally assigned the mission along with the resources necessary to execute these responsibilities fully. The committee notes that these actions are not the fault of the DHS program staff and management of the NTNFC; the decisions were made at higher levels (CWMD, 2018).<sup>6</sup>

Also in 2018, DTRA, which had previously managed DoD nuclear forensics R&D programs, shifted focus away from nuclear forensics to better align with the Trump administration's priorities, outlined in the National Defense Strategy (NDS) (OSD, 2018a) and the Nuclear Posture Review (NPR) (OSD, 2018b), to counter "great powers" (near-peer state competitors like Russia and China). The NDS and NPR emphasized support for the combatant commands, leading DTRA to shift focus to supporting the nuclear warfighter. This decision included ending support for many of the nuclear forensics R&D programs that DTRA funded at the national laboratories. It is unclear whether these programs will be continued without DTRA funding.

As a consequence, the committee's assessment of the national nuclear forensics organization and capabilities is handicapped by the fact that it observed a program undergoing significant change in structure and budget. While some of this restructuring was completed during the study data-gathering period, there were limited opportunities to observe the proposed restructured program's performance.

Even with the program undergoing significant change, it was clear that many employees across the federal government remain committed to the nuclear forensics mission. Departments, agencies, and offices actively involved in nuclear forensics have been very cooperative and helpful to this study, providing briefings, documents, and access to experts. Any difficulty the committee experienced examining nuclear forensics operations and technical analysis capabilities was primarily a result of the broader ongoing reorganization and not the fault of dedicated federal and laboratory employees working under difficult circumstances.

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<sup>5</sup> A corresponding NSPM Implementation Plan is dated October 13, 2020 (NSPM-35 IP, 2020).

<sup>6</sup> CWMD's Congressional Justification for FY 2019 offers the following justification for decreases in the Advanced Research Initiative and Exploratory Research programs: "efforts were not directly linked to an end user and shifting research from these programs will allow resources to be reallocated for efforts to immediately improve capabilities for operational users" (CWMD, 2018).



The next chapter presents the committee's explanation of the importance of the NTNF mission, assessment of U.S. NTNF capabilities, recommendations to improve NTNF, and its vision for NTNF's future. This document is the public summary of the committee's restricted report (see Box 1-2). The committee's findings and recommendations in this summary report are identical to those in the restricted report except where specificity was removed to allow for the information to be released publicly.

## 2

## Assessing U.S. Nuclear Forensics: Findings, Recommendations, and Conclusion

### 2.a THE NATIONAL TECHNICAL NUCLEAR FORENSICS MISSION

The United States uses its early warning system and a robust and reliable retaliatory nuclear and conventional counterstrike capability to deter overt attack from states with nuclear weapons. Deterrence of a covert, undeclared, or disguised nuclear attack, or the smuggling of material or devices needed to carry out the attack, requires the ability to identify who is responsible and the knowledge that the perpetrator will be identified in a timely fashion. By analyzing interdicted nuclear material, an interdicted nuclear device, or the signals and debris produced by the device after it is used, nuclear forensics supports attributing who provided the materials and expertise used to make the device and helps to determine the history of those materials and nature of the expertise. National technical nuclear forensics (NTNF) goals include enhancing deterrence and enabling prevention with credible, publicized NTNF capabilities. Those capabilities are implied publicly in part by, for example, U.S. national laboratory experts' relevant and significant scientific academic publications. National Security Presidential Memorandum 35 (NSPM-35) includes as a primary objective to "convey the message to potential adversaries that a nuclear or radiological attack will be investigated and attributed to the state, terrorist group, or non-state sponsor responsible" (NSPM-35, 2021, p. 4).

The deterrence value of nuclear forensics has increased in importance since the end of the Cold War. This is due to the multiplicity of states with nuclear weapons, an increase in states with emerging or latent nuclear capabilities, interdictions of fissile materials outside of regulatory control that indicate the existence of a black market for such materials, the proliferation of terrorist organizations that might use nuclear weapons if they could, and the increased interest that some nations have shown in harboring terrorist organizations to execute attacks on their behalf.

*FINDING A.1: A robust NTNF capability is an important element of deterring, preventing, and responding to an unclaimed nuclear attack or smuggling incident, much as the nuclear weapons enterprise deters overt nuclear attacks and offers response options if that deterrence fails.*

*FINDING A.2: U.S. nuclear forensics and attribution efforts are currently focused on preventing attacks in the United States. However, the United States would have an intense interest in the attribution of nuclear attacks or attempted attacks that occur anywhere in the world. The United States may be obliged to respond to attacks on allies as if the attack were on the United States itself. (One priority would be to assess the likelihood of subsequent attacks against the United States, and to attempt to prevent those attacks.) U.S. nuclear forensics and attribution capabilities may be required to prevent retaliation against the wrong country or to*

*limit escalation. International collaboration (observation, collection, and cooperative activities) is key to better global forensics, attribution, and deterrence.*

*RECOMMENDATION A.1: The United States should further develop global sensor and material collection networks and global forensics capabilities, preferably in partnership with allies.*

There are several multilateral sensor networks, such as the International Monitoring System of the Comprehensive Nuclear Test Ban Treaty Organization, which can provide valuable information in the event of a nuclear attack. Implementation of Recommendation A.1 could also take the form of support for materials collaborations with the United Kingdom and France through bilateral exchanges that already exist.<sup>1</sup>

## 2.b THE STATE OF NTNF

The 2010 National Academies report described the U.S. government's nuclear forensics operations and analysis capabilities as substantial but not yet operational.<sup>2</sup> The current committee assesses that U.S. nuclear forensics capabilities have further advanced since that time, but that the program is undergoing significant reorganization, and remains under-resourced in most areas.

*FINDING A.3: U.S. NTNF capabilities have advanced since 2010 and received increased funding until 2016. Without sufficient and consistent leadership, support, and priority by the White House, NTNF agencies, and Congress, U.S. NTNF capabilities will atrophy.*

There have been advances in both the technical and operational aspects of the U.S. NTNF program since 2010. Scientists at the national laboratories and at universities have developed new and improved techniques for characterizing nuclear material and devices. Scientists and federal program staff are continuing to populate databases and archives. Federal program staff and laboratory managers have established new emergency operations centers with the ability to handle and communicate different levels and types of classified information. The attribution support timeline has improved, although there have been recent organizational setbacks. Many of the improvements for post-detonation analysis have been achieved after the Air Force Technical Applications Center (AFTAC) and the laboratories that support it examined the detection-collection-analysis task list and found potential efficiencies, including work that can be done simultaneously. The committee applauds this effort and endorses this and future systems-level approaches to identify additional opportunities to improve results through increased efficiency. In addition, improvements in techniques, driven by additional investment in research and development (R&D) and infrastructure, will also be needed to further improve timelines and accuracy. Clear requirements developed by the consumers of NTNF information will be useful to identify the improvements that, if achievable, would make a significant difference. These advances are important and many of them are highlighted in this report summary.

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<sup>1</sup> 2010 Report 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" (NAS, 2010, p. 53).

<sup>2</sup> 2010 Report Finding 1: "The United States currently has substantial nuclear forensics capabilities. However, the U.S. nuclear forensics capability [in 2010] is not yet an operational program" (NAS, 2010).

As the committee was gathering data and writing this report, Presidential policy guidance designed to replace a previous Obama administration Presidential Policy Directive was being developed. Signed on January 19, 2021, NSPM-35 and the Implementation Plan transitions several of the DHS's NTNF roles to the NNSA and codifies existing interagency and National Security Council (NSC) entities to provide the primary oversight, guidance, and coordination for the NTNF program. Congress was also considering language for legislation to transition the legal authority for interagency coordination of the NTNF Center from DHS to NNSA.<sup>3</sup> Under this new structure, NNSA leadership and those overseeing the NTNF program at the NSC level will need to ensure that intra- and inter-agency communication, coordination, and cooperation function smoothly. NNSA communicated to the committee in September 2020 that it plans to consolidate some of the NTNF functions currently housed in different offices in NNSA into one office, which may help; colocation sometimes improves collaboration.

*RECOMMENDATION A.2: To support nuclear deterrence through a robust attribution capability, the NTNF program must be sustainable. The Executive Office of the President should issue a policy memorandum or policy directive elevating the importance of NTNF within the national security enterprise, stating that the mission of the program is both national and global, driving the need to detect, analyze, and support the attribution of nuclear events domestically and worldwide. Following the issuance, the NSC should direct, coordinate, and oversee actions to demonstrate commitment commensurate to that importance.*

The policy memorandum or directive should (1) state that preventing, deterring, and responding to an unclaimed or unattributed nuclear attack is a national priority similar in type if not in scale to deterring and responding to an overt nuclear attack; (2) state that a robust and improving nuclear forensics capability is essential for attribution and deterrence of such an attack; (3) provide coordination authority for multi-agency activities contributing to nuclear forensics to an agency with the requisite expertise and commitment as a core element of its mission; and (4) commit to seeking stable funding adequate to support the development and deployment of the necessary technology and facilities and to sustain a cadre of experts that are devoted to the mission. The newly issued NSPM-35 is a good start and does most of these things.

