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Report to the Committee on Homeland Security, House of Representatives

March 2015

COMBATING NUCLEAR SMUGGLING

DHS Research and Development on Radiation Detection Technology Could Be Strengthened

GAO-15-263

GAO Highlights

Highlights of GAO-15-263, a report to the Committee on Homeland Security, House of Representatives

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Why GAO Did This Study

Preventing terrorists from smuggling nuclear or radiological material to carry out an attack in the United States is a top national priority. DNDO's mission is to improve capabilities to deter, detect, respond to, and attribute responsibility for nuclear terrorist attacks, in coordination with domestic and international partners. As part of this mission, DNDO conducts R&D on radiation and nuclear detection devices.

GAO was asked to review DNDO's management of its R&D program. This report (1) provides information on the types of R&D projects DNDO started in fiscal years 2008 through 2013, (2) examines the extent to which DNDO's process for planning and selecting R&D projects to fund aligns its investments with gaps in the GNDA, and (3) examines the steps DNDO takes to evaluate the outcomes of R&D projects in which it invests. To conduct this work, GAO analyzed DNDO program documentation and R&D project data for projects starting in fiscal years 2008 through 2013, and interviewed DNDO and other DHS component officials, among other actions.

What GAO Recommends

GAO recommends, among other things, that DNDO document how its research investments align with its research challenges and gaps in the GNDA, and that it take a systematic approach for evaluating the extent to which outcomes of its R&D investments collectively contribute to addressing its research challenges. DHS agreed with GAO's recommendations.

View GAO-15-263. For more information, contact David C.Trimble at (202) 512-3841 or trimbled@gao.gov or Timothy M. Persons (202) 512-6412 or personst@gao.gov.

What GAO Found

During fiscal years 2008 through 2013, the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office (DNDO) started 189 research and development (R&D) projects that it grouped into various scientific or technological focus areas, known as portfolios. These projects are intended to address gaps in the Global Nuclear Detection Architecture (GNDA), a U.S. government framework to detect and interdict nuclear smuggling. As of September 2014, DNDO had obligated approximately $350 million to these projects. For example, DNDO's shielded detection portfolio, which investigates methods for detecting shielded nuclear material, had the most projects start during this time—48 projects—and received the most obligations—approximately $103 million, or about 30 percent of obligations.

Because of limitations in DNDO's documentation, it is unclear to what extent DNDO's process for planning and selecting R&D projects to fund aligns these investments with gaps in the GNDA. According to DNDO officials, they developed high-level goals—known as research challenges—to align with gaps in the GNDA and guide R&D investment planning. Officials said they regularly discuss how ongoing R&D projects align with these research challenges and gaps in the GNDA. However, DNDO does not document this alignment, consistent with federal standards for internal control. Without such documentation, it is unclear to what extent DNDO's investments are positioned to address gaps in the GNDA.

DNDO has taken some steps to evaluate the outcomes of individual R&D projects, which may demonstrate the success of specific technologies, but it does not have a systematic approach for evaluating how the outcomes of projects may collectively contribute to addressing its overall research challenges. Under federal standards for internal control, managers are to compare actual program performance to expected results and analyze significant differences. Such analysis can help managers identify program problems, if any, and make improvements. Without a systematic approach for evaluating the results of its investments in R&D projects more broadly, DNDO cannot demonstrate the extent to which its investments contribute to addressing its overall research challenges.

Examples of DNDO-Funded R&D Projects

Source: Oak Ridge National Laboratory (photo). | GAO-15-263

Prototype to detect and identify sources of illicit material traveling at normal speed over multiple lanes of traffic.

Source: InradOptics (photo). | GAO-15-263

Stilbene, a new material developed for detecting nuclear threats.

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Abbreviations

ASP	advanced spectroscopic portal monitor
CAARS	cargo advanced automated radiography system
CBP	Customs and Border Protection
COTS	commercial-off-the-shelf
DHS	Department of Homeland Security
DNDO	Domestic Nuclear Detection Office
DTRA	Defense Threat Reduction Agency
GNDA	Global Nuclear Detection Architecture
HSPD	Homeland Security Presidential Directive
NNSA	National Nuclear Security Administration
NSPD	National Security Presidential Directive
R&D	research and development
ROC	receiver operating characteristics
SAFE Port	Security and Accountability for Every Port Act of 2006
TAR	Transformational and Applied Research
TSA	Transportation Security Administration

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March 6, 2015

The Honorable Michael McCaul
Chairman
The Honorable Bennie G. Thompson
Ranking Member
Committee on Homeland Security
House of Representatives

Preventing terrorists from smuggling nuclear or radiological materials to carry out an attack in the United States is a top national priority. Terrorists could use these materials to make an improvised nuclear device or a radiological dispersal device (also called a "dirty bomb"). The detonation of an improvised nuclear device in an urban setting could cause hundreds of thousands of deaths and devastate buildings and physical infrastructure for miles. A radiological dispersal device would not be as damaging but could nonetheless inflict hundreds of millions of dollars in socioeconomic costs if a large part of a city had to be evacuated—and possibly remain inaccessible—until extensive radiological decontamination was completed. The mission of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office (DNDO) is to counter the risk of nuclear terrorism against the United States by continuously improving capabilities to deter, detect, respond to, and attribute attacks, in coordination with domestic and international partners.[1] To fulfill its mission, DNDO's activities are focused on developing the Global Nuclear Detection Architecture (GNDA), which is a multilayered framework encompassing approximately 74 independent federal programs, projects, or activities to detect and interdict nuclear smuggling in foreign countries, at the U.S. border, and inside the United States. Within DNDO, the Transformational and Applied Research (TAR) Directorate conducts research and development (R&D) related to radiation and nuclear detection devices and furthers development of technologies to support the domestic component of the GNDA.

[1]DNDO was established in 2005 by National Security Presidential Directive (NSPD)-43/Homeland Security Presidential Directive (HSPD)-14 and codified in statute by the Security and Accountability for Every Port Act of 2006 (SAFE Port) Act, Pub. L. No. 109-347 § 501, 120 Stat. 1884, 1932 (codified as amended at 6 U.S.C. § 591). DNDO's domestic partners include state, tribal, and local governments, as well as the private sector. Its international partners include foreign governments.

In September 2013, we found that DHS faced challenges with coordinating maritime and border R&D efforts across the department, including the extent to which DNDO and other DHS components obtained and evaluated feedback on their efforts, and coordinated their efforts internally and externally.[2] As a result, we made recommendations to help ensure that DHS effectively manages and coordinates its border and maritime R&D efforts. DHS concurred with our recommendations and described actions it would take to address them. In addition, we have previously reported on challenges DHS has faced with specific technology programs at DNDO.[3] As a result of past technology challenges and questions about how DNDO is managing its R&D investments, you requested that we review DNDO's R&D efforts. This report (1) provides information on the types of R&D projects DNDO started in fiscal years 2008 through 2013; (2) examines the extent to which DNDO's process for planning and selecting its R&D projects aligns those investments with gaps in the GNDA; and (3) examines the steps DNDO has taken to evaluate the outcomes of its R&D projects.

To address our first objective, we analyzed data on DNDO R&D projects that, based on contract work start dates, started in fiscal years 2008 through 2013. Projects started in fiscal years 2008 through 2013 can be ongoing for multiple years. Therefore, we collected and analyzed data related to these projects through September 30, 2014, the most recent period for which information was available during the course of our review. Specifically, we reviewed the research sectors (e.g., private industry, academic institutions, or government laboratories), amount of funding obligated, and outcomes for R&D projects funded within the five DNDO portfolios focused on radiation and nuclear detection. We did not

[2]GAO, *Department of Homeland Security: Opportunities Exist to Better Evaluate and Coordinate Border and Maritime Research and Development*, GAO-13-732 (Washington, D.C.: Sept. 25, 2013).

