A Technical Review:

The Domestic Nuclear Detection Office Transformational and Applied Research Directorate R&D Program

AUGUST 2013

A Report of:

The APS Panel on Public Affairs
The IEEE

A Technical Review

The Domestic Nuclear Detection Office
Transformational and Applied Research Directorate
R&D Program

A Report of
The APS Panel on Public Affairs
The IEEE

ACKNOWLEDGMENTS

Many thanks to Jay Davis for managing a thoughtful independent review of this paper and the numerous experts from DHS and elsewhere who provided background and briefings at the informational Workshops. Support for this project was provided by the American Physical Society and the IEEE.

BACKGROUND/DISCLAIMER REGARDING LIMITED SCOPE

This study was initiated as follows: the Domestic Nuclear Detection Office (DNDO) of the Department of Homeland Security requested APS carry out an independent review of the Transformational and Applied Research Directorate (TARD). The report was supported by and overseen by the APS Panel on Public Affairs (POPA) and IEEE leadership. The findings and recommendations contained in this report do not necessarily represent the views of the APS Council, the APS membership, or the IEEE membership. The recommendations in this report are meant to help TARD improve their activities and are not an endorsement of the DNDO or of TARD.

ABOUT APS & POPA

The American Physical Society was founded in 1899, with a mission of advancing and diffusing the knowledge of physics. APS is now the nation's leading organization of research physicists with approximately 50,000 members in academia, national laboratories, and industry. The APS Panel on Public Affairs occasionally produces reports on topics currently debated in government in order to inform the debate with the perspectives of physicists working in the relevant issue areas. Indeed, APS has long played an active role in federal government with its members serving in Congress and having held positions such as Science Advisor to the President of the United States, Director of the CIA, and Director of the NSF.

ABOUT IEEE

The Institute of Electrical and Electronics Engineers is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards, and professional and educational activities.

COMMITTEE MEMBERS

Anthony D. Lavietes (Co-Chair), International Atomic Energy Agency, Vienna, Austria

James Trebes (Co-Chair), Lawrence Livermore National Laboratory, Livermore, CA USA

Robert Borchers, Maui High Performance Computing Center

Jill Dahlburg, Naval Research Laboratory

John Donnelly, District of Columbia, Fire & EMS

Adam Isles, The Chertoff Group

Neil Johnson, Naval Research Laboratory

Glenn Knoll, University of Michigan

Richard Kouzes, Pacific Northwest National Laboratory

Richard Lanza, Massachusetts Institute of Technology

James Lund, Sandia National Laboratory

Stanley Prussin, University of California, Berkeley

APS STAFF

Jodi Lieberman

Jeanette Russo

Francis Slakey

For additional information, including member bios and the committee charge and workshop agenda, please visit http://www.aps.org/policy/reports/popa-reports/index.cfm

TABLE OF CONTENTS

Executive Summary

At the request of the Domestic Nuclear Detection Office (DNDO), a Study Committee comprised of representatives from the American Physical Society (APS) Panel on Public Affairs (POPA) and the Institute of Electrical and Electronics Engineers (IEEE) Nuclear and Plasma Sciences Society (NPSS) performed a technical review of the DNDO Transformational and Applied Research Directorate (TARD) research and development program. TARD's principal objective is to address gaps in the Global Nuclear Detection Architecture (GNDA) through improvements in the performance, cost, and operational burden of detectors and systems. The charge to the Study Committee was to investigate the existing TARD research and development plan and portfolio, recommend changes to the existing plan, and recommend possible new R&D areas and opportunities.

The recommendations in this report are meant to help TARD improve their activities and are not an endorsement of the DNDO. The Study Committee believes that DNDO should pursue a future study — carried out by an organization such as the National Academies — of its management approach and that it be undertaken at the earliest possible date, preferably prior to making long-term commitments to additional technology development projects.

The Study Committee has the following general recommendations regarding TARD:

- Create a detailed strategic plan and implementation road map for the development of the GNDA. The plan and road map should be much more specific and quantitative than the current implementation plan, which is highly conceptual and process oriented.
- Create a broad, interactive effort among all of the Directorates of DNDO, the intelligence and user communities, and other government agencies to generate system-wide optimal solution paths for the GNDA. Every component of TARD, from intelligence to operations to detector technology, should be open to review for possible changes in policies and priorities. The review process should particularly inform TARD research and development priorities.
- Develop a clear definition of the end user and the end user needs. The end user needs and constraints must be taken into account at all levels and timescales of the process of developing and carrying out the GNDA and required R&D.

- Conduct a national study to determine the right balance and priorities for security capabilities and R&D for the possible GNDA pathways. The study should include ports, roads, railways, small aircraft, and boats, as well as the use of "surge" capabilities and of standing, networked, and distributed capabilities. We define surge capabilities as the temporary, concentrated deployment of mobile federal, state, and local capabilities in areas where portal-based detection at natural chokepoints is inappropriate (such as within cities and outlying areas). A more comprehensive definition of operations, including associated concepts, should be developed as part of the study. The study should also include the acceptance of risk as a trade-off against unacceptable costs, non-implementable capabilities, and unacceptable courses of action.

- Conduct research into deterrence theory, decision making, uncertainty creation, risk acceptance, the shaping of adversary behavior, and courses of action and adversary responses to US actions, as a means of optimizing GNDA as an overall system.

The Study Committee has reviewed the technical programmatic areas within the TARD R&D portfolio, and makes the following specific recommendations for each technical area:

SHIELDED NUCLEAR MATERIALS

- Of paramount importance is the ability to detect shielded special nuclear material (SNM) with sufficient sensitivity and reliability across a wide spectrum of conditions of presentation and within the constraints of geometry and time. This is one of the stated objectives of the Presidential order establishing DNDO. Given the complexity of the problem a long-term roadmap and strategy needs to be developed.

ALGORITHMS AND MODELING

- Developing new and improved detection algorithms can have a significant, and potentially near-term, impact on nuclear detection capabilities in every area of the GNDA. However, greater coordination is required between TARD and the other DNDO directorates charged with bringing new technology to the user. Metrics for the comparison of algorithms among the Directorates should be developed. The focus of the algorithms and modeling efforts should include not just substantially improved detections of radiation measured by individual detectors, but also responses to detections of threats inferred from measurements of systems of sensors and relevant data sources.

MATERIALS

- TARD should continue to seek new materials for both scintillation and semiconductor radiation detectors. The work should focus more strongly on materials that have breakthrough potential, rather than those offering incremental improvements. TARD should reexamine its funding of materials that have shown only incremental improvements.

- Despite limited success to date, efforts to develop semiconductor-based substitutes for vacuum photomultiplier tubes should continue. TARD should more fully exploit advances in microelectronics to improve the performance of both new and existing materials and TARD should explore the potential markets for the use of new materials in areas beyond the current DNDO applications.

NUCLEAR FORENSICS

- TARD should fund research and development programs focused on signature identification, understanding of signature transport through the fuel cycle, and detailed experimental measurements on materials of interest in order to develop libraries for comparisons with unknowns.

These R&D programs should also support the development of correlations and comparisons with model computations that could lead to signature development.

- The Directorate should remove all artificial divisions that currently exist between the pre- and post-detonation missions, and should increase coordination with relevant agencies to ensure a continuous and well-funded forensics program. Having one government organization be responsible for both pre- and post-detonation forensics may be the best long term path forward.

RADIATION AND NEUTRON DETECTION

- TARD should work more closely with the user community in developing projects and metrics so that efforts in detector development and operational approaches, such as "surge," are more responsive to end user needs.
- The Directorate must continue to develop its understanding of "surge" concepts of operations, as well as networks of systems, and assess their impacts on detection systems and capabilities being developed.
- TARD should support radiation detection developments, such as ultra-low dose radiography and neutron detection alternatives. The Directorate should also support improved scientific understanding of existing polyvinyl toluene (PVT) detectors with the goal of extending the lifetime and enhancing the capabilities of systems that will likely remain in use for the foreseeable future.

Within the TARD research programs, the committee notes that past Advanced Technology Demonstrations have lacked adequate analysis, laboratory testing, and quantitative metrics, as well as user input prior to execution of the extensive technology demonstrations. The committee therefore recommends changes to the Advanced Technology Demonstration Program.

TARD experienced significant budget cuts in FY12 disrupting its overall research program. The FY13 budget did restore significant funding enabling TARD to fund a broader range of research projects required for TARD to achieve its overall mission. But the Study Committee notes that ARI funding aimed at university basic research programs has still suffered disproportionate cuts relative to the ATD program; the Committee urges DNDO to carefully examine and evaluate the impact of the budgetary ARI reductions on the prospects for vital long-term transformational discoveries.

1

Introduction

A. Study Charge

At the request of the Domestic Nuclear Detection Office (DNDO), a Study Committee comprised of representatives from the American Physical Society (APS) Panel on Public Affairs (POPA), and the Institute of Electrical and Electronics Engineers (IEEE) Nuclear and Plasma Sciences Society (NPSS) performed a technical review of the DNDO Transformational and Applied Research Directorate (TARD) research and development program. The charge to the Committee was to investigate the strengths and weaknesses of the existing TARD R&D plan and portfolio, recommend changes to the plan, and recommend possible new R&D areas and opportunities. The Study Committee also investigated a broader range of issues that impact the overall TARD mission. The Study Committee membership and the review methodology are covered in detail in Appendix 1. Funding for the review was provided by the APS and the IEEE.