If U.S. leaders agree that a robust NTNF program is an important element of deterring, preventing, and responding to nuclear incidents, then more must be done to support, sustain, and advance the program. The committee does not have a specific estimate for the appropriate size of the program—that should come from the process described in the recommendations below—but it is certainly larger than it is now. The NTNF mission is too important to depend solely on inconsistent R&D funding and laboratory overhead budgets generated as residuals from the nuclear weapons program as it has in the past.

To support item four above, the NTNF federal agencies, the Office of Management and Budget, and Congress will need to know what is needed—personnel, facilities, equipment, R&D—for a vital, operational program that is effective and sustainable for the long term. A description of needs

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<sup>3</sup> H.R. 6596 proposed to realign the federal nuclear forensics and attribution activities from DHS to the Department of Energy (DOE) (NNSA), renaming and outlining the mission of the coordination entity the “National Nuclear Forensics Center” to replace the National Technical Nuclear Forensics Center (NTNFC). The bill also proposed to expand NNSA’s university program to include nuclear forensics expertise. It did not receive a vote and signature in 2020 and so would have to be reintroduced in a new Congress.

can then form the basis for a plan to meet those needs and a corresponding budget. Effectiveness has to be evaluated against requirements (addressed in Section 2.e, Vision and Goals) and the needs of the consumer of the results. Sustainability is difficult to evaluate, but it is reflected in whether the capabilities are seen to degrade, maintain, or improve over some timeframe (perhaps five years) at level funding.

*RECOMMENDATION A.3: In its annual report to Congress, the NTNF program should provide a description of the steps needed to make the program more effective and sustainable.*

## **2.c WAYS TO IMPROVE NTNF AND A VISION FOR ITS FUTURE**

A program benefits when its mission, objectives, and requirements are clear and flow through the program, guiding decisions about what work to undertake and what levels of effort are needed, with regular assessments of the program to identify where improvements are necessary to achieve the mission. If the NTNF program is given a high priority and equipped with a clear mission that establishes goals and strategies, NTNF entities will be better enabled to fulfill that mission. A mission-driven approach is especially important in a multi-agency, multi-actor program such as NTNF to help with coordination and cooperation and also with focus and commitment. Commitment to the NTNF program mission has been inconsistent.

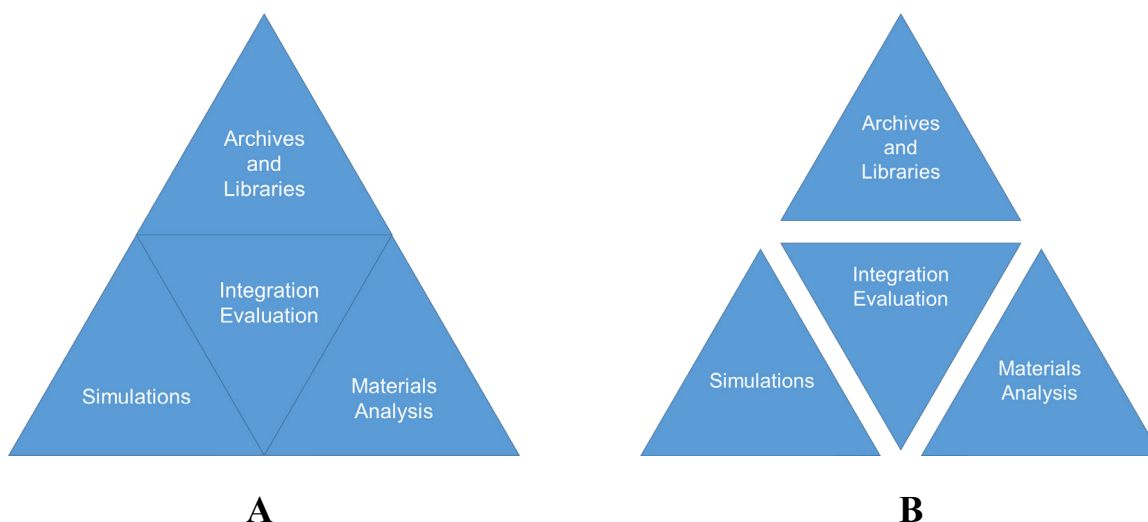
The Executive Office of the President, federal agencies, namely NNSA, the Departments of Homeland Security, Defense, Justice, and State, the Office of the Director of National Intelligence and the intelligence community, and Congress should take the steps listed in the following recommendations concerning interagency functionality, vision and goals (and timeline), assessment, implementation, and operational capability.

## **2.d INTERAGENCY FUNCTIONALITY**

An old adage states that “hard times clarify priorities.” One way of understanding agency priorities, and where support might best be placed in the future of a government program, is to review where support for the program has persisted the longest, even through hard times. That is often the location of the most dedicated program supporters and program personnel. For the nuclear forensics program, the stalwarts have clearly been NNSA (and the DOE national laboratories), the Federal Bureau of Investigation (FBI), and AFTAC. As legislated changes to the nuclear forensics program are considered, moving national accountabilities, programmatic authorities, and sufficient funding to NNSA, FBI, and AFTAC can be looked upon as an opportunity to simplify and improve the federal leadership of the nuclear forensics program.

The committee emphasizes the need for coordination, clarity, and consistency of goals, requirements, strategy, and implementation because NTNF responsibilities are shared among several agencies. When one agency owns the whole mission, it is simpler for the agency to take an integrated view and ensure that the functions interface well. When different agencies or funding streams are responsible for the different pieces or parts of the different pieces, the functions do not change, but it is more difficult to take that integrated view. Each function is treated separately, and it is unclear who is responsible for the gaps and making sure that the functions connect across the interfaces (see Figure 2-1). Divided responsibility also creates a kind of tragedy of the commons,

where a program would like to pay for the laboratory services that support the program's piece of the mission, but not for the physical infrastructure or routine work that supports the staff between the requests for services. A senior NNSA official who then led the NNSA nuclear forensics program described the latter problem to the 2010 National Academies nuclear forensics study committee in this way: "Everyone wants to buy wine by the glass, but the first glass is pretty expensive if you have to build the winery to get it."



**FIGURE 2-1** Illustrative sample of functions needed for nuclear forensics and how they fit together in (a) an integrated view and (b) a separated view, based on having a single or multiple separate sponsors.

SOURCE: Adapted by the committee from a presentation at Los Alamos National Laboratory (Scott, 2019).

As noted earlier in this report, in September 2020, federal program managers described plans for the transfer of NTNF program leadership and reestablishment of NTNF capabilities. They outlined many of the steps that the committee independently and concurrently developed in this study. The findings and recommendations below provide a map for strategic planning, assessments, gap analyses, priority setting, and increased funding. Most of these elements and processes were in place and functional prior to January 2017. The findings and recommendations listed here, if followed, would make real the commitment to the NTNF mission and maintain and improve the program.

An effective NTNF interagency function could be fulfilled by an NSC sub-interagency policy committee as it has in the past, or perhaps by a national coordination office. There currently exists a Nuclear Forensics Executive Council (NFEC) at the assistant secretary level, and the NSPM-35 Implementation Plan details an effort to revive the Nuclear Forensics Steering Committee, a committee of federal stakeholders at less senior levels who would implement NFEC decisions. A functional coordination committee—the NFEC or something more senior—is necessary to properly place NTNF among competing interests and elevate attention above the authorities within the programs themselves, as well as to place the program needs in a larger context.

*FINDING B.1: NTNF is a multi-agency mission with no overarching entity to provide prioritized funding guidance. The NTNF mission needs strong interagency coordination to provide clear and consistent goals, requirements, strategy, and implementation plans.*

*RECOMMENDATION B.1: The NFEC should coordinate development of the goals, assessments, implementation, and capabilities, and should promote interagency cooperation and functionality at all levels within the relevant organizations. An effective interagency function will have clear lines of responsibility and authority that indicate who will do what, and will hold organizations accountable for those responsibilities. Furthermore, those involved should persistently seek improvements and synergies with other programs.*

To better enable the interagency process to fulfill its NTNF mission, the agencies may also need to make internal changes to better align responsibility with authority. Currently, if operational organizations like AFTAC identify operational deficiencies, they do not have direct reporting paths to seek solutions, whether they pertain to policy, personnel, infrastructure, or technology. A potential solution to this issue could be to have the AFTAC Commander report both up the chain of command in the Air Force and also to the Office of Nuclear Matters in the Office of the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs, which has responsibilities and authorities relevant to nuclear forensics that the Air Force does not.