[3]We reported for several years on DNDO's development of the advanced spectroscopic portal monitor (ASP), which was canceled in 2011, and the cargo advanced automated radiography system (CAARS), canceled in 2007. See, for example, GAO, *Combating Nuclear Smuggling: Lessons Learned from Cancelled Radiation Portal Monitor Program Could Help Future Acquisitions,* GAO-13-256 (Washington, D.C.: May 13, 2013); *Combating Nuclear Smuggling: Inadequate Communication and Oversight Hampered DHS Efforts to Develop an Advanced Radiography System to Detect Nuclear Materials*, GAO-10-1041T (Washington, D.C.: Sept. 15, 2010); and *Combating Nuclear Smuggling: Additional Actions Needed to Ensure Adequate Testing of Next Generation Radiation Detection Equipment*, GAO-07-1247T (Washington, D.C.: Sept. 18, 2007).

review projects funded under DNDO's sixth portfolio—the nuclear forensics portfolio—because they are planned and selected using a different process than DNDO's other five portfolios.[4] We also did not review DNDO contracts for technical or testing support of its R&D projects. To assess the reliability of the project data, we reviewed agency documentation including program and financial management guidance that outlined the processes for entering and maintaining the data; we also spoke with DNDO officials about these processes. We also reviewed the data for any obvious errors or outliers and clarified discrepancies with program officials. We determined that the project information and obligations data were sufficiently reliable for the purposes of providing an overview of DNDO's R&D investments.[5] To address our second and third objectives, we reviewed agency documents and interviewed DNDO officials to identify DNDO's processes for planning and selecting R&D investments in nuclear and radiation detection and evaluating their outcomes. We did not review R&D investments related to nuclear forensics, which is used to determine the origin of interdicted materials. We spoke with DNDO's interagency partners—the Department of Defense's Defense Threat Reduction Agency (DTRA) and the Department of Energy's National Nuclear Security Administration (NNSA)[6]—to understand their involvement in DNDO's process for planning, selecting, and evaluating R&D efforts. In addition, we spoke with potential federal end users of technology developed under DNDO's R&D program—DHS's Customs and Border Protection (CBP), Transportation Security Administration (TSA), and Coast Guard to understand their role in the TAR Directorate's process for planning,

[4]Projects in DNDO's forensics portfolio are directly funded to address the nuclear forensic national objectives and corresponding investment areas specified in the President's *National Strategic Five-Year Plan to Improve the Nuclear Forensics and Attribution Capability of the United States.*

[5]Obligations data represent agency-reported estimates. According to a DNDO official, the first-year obligation data provided for R&D projects conducted by academic institutions are estimates because they were coordinated through the National Science Foundation using a lump sum disbursement and de-obligation process. The official stated that any difference between the estimated and actual obligation amount is negligible because most academic-led projects receive full funding and any lump sum de-obligation amount would be shared over a number of projects.

[6]DTRA focuses on the nuclear threat in support of military-specific interdiction and detection activities. NNSA is a separately organized semiautonomous agency within the Department of Energy that is responsible for the management and security of the nation's nuclear weapons, nuclear nonproliferation, and naval reactor programs.

selecting, and evaluating R&D projects. We also spoke with officials from DHS's Science and Technology Directorate, which is responsible for conducting basic and applied research of technologies and overseeing the testing and evaluation of component acquisitions and technologies to ensure that they meet DHS acquisition requirements before implementation in the field, to understand the directorate's role in managing DNDO's R&D program.[7] Additionally, we reviewed national policies and directives,[8] reports by the National Academy of Sciences that outline best practices for planning and evaluating federal R&D investments,[9] and the Standards for Internal Control in the Federal Government.[10]

We conducted this performance audit from November 2013 to March 2015 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[7]DHS' Science and Technology Directorate has responsibility for coordinating and integrating R&D activities across DHS. DNDO assumed responsibility from the Science and Technology Directorate for conducting nuclear and radiological R&D activities after its creation in 2005.

[8]For example, see Executive Office of the President National Science and Technology Council, *Nuclear Defense Research and Development Roadmap, Fiscal Years 2013-2017* (Washington, D.C.: Apr. 16, 2012) and National Science and Technology Council Office of Science and Technology Policy, *The Science of Science Policy: A Federal Research Roadmap* (Washington, D.C.: November 2008).

[9]For example, see National Academy of Sciences, National Research Council, *Best Practices in Assessment of Research and Development Organizations* (Washington, D.C.: National Academies Press, 2012); National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Implementing the Government Performance and Results Act for Research: A Status Report* (Washington, D.C.: National Academies Press, 2001); and National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Evaluating Federal Research Programs: Research and the Government Performance and Results Act* (Washington, D.C.: National Academies Press, 1999).

[10]GAO, *Standards for Internal Control in the Federal Government*, GAO/AIMD-00-21.3.1 (Washington, D.C.: November 1999).

Background

The TAR Directorate was established in 2005 to identify, explore, develop, and demonstrate scientific and technological approaches that meet one or more of the following characteristics:

- address gaps in the GNDA,
- improve the performance of domestic radiological and nuclear detection systems and enabling technologies, or
- increase the operational efficiency of detection technology for domestic end users.

The end users of technology developed under DNDO's R&D program include DHS' CBP, TSA, and Coast Guard, as well as state and local law enforcement agencies. Gaps in the GNDA are identified by DNDO's Architecture and Plans Directorate, which analyzes the existing GNDA framework to identify areas where there may be weaknesses in the nation's ability to detect and prevent a radiological or nuclear attack. Each year, the Architecture and Plans Directorate summarizes gaps in the GNDA that may have a technological solution and provides this summary to the TAR Directorate as guidance for planning its R&D program.[11] DNDO's TAR Directorate plans and selects R&D investments through an annual process of developing solicitations for competitive awards for research projects conducted by researchers in private industry, academic institutions, and government laboratories.[12]

The amount of total funding DNDO dedicates to R&D projects, as well as the final result and impact of these projects, can vary dramatically based on the scope and purpose of the research. Individual R&D projects can cost from several thousand dollars to millions of dollars per fiscal year. Some R&D projects aim to produce a specific prototype or piece of technology for an end user, such as a radiation portal monitor—a large stationary radiation detector through which trucks and cargo containers

[11]The Architecture and Plans Directorate identifies gaps in capability across multiple modes of operation and transportation, regardless of the feasibility of potential solutions, resulting in a large number of individual gaps. The individual gaps are then aggregated, and those with a potential technological solution are provided to the TAR Directorate. This process resulted in the following three gaps being provided to the TAR Directorate: (1) standoff detection capabilities, (2) the ability to detect shielded nuclear and radiological material, and (3) the ability to identify adversaries operating in all pathways.

[12]Competitive awards include contracts to private industry, grants to academic institutions, and interagency agreements with government laboratories for R&D projects.

Examples of Radiation Detection Prototypes

In June 2011, the Domestic Nuclear Detection Office tested three prototype detection systems at the Belmont Stakes in Elmont, New York, for potential future use in preventing a dirty bomb from being smuggled into the vicinity of a large-scale event. Two prototypes were designed to detect and identify distant radiation sources from a mobile platform. The third prototype, pictured below, was designed to detect and identify sources of illicit material traveling at normal speed over multiple lanes of traffic.

Source: Oak Ridge National Laboratory. | GAO-15-263

pass—capable of detecting radiological and nuclear threats regardless of the amount of shielding. Other projects may produce software to integrate information technology systems, such as software to maximize the performance of multiple independent radiation sensors communicating through a flexible wireless network. Still, other projects may produce a report or knowledge product—such as data in support of an analysis of alternative solutions to meet an end user's capability need—that aims to inform an acquisition decision. The challenge for federal R&D programs is finding the right balance between taking risks to develop breakthrough technologies that may not succeed and investing in moderate technological enhancements that are more likely to transition to an end user.

The TAR Directorate has organized its R&D program into research portfolios, which group projects focusing on similar scientific or technological areas. See table 1 for a description of the TAR Directorate research portfolios that focus on addressing nuclear and radiation detection.

Table 1: DHS' Transformational and Applied Research (TAR) Directorate's Research and Development Portfolios

Portfolio	Description
Algorithms and modeling	Investigates innovative data processing and analysis techniques to enhance the ability to detect, locate, track, and identify potential threats across a broad range of environments; utilizes advanced simulation tools to support personnel training.
Materials development	Investigates improved radiation detection materials, such as scintillators and semiconductors, which are materials that convert the energy of incoming particles to an electronic signal.
Neutron detection	Investigates improved neutron detection capabilities, including alternatives to the neutron detectors used in various portal monitor applications that rely on Helium-3, which is scarce.[a]
Radiation detection techniques	Investigates new approaches to improve the detection of threats and their localization and tracking based on readings of their unique radiological characteristics (signatures), known as passive detection.
Shielded detection	Investigates methods for detecting nuclear material that is shielded, especially methods using active detection techniques such as radiography and particle interrogation to produce detectable nuclear signatures.

Source: Transformational and Applied Research (TAR) Directorate documents. | GAO-15-263

Notes: The TAR Directorate of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office conducts research and development related to radiation and nuclear detection devices and furthers the development of technologies. The TAR Directorate also has a nuclear forensics portfolio. We did not include this portfolio in our review because the TAR Directorate uses a different process for planning and selecting which nuclear forensics projects to fund than it does for projects funded under its other portfolios.

[a]Neutron detectors are used to detect neutron radiation, a type of ionizing radiation composed of neutron particles. Helium-3 gas— a by-product of the radioactive decay of tritium, a key component of the U.S. nuclear weapons program—is a critical component of neutron detection equipment, including radiation detection portal monitors that are used to screen cargo and vehicles at ports and border crossings around the world to prevent nuclear material from being smuggled into the United States. For more information on neutron detection and the Helium-3 shortage, see GAO, *Managing Critical Isotopes: Weaknesses in DOE's Management of Helium-3 Delayed the Federal Response to a Critical Supply Shortage*, GAO-11-472 (Washington, D.C.: May 12, 2011) and *Technology Assessment: Neutron Detectors: Alternatives to Using Helium-3,* GAO-11-753 (Washington, D.C.: Sept. 29, 2011).

