CWMD Research & Development

FY 2015–FY 2019

August 7, 2020

Fiscal Year 2020 Report to Congress

Homeland Security

Countering Weapons of Mass Destruction Office

Message from the Assistant Secretary

August 7, 2020

I am pleased to present the following report, "CWMD Research & Development," which has been prepared by the Countering Weapons of Mass Destruction Office (CWMD).

This document has been compiled pursuant to language in Senate Report 116-125, which accompanies the Fiscal Year (FY) 2020 Department of Homeland Security (DHS) Appropriations Act (P.L. 116-93). The language directs CWMD to report upon:

- All research and development (R&D) projects and partners for the last 5 completed fiscal years and the accomplishments related to such projects;
- A strategic plan for completing, maintaining, or initiating new R&D projects; and
- A projection of R&D needs for the following 3 years.

This report covers two periods of DHS R&D efforts for countering weapons of mass destruction (WMD). The first, from FY 2015–FY 2018, presents projects and programs sponsored by the Domestic Nuclear Detection Office (DNDO). During this time period, DNDO focused its R&D on technologies to counter radiological/nuclear (R/N) WMDs. With the formation of CWMD in December 2018, the current R&D efforts that began in FY 2019 focus on technologies to counter chemical, biological, radiological, and nuclear (CBRN) WMDs. The report also includes a strategic plan for CWMD R&D and discusses the office's efforts to coordinate counter-WMD research across the interagency and within DHS.

Pursuant to congressional requirements, this report is being provided to the following Members of Congress:

The Honorable Lucille Roybal-Allard
Chairwoman, House Appropriations Subcommittee on Homeland Security

The Honorable Chuck Fleischmann
Ranking Member, House Appropriations Subcommittee on Homeland Security

The Honorable Shelley Moore Capito
Chairman, Senate Appropriations Subcommittee on Homeland Security

The Honorable Jon Tester
Ranking Member, Senate Appropriations Subcommittee on Homeland Security.

I would be pleased to respond to any questions that you may have. Please do not hesitate to contact my office at (202) 254-8866.

Sincerely,

David Richardson
Assistant Secretary
Countering Weapons of Mass Destruction Office

Executive Summary

On December 21, 2018, the President signed into law the Countering Weapons of Mass Destruction Act of 2018. This Act codified CWMD in DHS. CWMD was created to elevate and streamline DHS efforts to prevent the use of WMDs against the homeland and to promote readiness for CBRN and health security threats.

Technological advances compound the difficulty of restricting terrorist access to WMD and of preventing its proliferation among potential state adversaries. Clandestine chemical, biological, and nuclear weapons programs around the world create the potential for unwitting or malign state actors to serve as sources for material and knowledge for terrorists seeking to harm the United States or its interests.

CWMD is tasked with conducting transformational R&D efforts that will identify and develop the new technologies needed to improve operational capabilities to counter WMD. This report covers two periods of DHS R&D efforts for countering WMDs. The first, from FY 2015–FY 2018, presents projects and programs sponsored by DNDO. During this time period, DNDO focused its R&D on technologies to counter R/N WMDs. With the formation of CWMD in December 2018, the current R&D efforts that began in FY 2019 focus on technologies to counter CBRN WMDs. The report also includes a strategic plan for CWMD R&D and discusses the office's efforts to coordinate counter-WMD research across the interagency and within DHS.

CWMD Research & Development
FY 2015 to FY 2019

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I. Legislative Language

Senate Report 116-125, which accompanies the Fiscal Year (FY) 2020 Department of Homeland Security (DHS) Appropriations Act (P.L. 116-93), includes the following requirement:

> The CWMD Office is directed to provide a report to the Committee no later than 180 days after the date of enactment of this act on all research and development projects and partners for the last five completed fiscal years and the accomplishments related to such projects. The report shall also include a strategic plan for completing, maintaining, or initiating new research and development projects, along with a justification that such projects are filling a gap and are not duplicative of R&D from other partners. Finally, the report shall include a projection of R&D needs for the following 3 years.

II. Background

On December 21, 2018, the President signed into law the Countering Weapons of Mass Destruction Act of 2018, which authorized the Countering Weapons of Mass Destruction Office (CWMD) in DHS. CWMD was created to elevate and streamline DHS efforts to prevent the use of weapons of mass destruction (WMD) against the homeland and to promote readiness for chemical, biological, radiological, nuclear (CBRN), and health security threats. The President's National Security Strategy discusses the growing prospect of terrorism involving WMDs as well as the increased biological risk to the United States—whether as a deliberate attack, accident, or a naturally occurring outbreak.

Technological advances compound the difficulty of restricting terrorist access to WMD and of preventing its proliferation among potential state adversaries. Clandestine chemical, biological, and nuclear weapons programs around the world create the potential for unwitting or malign state actors to serve as sources for material and knowledge for terrorists seeking to harm the United States or its interests.

Upon its formation, CWMD developed a strategy[1] to meet its stated mission to enable operational partners to prevent the use of WMD against the homeland and to promote readiness for CBRN and health security threats. The strategy establishes the goal for CWMD to "anticipate, identify, and assess current and emerging WMD threats." Additionally, pertinent to the CWMD research and development (R&D), the strategy identifies the objective to "anticipate emerging CBRN threats and avoid technological surprise through transformational research and development," with the following elaboration:

> CWMD, in collaboration with interagency and private-sector partners, will identify technological trends and advancements relevant to CBRN security and will act quickly to counter them. Through R&D, CWMD will identify and pursue transformational advancement opportunities in data analytics, screening and detector technologies, and other scientific areas to ensure that operators have the equipment and tools needed to address incipient threats and are always at least one step ahead of potential adversaries.

CWMD R&D manages efforts to identify, explore, develop, and demonstrate science and technologies that address gaps in the detection architecture and that meet operational customer requirements. Activities also improve the performance of detection and analysis and forensics capabilities, and/or significantly reduce the operational burden of detection systems in the field. The program works closely with supported operational customers to ensure the effective transition of technologies to the field. This program includes technology advancement (nuclear forensics) projects as well as small business innovation research (SBIR) projects.

This report covers two periods of DHS R&D efforts for countering WMDs. The first, from FY 2015–FY 2018, presents projects and programs sponsored by the Domestic Nuclear

[1] Countering Weapons of Mass Destruction Office Strategy 2020-2024.

Detection Office (DNDO). During this time period, DNDO focused its R&D on technologies to counter radiological/nuclear (R/N) WMDs. With the formation of CWMD in December 2018, the current R&D efforts focus on technologies to counter CBRN WMDs.

III. Research and Development: FY 2015 to FY 2019

A. R&D Projects for FY 2015 to FY 2019

The R&D projects reported in this section for this time period correspond to programs managed under the moniker of DNDO prior to December 21, 2018, when CWMD was authorized by the Countering Weapons of Mass Destruction Act of 2018. As such, the conceptual structure for R&D programs used by DNDO will guide the discussion for FY 2015–FY 2018 in this section, with reporting for FY 2019 under the new categorization used under the Act.

Because legacy DNDO's mission did not include biological and chemical detection, most projects describe R/N research efforts. Section IV will provide the path forward for biological and chemical detection research areas.

The six main categories of legacy DNDO R&D (FY 2015–FY 2018) were:

1. Academic Research Initiative (ARI)
2. Advanced Technology Demonstration (ATD)
3. Exploratory Research Program (ERP)
4. SBIR
5. Technology Advancement (Nuclear Forensics)
6. National Nuclear Forensics Expertise Development Program (Nuclear Forensics)

With the formation of CWMD during FY 2019, the programs were recategorized into:

1. Detection Capability Development (including the ATD projects)
2. Rapid Capabilities
3. R&D (including ARI, ERP, and SBIR work)
4. Technical Forensics (including Technology Advancement and the National Nuclear Forensics Expertise Development Program)

Across these categories, the R&D projects could range from high-risk, long-term research performed at universities, to higher technology readiness level (TRL) development work performed by small businesses, with a robust portfolio of R&D in between. The following discussion highlights key programs performed under each of these areas, as well as accomplishments and performers[2]. Interagency, intra-agency, state and local, and international partners who participated in or were supported through the R&D also are identified.

[2] For this report, "performers" are defined as the university, national laboratory, and/or industrial scientists, engineers, and technical staff conducting the R&D studies for DHS CWMD.

B. FY 2015 to FY 2018 Efforts

Academic Research Initiative (transitioned to the Research and Development Program in FY 2019)

The ARI program had two primary objectives: (1) advance fundamental knowledge in the sciences and engineering related to R/N threat detection and forensics needed to solve long-term, high-risk challenges and (2) develop the next-generation workforce in the nuclear sciences, engineering, and related fields. The ARI program provided continued investment in fundamental science, engineering, and related R/N detection and nuclear forensic fields to build capability at the university level. Students supported by the program were provided funding to help them in their work toward undergraduate and graduate degrees. The ARI program also reached out in nontraditional areas to solicit their ideas to solve R/N detection and forensics challenges.

Research areas under the ARI program included the following:

- Materials: Research in this area focused on high-risk, long-term research aimed at developing greatly improved radiation detector materials for gammas and neutrons that are highly sensitive, selective, low-cost, and rugged. This research's aim was to understand the fundamental properties of radiation-sensing materials, such as mechanisms of light production in scintillator materials and charge mobility and lifetimes in semiconductor materials.

- Advanced Analytics: Investigated innovative data processing and analysis techniques that would lead to major performance improvements through state-of-the-art computational methodologies. Current and prior research in this area has included algorithm development for real-time gamma-ray imaging and radionuclide identification and application of machine learning to facilitate mobile search and detection performance. The research also included advances in simulation and modeling techniques to provide early understanding of the operational benefits of new threat-detection approaches or background suppression.

- Radiation Techniques: Research in this area explored radically new approaches to threat detection, eventually leading to sensor or detection system concepts that are highly sensitive to R/N signatures and selective in their ability to distinguish and locate these materials from naturally occurring background radiation. This work included fundamental research into new detection system concepts that provide new insights in how threat materials can be detected even in challenging pathways.

- Shielded Special Nuclear Material (SNM) Detection: This research area included investigations to overcome the challenge of detecting shielded SNM, principally through advanced or enhanced nonintrusive inspection (NII) or active interrogation approaches for cargo scanning, vehicle scanning, and human-portable scanning applications. Fundamental research in this area addressed a range of studies to augment conventional NII approaches including: (1) transformational low-power, low-weight, high-yield neutron and gamma-ray producing sources; (2) high-efficiency, fast-recovery, low-cost

detectors for active detection; (3) novel active interrogation inspection concepts; and (4) investigations into unique signatures and fundamental data associated with active detection methods such as nuclear resonance fluorescence.