B. Review Organization

The results of this review consist of several components, beginning with a brief discussion of DNDO, TARD, TARD's mission, and how that mission is carried out. We then discuss issues that affect TARD broadly, such as DNDO coordination, DNDO's budget, user interactions, technical coordination, and Advanced Technology Demonstrations. We provide multiple recommendations related to these issues. We should note that many of these issues and recommendations are beyond the scope of the TARD mission and responsibilities but directly affect the Directorate and its potential for success. The heart of the review then follows with an analysis of the TARD technical research programs and projects. Detailed observations and recommendations are made for each technical research area. We conclude with an overall summary. Substantial information on the review methodology and on TARD and DNDO is provided in in the Appendix. All of the recommendations contained in this report are offered from a perspective of helping TARD to improve their activities, and are intended to be technical rather than fiscal in direction.

C. DNDO and TARD

The Domestic Nuclear Detection Office (DNDO) was established to serve as the primary entity in the United States Government to further develop, acquire, and support the deployment of an enhanced domestic system to detect and report on attempts to import, process, store, transport, develop, or use an unauthorized nuclear explosive device, fissile material, or radiological material in the U.S., and to improve that system over time.

When the DNDO was created, the organizers recognized that resources must be prioritized based on an umbrella architecture anchored in an assessment of the nation's existing nuclear detection capabilities and matched against the threat. DNDO was tasked with developing the "enhanced global nuclear detection architecture" (GNDA) in coordination with the Departments of State, Defense, Energy, and Justice.

The GNDA is an integrated system of radiation detection equipment and interdiction activities to combat nuclear smuggling in foreign countries, and both at the border and within the U.S. This architecture encompasses efforts by the State Department and the National Nuclear Security Administration (NNSA) that include securing foreign materials, screening and detection at foreign and U.S. ports, and monitoring pathways into the U.S. The architecture also includes Department of Defense capabilities, inputs for the U.S. Intelligence Community, and State, Local, and Tribal capabilities. DNDO is responsible for the overall development of the GNDA and, as the name implies, the implementation of the domestic activities and policies.

The challenge faced by DNDO is immense. It is a very real possibility that a nuclear weapon, nuclear materials, or radiological materials could be smuggled into the U.S. via a vast number of possible pathways, mixed within an immense and continuous flow of legitimate commerce and traffic. Additionally, there is the possibility of the diversion of legitimate nuclear and radiological materials within the U.S. The solution to this challenge requires a detailed analysis that considers the problem from a systems point of view. DNDO recognizes the need and is organized to use a systems approach. The five DNDO Directorates and their missions are:

- ***Architecture and Plans Directorate*** – Determine the gaps and vulnerabilities in the existing global nuclear detection architecture, and then formulate recommendations and plans to develop an enhanced architecture.

- ***Product Acquisition & Deployment Directorate*** – Carry out the engineering development, production, developmental logistics, procurement, and deployment of current and next-generation nuclear detection systems.

- ***Transformational & Applied Research Directorate*** – Conduct, support, coordinate, and encourage an aggressive, long-term research and development program to address significant architectural and technical challenges unlikely to be resolved by R&D efforts in the foreseeable future.

- ***Operations Support Directorate*** – Develop the information sharing and analytical tools necessary to create a fully integrated operating environment. Residing within the Operations Support Directorate is the Joint Analysis Center, which is an interagency coordination and reporting mechanism and central monitoring point for the GNDA.

- ***Systems Engineering & Evaluation Directorate*** – Ensure that DNDO proposes sound technical solutions and thoroughly understands systems.

The Transformational & Applied Research Directorate was established within DNDO to develop breakthrough technologies that could have a dramatic impact on capabilities to detect nuclear threats through an aggressive and expedited R&D program. Its objectives include addressing gaps in the Global Nuclear Detection Architecture, improving the performance, reducing the cost, and reducing the operational burden of detectors and systems. TARD programs, by design, include industry, national laboratories, and academia. TARD coordinates with related R&D organizations in other agencies, in particular the Department of Energy's National Nuclear Security Administration and the Defense Threat Reduction Agency. In addition, TARD has as an explicit objective the transition of successful technologies to system development, acquisition, deployment, and possibly commercialization.

TARD research and development priorities are driven by gaps in the GNDA. These are determined through an annual gap analysis. TARD then utilizes subject matter experts, including those from the national laboratories and the materials communities, to develop R&D requirements. The process includes evaluating the effectiveness of the existing architecture, understanding stakeholder needs, developing options, and establishing priorities. The prioritization includes budget limitations. These research and development requirements are then met through R&D projects, which are managed within the following focus areas:

- Shielded nuclear material detection
- Algorithms and modeling
- Materials
- Forensics
- Radiation detection
- Neutron detection

Within these focus areas, TARD attempts to maintain a balance between addressing the gaps and costs issues for the GNDA and carrying out long-term research that will be truly transformational.

The R&D projects are funded through four mechanisms, each with its own emphasis and scope:

- ***The Small Business Innovative Research (SBIR) Program***, which seeks to utilize small businesses to meet R&D needs and increase private sector commercialization.
- ***The Academic Research Initiative (ARI)***, which funds academic exploratory and basic research to stimulate many radiation detection sectors. These projects help create the next generation of scientists and engineers needed to advance the field of radiation detection.
- ***The Exploratory Research Program (ERP)***, which sponsors investigations to show feasibility through Proof of Concept. These projects are driven by gaps in the GNDA.
- ***The Advanced Technology Demonstration (ATD) Program***, which builds on technology concepts previously demonstrated under the Exploratory Research Program (ERP). ATD objectives are to develop and characterize technology in a simulated operational environment in order to generate performance data for cost-benefit decisions for transition to commercial system development and acquisition.

A detailed description of TARD and DNDO is provided in Appendix 2.

D. Broad Issues Affecting TARD

The Study Committee found a number of issues affecting TARD that are well beyond the control of TARD. The following section will address these as they have direct impact on TARD's R&D programs.

Evaluating TARD's research programs requires determining TARD's goals and then measuring the degree to which TARD is achieving these goals. Filling the capability gaps within the GNDA is clearly a key goal for TARD. The challenge facing TARD and DNDO is that the GNDA is a work in progress and the latest Implementation Plan [1] is highly conceptual and process oriented. It is difficult to determine from the Implementation Plan what the long-term architecture will be and what quantitative technical challenges will have to be addressed by the architecture.

Conceptually the GNDA consists of foreign efforts executed by the State Department and NNSA, Defense Department components, fixed capabilities at US ports and major border crossings, distributed capabilities operated by law enforcement, Federal, State, Local, and Tribal entities, intelligence capabilities, and intelligence-cued "surge" capabilities composed of these entities.

The development of the GNDA is a broad systems challenge. Determining the necessary R&D requires substantial interactions between the intelligence community, Federal, State, and Local operations communities, and all of the DNDO Directorates. A high degree of interaction will be required to develop mobile, flexible, intelligence-cued "surge" capabilities [2], as well as for the creation of highly networked local capabilities operating day-in and day-out nationwide. The existing collaboration and coordination observed by the Study Committee is substantially less than required for meeting the challenges of nuclear terrorism. Determining optimum investments and developing optimal solutions will necessarily cut across existing organizational boundaries. The development of a much higher systems level of coordination is a challenge from the Study Committee to the TARD and DNDO leadership.

The Study Committee recommends the creation of a highly-interactive environment in which the proposed architecture, the intelligence indications and warnings, the operations procedures and practices, the deterrence and shaping of adversary behaviors, and the development of detection systems are all evaluated and traded-off to create optimal solutions. Within this highly interactive environment, TARD must be a full participant and not just the recipient of requests for specific capabilities and technologies. TARD's science and technology knowledge must help shape architectures, concepts of operations (CONOPS), and strategies. A successful, highly reduced-scope version of such an environment already exists in the ongoing collaboration and coordination between TARD, DTRA, and NNSA on detection science and technology.

A national-level study conducted within this highly interactive environment should determine the right balance and priorities for security capabilities and R&D for all the possible GNDA pathways. These should include ports, roads, railways, small aircraft and boats, the use of "surge" capabilities, and the use of standing networked capabilities. A program driven by one single threat location, such as protection of ports, must be analyzed carefully to determine whether the approach provides the most protection for a given expenditure on distributed capabilities. As part of this broad, highly interactive approach, a clear definition must be developed that clearly identifies the end user and the end user state. The end user's needs and constraints must be included at all levels and timescales within the process of developing the GNDA, as well as in TARD's development and carrying out of the required research.

The roles of deterrence and decision-making theory, uncertainty creation, methods for shaping adversary behavior, and course of action do not appear to have a significant presence in the development of the GNDA. A systems-level analysis of potential components for the GNDA would include questions addressing whether such a system would deter adversaries or, instead, push them to use less defended pathways with more likelihood of success. The Committee strongly encourages the exploration of deterrence theory, decision-making, uncertainty creation, and the shaping of adversary behavior and courses of action as a key component of the TARD research and development portfolio.