Other federal agencies also have R&D programs to address other aspects of U.S. radiological or nuclear detection capabilities. Specifically, the Department of Defense's R&D program is led by DTRA and focuses on the nuclear threat in support of military-specific interdiction and detection activities. The Department of Energy's R&D program is led by NNSA and emphasizes international proliferation detection.

DNDO Started a Variety of Projects in Each of Its R&D Portfolios Addressing Nuclear and Radiation Detection

DNDO's TAR Directorate started 189 R&D projects within the five research portfolios that focus on addressing nuclear and radiation detection during fiscal years 2008 through 2013 and, as of September 2014, obligated approximately $350 million to these projects. As shown in table 2, the shielded detection portfolio, which investigates methods for detecting nuclear material that is shielded, had the most projects start during the period of our review—48 projects or 25 percent of the total projects started. The TAR Directorate also obligated the most funding to this portfolio—approximately $103 million or almost 30 percent of the total funding obligated during this period.

Table 2: Number of Projects Started in Fiscal Years 2008-2013 to Which DHS' Transformational and Applied Research (TAR) Directorate Obligated Funding in Portfolios Addressing Nuclear and Radiation Detection

Dollars in millions

Portfolio	Number of projects	Percentage of total projects	Funding obligated[b]	Percentage of total funding obligated[b]
Algorithms and modeling	25	13.2%	$40.4	11.6%
Materials development	46	24.3%	$65.7	18.9%
Neutron detection	43	22.8%	$52.7	15.1%
Radiation detection techniques	27	14.3%	$86.5	24.8%
Shielded detection	48	25.4%	$103.1	29.6%
Total[a]	**189**	**100.0%**	**$348.5**	**100.0%**

Source: GAO analysis of Transformational and Applied Research (TAR) Directorate data. | GAO-15-263

Notes: The TAR Directorate of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office conducts research and development (R&D) related to radiation and nuclear detection devices and furthers the development of technologies. The table includes projects focused on primary R&D efforts related to nuclear and radiation detection that started in fiscal years 2008 through 2013 and does not include contracts that provided technical or testing support to these efforts.

[a]Total may not add up due to rounding.

[b]Projects started in fiscal years 2008 through 2013 can be ongoing for multiple years. Therefore, we collected and analyzed data related to these projects through September 30, 2014, the most recent period for which information was available during the course of our review.

Example of Material Development

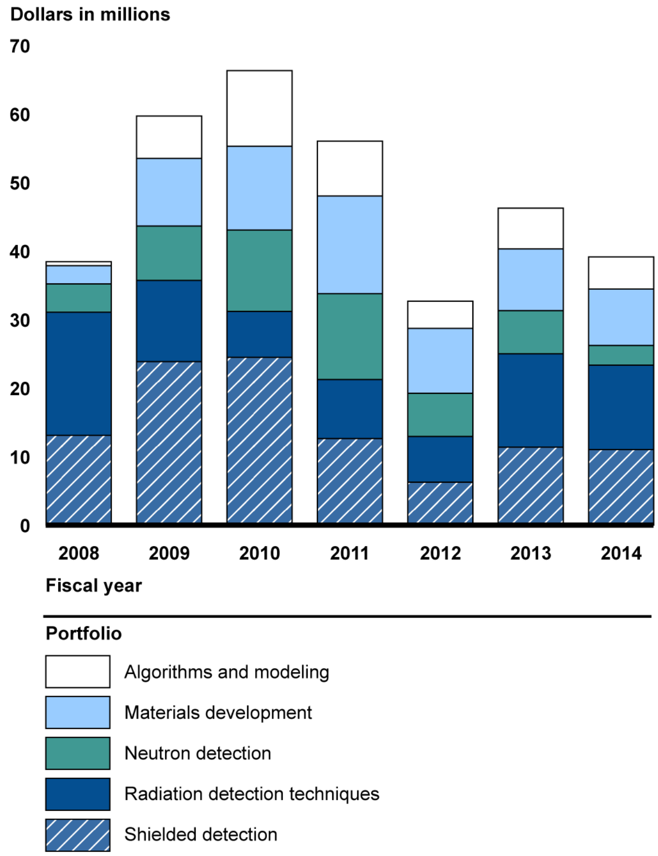
The detection of neutrons is one method of detecting nuclear materials. The Domestic Nuclear Detection Office's (DNDO) research and development program supported industry's development of a new solid crystalline scintillator called stilbene, which is a material that can be used in neutron detector devices. As with other scintillators, stilbene emits a small amount of light when struck by a neutron that is converted into an electric signal that can trigger an alarm. According to DNDO, the development of the stilbene crystalline scintillator provides the U.S. market with a highly sensitive neutron detecting material.

Shown are 1" and 2" diameter cylinders of stilbene.

Source: Copyright © InradOptics. | GAO-15-263

As shown in figure 1, the amount of funding that the TAR Directorate obligated to projects in each portfolio varied by fiscal year. For example, the radiation detection techniques portfolio—which investigates methods for improving current detection techniques based on readings of radiological signatures—received the most obligations of any portfolio in fiscal years 2008, 2013, and 2014 but received the least in fiscal year 2010.

Figure 1: Total Obligations in Portfolios Addressing Nuclear and Radiation Detection for Projects Started by DHS' Transformational and Applied Research (TAR) Directorate in Fiscal Years 2008-2013



Source: GAO analysis of Transformational and Applied Research Directorate data. | GAO-15-263

Note: The TAR Directorate of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office conducts research and development (R&D) related to radiation and nuclear detection devices and furthers the development of technologies. Projects started in fiscal years 2008 through 2013 can be ongoing for multiple years. Therefore, the figure includes obligation data related to these projects through September 30, 2014, the most recent period for which information was available during the course of our review. The figure includes projects focused on primary R&D efforts related to nuclear and radiation detection and does not include obligations to contracts that provided technical or testing support to these efforts. The figure does not include approximately $10 million in funds prior to fiscal year 2008 that was used to start projects in fiscal years 2008 through 2013.

The TAR Directorate invests in R&D projects through solicitations for competitive awards to researchers in several sectors such as private industry, academic institutions, and government laboratories. As shown in table 3 and figure 2, private industry conducted a majority of the TAR Directorate's R&D projects started during fiscal years 2008 through

2013—114 projects or 60 percent of the total number of projects started—and received the most obligations—approximately $230 million or 66 percent of the total funding obligated. For the number of projects and total funding obligated to each research recipient of competitive awards for the TAR Directorate-funded R&D projects in our review, see appendix I.

Table 3: Sector in Which DHS' Transformational and Applied Research (TAR) Directorate's Research and Development (R&D) Program Awarded Projects Addressing Nuclear and Radiation Detection in Fiscal Years 2008-2013

Dollars in millions

Sector	Number of projects	Percentage of total projects	Total obligations[b]	Percentage of total obligations[b]
Private industry	114	60.3%	$230.0	66.0%
Academic institutions	40	21.2%	$58.0	16.7%
Government laboratories	33	17.5%	$59.5	17.1%
Interagency	2	1.1%	$0.9	0.3%
Total[a]	**189**	**100.0%**	**$348.5**	**100.0%**

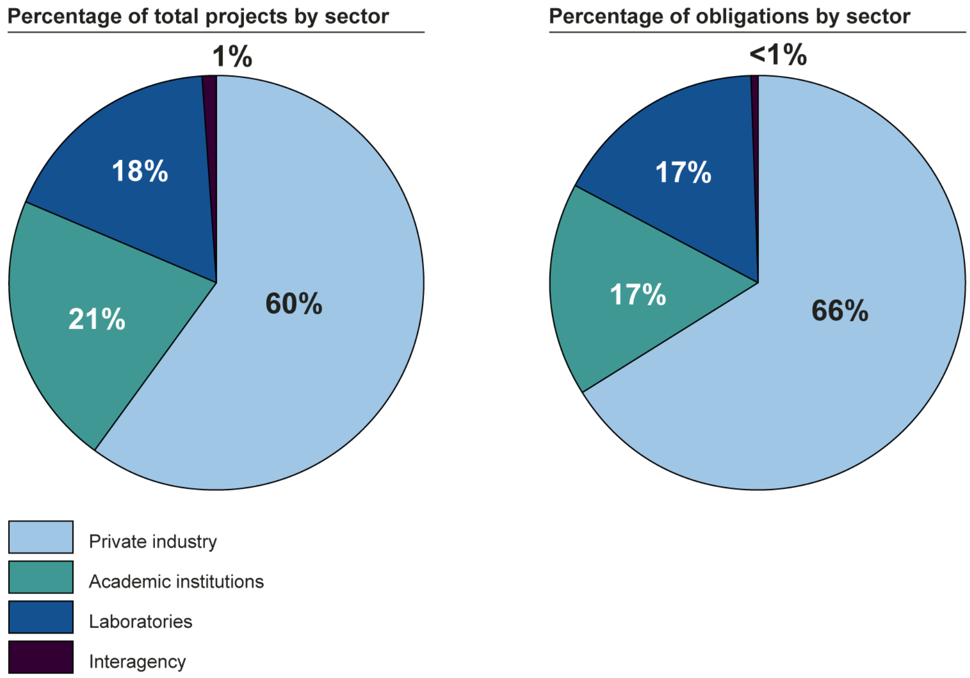
Source: GAO analysis of Transformational and Applied Research (TAR) Directorate data. | GAO-15-263

Notes: The TAR Directorate of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office conducts research and development (R&D) related to radiation and nuclear detection devices and furthers the development of technologies based on competitive awards. The table includes projects focused on primary R&D efforts related to nuclear and radiation detection and does not include contracts that provided technical or testing support to these efforts.