- Nuclear Forensics: Investigated advanced analytical techniques used to determine the processing history and transit route of pre-detonation nuclear materials. Research emphasis included identifying ways to improve analytical techniques and methodologies (e.g., speed, accuracy, and precision) for determining the physical, chemical, radiological, or morphological properties of nuclear or other radioactive materials. Objectives included determining the specific processing that the material underwent, geographic origins, transport pathways, and intended use.

FY 2015 Accomplishments:

- A Notice of Funding Opportunity (NOFO) was issued for ARI activities, resulting in eight new activities that address gaps in the Global Nuclear Detection Architecture (GNDA) and technical nuclear forensics.
    - Three grants were awarded for research in technical nuclear forensics,
    - Two grants were awarded for research in algorithms and radiation detection, and
    - Three grants were awarded for research in the detection of shielded SNM.

- Completed first year evaluation of the 11 new activities awarded under the FY 2014 NOFO.

- Funded 46 research efforts at 34 universities in the following areas:
    - Radiation detector materials development and supporting technology,
    - Radiation detection concepts, approaches, and architectures,
    - Shielded SNM detection, sources, and signature technology,
    - Advanced analytics and data processing, and
    - Nuclear forensics.

- Completed feasibility evaluation for the ARI activities investigating the following:
    - Machine-learning approaches to effective search and wide-area monitoring,
    - Graphene-based sensors for detecting SNM, and
    - New detectors, electronics, and algorithms for neutron spectroscopy.

FY 2016 Accomplishments:

- Issued a NOFO for ARI activities across four research topics addressing gaps in the GNDA and nuclear forensics. This notice resulted in the award of 10 new research grants:
    - Two grants were awarded for materials research,
    - One grant was awarded for forensics/algorithms and nuclear data,
    - Five grants were awarded for approaches to detect shielded SNM, and
    - Two grants were awarded for the science and engineering of R/N threat detection and localization through sensor integration and data fusion.

- Completed first-year evaluation of the eight activities awarded under the FY 2015 NOFO.

- Funded 46 grants to 31 universities, a total that included 3 collaborations between university partners in the following areas:
    - Radiation detector materials development and supporting technology,
    - Radiation detection concepts, approaches, and architectures,
    - Shielded SNM detection, sources, and signature technology,
    - Advanced analytics and data processing, and
    - Nuclear forensics.

- Completed feasibility evaluation for the ARI activities investigating the following:
    - Systematic approach to cadmium zinc telluride detector material development,
    - Development of new signatures for interrogation of SNM,
    - Assessment of unique trace elements and isotope ratios in plutonium from depleted uranium irradiated in fast reactor blankets,
    - Informatics-aided design of inorganic scintillator materials,
    - Use of laser cooling to extend the peak current and duty performance of thermionic guns, and
    - Exploiting time-correlated signatures and directionality of interrogation to detect shielded highly enriched uranium.

FY 2017 Accomplishments:

- Performed project reviews of each ARI grantee at the site of lead performer.

- Funded 45 research efforts at 29 universities to address long-term, high-risk challenges in R/N detection and forensics.

- Completed feasibility evaluation for the ARI activities investigating the following:
    - Advanced concepts of gamma-ray imaging and evaluation of their impact in real-world environment,
    - Gamma-ray imaging of SNM with a liquid xenon time projection chamber, and
    - Superheated emulsions for nuclear material detection.

FY 2018 Accomplishments:

- Released a NOFO announcement to solicit new proposals for research and awarded seven new grants.

- Completed annual reviews of all 38 ARI grantees.

- Funded more than 40 research efforts at more than 30 universities to address long-term, high-risk challenges in R/N detection and forensics.

- Completed feasibility evaluation for the ARI activities investigating the following:
    - Approaches to improve the performance of plastic scintillators through loading and conjugated polymers,
    - Monochromatic x-rays and their ability to enable low-dose scanning, and
    - Modeling actinide metals for use in nuclear forensics.

FY 2015 to FY 2018 Performers:

- Alabama Agricultural and Mechanical University
- Arkansas State University
- Arizona State University
- Carnegie Mellon University
- Colorado School of Mines
- Colorado State University
- Duke University
- Fisk University
- Georgia Institute of Technology, Georgia Tech Research Corporation
- Massachusetts Institute of Technology
- North Carolina Agricultural and Technical State University
- Northern Illinois University
- Northwestern University
- Oregon State University
- Pennsylvania State University
- Purdue University
- Rensselaer Polytechnic Institute
- Texas Agricultural and Mechanical University
- University of California, Berkeley
- University of California, Los Angeles
- University of Florida
- University of Maryland
- University of Michigan
- University of Minnesota, Twin Cities
- University of Nebraska
- University of Notre Dame
- University of Tennessee, Knoxville
- University of Texas, Dallas
- University of Utah
- University of Wisconsin, Madison
- University of Wisconsin, Milwaukee
- Wake Forest University
- Yale University

FY 2015 to FY 2018 Interagency, Intra-agency, State and Local, and International Partners:

- Department of Defense (DOD), Defense Threat Reduction Agency (DTRA)
- Department of Energy (DOE), National Nuclear Security Administration (NNSA)
- DHS, U.S. Customs and Border Protection (CBP), Office of Field Operations

Advanced Technology Demonstration (transitioned to the Detection Capability Development Program in FY 2019)

The ATD projects performed accelerated development, characterization, and demonstration of leading-edge technologies that addressed critical gaps in R/N detection capabilities. They build on technology concepts previously demonstrated under ERP, research conducted by our interagency partners, or privately funded research. ATD projects from FY 2015–FY 2018 are summarized below:

- Advanced Radiation-Monitoring Devices (ARMD): The ARMD project builds upon advances in new detection materials discovered under previous R&D projects utilizing advanced scintillator materials and neutron-detection techniques.

- Airborne Radiological Enhanced-sensor System (ARES): The ARES project develops and characterizes standoff radiation measurement technology to detect radiological material from an airborne platform to locate point-like sources in a complex and dynamic background.

- Shielded Nuclear Alarm Resolution: The project develops and characterizes advanced technologies required to resolve alarms and to detect SNM, even when heavily shielded or masked. Technologies of interest include induced fission, high-energy backscatter, advanced radiography, and nuclear resonance fluorescence.

- Nuclear and Radiological Imaging Platform (NRIP): This activity leverages recent advancements in the commercial sector as well as prior transformational R&D work. By combining the merits of passive and active technologies, new systems are being developed so that a single system can detect R/N threats, regardless of the amount of shielding or the complexity of cargo, in primary mode with minimal impact to the flow of commerce.

- Radiation Awareness and Interdiction Network (RAIN): This activity is intended to develop and characterize technologies for monitoring highway traffic and their on-ramps for vehicles carrying nuclear or other radioactive threat materials. RAIN technologies have integrated networked radiation sensors with vehicle detection and identification systems to allow actionable information on threat-carrying vehicles to be passed to law enforcement.

- Enhanced Radiological Nuclear Inspection and Evaluation (ERNIE): The ERNIE system is an advanced machine-learning-based approach to analyze radiation portal monitor (RPM) scans for greater overall system performance (improved threat detection with

reduced nuisance alarm rates). This effort includes spiral development of improvements to ERNIE machine-learning algorithms.

- Wearable Intelligent Nuclear Detection (WIND): The WIND effort will develop and characterize a highly modular, multipurpose, and human-portable (e.g., backpack or vest) system that greatly advances the ability to detect and interdict threats during wide-area search missions.

- Mobile Urban Radiation Search (MURS): The goal of the MURS effort is to migrate the knowledge and technology of previous standoff and long-range detection projects efficiently into a production-ready, compact, next-generation mobile radiation detection platform. The program emphasizes spiral development based on operational feedback from a variety of DHS end-users.

- SIGMA: SIGMA is a multipronged approach to the wide-area monitoring and search problem for R/N threats. The technology was transitioned to DNDO (now CWMD) from the Defense Advanced Research Projects Agency (DARPA) with shared funding in FY 2018. SIGMA is a cost-effective, operationally practical, continuous, and ubiquitous R/N detection capability. It includes low-cost radiation detectors with spectroscopic gamma- and neutron-sensing capability, packaged as automated and networked threat detection and identification capability with web-based command and control. The activity is developing human portable and mobile detection equipment.

FY 2015 Accomplishments:

- ARMD project: Completed the final report of the characterization of new scintillating materials.
- ARES project: Completed the ARES hardware system and data-collection campaigns. The prototype system has been flown over Baltimore/Washington, Las Vegas, and the San Francisco Bay area.
- NRIP project: Completed government analysis of the muon tomography system and the CBP cargo scanning systems. Began construction of the high-energy backscatter-based NRIP system at the Conley Terminal in Boston.
- RAIN project: Conducted preliminary design and critical reviews for three selected vendors and assessed worthiness to move on to the vendor development and test stage.
- WIND project: Completed development of R&D solicitation requirements, goals, and operational concepts; initiated R&D solicitation.
- MURS project: Kicked off the MURS ATD, stood up the end-user panel, and completed the development and integration of the first MURS prototype radiation detection module.

FY 2016 Accomplishments:

- ARES project: Completed government characterization of ARES system algorithms being run on aerial data collected by the prototype system in FY 2015.
- NRIP project: Completed the final report describing the characterization of the Multimodal Passive Detection System developed by Decision Sciences International Corporation.
- RAIN project: Completed the vendor development and test phase and conducted characterization readiness review for the three developed technologies. Prepared for government characterization activities. Coordinated with New York City Police Department stakeholders on the operational demonstrations of the systems.
- WIND project: Initiated efforts with four vendors and began work toward concept preliminary design.
- MURS project: Completed integration of two MURS prototypes. Deployed a MURS prototype with the Federal Bureau of Investigation (FBI) and DARPA SIGMA program. Participated in the DNDO test campaign for mobile systems.

FY 2017 Accomplishments:

- ARES project: Continued data analysis and replay to populate analysis products for final report.
- NRIP project: Commenced Technology Demonstration and Characterization of Passport NRIP system at Conley Terminal.
- RAIN project: Conducted government characterization of RAIN performance test units that successfully complete a characterization readiness review. Worked with stakeholders to plan and execute an operational demonstration of the systems around New York City.
- ERNIE project: Completed an Operational Assessment report.
- WIND project: Completed a spiral development event to provide end-user feedback on initial vendor designs. Validated the interface control document to demonstrate interoperability among multiple hardware and algorithm vendors and to validate open-architecture development framework.
- MURS project: Integrated MURS system into an FBI vehicle to further operational development. Participated in FBI deployments for the Presidential Inauguration, State of the Union Address, and 4th of July to refine the operational usability of the developmental technologies.

FY 2018 Accomplishments:

- NRIP project: Completed a stream-of-commerce data collection at Conley Container Terminal with data analysis being completed in late FY 2018.
- RAIN project: Completed government characterization of RAIN prototype systems. Initiated planning for an operational demonstration in the San Francisco Bay area.
- ERNIE project: Initial phased deployment in conjunction with CBP completed at the Virginia International Gateway.