## 2.e VISION AND GOALS

There has been some progress since 2010 in connecting and integrating operational capabilities, due to better communication and policy guidance, but more progress is needed. Both operational and R&D programs generally are driven by documented program requirements; the requirements are essential to both assessment and program direction. However, there is no single, high-level requirements document for the entire NTNF program or even across use cases. Instead, NTNF program success is measured against a variety of metrics and goals linked to independently developed requirements from each department or agency involved in NTNF and attribution.

Program managers in the agencies and in the laboratories need coordinated, clear, and consistent guidance from the policy leadership as well as the requirements that would support their efforts to get the necessary resources for sustainment and improvement.

Establishing a program requirement is a balancing act between what is needed and desired on the one hand and what is feasible given time, resource, and other constraints on the other hand. In addition to the obvious challenges associated with finding that balance, there are implicit challenges in developing and revising requirements. In the DoD, the requirements structure is formalized and there is pressure for programs to not have any unmet requirements. This results in a deep reluctance to issue more demanding requirements, even when improvement is needed and feasible.<sup>4</sup> Because requirements drive funding priorities, if the requirements do not push for improvement, then no funds are allocated for improvement. To implement the commitment to continuously improve nuclear forensics operational capabilities, the Executive Office of the President and agency leadership can direct the responsible agencies to revise requirements and better align them with the importance of the program and a realistic view of the demands it will face in a post-detonation scenario.

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<sup>4</sup> NTNF efforts also suffer from inherent organizational challenges. For example, the low hierarchy and less senior rank of the AFTAC commander in comparison to other Air Force and DoD entities and other agencies engaged in NTNF may create a mismatch between AFTAC's mission requirements and its ability to address deficiencies.

*FINDING C.1 A robust, reliable, clear, and consistent system is needed so that gaps and opportunities can be identified and capabilities are required to improve to better address the needs of the policymakers.*

DHS (via the NTNFC) issued five-year NTNFC strategic plans in 2010 and 2015, but a plan for fiscal year (FY) 2020 to FY 2024, which should have been issued by October 2019, has not been released as of April 2021. Past cross-cut budgets show funding allocation information from each of the NTNFC-participating agencies listed by the strategic plan's main objectives, but there is no indication that objectives in the strategic plan led to a coordinated plan for those budgets (CWMD, 2020). Furthermore, the National Science and Technology Council's 2019 Nuclear Defense R&D (NDRD) report, which assesses capability and gaps and outlines R&D needs aligned with strategic plan objectives, is significantly less detailed than previous iterations (e.g., 2008 and 2011) and seems to describe the program as it should be rather than as it is (NDRD, 2008, 2011, 2019). These observations suggest that the strategic plan is not driving budgets and capabilities coordination among the agencies. Additionally, the interagency does not currently have concepts of operations (CONOPS) for pre-detonation materials and devices. The fact that practitioners and managers of nuclear forensics do not have clear and consistent mechanisms to give input to affect program direction in the future is a major barrier to improvement. The resolution of these issues requires an improved interagency function.

*RECOMMENDATION C.1: An NSC Interagency Policy Committee should coordinate issuance of a high-level requirements document for the NTNFC program, covering the elements of a capable, reliable, sustainable, and improving program, taking into account its interfaces with the attribution process and the other programs that feed into it. The requirements should derive from both minimum needs and goals for the capabilities of the program, agreed to at the highest level of the interagency.*

The 2010 National Academies report states that the most important improvements to NTNFC are increases in analytic and operational capabilities that reduce timelines and uncertainties in findings.<sup>5</sup> This point has been noted in many other reports and current program documents recognize that this is still the case in 2020.<sup>6</sup> The committee agrees that the goal is to increase overall confidence in findings, focusing on reducing uncertainties in ways that meaningfully inform decisions, while still striving to provide timely results (see Box 2-1). There is evidence that performance has improved, but improvements are at risk if not prioritized and funded.

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<sup>5</sup> 2010 Report Finding 8: "There are numerous opportunities for the United States to improve its technical nuclear forensics capabilities and performance. The top priorities for improving the U.S. nuclear forensics program are to increase analytic and operational capabilities in ways that reduce timelines and uncertainties in findings" (NAS, 2010, p. 90).

<sup>6</sup> For example, an NNSA report notes, "Interagency Coordination through Nuclear Forensics Executive Council (NFEC) and White House National Security Council (NSC)...Senior executive leadership communicate need to improve current timelines for TNF and attribution to match anticipated decision-making urgency in national response" (NNSA, 2020, p. 13).



**BOX 2-1****Improving Timelines and Timeliness While Ensuring Integrity**

If a nuclear device were to be detonated on U.S. soil, the pressure to identify those responsible would be tremendous. Decision makers need both fast and high-quality nuclear forensics results. However, there is an ongoing debate about how to handle the tension between the need for rapid results, even if they are preliminary, and the need for high-quality results, which take longer to develop.

On the one hand, national leadership will be quick to make some decisions, so it is important to inform those decisions with the best understanding available, but a thorough NTNF-based analysis takes time. On the other hand, law enforcement and intelligence agencies have experience conducting investigations under high pressure and scrutiny, and they have emphasized that following established procedures is critical in these circumstances because the procedures are established to avoid errors, which is all the more important when the stakes are so high.

It would be difficult to overstate either the need for faster results or the need for accurate results. As noted by several studies on nuclear forensics, this underscores the importance of

1. communicating to national leadership and decision makers the timelines for a thorough NTNF analysis to set expectations;
2. streamlining processes and qualifying faster procedures wherever possible;
3. prioritizing analyses that provide the most probative value for decision makers; and
4. communicating uncertainties in results clearly and accurately.

**2.e.i Biennial Assessment**

The nuclear forensics component of the deterrent would benefit from an assessment modeled on the congressionally mandated letters on the status of the nuclear stockpile, which are written by the relevant laboratory directors and provided to the President and Congress, delivered in unaltered form by the Secretaries of Energy and Defense (GAO, 2007). These letters ensure that the current state of the stockpile, as assessed by the relevant experts at the national laboratories, rather than the federal program managers, is communicated and documented and that any deficiencies and risks are communicated and either accepted or addressed. NNSA and DoD (via the Deputy Assistant Secretary of Defense/Nuclear Matters) have experience conducting and communicating these assessments.

Under current statutory requirements, a Joint Interagency Annual Report for Improving the Nuclear Forensics and Attribution Capabilities (the Joint Interagency Annual Report) is produced by the six agencies and departments involved in NTNF and delivered to the President, and committees within the House and Senate.<sup>7</sup> While valuable, these joint interagency annual reports have not adequately described the state of the program or provided sufficient input from the people that do the work, which is to say run NTNF operations, conduct NTNF analyses, maintain the workforce and the infrastructure, and perform the R&D. For nuclear forensics assessments, it would be important to have input from the leaders of the organizations that play critical roles in the NTNF mission, as well as the customer for NTNF analysis.

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<sup>7</sup> Required by Public Law. 111-140.

Under the new NTNF structure, with NNSA eventually leading interagency coordination efforts,<sup>8</sup> directors of the DOE laboratories involved most directly with NTNF activities, along with AFTAC leadership, are best suited to regularly assess NTNF capabilities from the performer side. The Joint Atomic Energy Intelligence Committee (JAEIC), as the standing customer of technical nuclear forensic results, is best suited to describe known deficiencies and efforts under way to resolve them. These organizations are where the technical capabilities, infrastructure, and expertise reside to conduct the assessment. This assessment could be communicated in the form of a letter or letters sent to high-level government officials who are responsible and accountable for ensuring the NTNF capability and have the authority to make the necessary changes to address deficiencies in the program(s) (see Box 2-2). Such assessments and reporting would help monitor nuclear forensics program effectiveness and signal a robust capability, thus improving the deterrent aspect of technical nuclear forensics. Biennial or more frequent assessment would also increase the visibility of the NTNF program to the President and Congress through successive administrations.

The letters would be important for conveying the state of the program to senior leadership. This assessment process would guide the improvement of the program, with the goal of making NTNF more robust and reliable, leading to faster and more accurate results.