[a]Total may not add up due to rounding.

[b]Projects started in fiscal years 2008 through 2013 can be ongoing for multiple years. Therefore, we collected and analyzed data related to these projects through September 30, 2014, the most recent period for which information was available during the course of our review.

Figure 2: Percentage by Sector in Which DHS' Transformational and Applied Research (TAR) Directorate's Research and Development (R&D) Program Started Projects Addressing Nuclear and Radiation Detection in Fiscal Years 2008-2013 and Total Obligations



Source: GAO analysis of TAR Directorate data. | GAO-15-263

Note: The TAR Directorate of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office conducts research and development (R&D) related to radiation and nuclear detection devices and furthers the development of technologies based on competitive awards. Projects started in fiscal years 2008 through 2013 can be ongoing for multiple years. Therefore, the figure includes obligation data related to these projects through September 30, 2014, the most recent period for which information was available during the course of our review. The figure includes projects focused on primary R&D efforts related to nuclear and radiation detection and does not include contracts that provided technical or testing support to these efforts. Additionally, total may not add up due to rounding.

Extent to Which DNDO's Process to Plan and Select R&D Projects Aligns with Gaps in the GNDA Is Unclear Because of Limited Documentation

The DNDO TAR Directorate's process for planning and selecting R&D projects to fund is intended to invest in research projects that will fill gaps in the GNDA but, according to our analysis, it is unclear to what extent these investments align with gaps in the GNDA because of limitations in DNDO's documentation. Specifically, in its annual process for planning and selecting R&D projects, the directorate develops high-level goals—known as research challenges—based on gaps in the GNDA to guide its R&D investment planning, but our analysis did not find a clearly documented alignment between the research projects TAR funds and the directorate's research challenges. Moreover, as part of this annual process, the TAR Directorate does not document the rationale for how its immediate funding priorities are intended to fill gaps in the GNDA.

DNDO's Annual Process Uses Research Challenges to Guide Its Planning of R&D Investments but Has Not Clearly Documented How the Research Challenges Align with Investments

The TAR Directorate has developed high-level goals, referred to as research challenges, to guide the planning of its R&D investments. These challenges include

- developing cost-effective detection equipment with sufficient technical performance to ensure widespread deployment;
- detecting nuclear material even when it is heavily shielded;
- enhancing capabilities for wide-area searches in a variety of environments; and
- monitoring along challenging GNDA pathways including general aviation, small maritime vessels, and between points of entry to the United States.[13]

According to TAR Directorate officials, these challenges are based on the gaps in the GNDA identified annually by DNDO's Architecture and Plans Directorate. The officials also stated that the TAR Directorate's research portfolios are organized to align with the research challenges. According to these officials, as a result of this organization, any project the TAR Directorate invests in within the portfolios will generally align with the research challenges and GNDA gaps. These officials also stated that they discuss how planned R&D investments align with their challenges during portfolio and project review meetings—meetings designed to discuss the

[13]The TAR Directorate has developed a fifth research challenge related to the use of nuclear forensics to determine the origin and history of interdicted materials, which is outside the scope of this work.

status of ongoing projects and inform DNDO management of the TAR Directorate's plans for future research.

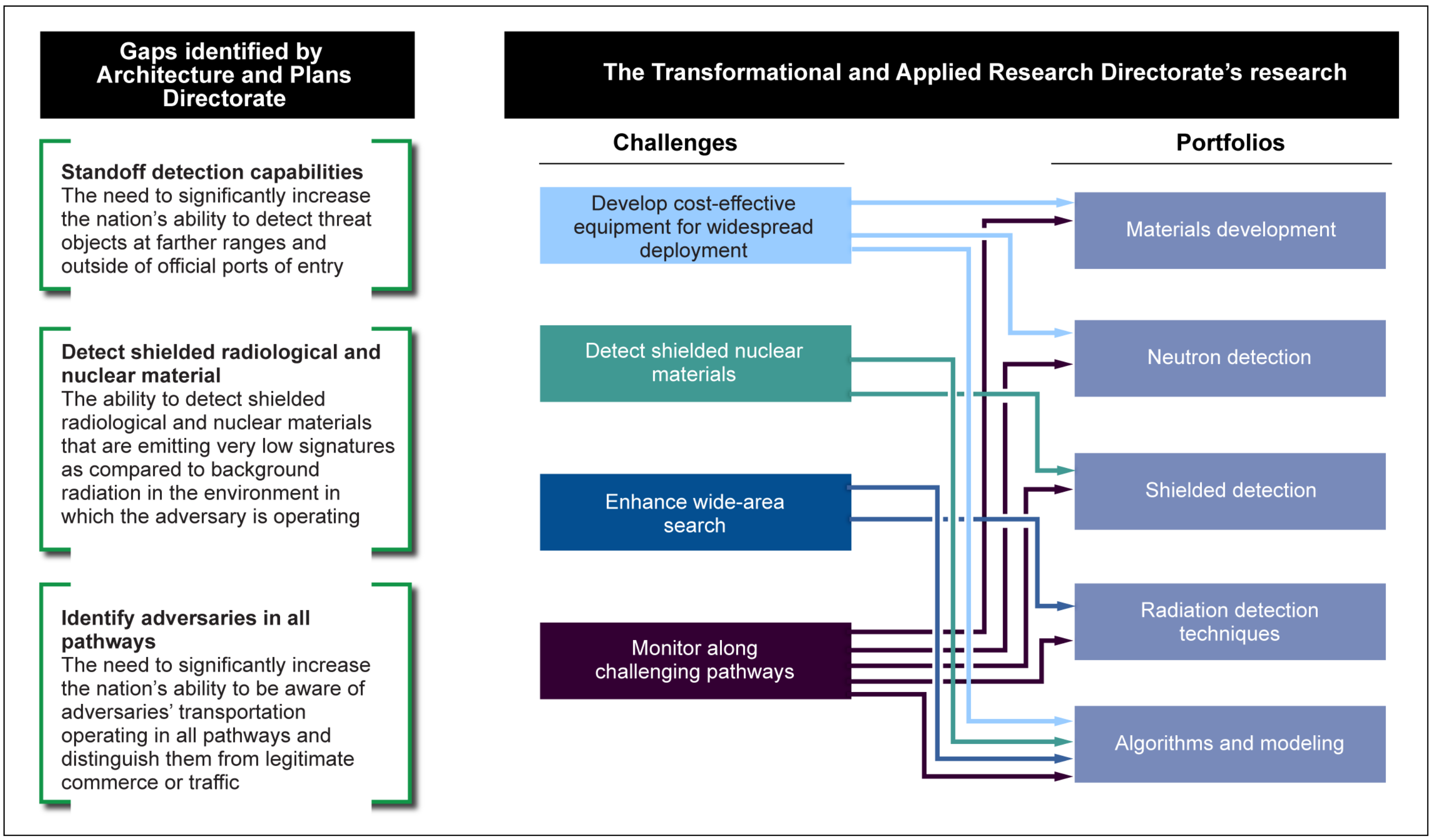
However, one federal end user of technology developed under the TAR Directorate's R&D program may not understand the relationship between the research projects TAR funds and the directorate's research challenges. Specifically, according to officials we interviewed from CBP, which uses radiation detection technology at ports of entry, because CBP was not always involved in the TAR Directorate's portfolio or project review meetings where this information is discussed, it is not always clear to them how the TAR Directorate's R&D projects align with gaps in the GNDA. In addition, these officials said they were uncertain of the purpose of some of the TAR Directorate's R&D projects. The officials stated that they are asked by the TAR Directorate to evaluate technology when a project may be related to detecting radiation at ports of entry, but they are not provided a clear explanation of the purpose of the project. For example, these officials told us that the TAR Directorate is investing in an applied research system designed to detect multiple types of threats—radiological, nuclear, and contraband—in vehicles and that the directorate has developed prototypes of the technology. However, these prototypes would not meet CBP requirements for deployment at ports of entry. CBP officials explained that the TAR Directorate did not make clear whether the prototypes were being developed as candidates for future use by CBP or were to test a theoretical concept, making it difficult to evaluate the performance of the prototypes.[14] In addition, for its technology evaluations, CBP receives reports on individual projects, but the officials stated that these documents often contain several hundred pages of scientific details and do not explicitly discuss how the projects contribute toward addressing the TAR Directorate's research challenges or the GNDA gaps.