- MURS project: Deployed one MURS system to federal partners for rapid prototyping and commercialization. Prototyping efforts will inform mobile system requirements for broader future deployment. Six additional systems are in development and will be transitioned to other DHS Components.
- WIND project: Completed the characterization readiness reviews with WIND vendors. Finalized analysis and characterization plans to evaluate prototype performance during Technical Demonstration and Characterization.
- SIGMA project: Transitioned SIGMA from DARPA to CWMD. Developed a SIGMA pilot plan for CWMD. Began SIGMA pilot.

FY 2015 to FY 2018 Performers:

- Bubble Technology Industries
- Counterterrorism Operations Support, Center for Radiological/Nuclear Training
- CBP
- Decision Sciences International Corporation
- General Electric Global Research
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Leidos
- Los Alamos National Laboratory
- National Security Technologies, LLC
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Passport Systems, Inc.
- Physical Sciences, Inc.
- Rapiscan
- Remote Sensing Laboratory
- SAIC
- Sensor Concepts & Applications, Inc.
- Y-12 National Security Site

FY 2015 to FY 2018 Interagency, Intra-agency, State and Local, and International Partners:

- DOD, DARPA
- DOD, DTRA
- DOE, Remote Sensing Laboratory
- DOE, NNSA
- DHS, CBP: Office of Field Operations, Office of Border Patrol
- DHS, U.S. Secret Service
- DHS, DNDO: Securing the Cities, Mobile Detection and Deployment Units Program, Product Acquisition and Deployment Directorate
- Department of Justice (DOJ), FBI
- Massachusetts Homeland Security and Department of Transportation

- Port Authority of New York and New Jersey
- New York City Police Department
- United Kingdom Home Office

Exploratory Research Program (transitioned to Research and Development Program in FY 2019)

ERP projects explore innovative, high-risk, early-to-later-stage technologies, specifically research technologies and techniques that:

- Address capability gaps and weaknesses in the framework of R/N detection capabilities;
- Provide substantial performance improvement and/or cost reduction of R/N detection capabilities; and
- Improve nuclear forensics capabilities.

Research efforts under ERP include:

- Materials Research and Supporting Technologies (Materials): The Materials project has the technical objective of discovering new gamma-ray and neutron-sensing materials. These materials then could enable the next generation of passive or active threat-sensing technologies, including RPM, handheld radiation isotope identification detectors (RIID), and a range of other detection technologies.

- Radiation Detection Technology (Radiation): The Radiation project emphasizes investigating novel approaches to improve greatly the ability to detect, identify, locate, and track threat materials on the basis of their intrinsic radiological signatures and the fusion of auxiliary sensors.

- Shielded Special Nuclear Material (Shielding): The Shielding project addresses the critical challenge of being able to detect threats even when heavily shielded or masked, with a specific focus on the detection of SNM.

- Advanced Analytics (Analytics): The Analytics project utilizes advanced signal-processing and cutting-edge analyses to enhance greatly the ability to detect, locate, track, and identify potential threat materials and devices across a broad range of environments.

- Nuclear Forensics (Forensics): The Forensics project coordinates with DNDO's National Technical Nuclear Forensics Center mission to execute transformational R&D to discover new forensics signatures or to develop the tools to enable comprehensive and timely analytical results.

FY 2015 Accomplishments:

- Materials:
  - Completed two breakthroughs in radiation detection using solid-state detectors. First, achieved 50-percent intrinsic thermal neutron detection sensitivity in a bulk semiconductor material (lithium indium di-selenide) that has the potential to provide extremely low-power and efficient neutron detection capability for personal radiation detectors. Second, the new sensor material thallium bromide achieved over 2-year stable operation with gamma-ray energy resolution better than 1-percent without any cooling.

- Radiation:
  - Demonstrated a proof of concept of compact, hybrid neutron and gamma-ray detection and imaging system and demonstrated the ability to track vehicles even when not visible (e.g., at night without lights).

- Shielding:
  - Demonstrated proof of concept of an algorithm for improved material discrimination in x-ray cargo inspection systems by measuring statistical noise. It was determined that this technique could be used to separate high-Z (such as uranium or lead) and medium-Z materials (such as steel), where Z is the atomic number.

- Analytics:
  - Completed a study of research strategies that would support improvements in domain awareness to enhance the likelihood of an R/N detection in U.S. non-port-of-entry (POE) domains. Also initiated an effort to develop advanced, comprehensive model to quantify cost-to-benefit for GNDA nodes.

- Forensics:
  - Expanded the nuclear forensics image quantification tool to include additional features and to support the ingestion of other nuclear forensics R&D projects, including morphological and microstructural feature discrimination.

- Solicitation for New ERP Activities: Initiated activities through a new broad agency announcement and call for proposals, resulting in 17 new awards.

FY 2016 Accomplishments:

- Materials:
  - Demonstrated proof of concept for several activities in the area of very low-cost, very large-scale detector materials with high sensitivity and good (medium-energy resolution) selectivity to isotope identification, based on advances made in plastics. This led to a proof of concept for scaling up metal-loaded plastic scintillators (larger than 2-inch diameter) performing at performance comparable

to or better than the most commonly used radiation detector scintillator, sodium iodide.

- Shielding:
  - Completed proof of concept for enabling technologies for low-dose radiographic applications to include a source developed utilizing laser-driven x-rays and a radiographic imaging system capable of reducing the dose to cargo by at least an order of magnitude while maintaining performance equivalent to state-of-the-art x-ray systems.

  - Completed feasibility evaluations for technologies able to provide signatures indicative of shielding anomalies such as fluctuations in gravity and magnetic fields and radar scanning. These signatures do not rely on the use of ionizing radiation and could pave the way to development for no-dose scanning capabilities for SNM in conveyances.

- Radiation:
  - Completed two proofs of concept on use of three-dimensional (3D) optical cameras/light detecting and ranging data and shortwave infrared imaging to estimate background radiation environments and to improve threat-detection sensitivity; conducted a field assessment of a DNDO-developed long-range radiation detection prototype system in Singapore.

- Analytics:
  - Completed proof-of-concept capability for packaging Intelligent Radiation Sensor System (IRSS) replay data sets to support external collaborations, injection modeling to emphasize threats, and advanced spatial network algorithm development to compare against IRSS baseline results.
  - Released MCNP6 Version 6.2.0 (a Monte Carlo particle transport modeling tool) to include 6 new radiation transport features and 50 new test sets. Finished the technical feasibility study to describe how other contraband detection technologies could be integrated into R/N detection systems.

- Forensics:
  - Completed proof-of-concept demonstration for using a focused ion beam to develop 3D images of forensics samples.

- Solicitation for New ERP Activities:
  - Conducted feasibility evaluation reviews and preliminary design reviews of the activities awarded in FY 2015 to determine worthiness to proceed to a critical design review. Initiated activities through a new broad agency announcement/call for proposals, resulting in eight new awards.

FY 2017 Accomplishments:

- Materials:
  - Initiated one new R&D activity to investigate defect formation and mechanisms of plastic scintillators in the short and long terms upon exposure to environmental conditions such as varying temperature and moisture.

  - Discovered and documented the root cause of plastic degradation in portal plastics due to long-term exposure to environmental conditions such as varying temperature and moisture and found alternate nondegrading-formulation solutions for the plastics.

  - A full-up prototype handheld RIID based on a newly developed, high-energy resolution material (strontium iodide) with advanced isotope identification algorithms was delivered to DNDO for inclusion in future tests.

  - Three different new higher performance, lower cost material technologies integrated into submodules have been supplied to active interrogation and radiography system integrators for test and evaluation. These materials were outgrowths of an active interrogation materials workshop several years ago that included both materials experts and active interrogation system integrators.

- Radiation:
  - Completed a baseline study of personal and mobile detection assets used for the current monitoring mission and to provide assessment critical areas for performance improvement.

  - Initiated one new R&D activity to develop a machine-learning algorithm to predict and mitigate proactively maintenance issues arising within the currently deployed RPM fleet.

  - Initiated one new R&D activity exploring approaches to make low operational burden R/N sensors available for a wide variety of law enforcement vehicles. This effort will integrate proven computer vision algorithms for real-time tracking of pedestrians and vehicles.

- Shielding:
  - Completed proof-of-concept demonstration for a human-portable neutron source suitable for mobile scanning applications.

- Analytics:
  - Initiated two new R&D activities to investigate application of big data analytic techniques to seek indicators of proliferation, loss of control, or imminent loss of control of R/N materials that may be more effective in material interdiction than current material pathway analysis.

- Initiated one new R&D activity to develop a modeling capability to anticipate where adversaries will deviate from normal travel routes to avoid POEs into the United States, and to estimate the probability of encounter over broad geographic regions.

- Completed a proof of concept for an ERP project examining the physical interoperability and validation of the MCNP6.

- Completed two feasibility evaluation reviews for two projects exploring competing approaches for autonomous gain stabilization of gamma-ray spectra. These projects have the potential to enhance the efficacy and to reduce the downtime of gamma detectors in operational use.

- Forensics:
  - Initiated two new R&D activities investigating development of production techniques for nuclear forensics reference materials.

  - Completed a proof-of-concept demonstration for image analysis software that will help to enable consistent and defensible nuclear material analysis of morphology.

FY 2018 Accomplishments:

- Materials:
  - Initiated two new R&D activities leading to demonstrations in a simulated operational environment of a prototype RIID based on the newly developed, high-efficiency, high-energy resolution semiconductor gamma-detector material thallium bromide. This material would provide a low-cost and operationally effective alternative to the commercial off-the-shelf (COTS) cadmium zinc telluride and high-purity germanium detector material.

- Radiation:
  - Initiated and conducted feasibility evaluation of one new R&D activity exploring approaches to make low-operational burden R/N sensors available for a wide variety of law enforcement vehicles. This approach will fuse radiation data with contextual sensors and computer vision algorithms that continuously identify, track, and classify objects in the scene into categories useful for radiation propagation modeling.

- Shielding:
  - Initiated one new R&D activity aimed at developing the next-generation pulsed x-ray source suitable for true active interrogation applications and high throughput for shielded threat detection. The effort is working toward high-pulse-rate and better pulse flexibility (energy, intensity, and timing) in a comparable size and cost to existing commercial x-ray sources.

- Initiated two new R&D activities for development of a continuous output x-ray source that will enable high-throughput scanning for active interrogation for shielded threat detection.

- Initiated two new R&D activities leading to demonstration of a prototype mobile active interrogation system using neutrons in a simulated operational environment.

- Completed proof-of-concept demonstration for a series of enabling technologies to support rail cargo inspection to include fast detectors and a radiation source specifically designed to improve dramatically R/N detection in rail cargo.