A symptom of the current, more limited approach to looking at GNDA gaps and issues is TARD's focus on the development of lower-cost detectors. While conducting research to develop lower-cost detectors may have significant payoff for the nation, the lack of a thorough understanding of how the detectors will be used makes the potential value of the research efforts difficult to determine. Developing algorithms, information processing methods, and complete concepts of operations that enable the deployment of large numbers of low-cost radiation sensors in networks may have significant payoff. The real goal should be to develop capabilities that generate information that enables practical courses of action. It is important to fully understand the cost/benefit trade-off for these capabilities. A full system-level evaluation needs to occur, and then, if justified and required, projects aimed at reducing detector costs should be carried out. The detector and its costs may represent an appropriate near-term focus, particularly given current budget constraints, but will only represent a limited longer-term capability unless framed within a system-wide approach. The ultimate goal is actionable information with an acceptable cost. A low cost system that does not enable practical courses of action has no value.

E. TARD Budget

TARD has experienced significant budget cuts. In FY11, TARD had a budget of $96.3M. That was cut to $40M in FY12 by congressional action. The TARD staff responded by prioritizing the research and stopping many projects. This method was considered to be less disruptive than distributing the cuts across all projects. This resulted in some projects making significant progress, but was still disruptive for the overall academia/industry/national lab efforts and workforce supporting TARD. The budgets for the program funding areas for FY11, FY12, and the proposed budgets for FY13 are shown in Table I.

TABLE I: TARD BUDGET

	FY11 ($M)	FY12 ($M)	FY13 ($M proposed)
ARI	18.2	5.2	8.8
ERP	48.1	13.6	44.5
ATD	30.0	21.2	30.6

While the budget was cut, the mission of TARD has broadened to include: addressing GNDA gaps, continuing long-term workforce development with academia, transferring technologies and developing capabilities with industry, driving down the cost of detection while steadily increasing capabilities, and now developing mobile capabilities as well as networked fixed capabilities and expanded collaborations. The Study Committee notes that ARI funding aimed at university basic research programs has been cut disproportionately relative to the ATD program; the Committee urges DNDO to carefully examine and evaluate the impact of the budgetary ARI reductions on the prospects for vital long-term transformational discoveries.

F. Advanced Technology Demonstrations

One of the largest programs in TARD is the Advanced Technology Demonstration Program (ATD). Because of the size and presumed importance of this program, we will examine it in considerable detail. The ATD was conceived, as its name implies, to demonstrate some of the technology that was reviewed in other, smaller TARD programs, such as the Exploratory Research Program (ERP) or the Academic Research Initiative (ARI) program.

MOTIVATION FOR ATD PROGRAM

Two rationales are used by TARD to justify the ATD Program:

1. New or existing technologies that are demonstrated in the laboratory may not function as intended when deployed in the field. This is particularly true of radiation detection technologies in which the "detection probability" versus "false positive" characteristics can change significantly when the technology, tested only in a simplified laboratory environment, must operate in a realistic field scenario.

2. To convince a skeptical user community of the efficacy of technology, it may be necessary to demonstrate the technology concretely in a field demonstration.

DNDO felt that some of the technologies shown in the smaller research programs (ERP, ARI, etc.) needed to be demonstrated outside of the laboratory environment to showcase their effectiveness. This committee agrees with this sentiment, as it can be difficult to prove the importance and functionality of a new detection technology based on a controlled laboratory demonstration.

Another motivation for creating and executing the ATD program was to determine if technologies that showed promise in the laboratory might be eliminated from further consideration due to unforeseen practical considerations that arise during field testing. This committee feels that this is a justifiable motivation, as history is littered with examples of advanced technology solutions that failed based on unforeseen real-world problems.

ISSUES WITH THE ATD PROGRAM

The fundamental problem posed by a field test program like ATD is that a large fraction of the program's money is consumed by engineering the field test units and not the research itself. Since the ATD program is a substantial fraction of TARD's total budget, the program presents a philosophical risk in that it could divert a significant amount of TARD's resources away from their primary purpose, which is finding transformational solutions to radiological threat detection. The risk is that those resources would be spent, instead, on straightforward field engineering with no guarantee that it would be effective.

In order for the ATD program to succeed in demonstrating technologies without spending excessive resources on engineering, it is critical that the technologies prove through laboratory testing that they have a good chance of working in the field. Technology demonstrations should be structured so that a series of well-defined hierarchical tests are performed to identify and select only technologies that have a reasonable chance of working in field tests. Fundamental aspects of a particular technology should be investigated before a field unit is engineered and constructed. All fundamental aspects of the technology's behavior should first be demonstrated in the laboratory and, if possible, in a small-scale version.

TARD management acknowledged that they recognized these ATD program shortcomings and have taken steps to correct them. For instance, in the recent Airborne Radiological Enhanced-sensor System (ARES) solicitation, TARD had extensive computer modeling and simulation conducted to estimate the performance envelope of the proposed designs. Comparisons of the simulations established the basis for selecting awardees. The Committee believes that TARD is moving in the right direction with the approach to the ARES ATD solicitation, and the Directorate is now doing a better job in this regard than many government and private R&D agencies. However, the Committee suggests that the Directorate could do more.

RECOMMENDATIONS FOR THE ATD PROGRAM

The Committee recommends that TARD adopt a "stage gate" process, whereby clear objective and quantitative criteria must be met by a technology in the laboratory before it can be selected for field deployment. This selection could be accomplished in two ways: Candidate technologies chosen during an ATD program could pass rigorous exit criteria before the engineering and field deployment phase of the ATD project is initiated; exit criteria could be defined for technologies during the ARI, ERP, or SBIR projects, and only those technologies that passed a predefined definition of success could be selected as candidate technologies for subsequent ATD projects. This committee prefers this "exit criteria" approach.

The ATD program, while well intentioned, did not at its outset deliver good return on investment. A substantial amount of money was spent engineering prototypes for field deployment, only to find that the technical basis for these prototypes was flawed. Moreover, these flaws likely could have been discovered in lower-cost laboratory experiments or simulations, ultimately saving significant money. To TARD's credit, Directorate officials became aware of this problem in managing the ATD program and have taken decisive steps to correct it.

G. Operator Input

DNDO's strategy and technology roadmap is informed by the GNDA Implementation Plan and associated risk assessments. GNDA is a starting point for setting DNDO priorities and bringing them into alignment with user needs. However, the lack of consideration of end-user buy-ins appears, based both on GAO commentary and executive branch testimony, to have been a significant stumbling block in several key Product Acquisition & Deployment Directorate programs [3, 4, 5].[1]

Early-stage exploratory research efforts should have some degree of freedom from rigidly defined user requirements. Indeed, transformational technology development may, when offering credible promise of major performance gains, merit some modification of existing CONOPs. That said, as technology progresses closer to transition and more labor-intensive advanced technology demonstrations, it must be bounded by the real-world constraints frontline operators actually face.

Part of the value of TARD is to help DNDO and DHS understand the limits of technology and set realistic requirements. But the process should be iterative; to wit, prospective users identify thresholds that must be addressed for a development program to advance through stages of greater maturity.

Moreover, front-line GNDA implementation responsibility for the US interior falls in significant part to state, local, territorial, and private sector organizations. While there is evidence of widespread participation in Preventative Radiation Nuclear Detection Programs among these entities, meeting GNDA priorities is a challenge. This is particularly true if doing so requires a significant change in individual daily operational priorities (e.g., frontline personnel whose only steady-state function is to support detection operations).

To address these challenges, the requirements development process should not only acknowledge end-user constraints as a general principle, but also pay particular attention to the operational implementation limitations of state, local, tribal, and private organizations. As TARD plans, initiates, and completes an Advanced Technology Demonstration and presents a technology for transition, it should be mindful of who the user is likely to be and how a detector would actually work within the user's enterprise. The TARD requirements development process should be bounded by end-user feedback on response-related constraints, which should then be factored into the program planning and assessment process during development activity. The completed Standoff Radiation Detection Systems (SORDS) ATD and Roadside Tracker and Target-Linked Radiation Imaging (TLRI) projects are examples of projects that increase end user capability without significant changes in detector technology. Future investments in national reporting systems for detection activity will provide similar benefits for end users and increased support of the GDNA.

1 The 2011 GAO Report [4] noted that, with respect to the CARRS program, "DNDO pursued the deployment of CAARS without fully understanding that it would not fit within existing inspection lanes at ports of entry and would slow down the flow of commerce through these lanes, causing significant delays." The 26 July 2012 Congressional Transcript [5] answer of Acting DNDO Director Huban Gowaida: "Chairman Lungren, as we were going through our field validation, we discovered that the jointly developed specifications for the ASP program … no longer reflected accurately the operational concerns that CBP [sic] faces. So specifically, truck speed in secondary inspection exceeds two miles an hour, and the design specification called for two miles an hour."

2

TARD Research Focus Areas

The heart and soul of TARD is its research programs; therefore, most of the review focuses on these programs. Within these programs TARD attempts to address the gaps in the GNDA, improve performance, reduce costs and operational burdens, explore long-term, potentially transformational capabilities, and develop the R&D workforce of the future. To accomplish these many tasks, TARD has divided its research portfolio into the following six focus areas:

A. Shielded nuclear material detection

B. Algorithms and modeling

C. Materials

D. Forensics

E. Radiation detection

F. Neutron detection

The Committee looked at each of these R&D efforts in detail. One common issue that emerged from all areas is the need to establish methodologies for terminating projects that have not shown success. The following section includes detailed discussions, observations, and recommendations for each of the research areas.