As shown in figure 3, our analysis of the gaps in the GNDA identified by DNDO's Architecture and Plans Directorate, as well as the TAR Directorate's research challenges and portfolios found that there is not a clear alignment among them. For example, a GNDA gap identified by the Architecture and Plans Directorate is the ability to identify adversaries in all pathways of entry into the United States. The TAR Directorate has

[14]According to TAR Directorate officials, they selected the project to test a new application of a theoretical concept and are working with CBP to determine whether the project may result in a system for future deployment by CBP.

developed a similar research challenge—to monitor along challenging GNDA pathways—but there is no portfolio dedicated to this challenge. According to TAR Directorate officials, there are individual projects within all the portfolios that are intended to help address this challenge, but the TAR Directorate does not have documentation that clearly describes this alignment. In addition, the TAR directorate has developed a research challenge—to develop cost-effective equipment for widespread deployment—that has no similar GNDA gap. According to TAR directorate officials, R&D projects within three portfolios—materials development, neutron detection, and algorithms—are intended to help address this challenge.

Figure 3: Relationship among Gaps in the Global Nuclear Defense Architecture, and the Transformational and Applied Research (TAR) Directorate's Research Challenges and Research Portfolios.



Source: GAO analysis of Domestic Nuclear Detection Office documents. | GAO-15-263

Note: The Department of Homeland Security's Domestic Nuclear Detection Office's (DNDO) Architecture and Plans Directorate analyzes the existing Global Nuclear Defense Architecture (GNDA) framework to identify gaps in the nation's ability to detect and prevent a radiological or nuclear attack. DNDO's TAR Directorate conducts research and development (R&D) related to radiation and nuclear detection devices and furthers development of technologies to support the domestic component of the GNDA. The TAR Directorate has organized its R&D program into research portfolios, which group projects focusing on similar scientific or technological areas.

According to officials from the TAR Directorate and the Architecture and Plans Directorate, they regularly discuss how ongoing projects align with their research challenges and gaps in the GNDA during portfolio and project review meetings, but the TAR Directorate does not have documentation that clearly describes this alignment. According to these officials, the discussions at these meetings create a common understanding among DNDO management, interagency partners, and potential end users of technologies developed from TAR Directorate-funded R&D of how ongoing projects align with gaps in the GNDA and research challenges. However, because these discussions are not documented, it is unclear to what extent these projects and research challenges align with gaps in the GNDA. Under federal standards for internal control, agencies are to promptly document transactions and significant events to maintain their relevance and value to management in controlling operations and making decisions.[15] Such documentation would help the TAR Directorate demonstrate to interagency partners and potential end users how projects selected for funding within the portfolios align with the research challenges and GNDA gaps. Without documentation that explains how the portfolios align with the TAR Directorate's research challenges and gaps in the GNDA, it is unclear to what extent its investments are positioned to address gaps in the GNDA.

Our previous work has found that, to be effective, an R&D program must be directed toward a clear goal and have a strategy that directly addresses that goal.[16] TAR Directorate officials told us that additional documentation, such as a research road map or strategy, could be beneficial for its research program, but it has not yet developed such

[15]GAO/AIMD-00-21.3.1.

[16]For examples, see GAO, *Pipeline Safety: Systematic Process Needed to Evaluate Outcomes of Research and Development Program*, GAO-03-746 (Washington, D.C.: June 30, 2003) and *Research and Development: Lessons Learned from Previous Research Could Benefit FreedomCAR Initiative*, GAO-02-810T (Washington, D.C.: June 6, 2002).

documentation.[17] As of May 2014, TAR Directorate officials said that the directorate was in the process of drafting a long-term research road map and strategy for one of its research portfolios—the shielded detection portfolio—in response to a recommendation by a committee of experts from the American Physical Society and Institute of Electrical and Electronics Engineers, which conducted a technical review of the directorate's R&D program in 2012.[18] That review found that, given the complexity of detecting shielded nuclear material, as well as the importance of this ability to DNDO's mission, a long-term research road map and strategy needed to be developed for that portfolio. The TAR Directorate Assistant Director and the shielded detection portfolio manager told us in May 2014 that they planned to complete an initial draft of a long-term research road map and strategy for this portfolio by September 30, 2014. As of October 2014, TAR Directorate officials stated they did not have a draft because this effort was more difficult than originally anticipated.

According to a cochair of the committee of experts whom we interviewed, developing a research roadmap and strategy is a best practice for research organizations, and the committee intended that a research road map and strategy for the shielded portfolio would be the starting point for the TAR Directorate in developing these documents for its entire R&D program. In addition, the National Academies of Science in a 2012 report stated that R&D organizations should have a research strategy that is

[17]TAR Directorate officials stated that they are also involved in an interagency effort, known as the Detection Working Group, to establish priorities for radiological and nuclear detection R&D and to coordinate R&D efforts. The working group is a component of the Subcommittee on Nuclear Defense Research and Development in the National Science and Technology Council. The subcommittee developed a nuclear defense R&D road map for fiscal years 2013 through 2017 that discusses limitations on current detection technologies and identifies broad research areas for system development address those limitations.

[18]According to TAR Directorate officials, they commissioned the study to obtain an independent peer review of the existing TAR Directorate R&D program, recommend changes to their existing approach, and recommend possible new R&D areas and opportunities. These officials told us they are currently implementing most of the study's recommendations. See American Physical Society Panel on Public Affairs and Institute of Electrical and Electronics Engineers, *A Technical Review: The Domestic Nuclear Detection Office Transformational and Applied Research Directorate R&D Program* (American Physical Society, August 2013) accessed November 20, 2013, http://www.aps.org/policy/reports/popa-reports/dndo.cfm.

consistent with the mission of the organization and defines in detail the path by which the organization will attain its goals.[19]

Officials we spoke to from the TAR Directorate's interagency partners and potential end users of its R&D efforts agreed that a research road map and strategy could help improve their understanding of the TAR Directorate's overall R&D program. For example, an official from NNSA stated that, at his organization, research road maps that outline the goal, technology requirements, and prioritized investment options, among other things, for each R&D program have been a useful tool for communicating NNSA's goals and research needs to a broad audience including interagency partners, private industry, and academia. Officials we spoke to from TSA, the Coast Guard, and CBP told us that a research road map or strategy explaining the TAR Directorate's R&D program would increase their understanding of and improve their interaction with the TAR Directorate regarding its R&D investments. The TAR Directorate's plan to draft a research road map and strategy for one of its research portfolios is a good first step, but additional documentation, such as a research road map or strategy for its entire R&D program, could help the Directorate demonstrate how its investments in R&D projects align with its research challenges and the specific path by which it will address its research challenges.

DNDO's Annual Process to Select R&D Projects to Fund Does Not Document the Rationale for How Funding Priorities Are to Fill Gaps in the GNDA

The TAR Directorate's annual process for selecting research projects to fund consists of two main phases, but the TAR Directorate does not have documentation concerning how its immediate funding priorities are intended to fill gaps in the GNDA. In the first phase, the TAR Directorate identifies research topics within each of its portfolios where research is most needed and develops these into solicitations for research proposals.[20] In the second phase, the TAR Directorate establishes review panels for each research topic to evaluate the proposals against the criteria included in the solicitations.

[19]National Academy of Sciences, National Research Council, *Best Practices in Assessment of Research and Development Organizations* (Washington, D.C.: National Academies Press, 2012).

[20]The solicitations developed by the TAR Directorate include Broad Agency Announcements for researchers in private industry, academic institutions, and nonprofit organizations, as well as Calls for Proposals for researchers at national and government laboratories.

According to TAR Directorate officials, the research topics represent the directorate's immediate R&D priorities for filling gaps in the GNDA because the projects selected in each topic will be funded for the next 1 to 3 years. According to the portfolio managers we interviewed, they use their professional judgment to identify the areas within their portfolios in which further research would help fill gaps in the GNDA and address the TAR Directorate's research challenges.[21]

According to TAR Directorate officials, the TAR Assistant Director makes the final decision on which research topics to pursue, and the TAR Directorate's portfolio managers present their proposed research topics to DNDO management during portfolio review meetings. These officials also told us that identifying research topics is a collaborative process in which all portfolio managers discuss ideas with each other during the course of their work to develop a common understanding of the directorate's research priorities. In addition, the officials stated that the topics are influenced by guidance from the DNDO Director, which may tell the directorate to concentrate on research in one particular portfolio or another.

However, during the course of our review, we found that the TAR Directorate does not document the rationale for which research topics should be included in the annual solicitations for research proposals. The federal standards for internal control state that internal control and all transactions and other significant events need to be clearly documented, and that the documentation should be readily available for examination.[22] TAR Directorate officials told us they do not document the rationale for these decisions because they discuss this information during the portfolio review meetings. The briefing slides presented by TAR Directorate portfolio managers during the portfolio review meetings note the proposed research topics for that portfolio but do not show the directorate's rationale for selecting the research topics or how the directorate prioritizes one topic over another. As noted above, potential end users we interviewed told us they cannot always attend these meetings, and they

[21]The TAR Directorate's decisions regarding the research topics to include in the annual solicitations are also discussed with officials from NNSA and DTRA. According to TAR Directorate officials, these discussions ensure that the three agencies have a common understanding of planned research and that research is not unnecessarily duplicated.