- Initiated a follow-up of R&D activity for a platform-agnostic algorithm that provides optimized detection of nuclear-threat anomalies in radiographic images across the entire fleet of current and planned NII radiography imaging systems, regardless of manufacturer.

- Analytics:
  - Initiated and conducted feasibility evaluation of one new R&D activity to conduct general research in how to use and extend a currently existing agent-based, physical security simulation package for the purpose of studying the probability of encounter for illegal, non-POE border crossings into the United States.

  - Demonstration of POE border crossings from the south was shown. Further improvements will be made for higher probability outcomes, but the proof of concept has been verified.

- Forensics:
  - Initiated and conducted feasibility evaluation of one new R&D activity for development of models to help to predict morphological signatures of uranium and plutonium materials that can be used to link measured data on morphology with the process from which it was made.

  - Continued evaluating the performance of a DNDO-developed image analysis software as implemented by technical nuclear forensics experts that included their input in the development of the tool. This resulted in development of a validated software tool to enable signature discovery, which has been reviewed and adapted to support a cross-section of nuclear forensics experts.

  - Completed a proof-of-concept demonstration of a method that will help to enable more efficient and timely production of neptunium-236 and other actinide forensics reference materials.

  - Completed a proof of concept (beta delivery) of mass bias/linear correction software to make measurements during forensics sample analysis more accurate.

FY 2015 to FY 2018 Performers:

- Argonne National Laboratory
- Bubble Technology Industries
- CapeSym, Inc.
- Carnegie Mellon University
- Fisk University
- Idaho National Laboratory
- Kromek
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Leidos
- Los Alamos National Laboratory
- MITRE
- National Strategic Research Institute
- Naval Research Laboratory
- Naval Sea Systems Command
- Nious Technologies, Inc.
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Physical Sciences, Inc.
- Radiabeam Technologies
- Radiation Monitoring Devices, Inc.
- Rapiscan
- Raytheon
- Rensselaer Polytechnic Institute
- Sandia National Laboratory
- Sanmina Corporation
- Savannah River National Laboratory
- Sensor Concepts and Applications, Inc.
- SLAC National Accelerator Lab
- SRI International
- Stanford University
- Starfire Systems
- University of Tennessee, Knoxville

FY 2015 to FY 2018 Interagency, Intra-agency, State and Local, and International Partners:

- DOD, DARPA
- DOD, DTRA
- DOE, NNSA
- DHS, CBP: Office of Field Operations

- DHS, DNDO: Securing the Cities, Mobile Detection and Deployment Units Program, Product Acquisition and Deployment Directorate
- DHS, Transportation Security Administration (TSA)
- DOJ, FBI

Small Business Innovation Research (transitioned to Research and Development Program in FY 2019)

The SBIR Program enables technological innovation by strengthening the role of small business concerns in federally funded R&D. The CWMD SBIR Program is focused specifically on meeting federal R&D needs for R/N detection. There is a need to identify, explore, develop, and demonstrate scientific and technological approaches that address gaps in R/N detection capabilities; significantly improve the performance of R/N detection, components, and systems; and/or significantly reduce the operational burden of these technologies. The SBIR Program stimulates technological innovation by strengthening the role of innovative small business concerns in federally funded R&D.

FY 2015 Accomplishments:

- Mass/Shielding Anomaly Passive Detector Module:
  - Initiated one Phase I contract to develop an innovative system to detect highly shielded SNM contained within personally owned vehicles (POV) through measurements of total mass, mass distribution, density, or whether it is high-Z material.

- Stable Semiconductor Modules as Core Component in Pager Radiation Detectors:
  - Initiated six Phase I contracts to develop a semiconductor-based module for enhanced radiation detectors in pager applications with neutron- or gamma-detection capability.

- Miniaturization of Support Infrastructure for NII X-Ray Systems:
  - Initiated two Phase II contracts for development of laboratory-scale prototypes of continuous wave x-ray systems with a smaller footprint than commercially available continuous wave x-ray systems to enable high-throughput scanning of cargo and conveyances for active interrogation applications used for shielded threat detection.

- Smartphone- or Tablet-Controlled Devices for Radiation Detection, Identification, Classification, and Quantification:
  - Initiated one Phase II contract for development of a prototype device that provides a compact, low-cost, high-performance, smartphone-compatible “module” to identify and categorize radiation sources readily.

FY 2016 Accomplishments:

- Mass/Shielding Anomaly Passive Detector Module:
  - Initiated one Phase II contract to develop an innovative system to detect highly shielded SNM contained within POVs through measurements of total mass, mass distribution, or density, or whether it is high-Z material.

- Stable Semiconductor Modules as Core Component in Pager Radiation Detectors:
  - Initiated four Phase II contracts to develop a semiconductor-based module for enhanced radiation detectors in pager applications with neutron- or gamma-detection capability.

- Smartphone/Smart Device Toolkit for Virtual and Actual Radiation Detection, Identification, and Localization:
  - Initiated two Phase I contracts for development of smart device toolkits that enable operator R/N training without a radiation source physically present to provide a capability to conduct R/N training at a much lower cost than training requiring the use of radiation sources.

- Embedding of Advanced Search Technique for Detect, Locate, and Track for Pedestrian-based Search:
  - Initiated Phase III of technology maturation of a real-time source localization and tracking capability leading to development of preproduction prototypes of an integrated photomultiplier tube base providing real-time detection and identification capability and a wide area search add-on module for a commercial handheld radiation detector.

- Miniaturization of Support Infrastructure for NII X-Ray Systems:
  - Continued two Phase II contracts investigating development of laboratory-scale prototypes of continuous wave x-ray systems with a smaller footprint than commercially available continuous wave x-ray systems to enable high-throughput scanning of cargo and conveyances for active interrogation applications used for shielded threat detection.

- Plastic Composite-Based Scintillators for Multi-Signature Radiation Detectors:
  - Initiated three Phase I contracts leading to feasibility evaluations of fabrication and testing of very low-cost composite plastic scintillator materials capable of combined gamma, thermal, and fast neutron detection for handheld and backpack applications.

- Portable Linear Accelerator (Linac) for Active Interrogation Systems for Radiological Gamma Isotope Source Replacement:
  - Initiated two Phase I contracts leading to feasibility evaluations of approaches for development of a compact x-ray radiation source that can be used for isotope source replacement and mobile radiography applications.

FY 2017 Accomplishments:

- Embedding of Advanced Search Technique for Detect, Locate, and Track for Pedestrian-based Search:
    - Continued technology maturation of a real-time source localization and tracking capability leading to development of preproduction prototypes of an integrated photomultiplier tube base providing real-time detection and identification capability and a wide-area search add-on module for a commercial handheld radiation detector.

- Miniaturization of Support Infrastructure for NII X-Ray Systems:
    - Completed two Phase II contracts for development of laboratory-scale prototypes of continuous wave x-ray systems with a smaller footprint than commercially available continuous wave x-ray systems to enable high-throughput scanning of cargo and conveyances for active interrogation applications used for shielded threat detection.

    - Initiated one Phase III contract for further development of a continuous wave x-ray system with a smaller footprint to support potential transition of the system to the commercial market.

- Stable Semiconductor Modules as Core Components in Pager Radiation Detectors:
    - Continued four Phase II contracts for development of modular high-efficiency gamma and high-efficiency neutron semiconductor-based detectors for pager radiation detectors.

- Mass/Shielding Anomaly Passive Detector Module:
    - Continued one Phase II contract for development of component technologies for a passive system that detects large mass anomalies through the sensing of changes in a gravity-based signal with an emphasis on POV applications without the use of ionizing radiation.

- Smartphone/Smart Device Toolkit for Virtual and Actual Radiation Detection, Identification, and Localization:
    - Concluded two Phase I contracts leading to feasibility evaluations of approaches for development of smart device toolkits that enable operator R/N training without a radiation source physically present to provide a capability to conduct R/N training at a much lower cost than training requiring the use of radiation sources.

    - Initiated two Phase II contracts for further development of smart device toolkits that enable operator R/N training without a radiation source physically present.

- Plastic Composite-Based Scintillators for Multi-Signature Radiation Detectors:
    - Concluded three Phase I contracts leading to feasibility evaluations of fabrication and testing of very low-cost composite plastic scintillator materials capable of

combined gamma, thermal, and fast neutron detection for handheld and backpack applications.

- Initiated two Phase II contracts for further development of very low-cost composite plastic scintillator materials capable of combined gamma, thermal, and fast neutron detection for handheld and backpack applications.

- Portable Linac for Active Interrogation Systems for Radiological Gamma Isotope Source Replacement:
  - Concluded two Phase I contracts leading to feasibility evaluations of approaches for development of a compact x-ray radiation source that can be used for isotope source replacement and mobile radiography applications.

  - Initiated one SBIR Phase II contract for further development of a compact x-ray radiation source that can be used for isotope source replacement and mobile radiography applications.

- Unattended Radiation Detection Systems:
  - Initiated three Phase I contracts for feasibility evaluations of unattended radiation detection systems that can be deployed rapidly and can run for multiple days at a time without operator intervention while providing data fusion capabilities such as radiation detection combined with video.

FY 2018 Accomplishments:

- Smartphone/Smart Device Toolkit for Virtual and Actual Radiation Detection, Identification, and Localization:
  - Continued one SBIR Phase II contract for further development of smart device toolkits that enable operator R/N training without a radiation source physically present to provide a capability to conduct R/N training at a much lower cost than training requiring the use of radiation sources.

- Plastic Composite-Based Scintillators for Multi-Signature Radiation Detectors:
  - Continued one SBIR Phase II contract for further development of very low-cost composite plastic scintillator materials capable of combined gamma, thermal neutron, and fast neutron detection for handheld and backpack applications.

- Portable Linac for Active Interrogation Systems for Radiological Gamma Isotope Source Replacement:
  - Continued one SBIR Phase II contract for further development of a compact x-ray radiation source that can be used for isotope source replacement and mobile radiography applications.

- Unattended Radiation Detection Systems:
  - Concluded three Phase I contracts leading to feasibility evaluations of unattended radiation detection systems that can be deployed rapidly and can run for multiple

days at a time without operator intervention while providing data fusion capabilities such as radiation detection combined with video.

  - Initiated one Phase II contract for further development of unattended radiation detection systems.

- Robotic Inspection for General Aviation:
  - Initiated two SBIR Phase I contracts for development of ground-based robotic technologies for autonomous R/N inspection of general aviation aircraft.

- Fusion of Radiation Detectors with Large-Scale Video Management Systems:
  - Initiated three SBIR Phase I contracts for development of software tools and associated algorithms and data analytics to support the ready integration of radiation sensors with existing security platforms and their associated video monitoring and management systems.