A. Shielded Nuclear Materials

The detection of illicit special nuclear materials (SNM) in general search-and-detect procedures, or in various conveyances at fixed locations, is the most challenging issue that TARD is charged with addressing. The Shielded SNM Portfolio within TARD has the objective of developing "operationally viable technologies that can detect shielded SNM and clear innocent objects for existing and new scenarios [6]." The means by which detection is attempted are divided broadly into categories commonly referred to as "passive" or "active" interrogation. Because of the confusion that might be implied by these descriptors and the complexities of different approaches, passive interrogation is taken here to refer to measurement of any characteristic property of the SNM that requires nothing more than a detecting system. This includes measuring the natural emissions emanating from the SNM, and the emissions that result from the interaction of these emissions with matter. Passive methods include measurements of neutrons, gamma rays, x- rays, or other emissions from SNM; measurement of the attenuated and scattered natural flux of muons passing through an object; and gravimetric measurements.

Active interrogation means measurement of the properties of an object inferred by irradiation with external radiation sources, or measurement of the radiations emitted following stimulation with external radiation sources. Active interrogation includes (1) the use of continuous bremsstrahlung to infer the atomic number of an object; (2) measurement of the attenuation and scattering of an incident monoenergetic photon beam that is resonant with a specific excited nuclear state of an isotope found in SNM; (3) measurement of the emission of both prompt and delayed radiations, primarily neutrons and gamma rays, emitted following irradiation with neutrons, and high-energy bremsstrahlung.[2]

These definitions are chosen because of their operational characteristics and are not universally accepted. In most normal applications, radiography is sensitive to electron density and thus is often not considered to be a form of active interrogation. However, interaction of the incident bremsstrahlung with a target produces high-energy electrons that produce secondary bremsstrahlung whose intensity is proportional to the atomic number of the element with which the electrons interact. This secondary bremsstrahlung can be observed at back angles and thus, at least in principle, variants of normal radiography can provide information that is a direct characteristic of high-density, high-Z materials such as SNM [7, 8]. One of the defining characteristics of SNM is that it undergoes fission by irradiation with low-energy neutrons and relatively low-energy photons. Active interrogation of this type has the unique characteristic of being independent of the geometrical form of the SNM. Within the range of masses that are most likely of interest, active interrogation is also essentially independent of the chemical form of the SNM or its dilution by the presence of other materials within an object.

The conditions under which the SNM might be presented include intermodal cargo containers, large truck trailers, and air freight, in which the time allowed for any measurement might be very limited. In ships and boats, geometry might be more of a constraint than time in making measurements.

Currently, passive detection is accomplished primarily by observation of either neutrons and/or photons emitted by spontaneous fission and by photons emitted in radioactive decay and neutron capture. Highly-enriched uranium (HEU) emits a number of relatively intense low-energy gamma rays that are largely absorbed by the material itself and are easily absorbed by most surrounding materials. The more penetrating photons emitted are of low abundance. If the HEU contains reactor-irradiated material, significant contamination by ^{232}U can be found that may be detected through the emission of the 2615-keV gamma ray in the decay of ^{208}Tl. Emission of neutrons from highly enriched uranium (HEU) is quite weak because of the low rate of spontaneous fission.

Typical weapons-grade plutonium (Pu) emits large numbers of neutrons and gamma rays as a result of spontaneous fission, including some highly penetrating gamma rays from short-lived fission products and from neutron capture in surrounding materials.

Under similar conditions of shielding, the probability for passive detection of weapons grade Pu will generally be much higher than for HEU. Nevertheless, in the presence of significant shielding, even detecting the presence of Pu can be challenging. The sensitivity for detection of small sources of SNM is limited by signal-to-noise ratios and is especially sensitive to general background radiations when significant time constraints are applied to minimize effects on the flow of commerce. Although we are concerned here primarily with shielded SNM, large passive systems such as the Airborne Radiological Enhanced-sensor System (ARES) are proposed for TARD in the future. We believe these systems are more appropriate detectors of radiation dispersal devices (RDD) than SNM because of the low intensity of emissions (especially for shielded SNM) and the large distances and short measuring times characteristic of such systems.

2 TARD divides technology in a slightly different manner by radiation detection techniques and shielded threat detection techniques. The shielded threat techniques include active, muon tomography, gravity techniques, etc.

When no prior information is available that identifies the type of SNM being sought, a robust detection system must be able to demonstrate the absence of both Pu and HEU. Given that the vast majority of conditions under which illicit HEU might be found include significant shielding and/or restricted detection time, essentially all passive approaches will be too insensitive to be useful as a robust detection system. We are largely in agreement with the earlier JASON and NNSA studies concerning the detection of heavily shielded material. This places the burden for detection primarily on active means of interrogation [9, 10, 11].

There are two general limiting applications for which active interrogation may be required: screening and absolute definition of the presence of SNM. In screening applications, a methodology need not provide absolute definition of the presence of SNM, but must ensure that a target is free of a significant quantity of SNM with a small well-defined false-negative probability, or that SNM may be present with a small well-defined false-positive probability. The methodology must provide such information in times acceptable for minimizing effects on traffic and be acceptable for inspection of virtually any material in the stream of objects interrogated, including foodstuffs. Possible screening methodologies include radiography in different formats and backscattering of incident photons that can determine or limit the atomic number of an object to exclude the possibility that it contains SNM. Irradiation by neutrons to produce fissions might be unacceptable because of the radioactivity induced by neutron capture in most elements. However, neutron irradiation or the use of high-energy bremsstrahlung to produce photofissions are examples of methodologies that can provide high-quality definition of the presence of fissionable materials, and thus approach absolute recognition.

Active interrogation of SNM, with either photons or neutrons as probing radiation, has been extensively studied. The physics is generally well-known, but the choice of method depends critically on the details of the intended measurement, such as the extent and nature of the shielding that might be present, limitations on dose to be delivered to the target, and limitations on the interrogation time. Additional requirements will be applied if a portable "surgeable" system is desired, in which issues of mobility, flexibility, cost, and size become important.

ONGOING AND PROPOSED TARD SNM PROJECTS

The following three ATDs directly associated with SNM detection are now being explored:

- The use of secondary bremsstrahlung for identifying the average atomic number of a voxel in a mass of material that might contain SNM, and the use of bremsstrahlung-induced nuclear resonance fluorescence for identifying specific isotopes of the elements contained in SNM.
- The use of differential die-away of the neutron signal from pulsed-neutron interrogation of a mass of material as a means of detection of the possible presence of SNM.
- The use of bremsstrahlung for radiographic determination of the atomic number of an object in a mass of material along with bremsstrahlung-induced photofission for discrimination of actual nuclear threats.

Testing these different technologies under realistic conditions will provide information on the strengths and weaknesses of the different systems and subsystems, and on the ability of the methodologies to provide for sufficient sensitivity and false positive and false negative signals. Possibly, it could also provide information on the strengths and weaknesses of the testing protocols that are used. These protocols will also provide information concerning practical aspects of their application to specific types of problems, such as physical dimensions and necessary shielding, the dose delivered to the material itself, or possible stowaways. All such information is important to the redesign of systems to overcome limitations found during the testing, to define the range of conditions for which the methodologies being tested are unlikely to apply, and to define the specifications for future calls for proposals to address alternative means for developing methodologies that can apply to conditions for which current methodologies do not apply.

The Committee strongly recommends that no new ATDs be instituted until a thorough analysis of the performance of those now being supported is completed. The Committee advises against any investment in future ATDs until review of all such proposed work provides reasonable evidence that a test system can meet the needs of the specific or general application for which it was proposed. The Committee judges that there is a need for a focused and rational re-examination of the properties of active interrogation methodologies that could approach the requirements for the search-and-detect mission and for screening/absolute recognition at fixed locations. The approach should use careful definitions of the requirements that systems must possess for the different missions. Demonstrations to be solicited through proposals must include requirements for sufficiently detailed calculations with deterministic models and Monte Carlo simulations and/or combinations of these to examine whether a suggested approach has a reasonable probability of achieving the desired goals. Laboratory-level experimentation to demonstrate key principles, or to establish the probability that key subsystems can operate as needed, should first be demonstrated through the Exploratory Research (ER) Program. ERs have in the past been largely concerned with components rather than systems, and, while useful, they should be more clearly defined with respect to how they would be incorporated into a system and how they would solve the problem of detection of shielded SNM under a range of realistic conditions.

The metrics established by DNDO for sensitivity and the probabilities for false-positive and false-negative signals must be established with confidence for each of the methodologies proposed for testing at the level of an ATD. The Committee recognizes that direct experimental demonstrations of the probabilities can require a time-consuming and extensive set of measurements. Nevertheless, the probabilities must be understood with high confidence. The Committee recommends that consideration be given to designing a system of experiments coupled with Monte Carlo simulations. The simulations might be able to infer the desired false positive and negative and guide the experiments, potentially reducing cost. Without setting limits on risk and detection probabilities in realistic situations, DNDO risks having "successful" outcomes that solve such a limited problem set that they can never be deployed in a practical system due to dose, footprint, and cost.