[22]GAO/AIMD-00-21.3.1.

are unclear on how the TAR Directorate's R&D investments are aligned with gaps in the GNDA. Documenting the rationale for its selection of research topics would help the TAR Directorate demonstrate to potential end users that its immediate funding priorities are well-positioned to fill gaps in the GNDA and address the directorate's research challenges.

In contrast, our review of TAR Directorate documentation found that the TAR Directorate documents its rationale for funding decisions made in the second phase. In this phase, the TAR Directorate establishes review panels for each research topic to evaluate the proposals against the criteria included in the solicitations. According to TAR Directorate officials, all portfolio managers, as well as officials from NNSA, DTRA, or other subject-matter experts identified by the TAR Directorate, as necessary, serve as evaluators of the proposals. These evaluators individually review each proposal against the solicitation criteria and make comments on the strengths and weaknesses of the proposed research before they meet as a panel to score the proposals in each research topic area. The panel then numerically ranks all the proposals by their scores to identify those projects that are most suitable for funding. The TAR Directorate maintains records of the evaluation panel's findings from this process including how the proposals were scored against the solicitation criteria and the rationale for the panel's final rankings. According to the TAR Assistant Director, he makes the final decision about which research proposals to fund by comparing the ranking of proposals to the available funding and considering other factors, such as balancing the number of projects among the portfolios.

DNDO Takes Steps to Evaluate Individual Project Outcomes but Does Not Have a Systematic Approach for Collectively Evaluating Its R&D Investments

DNDO's TAR Directorate has taken some steps to evaluate the outcomes of individual R&D projects that it has funded but does not have a systematic approach for evaluating how the outcomes of projects may collectively contribute to addressing its overall research challenges. The TAR Directorate's efforts to evaluate the outcomes of its R&D investments focus on individual projects and are based on the goals outlined in each project's contract. TAR Directorate officials told us that researchers are generally required to submit deliverables that describe how the outcomes of each project compared with the initial project goals. The officials also told us they have made efforts to disseminate the outcomes of individual projects by inviting key stakeholders—e.g., interagency partners and potential federal end users—to final project review meetings; posting articles on DHS's website; and discussing successes, such as research that transitioned into a commercial product, at conferences.

In 2013, the TAR Directorate started to track the outcomes of individual R&D projects in a database. As shown in table 4, our review of the TAR Directorate's R&D data found that projects started in fiscal years 2008 through 2013 had a variety of outcomes such as transferring technology to private industry for commercialization, determining that the technology was not feasible, or transitioning knowledge gained to a new TAR Directorate-funded R&D project or to another entity for further development and testing.[23]

Table 4: Outcomes of the Transformational and Applied Research (TAR) Directorate's Research and Development (R&D) Projects Started in Fiscal Year 2008 through 2013, as of July 2014

Outcome	Number of projects	Percentage
Project is ongoing	77	40.7%
Theoretical concept, technology, or device found not feasible	37	19.6%
Further research and development (R&D) planned for or conducted by the Transformational and Applied Research (TAR) Directorate	28	14.8%
Transitioned to private industry for commercialization	22	11.6%
Project discontinued or complete but no use for resulting knowledge, technology, or device	17	9.0%
Further R&D planned for or conducted by another federal agency, government laboratory, university, or private industry	8	4.2%
Total[a]	**189**	**100.0%**

Source: GAO analysis of TAR Directorate data. | GAO-15-263

Notes: The TAR Directorate of the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office conducts research and development (R&D) related to radiation and nuclear detection devices and furthers the development of technologies based on competitive awards. Analysis includes projects focused on primary R&D efforts related to nuclear and radiation detection and does not include contracts that provided technical or testing support to these efforts.

[a]Total may not add up due to rounding.

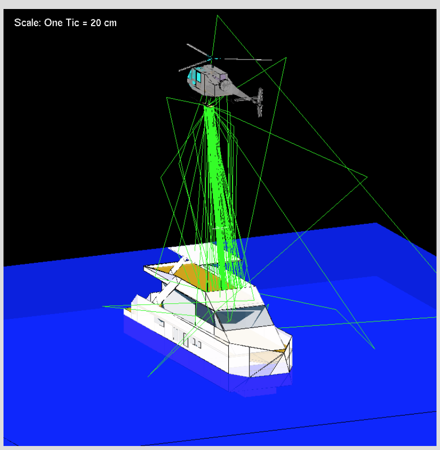
However, the TAR Directorate does not have a systematic approach for evaluating how the outcomes of projects may collectively contribute to addressing its overall research challenges. For example, as shown in table 4, 22 of the TAR Directorate's 189 R&D projects that started in fiscal years 2008 through 2013 transitioned to private industry for commercialization. These outcomes may demonstrate the success of specific technologies but do not provide insight into how these

[23]Further testing may include developmental testing of a prototype detection system. For a list of best practices that we previously identified for developmental testing of certain threat detection systems, see appendix II.

Example of R&D Project Outcome

The Software for the Optimization of Radiation Detectors (SWORD) program is a Domestic Nuclear Detection Office (DNDO)-sponsored research and development (R&D) effort that, according to DNDO documents, simulates real-world operational environments to enable development and evaluation of nuclear detection equipment without having to run multiple costly field tests. Since 2012, DNDO has been running comparisons between the SWORDs test results and real-world studies to build confidence in the accuracy of the SWORDs computer models. SWORDs is available to researchers through the Radiation Safety Information Computational Center, a Department of Energy specialized information analysis center for radiation transport and safety.

Below: SWORDs modeling of an airborne radiation detector



Source: Naval Research Laboratory. | GAO-15-263

technologies have contributed to addressing the TAR Directorate's research challenges of developing cost-effective detection equipment, detecting shielded nuclear material, enhancing wide-area search capabilities, or monitoring along challenging pathways. TAR Directorate portfolio managers told us they discuss with DNDO management how the outcomes of individual projects contribute to progress in each of the directorate's R&D portfolios during internal quarterly and annual portfolio reviews. However, the officials told us they do not have a systematic approach for evaluating how the outcomes of projects collectively contribute to addressing the directorate's overall research challenges. Under federal standards for internal control, managers are to compare actual program performance to planned or expected results and analyze significant differences.[24] Such analysis can help managers identify problems, if any, in a program's design and delivery, as well as make improvements in the program, as needed. Without a systematic approach for evaluating how the outcomes of its R&D projects collectively contribute to addressing the TAR Directorate's overall research challenges, the directorate cannot demonstrate the extent to which its investments contribute to addressing its overall research challenges.

We have previously found that evaluating research can be challenging because outcomes may not occur for a number of years and may be difficult to track.[25] However, the National Academies of Science has stated that both applied and basic research can be evaluated meaningfully on a regular basis and that the evaluations should incorporate methods and reporting time frames that match the character of the research.[26] For example, the Academies' Committee on Science, Engineering, and Public Policy recommended that the evaluation of applied research should measure progress toward practical outcomes and may be done annually. In contrast, the committee stated that the evaluation of basic research should focus on performance such as the

[24]GAO/AIMD-00-21.3.1.

[25]GAO-03-746.

[26]National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Evaluating Federal Research Programs: Research and the Government Performance and Results Act*. (Washington, D.C.: National Academies Press, 1999) and *Implementing the Government Performance and Results Act for Research: A Status Report* (Washington, D.C.: National Academies Press, 2001).

generation of new knowledge and the quality of the research, among other things, and be conducted on a 3-year or longer schedule.

Conclusions

The ability to detect smuggled radiological or nuclear materials is a key element of the nation’s strategy for preventing an attack within our national borders. Within DNDO, the TAR Directorate’s R&D program conducts R&D related to radiation and nuclear detection devices and furthers development of technologies to support the domestic component of the GNDA. To guide its R&D program, the TAR Directorate has identified research challenges that serve as high-level goals, and it has established a process for selecting R&D projects to fund. These goals are intended to ensure the TAR Directorate’s investments are aligned with gaps in the GNDA. However, the TAR Directorate does not clearly document, consistent with federal standards for internal control, the alignment among its research portfolios, research challenges, and gaps in the GNDA. Without documentation that explains how the portfolios align with the research challenges and gaps in the GNDA and defines in detail how the TAR Directorate will address its research challenges, it is unclear to some end users the extent to which the TAR Directorate’s investments are positioned to address gaps in the GNDA. As of May 2014, TAR Directorate officials said that the directorate was in the process of drafting a long-term research road map and strategy for one of its research portfolios—the shielded detection portfolio—in response to a recommendation by a committee of experts from the American Physical Society and Institute of Electrical and Electronics Engineers. However, with a research road map and strategy for its entire R&D program, the TAR Directorate could better demonstrate how its investments in R&D projects align with its research challenges and the specific path by which it will address its challenges. The directorate also does not document the rationale for why it selected specific research topics in the solicitations, consistent with federal internal control standards. As a result, the TAR Directorate cannot demonstrate whether its immediate funding priorities are well-positioned to fill gaps in the GNDA and address the directorate’s research challenges.