FY 2015 to FY 2018 Performers:

- Adelphi Technology
- AOSense
- ArchSmart
- BluEyeQ
- CapeSym, Inc.
- Charles River Analytics
- Deep Analytics
- Euclid
- Heron Systems, Inc.
- Inrad Optics
- Lithium Innovations
- Niowave
- NuHorizon Technologies
- Passport Systems
- Physical Sciences
- Radiabeam
- Radiation Monitoring Devices
- Silverside Detectors
- Spectral Labs
- TPL, Inc.

FY 2015 to FY 2018 Interagency, Intra-agency, State and Local, and International Partners:

- DOD, DARPA
- DOD, DTRA
- DOE, NNSA

- DHS, CBP: Office of Field Operations
- DHS, DNDO: Securing the Cities, Mobile Detection and Deployment Units Program, Product Acquisition and Deployment Directorate
- U.S. Small Business Administration

Technology Advancement Program (transitioned to Technical Forensics Program in FY 2019)

The Technology Advancement Program and activities explored innovative, low-risk, later stage technologies and methodologies that:

- Addressed capability gaps and weaknesses found in the National Strategic 5-Year Plan for Improving the Nuclear Forensics and Attribution Capabilities of the United States FY 2015–2019;
- Assessed current forensics laboratory performance, identified improvement areas, developed methodologies, and fielded solutions to enhance operational nuclear forensics capabilities; and
- Developed pre-detonation material nuclear forensics signatures to determine material and statistical population characteristics that can identify linkages uniquely with known or predicted material characteristics.

The Technology Advancement Program and activities provided long-term and continued investment to promote education and training within academia, the national and defense laboratories that perform nuclear forensics research, and the federal workforce.

FY 2015 Accomplishments:

- Produced two certified reference materials for forensic method improvement and quality assurance purposes.
- Operated the laboratory-scale uranium processing capability to produce uranium materials for signature development.
- Completed development of the laboratory-scale plutonium processing capability to produce plutonium materials for signature development.
- Began transition to operational use of an improved methodology for the forensic characterization of trace elements in uranium and plutonium.

FY 2016 Accomplishments:

- Produced two certified reference materials for forensic method improvement and quality assurance purposes.
- Fully characterized four nuclear forensic relevant samples to assist in populating the U.S. National Nuclear Forensics Library and to maintain a sharp operational nuclear forensics workforce.
- Operated the laboratory-scale uranium processing capability to produce uranium materials for signature development.

- Completed development of the laboratory-scale plutonium processing capability to produce plutonium materials for signature development.
- Continued the transition to operational use of an improved methodology for characterization of trace elements in uranium.
- Completed a benchmarking study for improving measurements of trace actinides in plutonium and began the transition to operational use.
- Continued method development of a new characterization methodology, resonance ionization mass spectrometry, to improve the speed of nuclear forensics analyses.

FY 2017 Accomplishments:

- Produced two certified reference materials for forensic method improvement and quality assurance purposes.
- Operated laboratory-scale uranium and plutonium processing capabilities to produce uranium and plutonium materials for signature development.
- Continued the transition of an improved methodology for characterization of trace elements in uranium to operational use.
- Began the transition of an improved methodology for characterization of trace elements in plutonium to operational use.
- Began a benchmark study for improving measurements of trace elements in uranium.

FY 2018 Accomplishments:

- Produced two certified reference materials for forensic method improvement and quality assurance purposes.
- Operated the laboratory-scale uranium and plutonium processing capabilities to produce uranium and plutonium materials for signature development.
- Completed the transition to operational use of an improved methodology for characterization of trace elements in plutonium and uranium.
- Continued a benchmarking study for improving measurements of trace elements in uranium.

FY 2015 to FY 2018 Performers:

- Argonne National Laboratory
- Idaho National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Institute of Standards and Technology
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Sandia National Laboratory
- Savannah River National Laboratory
- Y-12 National Security Site

FY 2015 to FY 2018 Interagency, Intra-agency, State and Local, and International Partners:

- DOE, NNSA
- DOD, DTRA
- DOJ, FBI
- Intelligence Community

National Nuclear Forensics Expertise Development Program (transitioned to Technical Forensics Program in FY 2019)

The Nuclear Forensics and Attribution Act of 2010 (P.L. 111-140), the National Nuclear Forensics Expertise Development Program (NNFEDP), and the Federal Expertise Development Program (FEDP) mandate that the U.S. Government pursue a comprehensive effort to address the enduring challenge of sustaining a preeminent workforce of scientists and policymakers educated and trained in nuclear-forensics-related specialties. NNFEDP initiatives aim to maintain the technical expertise required to execute the Nation's nuclear forensics mission through interdisciplinary R&D collaboration among students, academic departments, universities, and national laboratories. FEDP enhances the education of the federal workforce in areas critical to technical nuclear forensics, facilitates technical and professional development, and promotes understanding of partner department and agency missions. These programs were led by DNDO in close collaboration with the DOD, DOE, and DOJ (FBI) through a biannual Expertise Development Committee.

FY 2015 Accomplishments:

- Supported 10 Seaborg Institute nuclear science summer interns, 5 undergraduate scholars, 22 graduate fellows, 16 postdoctorate fellowship positions, 4 university education awards, 4 junior faculty awards, 1 minority serving institution award, and dedicated one-on-one senior scientist/student mentoring at the national laboratories.
- Sponsored three nuclear forensics courses as part of the FEDP: "Introduction to Nuclear Forensics for the Federal Workforce" at the Oak Ridge National Laboratory and two iterations of the "Nuclear Testing, Diagnostics, Forensics, and Stockpile Stewardship" at Lawrence Livermore National Laboratory and the Nevada National Security Site.

FY 2016 Accomplishments:

- Supported 10 Seaborg Institute nuclear science summer interns, 5 undergraduate scholars, 1 undergraduate summer school position, 16 graduate fellows, 17 postdoctorate fellowship positions, 1 university education award, 4 junior faculty awards, 1 minority serving institution award, and dedicated one-on-one senior scientist/student mentoring at the national laboratories.
- Explored opportunities to enhance university and student engagement in nuclear forensics-related R&D through a dedicated outreach strategy.
- Evaluated the state of the nuclear forensics workforce within the DOE national laboratories to inform and guide expertise development program efforts.

- Continued to sponsor two nuclear forensics courses for the federal workforce: "Overview of Nuclear Forensics for the Federal Workforce" and "Nuclear Testing, Diagnostics, Forensics, and Stockpile Stewardship." Explored opportunities for enhancing the FEDP to include improving the current two courses and/or expanding beyond these courses.

FY 2017 Accomplishments:

- Implemented three new initiatives supporting universities and students as well as scientific staff at the DOE national laboratories; focused on strengthening and sustaining the technical expertise of the nuclear forensics workforce.
- Supported 2 research awards, 10 Seaborg Institute nuclear science summer interns, 1 undergraduate summer school position, 8 graduate fellows, 14 postdoctorate fellowship positions, 1 early-career award, and dedicated one-on-one senior scientist/student mentoring at the national laboratories.
- Enhanced university and student engagement in nuclear forensics-related R&D through a dedicated outreach strategy.
- Sponsored one nuclear forensics course for the federal workforce: "Nuclear Testing, Diagnostics, Forensics, and Stockpile Stewardship."
- Initiated a study to evaluate the projected state of the nuclear forensics technical workforce within the next 20 years to determine long-term objectives and goals for the expertise development program efforts.

FY 2018 Accomplishments:

- Supported 2 research awards; 1 undergraduate summer school position; 3 graduate fellowships; 10 postdoctorate fellowship positions; and 1 early-career award.
- Evaluated the current state of the nuclear forensics workforce within the DOE national laboratories and the DOD radiochemistry laboratory to inform and guide expertise development program efforts.

FY 2015 to FY 2018 Performers:

- Air Force Institute of Technology
- Air Force Technical Applications Center
- Argonne National Laboratory
- Colorado State University
- Idaho National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Institute of Standards and Technology
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Sandia National Laboratory
- Savannah River National Laboratory

- South Carolina Universities Research and Education Foundation
- University of Texas, Austin
- Y-12 National Security Site

FY 2015 to FY 2018 Interagency, Intra-agency, State and Local, and International Partners:

- DOE, NNSA
- DOD, DTRA
- DOJ, FBI
- Intelligence Community

C. FY 2019 Efforts

Detection Capability Development

Capability gaps exist across multiple pathways through which WMD can be transported. These capability gaps, to some degree, can be mitigated with nonmatériel solutions but primarily require a matériel solution to be developed, acquired, and deployed to address the gap. Further, DHS operational users and CWMD recognize that many deployed systems will be reaching their respective end of life and that modernization and/or recapitalization efforts will be required to maintain or improve CWMD sensor capabilities. Additionally, potential COTS material solutions may require customization and always will require test and evaluation to ensure that they meet operational and functional requirements. Through analyses of alternatives, threat assessments, preparation of documentation to prepare for matériel solution acquisition, and test and evaluation activities, CWMD can conduct the capability development effort necessary to acquire and deploy matériel solutions.

Projects under Detection Capability Development include:

- Biological Detection for the 21st Century (BD21): The BD21 acquisition program is intended to modernize BioWatch by deploying an integrated capability that provides timely anomaly detection, onsite presumptive identification, and notification of the presence of aerosolized biological threat agents. The BioDetection 21 program will enable: (1) first responders to take quick actions that minimize the impact of a biological release on the surrounding population and (2) expeditious delivery of biological samples to diagnostic laboratories under the U.S. Department of Health and Human Services for confirmatory analysis that could inform decisions on deployment of medical countermeasures.

- International Rail: The International Rail program will analyze options and will develop a programmatic approach to procure and deploy solutions to detect and categorize nuclear or other radioactive materials out of regulatory control entering the United States via freight rail cargo through the active POEs. This program supports the CBP-led rail NII Recapitalization Program by leading the radiation detection equipment procurement as well as integration and test and evaluation with rail NII.

- Maritime Noncontainerized Cargo: This activity will provide efficient and effective scanning of the most diverse cargo types—break-bulk cargo (transported unpackaged in large quantities) and roll-on, roll-off cargo (vehicles, bags, bundles, crates, loose matériel, and containerized liquid)—for R/N material entering the United States at sea POEs. When break-bulk cargo is offloaded from ships, CBP officers scan it for R/N material, often using handheld devices. The Maritime Noncontainerized Cargo effort will conduct analysis to identify matériel, nonmatériel, or combined solutions that will reduce the risk of R/N material being offloaded at U.S. ports and inside break-bulk cargo not being detected.

- SIGMA: See description under Advanced Technology Demonstration.