Exploratory research programs include or have included:

- The development of a three-dimensional imaging system for computed tomography for air cargo inspection that utilizes a high-energy X-ray source and flat panel imagers, as well as a study to evaluate candidate techniques for aircraft inspection

- The measurement of prompt photo-neutron production from fission and development of algorithms to differentiate the presence of different actinides in the presence of background sources from the (g,n) reaction

- A study of fast detectors and electronics to perform waveform analysis on signals associated with the measurement of the average atomic number of inspected cargo for determination of signal variance

- Development of an automatic target recognition algorithm for use with high-energy radiographic images, development of an enhanced algorithm for automatic definition of the average atomic number of an object in radiographs, development of algorithms for prompt neutrons that differentiate fissile from fissionable materials, and nuclear resonance fluorescence for unambiguous definition of SNM

- A project to demonstrate the technical basis for a compact, high-gradient, high-current, laser-driven ion beam accelerator capable of delivering a large dose of protons or deuterons with energies of ~ 1 GeV for detection of SNM

- Demonstration of isotope-specific imaging using nuclear resonance fluorescence via tunable quasi-monoenergetic (Thompson) photon sources

- Improved performance of a system based on differential die-away of fission-induced neutrons for SNM detection

- Feasibility analysis, design, fabrication, and laboratory evaluation of a pulsed D-D neutron generator for active interrogation and development of an inexpensive field-portable neutron source

- Development of low-dose neutron-based active interrogation for vehicle inspection in the presence of occupants

Within the Academic Research Initiative (ARI) program, activities have been funded in support of:

- Measurements of cross-sections for nuclear resonance fluorescence on nuclides of interest for detection of SNM
- Characterization of the production of laser-driven beams of ~1 GeV electrons and optimization of parameters for production of g rays for active interrogation applications
- Identification of nuclear isotopes using polarized (g,n) asymmetries
- The use of time-correlated signatures and directionality of interrogation to detect shielded highly-enriched uranium
- The use of laser-initiated thermal diffusion to increase the pulse length of microwave thermionic electron guns for application to inverse Compton x-ray and g-ray sources

Within the Small Business Innovative Research (SBIR) program the following activities have been supported:

- The development of a software tool to assist human operator detection of contraband and thereby reduce the rate of false positive decisions and to reduce the time required for examination of a cargo conveyance
- Development of a low-cost miniature X-band linear accelerator to replace radionuclide g-ray sources and development of a compact D-D neutron generator to replace radioactive sources used in oil and gas exploration
- Development of a portable, cost-efficient accelerator capable of producing intense electron beams with high-duty cycle for non-intrusive inspection and verification applications

Finally, the Advanced Technology Demonstration (ATD) program has supported the Shielded Nuclear Alarm Resolution (SNAR) project that is specifically directed toward SNM detection. The goals of the program are to provide the means for uniquely detecting SNM in the presence of shielding and masking, provide for high-throughput radiography, and provide rapidly relocatable and human portable systems. Based on reports provided by TARD [6, 12, 13], the ATDs supported include:

- The Passport Multi-modal Automated Resolution, Location and Identification of Nuclear Material (MARLIN) system, which includes transmission radiography, secondary bremsstrahlung measurements, and photofission in a primary scan mode, and long dwell photofission and nuclear fluorescence in secondary scan mode
- The Rapiscan Photofission Based Alarm Resolution (PBAR) system, which incorporates transmission radiography and photofission
- The Rapiscan Differential Die-Away Analysis (DDAA) system, which uses analysis of the die-away of detected neutrons escaping from an object irradiated with neutrons as a measure of the presence of fission induced by the interrogating neutron flux

As of May 2012, the Passport system had completed characterization, but data analysis and issuing of a final report had not been accomplished. The Rapiscan systems are not expected to undergo characterization until late 2013 or early 2014.

TARD has proposed a number of R&D topics for the near future, FY13 budgets permitting. These include:

- Highly Mobile Radiographic Imaging System with Dose Mitigation--systems or components that can provide a variable dose at each object location to provide a meaningful image, which will, in turn, reduce shielding requirements

- Enabling Technology for Rail Cargo Inspection--new concepts and enabling technologies to support the high-confidence clearing of rail cargo from nuclear and radiological threats

- Integrated Mobile Threat Detection with Emphasis on Data Fusion, Informatics and/or Novel Signal/Signature Exploitation -- use of sensor or data fusion plus orthogonal signals or signatures to improve conventional threat detection

- Integrated Approaches to Clear Objects from Nuclear Threats--integrated multidisciplinary approaches to verify with high confidence that special nuclear material (SNM) is not present in an object

While the goals of the first two activities are clearly of great interest, it will be the specific details of the goals, i.e., masses of SNM that are to be detected, time permitted for the measurements, etc., that will define the quality of proposals that are submitted. The proposed area of Integrated Mobile Threat Detection with Emphasis on Data Fusion, Informatics and/or Novel Signal/Signature Exploitation appears to be highly speculative, and unless well-defined, well-thought-out limits are provided on key variables, it is not clear that any significant results can be expected. It would seem that such an area is more appropriate for ARI proposals than for ER proposals. Finally, the last proposed activity, "Integrated Approaches to Clear Objects from Nuclear Threats: Integrated multidisciplinary approaches to verify with high confidence that special nuclear material (SNM) is not present in an object" is somewhat of an enigma to the Committee. If it means to discover or uncover means by which multiple measurements on an object by different physical means, combined with high-quality intelligence information, can lead to increasing the confidence by which a target of interest is cleared as being free of significant quantities of SNM, then it is a reasonable goal. However, without clear definition of the limits for false-positive and false-negative rates, and without clear definition of the times required for measurement, the masses of materials that must be detected and the range and types of shielding that must be considered, such a call for proposals is highly questionable. On a longer timescale, TARD is considering:

- Human-portable active interrogation system (FY14)
- General aviation scanning system (FY15)
- High-throughput integrated rail scanner (FY16)
- Development of detector materials suitable for active interrogation
- Monoenergetic X-ray sources to enable low-dose scan

These possible proposal topics are reasonable, in principle. Those judged to be most significant are the General aviation scanning system (FY15), the High-throughput integrated rail scanner (FY16), and the Monoenergetic X-ray sources to enable low-dose scan.

OBSERVATIONS AND RECOMMENDATIONS

The ability to detect shielded SNM with sufficient sensitivity and reliability across the wide range of conditions of presentation and constraints of geometry and time is of paramount importance and is one of the key objectives of the Presidential order establishing DNDO. The Committee believes that this general problem should continue to receive intensive study over the next years. While the physics is well known, there are many avenues of exploration in the actual applications that have not been examined in detail and might lead to significant improvements in our ability to detect SNM. The path forward is complex. In principle, with sufficient shielding no SNM can be detected from its emissions, but the shielding weight and size makes it detectable by other means (radiography for example) and make it difficult to transport covertly. Radiography and still to-be-developed low-dose radiography may provide a partial solution. The use of muon scattering is also a possibility. These methods take considerable detection time and may have unacceptable operations impacts. The committee was divided on the degree of value for both low dose radiography and muon based methods. More analysis is needed to determine if there are viable paths forward for these methods. Nuclear resonance techniques appear costly and may be difficult to make portable for mobile operations, although it may be possible to develop portable units using compact cyclotrons. There has also been work reported on the use of mono-energetic photon sources based on nuclear reactions as both a low-dose screener and a material identification tool. Given new accelerator developments, these photon sources have the potential for being very compact. Given the severe technical challenge and the compelling need, the Study Committee recommends TARD develop a long-term strategy and road map for SNM. Specific actions recommended for SNM detection are:

- Clarify the significance of SNM detection to the DNDO GNDA relative to other threats
- For the stream of commerce, explore all avenues of SNM detection with the goal of identifying what each technology can deliver for use in primary screening. Define requirements for SNM detection in general search and detect missions where the constraints associated with interrogation of a variety of targets, such as cargo containers at seaports and vehicles at ports of entry, are not important
- Perform research on the above questions, but do not attempt an ATD until all options are understood in terms of where they could fit in the end user's concept of operation

B. Algorithms and Modeling

Algorithms and modeling research at DNDO serves three primary objectives: enhanced threat detection performance, development tools, and training tools. Each of these has different users, purposes, and metrics for success. It is useful to examine each area individually.

ENHANCING THREAT DETECTION

Advanced algorithms can have a truly transformational impact on the performance of existing and future instruments for nuclear detection. Algorithm development can often be the most cost-effective and expedient approach to improving performance. There are opportunities for performance enhancements in every area of radiation measurement and within all the gaps identified in the GNDA. Advanced detection algorithms can improve detection capabilities, particularly for mobile detectors. Imaging algorithms can locate sources and suppress noise from background and nuisance sources of radiation. Time-correlation algorithms can provide new signatures for the detection of different configurations of fissile material. Advanced spectral analysis algorithms can improve threat detection while reducing false alarms. And data fusion and sensor fusion can combine signals from multiple instruments, some of which may already be in place, to provide more security while reducing the disruption nuclear detection can have on users and detection operations.