*RECOMMENDATION D.1: The NTNF program should require key implementers (laboratories and operational military units) and consumers of NTNF results to conduct realistic evaluations of the capabilities, gaps, and opportunities for improvement of the program no less frequently than every two years, resulting in an assessment letter or letters from the heads of the implementing organizations to leadership in the agencies responsible and accountable for the mission, to the Executive Office of the President, and to Congress to drive an iterative process of revision for improvement. In years when full assessments are not provided, a brief update on changes in the program should be included in the annual report to Congress.*

The committee envisions that these assessments would inform the plans in Recommendation A.3.

#### BOX 2-2

##### A Possible Structure for Assessments of U.S. Nuclear Forensics Capabilities

While the U.S. government is best suited to make the final decision on who writes and receives an assessment letter, the committee provides an example below:

Directors of the weapons laboratories (Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratories) and other key implementers (e.g., Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Savannah River National Laboratory) would write letters no less frequently than every two years to the NNSA Administrator assessing pre-detonation (materials and devices) and post-detonation (nuclear and radiological) NTNF capabilities. AFTAC (with input from its support laboratories and the 20th Chemical, Biological, Radiological, Nuclear and Explosives [CBRNE] support command) would write a letter no less frequently than every two years to the Under Secretary of Defense for Acquisition and Sustainment assessing post-detonation collection and analysis capabilities. Finally, the JAEIC would write a letter to the Director of National Intelligence on the same schedule. These letters would be shared in unaltered form with the Deputy National Security Advisor and with relevant committees in Congress. No less frequently than every two years,

<sup>8</sup> Assuming that future statutory changes will replace DHS with NNSA to lead interagency coordination efforts.

the letters would be included as appendices to the Joint Interagency Annual Report to Congress. In years when full assessments are not provided, a brief update on changes in the program would be included in the annual report to Congress.

## 2.f IMPLEMENTATION

While the 2010 National Academies report recommended the creation of an implementation plan by DHS, this committee did not see evidence of such a plan.<sup>9</sup> During the data-gathering process, the committee obtained and assessed several other program plans from individual agencies and laboratories. As noted above, DHS (via the NTNFC) issued five-year strategic plans in 2010 and 2015, and cross-cut nuclear forensics budgets from agencies with nuclear forensics responsibilities are reported each year to Congress. However, no coordinated, integrated, long-term program plan to improve NTNFC capabilities was completed by the NTNFC. The committee encourages NNSA, the presumed leader of NTNFC coordination and future chair of the NFEC, to complete such a long-term program plan in the future. The production of an implementation plan to support NSPM-35 is an encouraging sign, but implementation plans are needed at both the inter- and intra-agency levels.

*RECOMMENDATION E.1: Based on the requirements and the biennial assessments, the NFEC should coordinate issuance of an interagency implementation plan. The agencies should also issue plans for their own organizations that are consistent with and support the interagency implementation plan. These plans should all derive from the same goals, requirements, and assessments; be consistent with each other; and be updated as necessary based on the results of the biennial assessments.*

## 2.g OPERATIONAL CAPABILITY

The committee found only a few people in the NTNFC program who could articulate what an operational NTNFC capability should look like and how the elements should fit together and interact.

*RECOMMENDATION F.1: The agencies involved in NTNFC should work to strengthen an operational NTNFC capability based on clear requirements, including the requirement to improve. This requires improving data sharing, mission-driven routine work, exercises and evaluation, sampling, R&D, quality assurance and quality control and uncertainty characterization, as well as more sustainable human resources and infrastructure. Improvements in these areas, along with an elevated national commitment to NTNFC guided by the organization, assessment,*

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<sup>9</sup> 2010 Report 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” (NAS, 2010, p. 86).

*and implementation processes detailed above will reduce timelines, improve accuracy, and ensure that the U.S. NTNF program can respond when needed.*

Details and related findings and recommendation are below.

### **2.g.i Data Sharing**

Virtually all phases of operations of the NTNF program rely upon a broad variety of databases and analyses at different levels and types of classification.<sup>10</sup>

Consistent with the 2010 National Academies report,<sup>11</sup> it is imperative that long before an event occurs the nuclear forensics community establish the policies and infrastructure for sharing information that enables a timely and effective response. It is a mistake to assume that barriers to information sharing would simply be lowered in the case of an event (the committee heard the phrase “the walls would come down” multiple times) without establishing and demonstrating effective procedures and infrastructure for sharing of the different types of classified information outside of standard protocols under challenging circumstances. Furthermore, post-detonation scenarios are not the only scenarios that would require data sharing and relaxation of classification compartmentalization, although Restricted Data has proven to pose special challenges. For example, for consequence management, program managers have talked about having tear lines, portions of documents that can be shared when separated from more sensitive information. Privacy-protecting query technologies are the equivalent for digital systems and might be useful for these applications. For training and exercises, they could enable exercise participants to access real classified data systems without accessing the real content.

*FINDING F.1: Some efforts to improve classified information sharing have been made. The committee assesses that more work on this problem is needed.*

*RECOMMENDATION F.2: NNSA and the other agencies involved in NTNF should establish and periodically exercise a plan to break down classification barriers, including operating the procedures and the infrastructure, in all cases of high-consequence NTNF events. This could be done with “dummy data,” but on real systems with people who do not initially have access. This may require a review of procedural, regulatory, and architectural barriers and cybersecurity issues that may arise. Problems and barriers should be identified and removed.*

### **2.g.ii Mission-Driven Routine Work**

It is important to sustain routine work that will improve the information and tools available for dealing with incidents by better understanding past incidents. Examples include analyzing the

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<sup>10</sup> 2010 Report Finding 10: “Databases are important tools in determining the possible origins and history of a material or an object. Databases populated with information relevant to nuclear forensics are maintained by a number of U.S. agencies. However, some of these databases are not shared among the agencies and are not readily accessible, which can be detrimental to performance of the program” (NAS, 2010, p. 92).

<sup>11</sup> 2010 Report 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 to enable analysts to use them” (NAS, 2010, p. 93).

backlog of samples from legacy testing and updating the contents and formats of databases, in addition to analyzing and managing the small flow of material from real-world incidents.

*FINDING F.2: The NTNF program would benefit from a more coordinated program working closely with the Nuclear Materials Information Program to consolidate knowledge of foreign nuclear materials.*

Concerns over the proliferation of weapon designs and materials continue to exist, so it is important to have consolidation and cooperation between scientists and intelligence analysts working on materials related to foreign weapons programs and fuel cycles.

With a larger international diversity of nuclear materials being generated (and potentially illicitly transferred and smuggled), the need to identify additional proliferation signatures and have a detailed knowledge of foreign-source nuclear materials is apparent. The committee recommends that the NTNF program consider strengthening this work through a Foreign Nuclear Materials Intelligence Initiative (FNMII). Such an initiative could provide great benefit to the nation in terms of preparing for a potential crisis-driven need for knowledge of all nuclear materials, both domestic and foreign. It would aim to

1. Broaden training of intelligence community (IC) analysts in nuclear weapon design and relevant materials—including older weapon variants and their materials as well as the current generation of U.S. weapons;
2. Ensure that a subset of weapons designers and analysts in the U.S. weapons laboratories remained apprised of foreign weapon development programs, including their designs and materials;
3. Initiate a series of regular meetings and workshops between NNSA’s offices of Defense Programs, Counterterrorism and Counterproliferation, and Defense Nuclear Nonproliferation, and DOE’s Office of Intelligence and Counterintelligence (DOE-IN) and other parts of the IC to share information and concerns; and
4. Develop and further train technical staff on materials including staff from relevant laboratories via a “practicum” approach.

Personnel working under the proposed FNMII would perform regular analysis of nuclear materials to populate databases and to encourage interactions and information exchanges between the technical-analysis experts and analysts in the intelligence community. The initiative would seek foreign materials that span the various production methods in use.<sup>12</sup> A FNMII would have a triple benefit: (1) Its analyses would populate the databases so that the data are available when needed; (2) it would help to ensure a robust and ready technical analytical capability by providing on going practical experience analyzing actual samples, an analytical capability that is needed to make proper use of the data in the databases; and (3) it would establish and exercise interactions between the IC and technical-analysis experts, improving coordination in a real-life incident.

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<sup>12</sup> Gathering a comprehensive worldwide set of radioactive and nuclear materials is impossible and unnecessary. An important benefit of FNMII could be an improved understanding of provenance and process signatures leading to better analytical predictions of materials characteristics. This could also identify knowledge gaps to guide experiments.

The committee does not make a recommendation on where organizationally FNMII should reside. This is an important question, but there are considerations outside of the committee's scope and data gathering. Wherever in NNSA or DOE it resides, FNMII will need strong connectivity to offices for defense programs, intelligence, nuclear forensics, and nonproliferation. The committee hopes that the NTNF policy community will establish the program first by funding the work and then finding a sensible home within DOE/NNSA so that the work is not delayed by bureaucratic negotiations that are important but might not reach resolution quickly.