In addition, the TAR Directorate does not have a systematic approach for evaluating how the outcomes of projects may collectively contribute to addressing its overall research challenges, consistent with federal internal control standards. Consequently, the TAR Directorate cannot demonstrate the extent to which its investments in R&D projects contribute to addressing its overall research challenges.

Recommendations for Executive Action

To improve DNDO's ability to demonstrate how its R&D investments contribute to addressing its research challenges, we recommend that the Secretary of Homeland Security instruct the Director of DNDO to take the following three actions:

- Develop documentation, such as a research road map and strategy, that clearly defines how the TAR Directorate's research investments align with its research challenges and gaps in the GNDA and describes how the directorate will address its research challenges.
- Document the TAR Directorate's rationale for prioritizing and selecting research topics.
- Develop a systematic approach for evaluating how the outcomes of its R&D projects collectively contribute to addressing the TAR directorate's overall research challenges.

Agency Comments

We provided a draft of this product to DHS for comment. In its written comments, reproduced in appendix III, DHS concurred with our recommendations. DHS also provided technical comments that were incorporated, as appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies of this report to the appropriate congressional committees, the Secretary of Homeland Security, the Secretary of Defense, the Secretary of Energy, and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or trimbled@gao.gov or Tim Persons at (202) 512-6412 or personst@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

David C. Trimble
Director, Natural Resources and Environment

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Chief Scientist

Appendix I: Number of Projects and Total Funding Obligated by Research Recipient of Competitive Awards for Domestic Nuclear Detection Office Research and Development Projects Started in Fiscal Years 2008-2013

Research recipient	Number of projects	Total funding obligated (as of Sept. 2014)
Private industry		
Accuray Incorporated	1	$1,120,300
Adelphi Technology Inc.	2	$1,749,778
Agiltron, Inc.	2	$1,019,455
Alameda Applied Sciences Corp.	1	$1,149,994
Applied Nanotech, Inc.	1	$414,138
ArchSmart, LLC	1	$1,150,000
Canberra Industries, Inc.	1	$5,086,624
CapeSym, Inc.	4	$2,647,188
Creative Electron Inc.	2	$1,268,872
Crisis Simulation International, LLC	1	$1,617,254
Decision Sciences International Corp.	2	$2,659,204
Forrell Enterprises Inc.	1	$149,596
General Electric	6	$29,781,763
HESCO	1	$1,149,672
Information in Place Inc.	1	$150,000
Innovative American Technology	3	$2,273,630
Inrad Optics, Inc.	1	$1,149,752
Intelligent Optical Systems	2	$299,734
Kromek	1	$628,049
L-3 Communications Corporation	1	$4,315,364
Materials & Electrochemical Research	1	$150,000
Nanotrons, Corp.	1	$149,981
Northrop Grumman	1	$1,302,072
NOVA R&D	1	$141,091
Passport Systems, Inc.	9	$37,389,369
Physical Sciences Inc.	4	$3,349,997
Proportional Technologies, Inc.	2	$1,955,271
Radiabeam Technologies LLC	3	$2,612,868
Radiation Monitoring Devices, Inc.	22	$25,664,362
Rapiscan Laboratories, Inc.	13	$30,033,071
Raytheon	3	$15,812,151
Sanmina-SCI Technologies Inc.	3	$11,392,934
Science Applications International Corporation	9	$28,594,883

Research recipient	Number of projects	Total funding obligated (as of Sept. 2014)
Smiths Detection, Inc.	1	$7,084,359
Spectra Labs, Inc.	1	$841,158
Spectral Labs Inc.	1	$1,613,403
Starfire Industries LLC	2	$1,024,999
Stellarray Inc.	1	$147,903
Telesecurity Sciences	1	$997,138
Academic institutions		
Alabama A&M University	1	$1,120,000
Arizona State University	1	$363,743
Boston University	1	$903,360
Carnegie-Mellon University	1	$1,287,755
Duke University	2	$3,139,920
Fisk University	2	$3,150,000
Illinois Institute of Technology	1	$596,455
Iowa State University	1	$1,834,972
Kansas State University	1	$208,097
Massachusetts Institute of Technology	1	$492,043
National Strategic Research Institute	1	$1,382,542
Northwestern University	1	$1,866,693
Purdue University	2	$2,494,208
Rensselaer Polytechnic Institute	1	$609,397
Stanford University	1	$1,140,608
Temple University	1	$755,816
Texas A&M University / Purdue University	1	$6,738,123
Texas Tech University	1	$1,753,690
University of California at Berkeley	3	$5,265,101
University of California at Berkeley / NavalPostgraduate School	1	$2,000,000
University of California at Santa Barbara	1	$1,027,015
University of Hawaii	3	$3,044,486
University of Michigan at Ann Arbor	2	$3,947,097
University of Minnesota at Twin Cities	1	$479,999
University of Tennessee at Knoxville	3	$5,082,653
University of Texas at Arlington	1	$1,293,747
University of Texas at Dallas	1	$1,134,072
Washington State University	1	$1,163,286
Yale University	2	$3,772,696

Research recipient	Number of projects	Total funding obligated (as of Sept. 2014)
Laboratories		
Jet Propulsion Laboratory	1	$400,000
Lawrence Berkeley National Laboratory	4	$10,767,964
Lawrence Livermore National Laboratory	11	$21,514,873
Los Alamos National Laboratory	4	$3,620,036
National Urban Security Technology Laboratory	1	$40,000
Naval Research Laboratory	2	$10,333,969
Oak Ridge National Laboratory	4	$5,461,037
Pacific Northwest National Laboratory	4	$6,778,713
Sandia National Laboratory	1	$600,000
Special Technologies Laboratory	1	$12,453
Federal agency		
Defense Threat Reduction Agency	2	$880,000

Source: GAO analysis of Domestic Nuclear Detection Office data. | GAO-15-263

Note: Analysis includes projects focused on primary research and development efforts related to nuclear and radiation detection and does not include contracts that provided technical or testing support to these efforts.

Appendix II: Best Practices for Developmental Testing of Binary Threat Detection Systems

To determine the best practices for developmental testing of binary threat detection systems,[1] we conducted a 1-day meeting on June 4, 2013, with 12 experts we selected with assistance from the National Academies (listed below). These experts were from academia, industry, and the federal government and had experience in developmental testing methodologies, binary threat-detection systems, automatic target recognition, and advanced imaging technologies, from fields that included homeland security, defense, and standards development. To identify the experts, the National Academies considered experts with previous experience on appropriate National Academy studies; requested suggestions from the members of the National Academies' National Materials and Manufacturing Board and the Computer Sciences and Telecommunications Board; searched internal databases and the Web; and contacted other relevant individuals for recommendations.

We facilitated the experts' identification of best practices with premeeting interviews, structured questioning during the meeting, and postmeeting expert voting and ranking procedures.

According to the experts, the best practices apply to the process of developmental testing of binary threat detection systems; they also apply if the system is commercial-off-the-shelf (COTS), modified COTS, or newly developed for a specific threat detection purpose being created by a vendor or the government. The identified eight best practices for developmental testing of binary threat detection systems are described below.

- Best Practice 1: Include representatives from the user community in design and developmental testing teams to ensure acceptance of the system by the user community. According to experts, design and developmental testing teams need to understand the needs, concerns, and capabilities of the user community, or they run the risk of designing and testing systems that are ineffective. In the case of airport security, for example, (1) operators may have difficulty operating these systems, (2) passengers may not want to use these systems, or (3) airport managers may have difficulty accommodating these systems. Also, experts told us that the user community may have suggestions that could improve systems or make the

[1] Binary threat detection systems indicate whether a potential threat is present or not. They do not identify gradations of threat.

developmental tests more realistic. Along with subject matter experts that monitor developmental testing, representatives from the user community should be integral parts of the design and developmental testing teams. The role of these team members from the user community, according to experts, is to make sure that the needs, concerns, and capabilities of the user community are considered throughout design and developmental testing efforts.

- Best Practice 2: Take a systems engineering view of the system prior to entering into any developmental test. Experts emphasized the importance of understanding the boundaries of what is being tested prior to developmental testing. For example, it is important to understand whether only a subsystem, such as an algorithm, is being tested (i.e., what our experts referred to as “the inner loop”) or whether the whole system including, for example, the system operator, is being tested (i.e., what our experts referred to as “the outer loop”). According to experts, different system boundaries will impose different testing methods and constraints.

- Best Practice 3: Use developmental testing to build in resilience. According to experts, resilience means the capability of a system to withstand or adapt to failures. Experts told us that this best practice entails building robustness into the system by eliminating as many vulnerabilities as possible so that the system performs according to requirements, even when faced with unforeseen obstacles. Experts stated that the way to improve resilience is to uncover vulnerabilities as early as possible through rigorous and comprehensive testing of the system, including independent vulnerability testing, against various scenarios. Developmental testing provides enough flexibility to explore for vulnerabilities. According to experts, the further the system matures, the more fixed the design becomes, and a system failure identified later can become increasingly expensive to fix. Experts told us that the expense increases not just because there may be a need to undo previous steps, but also because any time there is a change in the design, everything that worked before needs to be retested to make sure the change did not undo something that previously had been shown to work. Therefore, as experts stated, a focus on building in resilience during early and intermediate developmental testing helps to minimize the number of failures that are hidden until the later stages of testing.