While TARD has achieved some significant successes in developing algorithms to enhance performance, in many cases the algorithms have had only limited deployment to the users. For example, the most common radioisotope identifier (RIID) instruments use NaI-based detectors that provide only modest spectroscopy. A major effort has been launched to develop new materials and techniques to provide improved hand-held spectroscopic resolution. Significant advances have been made in the laboratory, and improved RIIDs are becoming available commercially and finding their way into the field. But replacing the many thousands of RIIDs currently in use will be costly and will take time. In the meantime, there have been significant improvements in analysis algorithms that can provide dramatic improvements in performance of the existing NaI-based instruments. TARD has played a role in some of this development work, but has not been effective in bringing this new capability to the users. For a fraction of the cost and time of replacement, existing instruments like the GR-135 and Identifier could be upgraded to enhance performance, improve accuracy, and reduce the need to call for reachback support. Coordination between the developers, manufacturers, and users is critical, and DNDO could provide the incentives and support to bring this about. Moreover, algorithm improvements could be important in enabling fixed portal and mobile spectroscopic systems to operate in closer alignment with existing user constraints.

Unfortunately, given the current DNDO structure, the mission of bringing new technology to the user rests more in the Systems Engineering and Evaluation Directorate and the Product Acquisition and Deployment Directorate than it does in TARD. The Committee finds improved coordination and cross-directorate prioritization is essential for TARD's transformational developments to reshape results in the field.

DEVELOPMENT TOOLS

Modeling and analysis tools are necessary to develop new and better detection systems and to assess their performance. Many new capabilities for radiation instrument modeling have been developed and incorporated into the MCNP and GEANT Monte Carlo modeling codes. Stand-alone tools have also been developed and improved, including SWORD and GADRAS. TARD has played an important role in supporting these activities. Operational simulation tools and capabilities are also required to assess the effectiveness of new instruments and algorithms, and to optimize their development, implementation, and deployment. In some instances, very similar modeling capabilities have been developed by multiple developers, sometimes in support of the same program. While this may seem redundant, it is often necessary to provide a crosscheck and validation of these complex codes and the many assumptions that are required. TARD has provided considerable support in this area and has encouraged various approaches to making the tools available to the radiation detection development community.

Several workshops in operational modeling have been sponsored by TARD, sometimes in cooperation with other agencies, such as the Defense Threat Reduction Agency (DTRA). Further dissemination could be facilitated by describing new capabilities in the various proposal announcement documents. Proposal review criteria could include the use of existing and newly developed capability rather than using research money to recreate capabilities that have already been developed, benchmarked, verified, and validated. Overall, development tools are only sometimes "transformational" in and of themselves, but more often they provide the necessary basis on which more transformational ideas can be built. In general, new analysis tools are required for advancing the state-of-the-art in detection and are an important component of the TARD portfolio. Operational modeling is generally more of a planning tool and might be a better match to the Architecture and Plans Directorate.

TRAINING TOOLS

The operation of radiation detection instruments, software, and systems typically requires training. Well-constructed training tools can also be used to help develop improved operating procedures and approaches, including optimizing deployment configurations, user interactions, and interpretation of results. One of the most important needs is for training to recognize nuclear threats, since these are rarely available for testing, and require significant training and appropriate clearances to study in detail. This area is rarely "transformational" and, in some cases, might be supported by other Directorates.

CURRENT PORTFOLIO

TARD is currently funding 16 projects focused predominately on algorithms and modeling. Advanced algorithm development is also a key component of many other projects, often being developed to work directly with instruments and systems under development, such as the SORDS, SNAR, ARMD, and NRIP ATDs, as well as numerous ERP and ARI projects (such as the roadside tracker). Those instrument development projects could, and often do, benefit from research done in the algorithms and modeling portfolio. Research in this area could be useful to those hardware projects. One challenge that TARD faces is to coordinate all of the algorithm developments throughout the portfolio, regardless of which research focus area the algorithm effort falls under.

ENHANCING THREAT DETECTION

Advanced algorithms, machine learning, and data fusion can dramatically improve threat detection capabilities. The Intelligent Radiation Sensor System (IRSS) is the largest project in the portfolio. This

ATD project has three vendors, each of whom made a prototype mobile detection network consisting of about 20 detectors, software, and algorithms to detect, locate, and identify sources. The project is closing out with a large collection of test data and prototype systems that could be exploited in the future. Several exploratory research projects are funded to enhance detection and identification of nuclear threats. There is one ER project using data fusion and working closely with Customs and Border Patrol (CBP) to enhance radiation screening operations at chokepoint inspections. Machine learning-based data aggregation is under development in the ARI program for mobile detection systems. The ARI program also supports a project modeling interdicted smuggled nuclear material that could be used to optimize current and future deployment of detection systems.

Two SBIR topics currently being investigated involve algorithms and modeling. One is embedding advanced search techniques to provide better localization of sources, and the other is developing smart phone apps for reachback type of operations. The latter includes a requirement that the vendor convene a group of users from various users, including local, state, and federal responders. This requirement to work closely with the users is an excellent model that should be expanded to more proposal requirements throughout TARD.

Development Tools: Two ER projects are ongoing in this area, including enhancements to MCNP and development of the Software for Optimizing Radiation Detection (SWORD).

Training Tools: Two SBIR projects and one ER project are developing simulation and training systems of various types. Some of these training aids are now under evaluation with users in pilot programs.

FY13 PLANS

The planned approach for FY13 includes a range of technical thrusts as well as encouraging partnerships between industry, vendors, national laboratories, academia, and operators. New initiatives that focus on, or take advantage of, advanced algorithms and modeling include:

MOBILE RADIATION IMAGING AND TRACKING SYSTEM (MRITS) – ATD

This project will develop a land-based radiation detection, identification, localization, and tracking system by integrating into a single mobile platform the technology and the lessons learned from the Stand-Off Radiation Detection System (SORDS) ATD, the Roadside Tracker ER Program, and DNDO's Long Range Radiation Detection (LRRD) Limited Use Experiment (LUE). While not part of the algorithms and modeling portfolio, algorithms will be a key part of this instrument, enabling high-sensitivity detection, localization, and identification using gamma-ray imaging and sensor fusion.

EXPLORATORY RESEARCH

Integrated Mobile Threat Detection with Emphasis on Data Fusion, Informatics and/or Novel Signal/Signature Exploitation: Research in needed to explore integrated approaches for detecting special nuclear materials (SNM) or the shielding that may be around these materials in cars, containers, or other conveyances, either during routine surveillance or during intelligence-directed surge efforts. Approaches should explore how conventional threat detection (using radiological or radiographic information) can be improved through sensor or data fusion and the use of signals or signatures that may be collateral or orthogonal to conventional sensing.

Nuclear Forensics Data Collection and Analyses: Research to develop new analytical techniques for determining the origin and transit route of nuclear materials. Advanced algorithms could have a significant impact on the analysis.

ACADEMIC RESEARCH INITIATIVE

Deterrence Theory and Analytics: Research is needed to develop a theory of deterrence as applied to developing and deploying capabilities for the GNDA, as well as a formalism for quantifying the deterrence value (i.e., measures of effectiveness) of these proposed capabilities. The approach (or approaches) may apply current state-of-the-art in informatics, game theory, adversary behavior modeling, and/or related deterrence theory, to enable the determination of the perceived deterrence value of current and proposed GNDA capabilities.

Threat Detection through Data Fusion, Informatics, and/or Non-Radiological Signal/Signature Exploitation: Research is needed to explore how detection of nuclear/radiological threats can be definitively made or enhanced through use of signals or signatures that may be collateral or orthogonal to conventional radiation sensing methods. Non-radiological signals may include thermal/infrared imaging, radar, electro-optical detection, acoustics, gravimetrics, other potential sensing modalities, or utilization of other available data concerning the vehicle or container.

Integrated Approaches to Clear Objects from Nuclear Threats: Research investigating integrated multidisciplinary approaches to verify with high confidence that special nuclear material (SNM) is not present in an object (e.g., truck, container, vessel). Research should emphasize both efficient and effective means of high-volume, low-dose screening/scanning for nuclear threats, with minimal impact on the flow of commerce and minimal operational burden. Research should encompass multi-sensor/multi-data source analyses, data fusion, modeling, and experimentation to support and defend the recommended approach.

There are two additional ATD concepts under development, the Radiological and Nuclear Detection Operational Model (RANDOM) and Vast Array of Mobile Tracked Sensors (VArMTs), which would use more than 100 sensors to track sources in a surge-type operation. The VArMTS project concept is being coordinated with users who staff operations at National Special Security Events (NSSEs), where a large number of sensors are deployed. Under the current planning these new ATD projects would mostly likely not be initiated until FY14 or later.

OBSERVATIONS AND RECOMMENDATIONS

Developing new and improved algorithms can have a significant impact on nuclear detection capabilities in every area of the GNDA. Compared with new instrumentation, advanced algorithms can be relatively inexpensive to develop and much quicker and dramatically less expensive to deploy. And in many cases, new algorithms can transform nuclear security operations by dramatically improving threat detection capabilities and enabling deployment of new systems that address the major gaps in the GNDA. That said, improved coordination and cross-directorate prioritization with SEED and PADD are essential for TARD's transformational developments to reshape results in the field.