*RECOMMENDATION F.3: NNSA and the IC should create a program focused on nuclear weapon-related materials. A dedicated Foreign Nuclear Materials Intelligence Initiative (FNMII) program would leverage and contribute to the archived materials to improve pre- and post-detonation forensics capabilities.*

It is likely that there are additional categories of routine work that provide value to the NTNF mission. Operational and R&D program managers in the implementing organizations are probably best equipped to identify these kinds of work, and the value of this work would need to be validated by federal program managers.

### 2.g.iii Exercises and Evaluation

Since the 2010 National Academies report, DHS, NNSA, and DoD have undertaken pre- and post-detonation device technology demonstrations and training exercises.<sup>13</sup> These exercises have gradually involved more parts of the U.S. government, including the IC and law enforcement, and have tested increasingly complex scenarios.

To enable more realistic exercises that test NTNF functions as intended, the NTNF program must be funded appropriately and seen by national leadership as a higher priority. The August 2019 *Pathfinder* exercise, originally envisioned as part of a technology demonstration and “end-to-end” exercise to test communication and information-sharing mechanisms, processes, and content in a post-detonation technical nuclear forensics CONOPS, was a positive step. Limitations made the organizers reduce the scope and the physical operations during *Pathfinder*, but the committee agrees with the ambitions of the activity and its implementation, even in its reduced form.

More full-scope exercises should be organized that involve the NTNF technical community with real decision makers from the policy community. *Pathfinder* was a step in the right direction, but future exercises should continue to be designed to be more realistic by testing the entire NTNF structure and by not providing advanced notice.<sup>14</sup> For example, the post-detonation *Pathfinder* exercise could be replicated for pre-detonation materials and pre-detonation devices once CONOPS are developed for these two use cases. Nuclear forensics capabilities could also be tested during a national-level exercise. Appropriately publicizing these national-level exercises would enhance the deterrent value of the NTNF capability.<sup>15</sup>

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<sup>13</sup> 2010 Report Finding 6: “Post-detonation nuclear forensics capabilities have been demonstrated in test and training exercises” (NAS, 2010, p. 88).

<sup>14</sup> The committee understands that it is difficult to engage leaders across multiple agencies, especially at the senior policy maker level. This is not unique to NTNF exercises; there is always competition for key participants' time in all exercises and indeed during real events. That is another reason why having a sufficiently sized and trained workforce to handle multiple demands is a key component of operational capability.

<sup>15</sup> 2010 Report 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

*FINDING F.3: NTNf exercises serve many different purposes—training, testing, demonstration—and all are needed to assess readiness and gaps in capabilities.*

*RECOMMENDATION F.4: NNSA and the other agencies involved in NTNf should design exercises that are realistic and engage higher-level officials, including some that test the entire NTNf structure and some undertaken with no notice.*

#### **2.g.iv Sample Collection**

Analyzing nuclear materials samples, whether pre-detonation interdicted materials or post-detonation debris, is one of the central functions of nuclear forensics. The following two subsections emphasize the importance of samples and expert guidance to NTNf analysis and the tools to ensure that high-quality samples are collected and that in-the-field observations and data are communicated at the earliest possible time.

*FINDING F.4: Collection of appropriate materials samples (the right sizes, radioactivities, compositions, locations) is essential to the NTNf analysis function. Deficiencies and uncertainties resulting from the collection of low-quality samples hinder every step of nuclear forensics analysis and evaluation that follows. Collection of appropriate, high-quality samples requires planning, training for personnel, equipment, and skilled operational execution, including adapting to circumstances.*

*FINDING F.5: AFTAC, via NNSA, conducts in-the-field evaluation of ground samples to determine whether they are of sufficient quality for analysis at centralized laboratories. Analysts could gain some useful information from these early measurements, particularly data on short-lived radionuclides in the sample and the evolution of the sample over time. These early measurements could provide preliminary estimates of isotope ratios, which, together with the prompt data available in the first hours after a detonation, could provide an earlier starting point for device reconstruction efforts. Some scientists have suggested that additional, more powerful techniques could be used in the field, such as simple chemical separations coupled with automated gamma spectroscopy to provide some perishable data earlier in the event evolution. The committee sees additional in-the-field measurements as potentially valuable as complements to, but not substitutes for, centralized laboratory analyses, which have much higher sensitivity.*

*RECOMMENDATION F.5: The R&D program manager for post-detonation nuclear forensics should continue to examine opportunities for sample measurements that could be performed in the field to reduce the analysis and evaluation timelines or improve accuracy of nuclear forensics results. They should seek to develop deployable procedures and technologies.*

#### **Sample Collection: Ground**

Ground-collection plans for sample collection are based on plume modeling, which is inexact and uncertain (especially soon after the event, when key inputs to the models are likely to be unknown),

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unannounced and that challenge regulations and procedures followed in the normal work environment, and should implement corrective actions from lessons learned” (NAS, 2010).

so there is a reasonable likelihood that a collection team would need to revise the plan based on observations and measurements in the field. DOE scientists on the collection team are trained to understand the characteristics of the environments and types of samples that are required for high-quality laboratory analysis, which will ultimately lead to more accurate results. Samples collected without benefit of expert knowledge run the risk of introducing uncertainties to downstream calculations (e.g., by not sampling a sufficient range of elements) or even violating key assumptions made by device-reconstruction teams (e.g., by not collecting a representative range of particle sizes or missing samples that would uncover unexpected heterogeneities across the debris field). The DOE technical staff will most likely be the team member with the most expertise and experience in identifying proper locations, types, and amounts of debris materials to collect after an event. Therefore, the DOE technical expert should be a required member of the ground collection team, as opposed to an optional one.

In addition, better coordination and integration between plume models and *in situ* systems would be beneficial to post-detonation debris collection. NNSA's consequence management program will be on the scene in a post-detonation environment and will be collecting data using the Aerial Measurement System, which uses gamma and neutron detectors to measure the radiation field on the ground. This additional data source could be useful to guide NTN collections. Coordination among these elements and integration of their data would likely improve the nuclear forensics results.

*FINDING F.6: Post-detonation material ground collection is currently the responsibility of military personnel from the Army's 20th CBRNE command. DOE technical experts are available to guide the collection.*

*RECOMMENDATION F.6: A DOE technical expert should always be included as a key member of the DoD ground-collection team as it collects samples in a post-detonation debris field and should be responsible for choosing sample locations and amounts and for interpreting the in-field measurements of each sample to assess its adequacy. Through leadership and training, the entire ground-collection team should be given an understanding of the importance of the samples that they collect for all of the analyses and decisions that follow.*

### **Sample Collection: Remotely Operated Platforms**

There are strong reasons to try to improve post-detonation sample collections. Remotely operated platforms for both ground and air sampling offer advantages over in-person sampling: Remotely operated platforms reduce the radiation doses incurred by personnel, which allows mission planners to take the time needed to select the location to collect the best samples, and the collections might be more timely. The obstacles include cost, the lack of a remotely operated platform for gas sampling, the complications of trying to compare results from new sampling methods to data from past collections, and operational problems encountered in past attempts to use unmanned aerial vehicles or drones for this purpose.

Given the importance of the samples, the potential advantages of remotely operated sample collection systems, and the practical difficulties that have been encountered, additional R&D could lead to significant improvements, but only if developers work with the operators to ensure that the solutions are suited to the end use.



*RECOMMENDATION F.7: The Defense Threat Reduction Agency (DTRA) should provide additional R&D funding to overcome the obstacles to using remotely operated ground and airborne particulate sampling platforms, and to translating data from newer, better collection platforms for comparison with legacy data. To better ensure that the products work in practical application, the R&D should be conducted in close cooperation with the intended users of the platforms developed.*

### **2.g.v Mission-Driven R&D**

Research and development are essential components of an effective NTNF program and are not separable from operational capabilities. Nuclear forensics operational analysis is inherently at the very low end of the work duty cycle for laboratory scientists and engineers: Very little of nuclear forensics personnel's typical workday will be spent doing operational analysis of nuclear forensics incidents. Ongoing R&D, in addition to improving tools and techniques, is the key to both maintaining an able (trained and sharp) workforce and a workforce that is available when it is needed. An excellent workforce is essential to an excellent program. R&D attracts a talented technical workforce, enables personnel to maintain and improve the skills needed to conduct nuclear forensics analysis, and builds intellectual capabilities that are better able to analyze unfamiliar or anomalous results.

A successful nuclear forensics program needs to improve continuously in order to retain scientific staff and develop and integrate new capabilities to keep it current with other systems (e.g., wireless communications). The NTNF program should continuously be striving to improve its capabilities.