- RPM Open Systems Architecture: The RPM Open Systems Architecture is a follow-on to the RPM Replacement activity and will explore an open systems architecture model as an option to recapitalize the remainder of the legacy RPM fleet beyond the approximately 200 units planned under the RPM Replacement Program. The RPM Open Systems Architecture will be modular with a defined a set of hardware and software interfaces that enable assembly of an RPM from a set of COTS components. An open systems approach allows for more agile technology insertion and reduced sustainment costs.

- ERNIE project: See description under Advanced Technology Demonstration.

- WIND project: See description under Advanced Technology Demonstration.

- RAIN project: See description under Advanced Technology Demonstration.

- NRIP project: See description under Advanced Technology Demonstration.

- MURS project: See description under Advanced Technology Demonstration.

- Helium-3 Alternative Implementation Backpack Program: This CWMD program intends to replace current capabilities provided by the legacy Helium-3 backpack detection systems. As part of this program, the Helium-3 Alternative Implementation Backpack Program prototype project will leverage the commercial market and will support a rapid modification to develop improved performance and suitability of the backpack- or vest-configured system and to expand the capability of the wearable detection system by including radionuclide identification and data transfer. Combining these capabilities into a single solution will shorten the amount of time required for alarm adjudication and will reduce the number of detection systems required in the field.

- Common Viewer Prototype: The Common Viewer Prototype program is intended to provide a single user interface for CBP personnel to access and control various systems (e.g., radiation detection equipment, NII systems, and ancillary control systems) simultaneously. This allows CBP officers on the ground and staff at the National Targeting Center and CBP remote operations/analysis centers to check real-time radiographic, spectrographic, optical, and x-ray imaging data against traveler, cargo, and

conveyance information for comparison against law enforcement, intelligence, and other enforcement data. It will provide CBP officers with capabilities to be more effective to detect, identify, and/or localize R/N threats (including material and other components) that may be smuggled via containerized and noncontainerized cargo at POEs into the United States.

- Next-Generation CWMD Sensor Programs: These initiatives include several required solutions based on capability gaps, anticipated recapitalization of deployed equipment, and/or solutions that otherwise have been identified and documented by DHS operational users as a required capability. This funding provides for the late-stage TRL R&D required for the capability development of these next-generation initiatives being identified by ongoing capability gap analyses. Additionally, these initiatives include continual efforts to improve legacy systems capabilities to communicate and network with next-generation control systems simultaneously.

FY 2019 Accomplishments:

- Biological Detection for the 21st Century (BD21): Completed initial requirements documents, an Acquisition Decision Event 1 "Analyze/Select" milestone, and initiated an alternative analysis.
- International Rail: Planning to conduct radiation detection equipment/NII integration and testing.
- Maritime Noncontainerized Cargo: Completed an analysis of alternatives and began to develop programmatic approach and artifacts required for program governance.
- SIGMA Project: Continued SIGMA pilots and technology demonstration opportunities.
- RPM Open Systems Architecture: Developed a programmatic approach and artifacts required for program governance.
- Nuclear and Radiological Imaging Platform Project: Completed a final report and closeout of the Passport Nuclear and Radiological Imaging Platform contract.
- Enhanced R/N Inspection and Evaluation Project: Kicked off an effort to develop land-border crossings, including POVs, and anomaly detection software versions.
- WIND Project: Completed the Characterization Readiness phase.
- RAIN Project: Completed government characterization of RAIN prototype systems. Initiated planning for an operational demonstration.
- NRIP: Completed closeout of the Passport Nuclear and Radiological Imaging Platform contract.
- MURS Project: Four prototypes completed. Established technology demonstrations with the U.S. Border Patrol (USBP).
- Next-generation sensors: Conducted market research and prototyping and prepared program documentation for one or more next-generation CWMD sensors.
- Helium-3 Alternative Implementation Backpack Project: Initial article delivery.
- Common Viewer: Prototype system deployed to initial CBP POEs.

FY 2019 Performers:

- Ametek
- Bubble Technologies Industries
- Defense Information Technology
- FLIR
- Johns Hopkins University Applied Physics Laboratory
- Kromek
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Leidos
- Mirion Technologies
- National Security Technologies, LLC
- Oak Ridge National Laboratory
- Passport Systems, Inc.
- Physical Sciences, Inc.
- Proportional Technologies, Inc.
- RAND
- Rapiscan
- RSI
- Sensor Concepts & Applications, Inc.
- Sensor Technologies, Inc.
- Smiths Detection
- Symetrica
- Target Systemelectronik
- Thermo Fisher
- TwoSix
- Y-12 National Security Site

FY 2019 Interagency, Intra-agency, State and Local, and International Partners:

- DOD, DARPA
- DOD, DTRA
- DOE, NNSA
- DHS, CWMD Office: Mobile Detection Deployment Program
- DHS, CBP: Office of Field Operations, USBP
- DHS, TSA

Rapid Capabilities

A quickly evolving threat environment can outpace traditional capability acquisition processes and timelines, make the Nation vulnerable to WMD attack, and/or can impede response to an attack. The Rapid Capabilities programs and activities place prototype capabilities in the field for operator use to support their mission.

Projects under Rapid Capabilities include:

- BD21 Technology Demonstration: Deployed 12 technology demonstration units to 12 cities across the United States to collect environmental data to support anomaly detection algorithm development and to assess performance of available capabilities to reduce cost, schedule, and performance risk for the BD21 Acquisition Program.

- Project ARCHER: USBP Kingsville Checkpoint installation was completed in 2019. ARCHER combines gantry-mounted gamma and neutron detectors to allow vehicle traffic to traverse under the detectors at the USBP Kingsville Checkpoint. The system offers better detection capability, standoff notification of potential threats, and vehicle attribution of potential threats. ARCHER is designed to make USBP R/N screening more effective and efficient. The 1-year operational evaluation period is underway with the goal to leave the prototype system in place while requirements and acquisition of final configuration of system is completed for all 31 USBP checkpoints.

- Handheld Trace Chemical Detection Pilot: This pilot will enable individual DHS operational Components to assess detection capabilities independently against their unique mission requirements. The 6-month pilot effort will collect operator feedback to support development of specific requirements for inclusion into a formal acquisition program to increase chemical detection capabilities. Several operational units have provided feedback of successful drug identifications/seizures, including fentanyl. Specifically, this chemical detection equipment allows identification to occur with minimal disturbance of suspect substances, which increases operator safety and reduces evidence contamination.

- San Francisco Airport Pilot: Installed various R/N detection equipment at San Francisco Airport to support operational evaluation for CBP to identify operational constraints and opportunities for different types of R/N detection equipment in a Federal Inspection Station. The different types of R/N detection equipment are not being compared against each other for their detection performance, but rather for their impact on concept of operations.

FY 2019 Accomplishments:

- BD21 Technology Demonstration: Began prototype operational evaluation of the Biological Detection Prototype effort via deployment of biodetection equipment prototypes to operators for evaluation.
- Project ARCHER: Began a 1-year operational evaluation of advanced R/N detection capability for USBP.
- Handheld Trace Chemical Detection Pilot: Deployed 60 chemical detectors with operator feedback on positive operational impact on their mission.
- San Francisco Airport Pilot: Deployed three different types of R/N detection technologies for concept of operations evaluation to fill mission gaps.

FY 2019 Performers:

- 908 Devices
- Alakai Defense Systems
- Kromek Group
- Logistics Management Institute
- Physical Sciences, Inc.
- Sensor Concepts & Applications, Inc.
- Thermo Fisher Scientific, Inc.

FY 2019 Interagency, Intra-agency, State and Local, and International Partners:

- DOD, Joint Program Executive Office for Chemical, Biological, Radiological, and Nuclear Defense (JPEO-CBRND)
- DHS, CWMD Mobile Detection Deployment Program, BioWatch state and local representatives
- DHS, U.S. Immigration and Customs Enforcement (ICE): Rapid Response Teams, Evidence Recovery Teams, and Special Response Teams
- DHS, U.S. Coast Guard: Maritime Security Response Teams, Tactical Law Enforcement Teams, Maritime Safety and Security Teams, National Strike Force Teams, Port Security Units, Aviation Special Mission Branch
- DHS, TSA: Visible Intermodal Prevention and Response Teams
- DHS, CBP: Office of Field Operations, USBP, Special Operations Division (Special Response Teams)
- DHS, U.S. Secret Service: Special Operations Division, Hazardous Agent Mitigation Medical Emergency Response Teams

Research and Development

The R&D program explores innovative technologies that address gaps in U.S. R/N detection capabilities and provide improvements in performance or reduction in cost of R/N detection capabilities in support of the CWMD mission. This program also will focus on transitioning chemical/biological technologies developed by interagency partners to operational capability for CWMD.

In FY 2019,[3] the R&D program consisted of the following:

- R&D: Enhances the Nation's ability to prevent the use of R/N WMD by developing breakthrough technologies that will have a dramatic impact on DHS operational capabilities. The CWMD refocused R&D efforts to meet DHS operational requirements. The change increases the priority of research involving anomaly detection and data

[3] In FY 2020, CWMD's R&D Program was restructured to include R/N R&D (formerly R&D in FY 2019), Chemical/Biological R&D (formerly Test and Evaluation for Chemical/Biological in FY 2019), Data Analytics, and SBIR (formerly the SBIR Detector/User Interface). CWMD Information Architecture is no longer a research area under the R&D Program.

streaming in support of DHS operational customers while decreasing basic long-term efforts. In turn, this R&D reprioritization will lead to more capability being delivered to operational customers in the field to fulfill CWMD's broader strategy of serving a role as an operational support organization.

- Test and Evaluation for Chemical/Biological: Focuses on transitioning chemical/biological technologies developed by interagency partners to operational capabilities for CWMD. This effort will review TRL-5 chemical/biological detection technologies developed by others and will transition them from the component or research prototype stage to higher TRL products that will serve as the basis for CWMD's operational capabilities. This includes R&D into anomaly detection and data analytics initiatives supporting the Biological Detection Prototype effort.

- Data Analytics: Data Analytics is a family of R&D initiatives focused on technologies to integrate physical sensor data and other information streams (e.g., nonphysical contextual and intelligence data), to perform data analytics to determine patterns, and to produce techniques for identifying anomalies to support global targeting and interdiction by domestic and global partners. The largest project within this program is SIGMA, a multipronged approach to the wide-area monitoring and search mission space that was transitioned to CWMD from DARPA with shared funding in FY 2018.

- CWMD Information Architecture: The CWMD Information Architecture Program supports CWMD's priorities to develop and implement a WMD detection sensor data and information integration system that supports global targeting and interdiction by domestic and foreign partners. The CWMD Information Architecture program is designed specifically to improve capabilities to prevent WMD terrorism as far away from targets in the homeland as possible.