There are no conventional approaches that are well suited to detecting threats that don't pass through Ports of Entry and other chokepoints. Other smuggling pathways, including small boats, small airplanes, and unattended borders and coastlines, are too vast to cover with detector installations or dedicated mobile detection systems absent a prior intelligence-based cue. In addition to the border, coast, and small airport gaps, there are many pathways by which one could obtain the necessary materials for a credible radiological threat from within the country and, therefore, never pass through a border. Addressing these gaps should be a significant objective of the TARD portfolio.

All of the major gaps in the GNDA involve long perimeters (unattended borders and coastlines), large numbers of locations (marinas and general aviation), and wide areas (around critical facilities and potential targets, at NSSEs, and along the vast network of roads and railroads throughout the country). Radiation has a limited range, particularly from nuclear threats that may be well shielded. To cover these gaps in the GNDA it is therefore essential to:

- Develop instrumentation, algorithms, and concepts of operations that can deploy large numbers of radiation sensors without high costs in equipment and/or operations
- Deploy and/or collect information from relevant non-radiation sensors and other sources

- Develop advanced algorithms to aggregate all the data to provide actionable threat detection information without excessive false alarms.

Such an approach requires a significant shift in nuclear detection philosophy. In all areas of the GNDA the focus needs to move from responding to detections of radiation measured by individual detectors to responding to detections of threats inferred from measurements of systems of sensors and relevant data sources.

TARD has achieved significant success in developing new nuclear search capabilities and is developing plans to enhance surge capabilities. Both search and surge address some aspects of the GNDA gaps, but as the "transformational" branch of DNDO, TARD should also seek out more radical solutions that can provide continual monitoring of wide areas and perimeters. The planned proposal topic in "Threat Detection through Data Fusion, Informatics, and/or Non-Radiological Signal/Signature Exploitation" is a step in the right direction. But TARD should push more explicitly for new concepts that use "data fusion, informatics and/or non-radiological signature exploitation" to create continuous wide area and perimeter monitoring that provides significant threat detection capabilities with a cost-effective approach.

There are two new ATDs planned in this area. The Vast Array of Mobile Tracked Sensors (VArMTs) project could greatly enhance a surge type capability and would be useful for monitoring or searching for nuclear materials within a confined region during a specified time. The scope and scale of the VArMTs project should provide some major advances. TARD should consider broadening this effort to solicit solutions that could be practical and affordable for covering broader areas or perimeters with continuous coverage. Such a solution would be truly transformational.

However, the Radiological and Nuclear Detection Operational Model (RANDOM) proposed ATD appears to be much more incremental. While it may likely provide a much-needed capability, the focus on operations and consolidation, coordination, and validation of modeling tools might be more appropriately addressed within the Architecture Directorate.

There are two critical issues with the development of new algorithms, and TARD should do more to address them.

The first is to develop and institute methods and metrics to better compare algorithm performance. The second is to encourage, facilitate, and, in some cases, require stronger coordination with end users who intend to employ the capabilities under development.

Direct quantitative comparisons of performance of advanced algorithms are rare and often poorly understood. The metrics for comparison, and the conditions or data for comparison, are often not available. This can make evaluation of the actual improvement provided by new algorithms difficult to determine. As one of the primary sponsors in this area, TARD should consider providing metrics for comparison, including appropriate test data or measurement conditions that can be made available to all potential developers. Another approach would be to require proposers to include the metrics and evaluation criteria in their proposals and only fund projects that demonstrate an appropriate level of understanding of the required comparisons.

The second new algorithm issue is to encourage, facilitate, and, in some cases, require stronger coordination with end users who intend to employ the capabilities under development. More coordination with users can keep the development focused where it needs to be and provide a quick and direct way to move the new capabilities from R&D to the field. Advanced algorithms and models cannot impact nuclear security unless they are used. Performance-enhancing algorithms must be incorporated into detectors and systems that are used in nuclear security operations. Development tools need to be used by planners and other detection system developers, and simulation tools need to be used by planners and responders. DNDO should consider doing more to foster participation by users. For example, the most recent SBIR solicitation for the advanced radiation detection smart phone app included an explicit requirement that the proposer include a user group to review and advise on the design and plan for the project. This approach could be used in other solicitations. For ATD, there should be early involvement of potential users to help select topics and define requirements and metrics for comparison. Proposers could be required to develop their own user advisory panels. End users and stakeholders could be more involved in reviewing proposals and projects that are underway. As important as creating a new capability is, the goal of the project should be to develop an end product that will be deployed and used by at least one user. This is particularly true in the area of algorithm development, because often once an algorithm is fully developed and tested, it can be deployed immediately, without the additional time and cost needed to develop hardware for production, new procurements, and deployments.

TARD might also consider doing more to enhance communications among the algorithm developers. Development tools are really intended for other developers to use, but the capabilities and availability of these tools are often not well understood. Operational algorithms, simulations, and training aids can also be useful to other developers, and enhanced communications can help avoid duplication and provide more of a common ground for evaluation metrics, data, and procedures. TARD might consider having developers focused on algorithm development participate in reviews of other projects in the portfolio that could use those capabilities. Similarly, developers of hardware that could use advanced algorithms and modeling capabilities should participate in reviews of the algorithms projects.

As for the portfolio plan, the emphasis on data fusion with non-radiation sensors is excellent. Radiation detection is severely limited by weak signals, shielding, absorption in air, and limited discrimination from common benign sources. It has already been demonstrated that properly fusing non-radiation measurements can dramatically increase the ability of the system to sense nuclear threats. In addition to pursuing innovative solutions for continuous perimeter-wide area detection, TARD should consider adjusting the balance of the portfolio and the priority of releasing new solicitations to further emphasize data fusion, including non-radiation sensors and other information sources. With these thrusts – and more focus on metrics, end users, and sharing among developers – advanced algorithms and modeling can provide transformational solutions to the outstanding gaps in the GNDA.

C. Materials

OVERVIEW

DNDO maintains an active program focused on advancing its capability to detect ionizing radiation and neutrons. Strong emphasis is placed on both the improvement of existing materials and the pursuit and development of new materials that exhibit the potential for significant improvements in radiation detection. There are two primary detection categories of these materials: those that rely on direct charge collection (semiconductors, ion chambers) and those that are based on scintillation light emission (crystals, plastics, glass, liquids). The key performance criteria of radiation detectors, such as detection efficiency and energy resolution, are often limited by imperfections in the materials from which they are fabricated. Therefore, progress in improving the sensitivity and specificity of detecting threat sources is fundamentally linked to either the discovery of new detector materials or the improvement of the materials currently in use. It is appropriate that TARD is taking an active role in supporting the advancement of such materials with the goal of improving the capability of instruments that are essential in the sensing and identification of illicit transport of radioactive material and SNM.

A review of the GNDA Implementation Plan reveals a broad and active program of research and development in new radiation detectors and materials. There have been some notable recent advances brought about by efforts sponsored by TARD, including the availability of several new scintillation materials that have either offered better performance (energy resolution) or significantly lower cost. These have come after a several-decade period of relatively little progress in introducing new scintillators. To help overcome some of the limitations inherent in the growth of some large crystals, TARD has also sponsored successful work in the fabrication of some crystals in ceramic form. Much of this work is more evolutionary than revolutionary, but is important due to the dominance of the material limitations on overall detector performance.

Because the improvement of sensor materials is so fundamental to improving detection in general, DNDO is not alone in providing federal support in this area of research and development. Active programs in the advancement of detector materials are also maintained by NNSA (DOE NA-22) and DOD (DTRA). While each program emphasizes its own mission space, there is excellent coordination between these agencies to share fundamental progress and prevent duplication of efforts.

DISCUSSION

The discovery and development of new materials that could lead to better detector performance are not simple tasks. Although the continuing increase in computational power has been leveraged to guide complex compound material analysis and new material development through modeling of the atomic and molecular structure of families of candidate materials, the subtleties of energy and charge transport mechanisms are difficult to accurately predict. The development of novel semiconductor materials continues to be hampered by physical and chemical material property issues. Complex compound material interactions, molecular structure defects, material impurities, and process environmental factors all constitute significant obstacles to creating new detector materials. Thus, much of the progress in scintillator materials over the past decade has been realized through patient trial-and-error investigations requiring extensive experimental efforts.

Adding to the challenge is the need to grow large-volume crystals for the most interesting candidates, a process fraught with uncertainties and requiring substantial time and effort. Despite these difficulties, there has been remarkable progress in advancing the performance of scintillation detectors over the past 15 years (an improvement of a factor of two in energy resolution), and DNDO has played an important role. The recent commercial production of two new scintillation materials, SrI_2 and CLYC, is clear evidence of the success of past DNDO sponsorship. Nonetheless, unfulfilled goals remain that should continue to be pursued so that further improvements in scintillator performance, cost, and detector volumes may be realized.

Using any scintillator as a radiation detector requires a light sensor to generate an electrical signal. The traditional means, using a photomultiplier tube, has significant limitations, and there is strong motivation to replace this carry-over from vacuum tube technology with semiconductor-based light sensors. As articulated in the document Nuclear Defense Research and Development Roadmap, Fiscal Years 2013–2017 (Chapter 4 – Detection), TARD has been sponsoring investigations of silicon-based alternatives, but none have yet emerged as options for widespread utilization. If successful, this effort could be revolutionary in advancing the performance and resulting applications for scintillator detectors in the field. The efforts in this area should be continued (and possibly broadened to include other semiconductor materials), since the benefits, especially for portable instruments, would be substantial.