Based on the 2019 Joint Interagency Annual Report and many earlier reports, the goals for the NTNF R&D program are to

- Decrease the time required to produce reliable results (as fast as possible);
- Increase the accuracy of results (no mistaken attribution);
- Provide national and global coverage (fast and accurate for events anywhere); and
- Train and support a cadre of experts that can provide surge capacity in case of an event.

There are many examples of R&D that could improve NTNF capabilities toward these goals. Some examples include new tracers for materials analysis, use of longer-lived nuclides and decay products for paleo-forensics, fast chemical separation methods, analytical approaches for smaller samples, faster and more uniform collection methodologies (e.g., using drones or robots) and faster in-field analysis of samples (e.g., by using gamma spectroscopy, perhaps after simple chemical separation, to provide preliminary analysis data to drive earlier device reconstruction efforts), analytic techniques that require less or almost no sample preparation, and more extensive analysis of foreign devices to produce outputs beyond yield (such as isotope ratios in debris), which would make foreign device intelligence work more useful for forensics.

An integrated evaluation of current and desired future capabilities, along with a cost-benefit prioritization, will help program managers decide how to invest in R&D to enhance the programs' utility for attribution and for meeting the needs of national leadership. Further R&D is necessary to simply stay current with technology maturation and improve transfer to operations.

It is not clear who can and should be responsible for later-stage technology development, but that organization needs technical capability, connections to the end users, experience overcoming the

challenges in readying technologies for production and deployment, and sufficient funding to support this technology transition process.

The new U.S. NTNF organizational structure, presumably with NNSA as the lead agency, will have fewer agencies participating in R&D efforts, which is an opportunity for NNSA to clarify the flow of requirements and focus on filling capability gaps.

*FINDING F.7: NTNF R&D is the foundation for nuclear forensics capability and underpins human resource development.*

*RECOMMENDATION F.8: The administration should size the NTNF R&D budget so that R&D improves operational nuclear forensics capabilities. R&D is also needed to help attract and retain nuclear forensics personnel by providing work that keeps their skills sharp and keeps them available for the mission. R&D budgets should therefore be aligned with human resource needs to sustain an operational NTNF program. The overlap in technical expertise with the weapons programs can be used to advantage here.*

*RECOMMENDATION F.9: The NSC Interagency Policy Coordinating Committee for Nuclear Forensics (or its successor) should agree on and formally task one or more departments or agencies with the responsibilities and resources (human and financial) for the ongoing mission of moving technology improvements through the often rocky transition between R&D and operational capability. This should be done as soon as is practical.*

### **Mission-Driven R&D: Reaction Time History**

Measurement of reaction-time history for nuclear detonations worldwide can be improved, especially in high-value locations. Experts in weapon design emphasized the importance of reaction-time history measurements for device reconstruction.

*FINDING F.8: Broader application of reaction-time history measurements may shorten the time required to accurately determine the design of a weapon that was detonated.*

The United States sustains a set of sensors on GPS satellites and ground-based support equipment for the nuclear detonation detection system, USNDS, which can be useful for some nuclear forensics scenarios, but they cannot measure reaction-time history. One possible solution might be to place advanced sensors on GPS satellites or less sophisticated sensors on small satellites in low earth orbit or on airships or balloons. Some signals are difficult to measure by satellite—clouds or the ionosphere block or filter them—but some observations are possible, so current nuclear detonation sensor systems and those in R&D focus on what can still be observed through these barriers, either separately or in combination. Another possibility might be electromagnetic pulse sensors that could be placed on commercial aircraft. The feasibility of these potential solutions remains unclear; the U.S. government should sponsor a systematic study to examine the feasibility of measuring reaction-time history using the phenomena associated with a detonation and of the different platforms that could be used for the measurements.

*RECOMMENDATION F.10: DTRA or NNSA should provide research funding to conduct a systematic study to identify, assess, and develop approaches to measure reaction-time history on a national or global basis.*

### 2.g.vi Quality Assurance/Quality Control and Uncertainty

Quality management is a critical element of laboratory analysis and indeed the whole lifecycle of nuclear forensics, from planning sample collection to communicating results. The validity and quality of nuclear forensics operations and nuclear forensics technical analyses contribute to scientific rigor, which can increase confidence in the analyses that are provided to policy makers.

Although guidance on quality assurance/quality control standards and methods of communicating uncertainty already exists, it was not clear to the committee that the laboratories always assess and communicate uncertainty in a uniform manner.

The 2010 National Academies report noted tension between collection efforts for technical nuclear forensics and the steps required for proper forensics science evidence collection and preservation to support criminal prosecution in court (see Box 2-1). Since 2010, great effort has been made to improve the ability to do technical work quickly and safely while maintaining chain of custody and evidentiary standards. For example, the Radiological Evidence Examination Facility at the Savannah River National Laboratory provides an extraordinary capability for the FBI to examine radioactive evidence while maintaining evidentiary chain of custody.

*FINDING F.9: Uncertainties are inherent in analyses and measurements, because of both experimental imperfections and limits to our understanding of the phenomena involved. However, the means by which these uncertainties are calculated and expressed vary across the NTNF program.*

*RECOMMENDATION F.11: NTNF practitioners should continue to adhere to standards and procedures of modern forensic science and recommended means of measuring uncertainty. The practitioners should continue to define/identify methods for communicating uncertainty and incorporate them uniformly across the laboratories and agencies involved in NTNF, with a focus on providing accurate information to decision makers who have little or no background in the scientific disciplines relevant to nuclear forensics.*

### 2.g.vii Improved Human Resources and Infrastructure

As noted elsewhere in this report, DHS and DTRA repurposed funds away from nuclear forensics due to the Trump administration's national security policies and guidance. One shift apparently precedes 2017. After the 2010 National Academies report was released, efforts were made to increase the number of technical nuclear forensics experts. The DHS-funded Nuclear Forensics Graduate Fellowship Program (NFGFP) functioned for several years and produced many new technical nuclear forensics specialists for the national laboratories. In 2015, DHS concluded that it had met its goal for bringing new radiochemists into the NTNF program and so terminated recruitment of new students for the program, shifting focus to later in the workforce development pipeline. This was a surprising decision and the justifications given by DHS were that (a) they had met a milestone erroneously attributed to the National Academies, and (b) that one of the graduates was unable to find a position within the NTNF program. However, the replenishment of human resources is not a one-time need, as experienced staff retire or move to other projects. Also, there are many reasons why a graduate might not be hired, so the inability of a single graduate to find employment within the program is not an indication that needs have been met.

Adequate staffing levels and pipelines must be maintained to ensure current and future NTNF functionality. Furthermore, sizable staffing is required to maintain a strong technology adoption

rate, including disruptive technologies adopted for NTNF. Finally, inconsistent funding of the student pipeline sends the chilling message to academic faculty and potential students that this mission is transient, unimportant, and a risky career choice.

*FINDING F.10: There is and will be an ongoing need for new staff as long as the nuclear forensics mission continues. How many new staff are needed depends on program needs and how long current staff plan to remain in the program, but it is appropriate to have a modest oversupply of new talent.*

*RECOMMENDATION F.12: To attract and retain an excellent workforce with the diverse skills needed for this mission, the agencies involved in NTNF must establish rewarding career paths with reliable, satisfying, and valuable work, and reestablish the educational and R&D investments that were supporting NTNF.*

NNSA should reconstitute the graduate student pipeline (i.e., NFGFP) and should use funding models and provisions best suited to building the nuclear forensics expert community. This means using not only the current consortium model, which concentrates efforts to gain the benefits of affiliated groups, but also student and postdoctoral fellowships and individual grants to principal investigators to support new ideas and talent outside of the consortia.

NNSA should not retain the requirement from the previous DHS program that students emerging from these programs must work in a NTNF field post-graduation. The technical expertise acquired by these students, in particular radiochemists, naturally encourages employment in the nuclear field, and NNSA should not be obligated to find federal employment for all graduates. This restriction discourages further production of students to support the nuclear forensics workforce. Instead, workforce needs should be assessed and adjusted annually by NNSA. Adjustments may be needed based on specificity of study. For example, if a student pipeline program is producing computational nuclear engineers, perhaps requiring that they work in the nuclear field after graduation is appropriate, as computational nuclear engineers frequently have high-quality opportunities working for tech firms (e.g., Google, Microsoft).

Nuclear forensics funding patterns are having an impact on infrastructure as well as personnel. An increase in funding led to investment in infrastructure, while a drop stopped the investment.