- The SBIR Detector: User Interface: The SBIR Program enables technological innovation by strengthening the role of small business concerns in federally funded R&D. The CWMD SBIR Program is focused specifically on meeting federal R&D needs for R/N detection. A need exists to identify, explore, develop, and demonstrate scientific and technological approaches that address gaps in R/N detection capabilities; to improve significantly the performance of R/N detection, components, and systems; and/or to reduce significantly the operational burden of these technologies. The SBIR Program stimulates technological innovation by strengthening the role of innovative small business concerns in federally funded R&D.

FY 2019 Accomplishments:

- R&D:
    - Completed feasibility evaluation of thallium bromide-based RIID activities.
    - Completed preliminary design and initiated critical design of systems based on active interrogation using neutrons.

- Test and Evaluation for Chemical/Biological:
    - Kicked off and initiated data survey and baseline analysis for BD21 Anomaly Detection Algorithm.
    - Identify technologies developed by interagency partners that have the greatest potential to provide an enhanced mission capability.
    - Coordinated with the DARPA SIGMA+ to identify and develop protocols used so that operational prototypes can be used on the same network.

- Data Analytics:
    - Continued SIGMA pilots and technology demonstration opportunities.
    - Mid-period review of the CWMD data analytics and anomaly detection strategy study and approach to supporting architecture.

- CWMD Information Architecture:
    - Completed a design and implementation roadmap delivery for CWMD Information Architecture.
    - Completed initial assessment of scenario visualization tools from operational usage to CWMD-relevant data sets.

- SBIR Detector/User Interface:
    - *Miniaturization of Support Infrastructure for NII X-Ray Systems:* Concluded the SBIR Phase III contract for further development of a continuous wave x-ray system with a smaller footprint to support potential transition of the system to the commercial market.
    - *Smartphone/Smart Device Toolkit for Virtual and Actual Radiation Detection, Identification, and Localization:* Concluded the SBIR Phase II contract for further development of smart device toolkits that enable operator R/N training without a radiation source physically present leading to proof-of-concept demonstration.
    - *Plastic Composite-Based Scintillators for Multi-Signature Radiation Detectors:* Concluded the SBIR Phase II contract leading to a successful proof-of-concept demonstration of very low-cost composite plastic-scintillator materials capable of combined gamma, thermal neutron, and fast neutron detection for handheld and backpack applications.
    - *Portable Linac for Active Interrogation Systems for Radiological Gamma Isotope Source Replacement:* Continued the SBIR Phase II contract for further development of a compact x-ray radiation source that can be used for isotope source replacement and mobile radiography applications.
    - *Unattended Radiation Detection Systems:* Continued the SBIR Phase II contract for further development of unattended radiation detection systems that can be deployed rapidly and that can be run for multiple days at a time without operator intervention while providing data fusion capabilities such as radiation detection combined with video.
    - *Robotic Inspection for General Aviation:* Initiated one SBIR Phase II contract for development of ground-based robotic technologies for autonomous R/N inspection of general aviation aircraft.

- *Fusion of Radiation Detectors with Large-Scale Video Management Systems:* Initiated two SBIR Phase II contracts for development of software tools and associated algorithms and data analytics to support the ready integration of radiation sensors with existing security platforms and their associated video monitoring and management systems.
- *Detector Integration with Current and Emerging Networked Systems:* Initiated two SBIR Phase I contracts for development of relevant communications protocols and appropriate interfaces to allow legacy and emerging detection systems in operational use to be integrated into current and emerging networked systems.
- *Unmanned Aerial System Autonomous Search of Limited Area for Radiological Threats:* Initiated three SBIR Phase I contracts for development of an unmanned aerial system capable of autonomous search for threats of a 3D complex environment such as a cargo container yard or stadium.

FY 2019 Performers:

- Auton Systems LLC
- BluEyeQ
- Bubble Technology Industries
- CapeSym, Inc.
- Carnegie Mellon University
- Charles River Analytics, Inc.
- Deep Analytics LLC
- Euclid
- Georgia Institute of Technology, Georgia Tech Research Corporation
- Heron Systems, Inc.
- Intelligent Automation, Inc.
- Idaho National Laboratory
- Johns Hopkins University Applied Research Laboratory
- Kromek
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Leidos
- Los Alamos National Laboratory
- MITRE
- National Security Agency
- National Security Technologies, LLC
- Naval Research Laboratory
- Northwestern University
- NuHorizon Technologies, LLC
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Passport Systems, Inc.
- Pennsylvania State University

- Physical Sciences, Inc.
- Proportional Technologies, Inc.
- Purdue University
- Radiabeam Technologies
- Radiation Monitoring Devices, Inc.
- Rapiscan
- Raytheon
- Sandia National Laboratory
- Savannah River National Laboratory
- Sensor Concepts & Applications, Inc.
- Silverside Detectors
- SLAC National Accelerator Lab
- Spectral Labs
- TwoSix Labs
- University of California, Berkeley
- University of Michigan
- University of Notre Dame
- University of Tennessee, Knoxville
- University of Utah
- University of Wisconsin, Madison
- WGS Systems
- Yale University

FY 2019 Interagency, Intra-agency, State and Local, and International Partners:

- DOD, DARPA
- DOD, DTRA
- DOD, JPEO-CBRND
- DOE, NNSA
- DHS, CWMD Office: Mobile Detection Deployment Program
- DHS, CBP: Office of Field Operations, USBP, Office of Trade
- DHS, ICE: Homeland Security Investigation
- DHS, Science & Technology Directorate
- U.S. Small Business Administration
- Montgomery County Police Department

Technical Forensics

The Technical Forensics Program[4] and activities explore innovative, low-risk, later stage technologies and methodologies that:

[4] In accordance with interagency policy changes, CWMD has not sought funds to support R&D for pre-detonation nuclear materials after FY 2020. This activity is aligned more operationally with NNSA, the operational user for the capabilities developed under this program via the National Laboratories.

- Address capability gaps and weaknesses found in the National Strategic 5-Year Plan for Improving the Nuclear Forensics and Attribution Capabilities of the United States FY 2015–2019;
- Assess current forensics laboratory performance, identify improvement areas, develop methodologies, and field solutions to enhance operational nuclear forensics capabilities; and
- Develop pre-detonation material nuclear forensics signatures to determine material and statistical population characteristics that uniquely can identify linkages with known or predicted material characteristics.

The Technical Forensics Program and activities provide long-term and continued investment to promote education and training within academia, the national and defense laboratories that perform nuclear forensics research, and the federal workforce.

NNFEDP comprises a number of student initiatives that range from the undergraduate to the postdoctorate level. NNFEDP scholars, fellows, university, and faculty awardees must pursue degrees, conduct research, and build academic programs that directly contribute to advancing the U.S. Government's nuclear forensics mission.

FY 2019 Accomplishments:

- Finished production and certification of two certified reference materials for forensic method improvement and quality assurance purposes.
- Maintained current inventory of certified reference materials and formalized the process to provide access to the technical community.
- Operated the laboratory-scale plutonium processing capability to produce two plutonium materials for signature development.
- Completed a proof-of-concept demonstration for the following ERPs:
    - Bonding and Distribution as a Function of Depth in Plutonium and Uranium Forensic Samples, with Los Alamos National Lab
    - Focused Ion Beam for 3D Microscopy, with Lawrence Livermore National Laboratory
- Completed initial data evaluation and draft of reference material report for a uranium-233 spike.
- Held joint CWMD/DTRA Nuclear Programs Technical Review to present and coordinate ongoing forensics research projects across both agencies.
- Nuclear/radioactive document repository beta site was released to production to be accessed and tested by a limited user base.
- Completed Pathfinder exercise.
- Continued sponsorship of expert panels and working groups that provide direction to the technical nuclear forensics community.
- Supported two Nuclear Forensics Research Awards, three nuclear forensics graduate fellows, one early career award, and nine postdoctoral fellowships.

FY 2019 Performers:

- Air Force Institute of Technology
- Argonne National Laboratory
- Colorado State University
- Idaho National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Institute of Standards and Technology
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Sandia National Laboratory
- Savannah River National Laboratory
- South Carolina Universities Research and Education Foundation
- University of Texas, Austin
- Y-12 National Security Site

FY 2019 Interagency, Intra-agency, State and Local, and International Partners:

- DOE, NNSA
- DOD, DTRA
- DOJ, FBI
- Intelligence Community

IV. Strategic Plan for CWMD R&D

CWMD R&D projects future R&D needs on the basis of high-level U.S. Government strategic plans and requirements identified by DHS Operational Components and partners. These needs and requirements are reviewed and generalized to create a series of research goals. The following strategy outlines the approach that CWMD R&D will take to identify and develop the advanced technologies required by operators to counter WMD. The following strategy outlines a vision, mission, goals, and objectives to guide CWMD R&D.

A. Vision

CWMD is the leader in preventing WMD attacks by anticipating emerging CBRN threats and by avoiding technological surprise through transformational R&D.

B. Mission

Provide operators and analysts with the advanced tools and capabilities needed to execute the CWMD mission by investing in transformational R&D.

Goal 1: Improve and decrease the cost of sensors

Detecting and identifying CBRN materials quickly and accurately is core to executing the CWMD mission. Although techniques and technologies currently exist, particularly in laboratory settings, they are not necessarily suitable for the needs of field operations. Some of the most effective technologies are prohibitively expensive for widespread deployment. Investments that will bring down per-unit costs while maintaining or increasing performance will bring dividends in detection coverage and mission effectiveness.

Objective 1.1: Improve detector and trigger materials and components.
Objective 1.2: Explore alternative signatures.
Objective 1.3: Decrease the time to detect and identify.
Objective 1.4: Model sensor behavior.

Goal 2: Leverage data analytics and sensor networking

The revolutionary growth in data analytic capabilities in recent years offers the tantalizing prospect of detecting threats in the outputs from sensors and other sources that might not be apparent without such "big data" techniques. The increased deployment of networked sensors offers the opportunity to leverage multiple devices for the detection of threats in motion. Algorithm development and data handling are key to both efforts.

Objective 2.1: Determine appropriate algorithmic techniques for different types of data sources.
Objective 2.2: Build or enhance data fusion techniques for multiple sources and types of sources.

Objective 2.3: Model patterns of behavior and the appearance of threats within data streams.
Objective 2.4: Utilize information technology capabilities of external partners during R&D.

Goal 3: Measure environmental baselines and intrinsic signatures

Crucial to detecting and identifying threats is the ability to discriminate against a background of similar but benign materials. For certain systems, an *in situ* recalibration is necessary as the device moves through the environment to adjust for changes in ambient signals. For others, a reliable baseline of daily and seasonal fluctuations should help to minimize false alarms and to increase probabilities of detection. In all cases, having a precharacterized temporal and/or spatial background can aid the operation of detection systems. Better understanding of the signatures of threats will enable systems to detect and identify them against the background.