- Best Practice 4: Use developmental testing to refine performance requirements. According to experts, developmental testing should be viewed as a critical tool in helping to refine performance requirements.

Further, experts told us that a meaningful performance requirement is one that is not only achievable but also strives to maximize the fulfillment of a mission need. While the minimum required performance thresholds may be achievable, they may fall short of the maximum achievable performance. Experts informed us that the maximum achievable performance can be uncovered only by understanding what the system is actually capable of doing through comprehensive developmental testing that unrestrainedly explores the performance boundaries of the system. These experts stated that, with later stage testing, such as confirmatory testing, the focus is on verifying that certain parameters can be met. In contrast, developmental testing is broader and may identify the true performance envelope of the system and better inform decisions regarding improved performance requirements.

- Best Practice 5: Engage in a continuous cycle of improvement by (1) conducting developmental testing, (2) conducting operational testing, and (3) incorporating lessons learned. According to experts, it is important to use lessons learned on preceding tests to improve the probability of success (proper system performance) on following tests and to use lessons learned from test failures as feedback into the design process to continuously improve system performance. Also, experts emphasized that, to improve the probability of passing operational testing, it is important to keep operational testing in mind throughout developmental testing by, for example, increasing realism of the test environment as developmental testing matures (i.e., as the system moves through development toward operational testing), including testing for reliability in developmental testing,[2] and increasing emphasis on testing for reliability as developmental testing matures. Further, experts told us that it is important to consider developmental testing and operational testing as a continuum rather than artificially limiting the development of a system to a fixed stage. Also, they emphasized looking for development (i.e., improvement) opportunities throughout the life cycle of a system.
- Best Practice 6: Ensure that accountability and engagement in developmental testing are commensurate with the amount of risk accepted. According to experts, the level of government involvement

[2]Reliability is the probability that an item will perform its intended function for a specified period of time under specific conditions.

in the development of a given system should be commensurate with the level of risk it is accepting. Risk needs to be assessed when the system is COTS, modified COTS, or a newly developed system. If a system is acquired as COTS, or modified COTS, a risk assessment needs to be performed because even with commercial items significant modifications may be needed. If the system is not COTS, but rather is being developed specifically for the government (particularly during acquisitions), the government may not "walk away" but must be actively engaged during all stages of developmental testing. Experts also told us that relying solely on the vendor and holding the vendor responsible for any problem that arises is not consistent with the accountability and engagement required for acquisitions where the government is accepting significant risk.

- Best Practice 7: Measure and characterize system performance with established procedures, methods, and metrics. According to experts, binary threat detection systems have an established body of statistically based methods and procedures used to evaluate and characterize them. Further, experts stated that, while many metrics can be derived from basic contingency table data, it is important to use certain objective metrics to characterize system performance. For example, the receiver operating characteristic (ROC) standard method provides an objective way of evaluating trade-offs between detection rate and false alarm rate when designing, testing, and using binary threat detection systems.[3]

- Best Practice 8: Use statistical experimental design methodology to establish a solid foundation for developmental testing. Experts told us that use of statistical experimental design methodology ensures that a test has been designed with a clear understanding of goals and acceptable limitations, that the test is clearly documented, and that the test results are rigorously analyzed. According to experts, statistical experimental design is the tool used to define the test goals, limitations, and procedures. Further, experts stated that the creation and use of an appropriate model against which system performance can be evaluated is fundamentally important when establishing the statistical experimental design. Experts emphasized that uncertainties should be provided with all system performance estimates. They told

[3] The ROC method uses a plot of the detection rate (observed true positive rate) against the false alarm rate (observed false positive rate) as the system sensitivity is varied to evaluate binary threat detection system performance.

us that a statistical experimental design establishes a detailed plan for conducting the experiment. According to experts, the decision maker's preference and user's needs should be identified before designing the experiment. Experts told us that well-chosen statistical experimental designs maximize the amount of information that can be obtained for a given amount of experimental effort.

List of Experts

1. Mongi Abidi, Professor, Electrical Engineering and Computer Science, University of Tennessee.
2. Pete Adolph, Consultant. Former Director of Test and Evaluation, Office of the Deputy Undersecretary of Defense (Acquisition and Technology).
3. Robert F. Behler, Chief Operating Officer and Deputy Director, Software Engineering Institute, Carnegie Mellon University. Former General Manager and Senior Vice President of the MITRE Corporation.
4. Philip Coyle, Senior Science Fellow, Center for Arms Control and Non-Proliferation. Former Assistant Secretary of Defense and Director, Operational Test and Evaluation.
5. H. Steven Kimmel, Senior Vice President, Director of Customer Relations, Alion Science and Technology. Former Deputy Director Defense Research and Engineering and Acting Director, Development Test and Evaluation.
6. Dennis Leber, Statistician, National Institute of Standards and Technology.
7. Harry Martz, Director, Center for Nondestructive Characterization, Lawrence Livermore National Laboratory and Principle Investigator on DHS S&T Explosive Detection Projects and DNDO Nuclear and Radiological Imaging Platforms.
8. Robert Nordstrom, Program Director, Cancer Imaging Program, National Cancer Institute.
9. Richard Roca, Director Emeritus, Johns Hopkins University Applied Physics Laboratory.
10. Ernest Seglie, former Science Advisor, Department of Defense Operational Test and Evaluation.
11. Brian Simmons, Senior Vice President, Sigmatech, Inc. Former Technical Director/Deputy to the Commander, U.S. Army Test and Evaluation Command.

12. David Woods, Professor, Department of Integrated Systems Engineering and Institute for Ergonomics, Ohio State University.

Appendix III: Comments from the Department of Homeland Security

U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

February 20, 2015

Mr. David Trimble
Director, Natural Resources and Environment Issues
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Re: Draft Report GAO-15-263, "COMBATING NUCLEAR SMUGGLING: DHS Research and Development on Radiation Detection Technology Could Be Strengthened"

Dear Mr. Trimble:

Thank you for the opportunity to review and comment on this draft report. The Department of Homeland Security (DHS) appreciates the U.S. Government Accountability Office's (GAO's) work in planning and conducting its review and issuing this report.

The Department is pleased with GAO's positive recognition that the Domestic Nuclear Detection Office (DNDO) has established a robust process for selecting individual research and development (R&D) projects to fund that includes inter-agency collaboration. DHS also values GAO's acknowledgement that DNDO has made efforts to evaluate the outcomes of the individual projects, which demonstrated the success of specific technologies. DHS is committed to developing break-through technologies that will have a clear and demonstrative positive impact on capabilities to detect nuclear threats.

The draft report contained three recommendations with which DHS concurs. Specifically, GAO recommended that the Secretary of Homeland Security instruct the Director of DNDO to:

Recommendation 1: Develop documentation, such as a research roadmap and strategy, that clearly defines how the TAR Directorate's research investments align with its research challenges and gaps in the GNDA and describes how the Directorate will address its research challenges.

Response: Concur. DNDO's Transformational and Applied Research Directorate (TAR) will develop a technology roadmap and strategy (the Roadmap) in coordination with stakeholders that describes its long term vision, the linkages between investments and challenges, the rationale for prioritizing and selecting investments, and a systematic approach to evaluate success. Estimated Completion Date (ECD): October 31, 2015.

Recommendation 2: Document the TAR Directorate's rationale for prioritizing and selecting research topics.

Response: Concur. The general process for prioritizing and selecting research topics will be included in the Roadmap described in the response to Recommendation 1 as well as in the next revision of DNDO's Solution Development Process. In addition, going forward, DNDO's TAR Directorate will document its rationale for prioritizing and selecting research topics for each specific R&D solicitation prior to the release of the solicitation. ECD: October 31, 2015.

Recommendation 3: Develop a systematic approach for evaluating how the outcomes of its R&D projects collectively contribute to addressing the TAR Directorate's overall research challenges.

Response: Concur. This will be part of the Roadmap described in the response to Recommendation 1. The approach will include both annual metrics as well as a periodic qualitative evaluation by experts. ECD: October 31, 2015.

Again, thank you for the opportunity to review and provide comments on this draft report. Technical comments were previously provided under separate cover. Please feel free to contact me if you have any questions. We look forward to working with you in the future.

Sincerely,

Jim H. Crumpacker, CIA, CFE
Director
Departmental GAO-OIG Liaison Office

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Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

In addition to the individual named above, Ned Woodward, Assistant Director; Kendall Childers; Michelle Cooper; Aryn Ehlow; Jane Eyre; Cindy Gilbert; Armetha Liles; Cynthia Norris; and Jennifer Whitworth made key contributions to this report.

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