*FINDING F.11: Because much of the infrastructure and equipment for nuclear forensics is shared with other missions, special focus and resources are required to ensure adequate support for and prioritization of nuclear forensics capabilities.*

## CONCLUSION

The conclusion of the 2010 National Academies report notes that a terrorist nuclear attack is “the most catastrophic threat the nation faces.” Recent events indicate that the need to deter nuclear threats and attribute an attack in the event that deterrence fails has not abated and may be growing (Tilden and Boyd, 2021). As noted in this report, a credible nuclear forensics enterprise is essential for deterring nuclear trafficking and attacks and supporting attribution after an attack. Nuclear forensics capabilities, along with engaging international partners and a robust and credible monitoring, detection, and verification enterprise, can help empower leaders to make informed decisions about nuclear threats on short timelines.

Ensuring that the United States has credible and robust nuclear forensics capabilities—a strong nuclear forensics community integrated into an attribution mechanism that embraces all components (i.e., technical nuclear forensics, the intelligence community, and law enforcement) in collaborative engagement that is routinely exercised and that evolves with threats—requires strong sustained leadership along with thoughtful and strategic investment of adequate resources. Nuclear forensics capabilities are an essential element of U.S. national security. A more unified vision, more consistent, reliable support, and a more effective and coordinated program is necessary to serve that critical mission.

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## Acronyms

AAAS	American Association for the Advancement of Science
AFTAC	Air Force Technical Applications Center
CBRNE	Chemical, biological, radiological, nuclear, and explosive
CONOPS	Concept of Operations
CWMD	Countering Weapons of Mass Destruction (DHS)
DHS	Department of Homeland Security
DNN	NNSA Office of Defense Nuclear Nonproliferation
DoD	Department of Defense
DOE	Department of Energy
DOE-IN	DOE Office of Intelligence and Counterintelligence
DOJ	Department of Justice
DTRA	Defense Threat Reduction Agency
FBI	Federal Bureau of Investigation
FNMI	Foreign Nuclear Materials Intelligence Initiative
IC	Intelligence Community
JAEIC	Joint Atomic Energy Intelligence Committee
LLNL	Lawrence Livermore National Laboratory
NDAA	National Defense Authorization Act
NDRD	Nuclear Defense Research and Development
NDS	National Defense Strategy
NFEC	Nuclear Forensics Executive Council
NFGFP	Nuclear Forensics Graduate Fellowship Program
NMIP	Nuclear Materials Information Program
NNSA	National Nuclear Security Administration
NPR	Nuclear Posture Review
NSC	National Security Council
NSPM	National Security Presidential Memorandum
NTNF	National technical nuclear forensics
NTNFC	National Technical Nuclear Forensics Center
ODNI	Office of the Director of National Intelligence
PNNL	Pacific Northwest National Laboratory
PPD	Presidential Policy Directive
R&D	Research and development
REEF	Radiological Evidence Examination Facility (FBI)
UAV	Unmanned aerial vehicle





## Appendix

### Committee Biographical Sketches

#### **Robert Rosner (Chair)**

Robert Rosner has been a theoretical physicist at the University of Chicago since 1987, where he is the William E. Wrather Distinguished Service Professor in the Departments of Astronomy & Astrophysics and Physics, as well as in the Enrico Fermi Institute and the Harris School of Public Policy Studies. He served as Argonne National Laboratory's Chief Scientist and Associate Laboratory Director for Physical, Biological and Computational Sciences (2002-2005), and was Argonne's Laboratory Director from 2005 to 2009. He was the founding chair of the Department of Energy's National Laboratory Directors' Council (2007-2009). His degrees are all in physics (B.A., Brandeis University; Ph.D., Harvard University). He was elected to the American Academy of Arts and Sciences in 2001, and to the Norwegian Academy of Science and Letters (as a Foreign Member) in 2004; he is also a Fellow of the American Physical Society. Most of his scientific work has been related to fluid dynamics and plasma physics problems, as well as in applied mathematics and computational physics, especially in the development of modern high-performance computer simulation tools, with a particular interest in complex systems (ranging from astrophysical systems to nuclear fission reactors). Dr. Rosner has previously served on over a dozen Academies study committees, including the Committee to Review the Quality of the Management and of the Science and Engineering Research at the Department of Energy National Security Laboratories and the Committee on Evaluation of the Quantification of Margins and Uncertainty Methodology Applied to the Certification of the Nation's Nuclear Weapons Stockpile. Recently, he has been increasingly involved in energy technologies, and in the public policy issues that relate to the development and deployment of various energy production and consumption technologies, including especially nuclear energy, the electrification of transport, and energy use in urban environments. He is the co-founding director of the Energy Policy Institute at Chicago, located at the Harris School of Public Policy Studies, Booth School of Business, and Social Sciences Division of the University of Chicago.

#### **Marvin L. Adams**

Marvin L. Adams is the HTRI Professor of Nuclear Engineering and director of the Institute for National Security Education and Research at Texas A&M University. Dr. Adams received his Ph.D. in nuclear engineering from the University of Michigan and is a Fellow of the American Nuclear Society. He was a physicist at Lawrence Livermore National Laboratory from 1986 to 1992 and has remained extensively engaged with the U.S. national security laboratories since then. He has served on a variety of review and advisory committees and panels, many of which advise the U.S. government on matters related to national security. Dr. Adams has served on several Academies committees including the Committee on Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty, the Committee on Sustaining and Improving the Nation's Nuclear Forensics Capabilities, and the Committee on Evaluation of Quantification of

Margins and Uncertainty Methodology Applied to the Certification of the Nation's Nuclear Weapons Stockpile. He has also served as Co-chair of the Committee on Mathematical Foundations of Validation, Verification, and Uncertainty Quantification. Dr. Adams currently serves as a member of the National Academies Committee on International Security and Arms Control.

### **Sue B. Clark**

Sue B. Clark is a Regents Distinguished Professor of Chemistry with tenure at Washington State University (WSU) in Pullman, Washington, and Battelle Fellow with Pacific Northwest National Laboratory (PNNL). In this joint appointment, she is currently serving as the Chief Science and Technology Officer in the PNNL Energy and Environment Directorate, where she stewards discretionary research investments within the directorate and leads research focused on the chemistry and chemical engineering of processing nuclear materials and associated environmental impacts. Her current research areas include chemistry of radioactive waste systems, environmental chemistry, actinide separations, and radioanalytical chemistry. She began her academic career at WSU in the Chemistry Department in 1996 as an assistant professor and served as Department Chair (August 2005 to December 2007). She also served as Interim Vice Chancellor for Academic Affairs at WSU's Tri-Cities campus in 2008 and Interim Dean of the College of Sciences (WSU system-wide) in 2010. Previously, she was a member of the U.S. Nuclear Waste Technical Review Board, appointed by President Barack Obama (2011-2014). Clark is a fellow of the American Association for the Advancement of Science, and the American Chemical Society (ACS), and she is the recipient of the ACS 2020 Glenn T. Seaborg award and the 2012 Olin-Garvan Medal. She is also an elected member of the Washington State Academy of Sciences. She was elected a member of the Governing Board for the U.S. Council for Chemical Research, serving as a board member from 2015 to 2020. She also served on the National Academies' Nuclear and Radiation Studies Board from 2004 to 2009, and as a member of many National Academies study committees. She serves on the Basic Energy Sciences Advisory Committee for the U.S. Department of Energy, and has served as a consultant to Battelle Memorial Institute and the Helmholtz Association of German Research Centers. Dr. Clark holds a B.S. in chemistry from Lander College and M.S. and Ph.D. degrees in chemistry from Florida State University.

### **Donald L. Cook**

Donald L. Cook served as the Deputy Administrator for Defense Programs at the National Nuclear Security Administration (NNSA) from 2010 to 2015. He was responsible for managing the U.S. nuclear security enterprise of laboratories and manufacturing facilities. Prior to his appointment to NNSA, Dr. Cook served as managing director and chief executive officer of the Atomic Weapons Establishment (AWE) in the United Kingdom from 2006 to 2009. In this capacity, he was accountable for AWE's performance on the contract with the UK Ministry of Defence, which includes support of the UK Trident warheads and development and sustainment of capability in nuclear weapon design, engineering development, manufacturing, qualification, assembly, transport, support in service, and finally, decommissioning, dismantlement, and disposal. From 1977 to 2005, Dr. Cook worked in Pulsed Power Sciences, Microtechnologies, Infrastructure, and Security at Sandia National Laboratories in Albuquerque, New Mexico. From 1999 to 2005, he was director of the Microsystems and Engineering Sciences Applications (MESA) Program Center, accountable for design and construction of the MESA complex. In 2003, he assumed program director responsibilities for Sandia's Infrastructure Program and for Sandia's Safeguards

and Security Technologies Program. Dr. Cook previously led efforts in pulsed power accelerator design and experimentation, fusion research, hydrodynamics, radiography, diagnostic development, and computational code development. Work during this period included construction and development of a number of accelerators, including the Z-machine. Dr. Cook is a graduate of the University of Michigan and the Massachusetts Institute of Technology, and a Fellow of the American Association for the Advancement of Science and the Institute of Physics.