Objective 3.1: Embark on comprehensive environmental measurements, with existing field detectors and sampling for laboratory instruments, to fill in gaps in understanding of CBRN backgrounds in urban and transportation environments.
Objective 3.2: Categorize unique signatures of threat CBRN materials.

Goal 4: Transition technology to acquisition and operations

The ultimate goal of all R&D efforts within CWMD is to transition useful technology to the hands of operational partners. Because of the high-risk nature of transformational R&D, all aspects of every single project may not achieve transition to operational use, but each project should inform the maturation of understanding about potential approaches, thereby ensuring that the best technologies end up in the field. Execution of this goal involves not only conducting the R&D, but also engaging with operators and analysts, determining their needs and offering solutions. It also requires a robust engagement with the technical community and interagency partners for awareness about other efforts and potential solutions.

Objective 4.1: Participate in industry engagement events.
Objective 4.2: Participate in interagency program reviews.
Objective 4.3: Exchange expertise with operators and analysts, determining their constraints and needs and offering technical solutions.

C. Projection of R&D Needs for FY 2020 to FY 2022

R&D needs for the next 3 years will be based on studies of gaps and requirement requests from operational users. Although specific needs or operational requirements can and will change during this time, the overall R&D focus will be based on the strategic goals listed in the previous section. The succeeding discussion focuses on the first three goals and their objectives; the fourth goal is concerned principally with process rather than particular research areas.

Goal 1: Improve and decrease costs of sensors

For CBRN research, there will be a continued effort to improve the capabilities of deployed sensors while reducing their cost. As discussed previously, detecting and identifying CBRN

materials quickly and accurately is core to executing the CWMD mission. Investments that will bring down per-unit costs while maintaining or increasing performance will bring dividends in detection coverage and mission effectiveness.

A primary focus of R/N threats will continue to be the development of materials that detect gamma rays and/or neutrons, because these materials drive the costs of detection systems. Previous years' efforts have resulted in great advancement in such materials, and further improvements still can be made. Another key focus will be sources of x-rays for inspecting cargo and vehicles for dense objects, which may be indicative of attempts to shield radioactive or nuclear material.

R&D efforts also will emphasize the study of alternative signatures for detection of threat materials. Alternative signatures could provide an avenue to decrease detection time while improving the ability to identify threats. A near-term focus of biological threats will be alternative signatures. For example, currently many off-the-shelf trigger technologies rely on fluorescence of biological materials under ultraviolet light. R&D into different detection modalities could help to improve the tools for operational users. The ultimate goal of standoff identification of biological materials is likely too ambitious in the near term, but CWMD would continue to explore the prospects to address this need.

The list of near-term R&D needs associated with Goal 1 would include:

1. Semiconductor and scintillator materials science for R/N detection,
2. Compact emission generators (e.g., x-rays, neutrons) for visualization of contents in sealed containers,
3. Electromagnetic spectral options for detection of biological and chemical agents, and
4. Laboratory and field-suitable alternatives for rapid identification of biological agents.

Goal 2: Leverage data analytics and sensor networking

In addition, research will exploit the revolutionary growth in data analytic capabilities. The increased deployment of networked sensors offers the opportunity to leverage multiple devices for detection of threats in motion. The recent work on data analytics has shown promise, but challenges remain. An important near-term focus will be determining the data sets and scenarios for which analytical tools have appropriate application.

The list of near-term R&D needs associated with Goal 2 would include:

1. Models of adversarial behavior that are potentially detectable in available data sets,
2. Generation and collection of sensor data libraries from simulated and operational environments, and
3. Mining of nonsensor-related data sets associated with acquisition and possession of CBRN threat materials.

Goal 3: Measure environmental baselines and intrinsic signatures

As the ability to gather and analyze large data sets increases, it becomes ever important to discriminate against a background of similar but benign materials. For certain systems such as

radiation detectors, an *in situ* recalibration is necessary as the device moves through the environment to adjust for changes in ambient signals. For others such as biological sensor networks, a reliable baseline of daily and seasonal fluctuations should help to minimize false alarms and to increase probabilities of detection. Among the near-term R&D efforts will be to gather these baselines across all threat agents to support future deployments.

The list of near-term R&D needs associated with Goal 3 would include:

1. Mapping genomic baselines of urban environments,
2. Collection of temporal variations in atmospheric chemistry, and
3. Literature survey and new research into phenomenology of biological agents.

D. Coordination with Partners

With multiple entities in the Federal Government conducting CWMD-related R&D, it is essential to avoid unnecessary duplication of effort as well as to ensure that all priorities are addressed; in other words, to strive to avoid overlaps and gaps. Historically, DNDO collaborated with interagency partners through a number of mechanisms to deconflict and synchronize work. Many of these efforts have continued under CWMD. With the broader portfolio, including countering biological and chemical threats, CWMD R&D's efforts will have new coordination responsibilities.

During FY 2015–FY 2018, DNDO engaged routinely with interagency partners conducting R/N R&D. These engagements included annual joint program reviews with DHS Operational Components; DOE/NNSA, DOD DTRA, and DARPA; and members of the Intelligence Community. DNDO also held and participated in reviews of research solicitation topics and proposals with its interagency partners. Since the creation of CWMD, R&D staff continue to take part in interagency program reviews with the groups listed above.

CWMD participated in the development of the *Nuclear Defense Research and Development Strategic Plan for Fiscal Years 2020-2024,*[5] under the auspices of the White House National Science and Technology Council. The strategic plan (formerly called the *Nuclear Defense Research and Development Roadmap*, to which DNDO contributed previously) provides a series of research priorities and responsibilities. The effort is a key enabler in ensuring that agencies conducting R&D in nuclear defense and detection are synchronized.

With CWMD's new chemical and biological research responsibilities, new partnerships are being formed and relationships are being fostered to avoid overlaps and gaps in that area. CWMD will conduct chemical and biological research to support its mission of protecting the United States against a biological or chemical WMD attack. This research will focus on developing and improving the deployed sensor technologies required to support operators in their efforts to provide prompt and effective early detection of a chemical or biological attack within the country. Efforts will focus on reducing the time of detection and improving the fidelity of that detection. Examples of potential research areas include studies of unique signatures of

[5] https://www.whitehouse.gov/wp-content/uploads/2019/12/Nuclear-defense-research-development-strategic-plan-2019.pdf. Accessed March 24, 2020.

biological material to improve sensor triggers, data collection and analysis to enhance the understanding of the biological backgrounds in urban environments, improvements to the ability to detect through fusion of data from heterogenous sensors networks, and studies comparing theoretical models of sensor system responses against actual data. These efforts will include basic, applied, and developmental research.

In an effort to coordinate DHS counter-WMD R&D activities effectively, CWMD and DHS S&T will establish a CWMD Integrated Product Team (IPT).[6] The IPT will identify, prioritize, align, and report on all countering WMD R&D activities across DHS. The IPT will ensure that R&D projects are filling a gap or requirement and are not duplicative of R&D from other partners.

Other new partners include DOD's JPEO-CBRND, formerly the Joint Program Executive Office for Chemical Biological Defense. Coincidentally, as CWMD's responsibilities have increased to include chemical and biological R&D, JPEO-CBRND's responsibilities have grown to include R/N, which has led to expanded opportunities for collaboration.

In addition to the coordination efforts described above, CWMD is bringing in new federal staff to increase the in-house chemical/biological expertise. Those staff would bring their own networks and connections, leading to further coordination opportunities. As of this writing, the hiring process is underway, with the expectation that several new staff will be added before the end of 2020.

Related to increasing the staff competencies in these areas, R&D conducts market research to stay abreast of current efforts in the fields. The broader scope has led to participation in new conferences and sessions, industry days, and interagency program reviews. These efforts already have informed R&D about the current state of technology and have led to an improved research focus and solicitation topics.

The multipronged approach—coordination, hiring, and surveying—will help to ensure that CWMD continues to focus on the key R&D areas within its purview.

[6] DHS Directive No. 069-02, Revision No. 02, "Research and Development Coordination."

V. Conclusion

CWMD and the legacy organization DNDO have conducted a vibrant transformation R&D program over FY 2015–FY 2019. Before the formation of CWMD on December 21, 2018, DNDO oversaw DHS's R/N detection and forensics R&D. The mechanisms developed by DNDO to solicit and sponsor the development of new technologies were successful and resulted in the development of new technical capabilities for DNDO's customers, DHS operational Components, and federal, state, local, and tribal responders. With the addition of chemical and biological research responsibility, CWMD is continuing its efforts to build internal scientific expertise, to coordinate within DHS and across the interagency, and to maintain awareness of technical advances in the community.

Appendix: Abbreviations

Abbreviation	Definition
3D	Three-Dimensional
ARES	Airborne Radiological Enhanced-sensor System
ARI	Academic Research Initiative
ARMD	Advanced Radiation-Monitoring Devices
ATD	Advanced Technology Demonstration
BD21	Biological Detection for the 21st Century
CBP	U.S. Customs and Border Protection
CBRN	Chemical, Biological, Radiological, and Nuclear
COTS	Commercial Off-the-Shelf
CWMD	Countering Weapons of Mass Destruction Office
DARPA	Defense Advanced Research Projects Agency
DHS	Department of Homeland Security
DNDO	Domestic Nuclear Detection Office
DOD	Department of Defense
DOE	Department of Energy
DOJ	Department of Justice
DTRA	Defense Threat Reduction Agency
ERNIE	Enhanced Radiological Nuclear Inspection and Evaluation
ERP	Exploratory Research Program
FBI	Federal Bureau of Investigation
FEDP	Federal Expertise Development Program
FY	Fiscal Year
GNDA	Global Nuclear Detection Architecture
ICE	U.S. Immigration and Customs Enforcement
IPT	Integrated Product Team
IRSS	Intelligent Radiation Sensor System
JPEO-CBRND	Joint Program Executive Office for Chemical, Biological, Radiological, and Nuclear Defense
Linac	Linear Accelerator
MCNP6 Version 6.2.0	a Monte Carlo particle transport modeling tool
MURS	Mobile Urban Radiation Search
NII	Nonintrusive Inspection
NNFEDP	National Nuclear Forensics Expertise Development Program
NNSA	National Nuclear Security Administration
NOFO	Notice of Funding Opportunity
NRIP	Nuclear and Radiological Imaging Platform
POE	Port of Entry
POV	Personally Owned Vehicle
R&D	Research and Development
R/N	Radiological/Nuclear

Abbreviation	Definition
RAIN	Radiation Awareness and Interdiction Network
RIID	Radiation Isotope Identification Detector
RPM	Radiation Portal Monitor
SBIR	Small Business Innovation Research
SNM	Special Nuclear Material
TRL	Technology Readiness Level
TSA	Transportation Security Administration
USBP	U.S. Border Patrol
WIND	Wearable Intelligent Nuclear Detection
WMD	Weapon of Mass Destruction