### **Donald J. DePaolo**

Don J. DePaolo received his Ph.D. in geology from Caltech in 1978, and has been a professor of geochemistry and geology at the University of California, Los Angeles (1978-1988) and the University of California, Berkeley (UC Berkeley) (1988-2016). He is currently graduate professor of geochemistry and Chancellor's Professor Emeritus at U.C. Berkeley. He served as chair of the Department of Geology and Geophysics at UC Berkeley, and was director of the Lawrence Berkeley National Laboratory (LBNL) Earth Sciences Division. From 2010 to 2016 he was Associate Laboratory Director for Energy Sciences at LBNL. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences, and has served on numerous advisory and study committees for federal agencies, universities, and the National Academies. His research involves the use of isotopic measurements as tracers and chronometers of Earth processes. From 2009 through 2018 he was the director of the Center for Nanoscale Controls of Geologic CO<sub>2</sub>, a U.S. DOE Energy Frontier Research Center led by LBNL.

### **Michael Dunning**

Michael Dunning retired from Lawrence Livermore National Laboratory (LLNL) in 2018, where he was principal deputy principal associate director of Weapons and Complex Integration. Prior to this role, Dr. Dunning was the program director and division leader for Primary Nuclear Design (PND). Under his leadership, PND operated a large-scale experimental facility at Site 300 and LLNL's High Explosives Applications Facility—both of which are national resources for the study of high explosives, conventional munitions, and propellants. PND also maintained a vigorous code-development and simulation capability, using some of the world's most capable supercomputers. Prior to 2006, Dr. Dunning served as the Nevada Experiments and Operations Program Leader and was responsible for the LLNL program and operations executed at the Nevada Test Site (now the Nevada Nuclear Security Site). Dr. Dunning also led LLNL efforts to detect, assess, and disable unauthorized nuclear and radiological dispersal devices. Dr. Dunning joined the Laboratory in 1989 as a postdoctoral researcher. He completed his bachelor's, master's, and doctoral degrees in nuclear engineering at the University of Michigan.

### **Steven Fetter**

Steve Fetter is Associate Provost, Dean of the Graduate School, and professor of public policy at the University of Maryland. He is a member of the Council on Foreign Relations and a fellow of the American Physical Society. Fetter worked for five years in the White House Office of Science and Technology Policy during the Obama administration, leading both the National Security and International Affairs and the Environment and Energy divisions. In 1993-1994 he served as special assistant to the Assistant Secretary of Defense for International Security Policy and he worked in the State Department as an American Institute of Physics fellow. He has been a member of the Director of National Intelligence's Intelligence Science Board and the Department of Energy's

Nuclear Energy Advisory Committee; served as president of the Association of Professional Schools of International Affairs and as vice chairman of the Federation of American Scientists; and has been a visiting fellow at Stanford's Center for International Security and Cooperation, Harvard University's Center for Science and International Affairs, Massachusetts Institute of Technology's (MIT's) Plasma Fusion Center, and Lawrence Livermore National Laboratory. He holds an S.B. in physics from MIT and a Ph.D. in energy and resources from the University of California, Berkeley.

### **Benjamin C. Garrett**

Prior to retiring in January 2015, Benjamin C. Garrett was assigned to the Federal Bureau of Investigation (FBI) Laboratory Division, Forensic Response Section, Quantico, Virginia. He had been appointed to the Senior Level Executive Service in July 2005 and served as the FBI's senior scientist for operational response to crimes or incidents involving weapons of mass destruction. As a member of the FBI Laboratory executive management, Dr. Garrett assisted with advancing the FBI's methods for crime scene processing and for examining evidence contaminated by toxic chemicals, biological pathogens, and radiological and nuclear materials. In addition to his responsibilities in the FBI Laboratory Division, Dr. Garrett has served as an instructor for the International Atomic Energy Agency (IAEA) for its Workshop on Radiological Crime Scene Management and Nuclear Forensics and in a similar capacity with INTERPOL, the international policing organization. He guided the development of the Implementing Guide for Radiological Crime Scene Management, issued in November 2014 by the IAEA and published jointly by the IAEA, INTERPOL, and the United Nations Interregional Crime and Justice Research Institute. From 2009 to 2014, he served as the co-chairman of the Nuclear Forensics International Technical Working Group. He holds a B.S. from Davidson College and a Ph.D. from Emory University.

### **Laura S. H. Holgate**

Laura S. H. Holgate, Ambassador (retired), is currently Vice President for Materials Risk Management at the Nuclear Threat Initiative (NTI), a nongovernmental organization dedicated to preventing catastrophic attacks with weapons of mass destruction and disruption—nuclear, biological, radiological, and cyber. She is also co-founder of Gender Champions in Nuclear Policy, a project of NTI. Ambassador Holgate leads NTI's efforts related to securing and reducing highly enriched uranium, plutonium, and radiological sources, as well as nuclear cooperation with Russia, Central Asia, and other countries. She served as U.S. Ambassador to the Vienna Office of the United Nations and the International Atomic Agency, where she implemented U.S. policy on nuclear nonproliferation, nuclear security, verification of the Iran Deal, nuclear testing, counterterrorism, anti-corruption, drug policy, export control, and the Nuclear Suppliers Group. Ambassador Holgate was previously the special assistant to the president and senior director for weapons of mass destruction terrorism and threat reduction on the U.S. National Security Council. In this role, she oversaw and coordinated the development of national policies and programs to reduce global threats from nuclear, biological, and chemical weapons; detect, identify, secure, and eliminate nuclear materials; prevent malicious use of biotechnology; and secure the civilian nuclear fuel cycle. She was also the U.S. Sherpa to the Nuclear Security Summits and co-led the effort to advance the President's Global Health Security Agenda. Prior to that, she held senior positions at NTI and the Departments of Energy and Defense. Ambassador Holgate graduated from Princeton University and the Massachusetts Institute of Technology. She was a researcher at

Harvard University's Belfer Center for Science and International Affairs, where she is now a senior non-resident fellow. She serves on several advisory boards and is a member of the Council on Foreign Relations.

### **William Jeffrey**

William Jeffrey, Ph.D., is chief executive officer of SRI International, a leading research and development organization serving government and industry. Jeffrey joined SRI in 2014. From 2008 to 2014, Dr. Jeffrey was president and CEO of HRL Laboratories, a corporate research and development organization owned by The Boeing Company and General Motors. Prior to joining HRL, Dr. Jeffrey served in the George W. Bush administration as director of the National Institute of Standards and Technology. He also served in the Executive Office of the President as senior director for homeland and national security and as assistant director for space and aeronautics within the Office of Science and Technology Policy. Earlier in his career, Dr. Jeffrey was deputy director for the Advanced Technology Office and chief scientist for the Tactical Technology Office at the Defense Advanced Research Projects Agency, and assistant deputy for technology at the Defense Airborne Reconnaissance Office. Dr. Jeffrey started his professional career at the Institute for Defense Analyses. He is an elected Fellow of the American Physical Society, an elected Honorary Member of the International Society of Automation, a recipient of the 2008 Navigator Award from the Potomac Institute for Policy Studies, and a recipient of the Secretary of Defense Medal for Outstanding Public Service. Dr. Jeffrey serves on the board of TE Connectivity, and serves on the Office of Director of National Intelligence Technical Advisory Board. He previously served on the Lawrence Livermore National Laboratory External Review Committee. Dr. Jeffrey received his M.A. and Ph.D. in astronomy from Harvard University, and his B.Sc. in physics is from Massachusetts Institute of Technology.

### **Jenifer Shafer**

Jenifer Shafer is an associate professor in the Chemistry Department and Nuclear Science and Engineering Program at the Colorado School of Mines. She received her Ph.D. from Washington State University in 2010, and a B.S. from Colorado State University in 2005. She is the 2019 Chair of the American Chemical Society (ACS) Division of Nuclear Science and Technology, a 2014 Department of Energy Early Career awardee and a member of the 2017 ACS Industrial and Engineering Committee Research's Class of Influential Researchers. Jenifer is interested in advancing f-element separations technology through the use of new materials, supramolecular assembly, unique oxidation states, and controlling electronic structure. Advancing f-element separations technology has broad applications from advanced nuclear fuel cycles, nuclear forensics, and renewable technology. She is the coauthor of several book chapters, over 40 technical manuscripts, and has led or collaborated on projects receiving approximately \$7 million in funding for her work in these areas.