Finding new semiconductor materials that can operate at, or near, room temperature, in order to replace cryogenically-cooled germanium, has been a long-standing goal. Progress has been slower than in scintillation materials, due in part to the need for extremely high material purity and crystalline perfection to avoid trapping of charges as they are drifted over substantial distances in the material. Currently, the most successful room temperature material is cadmium zinc telluride (CZT), and DNDO has played an important role in its development and applications in gamma-ray spectroscopy. TARD is also a pioneer in the recent development of a newer material, thallium bromide, which offers promise as an uncooled alternative to germanium with enhanced detection efficiency. Many other compound semiconductors have been investigated in the past, including mercuric iodide, gallium arsenide, indium phosphide, lead iodide, and aluminum antimonide. For a variety of reasons that may include low carrier mobilities, high leakage currents, and difficulty in growing large crystals, none of these materials have yet achieved practical success in gamma-ray spectrometers.

However, there are additional wide bandgap semiconductors that remain unexplored and could be potential room-temperature substitutes for germanium. In every case, the physical properties of a candidate detector material should be subject to initial screening and evaluated for specific material characteristics prior to being considered for development. CZT has experienced significant success, much of which is due to improvements in electronics and signal processing techniques. However, material properties have improved only slowly, with optimized growth techniques leading to some reduction in crystal defects. High-purity germanium (HPGe) and silicon semiconductors are premier, high-resolution detector materials, due to a shared, unique quality – an indirect bandgap that allows long-charge carrier lifetimes. The search for alternative semiconductor materials should favor candidates that share this property. Additional desired properties include cubic crystalline structure to favor growth of large crystals and allow possible production in ceramic form, and the absence of elements such as Lu and La with naturally radioactive isotopes. It is reasonable to assume that any new material development will be a lengthy activity, though the high potential benefit of such materials may moderate the risk.

To advance the capabilities and increase the application space of existing detection technologies, furthering the development of supporting technologies (e.g., analog and hybrid electronics, signal processing, advanced data harvesting, pattern recognition, real-time analysis) is strongly encouraged. The significant increase in CZT applications is a clear example of the effects of technology advances. Similar advances in a solid state replacement for photomultiplier tubes would have a dramatic effect on the utility of existing and new scintillator materials for numerous applications relevant to the DNDO mission. The ongoing series of ER projects in this area should be strongly supported. In addition, the accelerating advances in processing power should be harnessed in the creation of real-time, high-speed signal and data processing, as well as the development of advanced analysis algorithms (e.g., data fusion, informatics, signal/signature exploitation) that require extreme processing power for implementation.

Materials for neutron detectors have undergone a recent flurry of activity because of the disappearance of practical sources of ^{3}He, the near-universal component of traditional neutron detectors. Since commercial vendors have been quite successful in marketing acceptable substitutes for the important application in portal monitors (see elsewhere in this report), the need for DNDO to fund a large-scale effort for panel development is diminished. Nonetheless, there is still a need for innovation for the improved design of compact neutron detectors with good gamma-ray discrimination for use in hand-held, backpack, or similar systems. Recent significant advances in electronics and signal processing have enabled the use of liquid scintillators in field applications. Additionally, new plastic scintillator materials with pulse shape discrimination capability have been developed recently and are advancing rapidly. These areas should be leveraged into new portable detection capabilities and are particularly relevant to alternative neutron detection applications.

OBSERVATIONS

It would appear that the primary focus of radiation detection for most DNDO applications is related to the broad search mission, though the portfolio of materials research does not always support this mission. Driven by the inverse square law, search activities require efficiency above all other characteristics, and energy resolution may become less important. Sodium iodide (NaI) detectors can address many of the needs for search and are mature, inexpensive, and commercially available in a wide selection of size and quantity. When pursuing alternatives for search applications, priority should be given to candidates that offer the possibility of scaling to large size at a competitive cost.

The time and expense of developing a new material is significant, so focusing on materials with exceptional payoff potential should be a high priority. Incremental advances in capabilities, or investment in the development of alternative materials with characteristics similar to those that already exist, dilute available resources with no benefit to the mission. Additionally, a collaborative approach between synergistic organizations (e.g., federal security (NOTE: 'federal security' is the appropriate phrase, cf, e.g., [https://www.ida.org/upload/stpi/pdfs/p-4916-final-12-12-12.pdf] (IDA's Nov 2012 Study of Facilities & Infrastructure Planning, Prioritization, and Assessment at Federal Security Laboratories.) laboratories, academia, and industry) that collectively possess the experience and expertise necessary to pursue the research, development, and commercialization challenges is essential. The SBIR and ARI activities address some of this methodology and should be continually evaluated to ensure focus at the project level.

As a final note, many general terms such as "low cost," "large volume," and "high resolution" are used without definition or relevance. For example, a 1cm cube detector is not a large volume when considering a search operation, though it may be large when compared to other similar technologies. The concept of "low cost" is also relative, as most projects articulated in the GNDA Implementation Plan describe unique processes and/or materials that, in general, do not have an intrinsically large market. Small, limited markets typical in this field do not allow for the development and production cost amortization that is normally realized in large-scale manufacturing, resulting in relatively high cost per unit. In most cases, the detector material is not the cost driver of a system. In addition, intellectual property will often result in proprietary ownership of a product and the resulting sole-source supply environment that drives up costs (i.e., in the case of LaBr). In summary, the terms used to describe the characteristics of the candidate materials or related projects should be well defined and clearly articulated to manage expectations.

Observation: TARD has engaged in the pursuit of many new materials. A few candidate materials have shown potential for improved energy resolution performance over existing materials.

- **RECOMMENDATION:** Though these improvements are noted, they are incremental and may not substantially increase detection capabilities due to limited volumes and resulting small efficiencies. Strong emphasis should be placed on high-risk, high-payoff R&D on materials with the potential for revolutionary increases in capability.

Observation: TARD is aware that high cost is often a barrier for widespread introduction of sensors based on new materials. Several planned activities have the reduction of costs as their goal through alternative methods of crystal growth or other means.

- **RECOMMENDATION:** In examining the properties of candidate materials, their attractiveness for applications outside the DNDO world should not be overlooked. Opening other markets would help reduce costs for all users.

Observation: TARD's past efforts to develop solid state alternatives to the vacuum photomultiplier tube (PMT) for the readout of scintillators have not yet led to a successful solution.

- **RECOMMENDATION:** Because PMTs remain a substantial encumbrance to the convenient use of scintillation detectors, the search for solid state replacements should be given high priority.

Observation: The rapid pace of microelectronic development has opened possibilities of improving the performance of traditional sensors through digital pulse processing or the ASIC-based readout of multiple channels.

- **RECOMMENDATIONS:** TARD should remain receptive to proposed improvements in low-noise ASICs as a potential low-cost means to improve the performance of existing materials.

POTENTIAL FUTURE PROJECTS

The following comments on concepts for materials research being considered by TARD for FY13 and beyond.

- Commercial scale production techniques or other approaches for very low-cost detector materials

Reducing the cost of detector systems through enhanced production techniques is interesting, but may be difficult to achieve. In many cases, the cost of the sensor may be only a small fraction of the total system cost. Additionally, radiation detection is a relatively small industry, and mass production will not likely result in quantities that would benefit from scale.

Recent discussions with a major producer of HPGe detectors indicated that the most likely path to reducing production costs would be to eliminate the human element in the manufacturing process. However, the large cost of implementing an automated processing capability would need some up-front, multi-year guarantee of a continuous large volume purchase.

- Advances in the use of Thallium Bromide (TlBr) crystals for gamma radiation detection

Thallium bromide is a promising wide bandgap material that has several properties that are attractive as a gamma ray spectrometer. The high atomic number of thallium results in a stopping power for the material that is superior to the currently available alternatives. Some samples have demonstrated very good electron collection efficiency, necessary for good energy resolution. The material's performance is hampered by an inconsistency in the quality of the crystals that can be grown and by a phenomenon known as polarization. Work is underway to improve the crystal growth process and to understand the causes of the polarization behavior. If these limitations can be overcome, thallium bromide could become a viable room-temperature alternative to germanium for applications not requiring large volumes.

- Improved solid-state readout devices for scintillators and approaches for extremely low-cost monitoring for radiological and nuclear threats

Of all of the ER projects, this activity has the greatest promise for significant benefits. Scintillators are a mature technology, but are limited by the capabilities and performance of photomultiplier tubes (PMTs) and avalanche photodetectors (APDs). A solid-state, high-gain, and highly sensitive replacement with similar characteristics to PMTs would have immediate impact and directly benefit not only DNDO, but also every other scintillator-based detector application in existence. This activity is strongly supported and should be given very high priority.

- High purity precursor materials for growth of large single crystals

Material purification is a continuous pursuit of all detector manufacturers, and it is not clear what this activity can contribute. For example, germanium is the most processed and by far the purest material in this field, yet crystalline imperfections remain an issue. As the quality of starting materials is a primary aspect of the production process, any advances will contribute to better detector production. However, crystal growth has many variables, of which material purity is only one. While this investment may help, it should be determined if it can lead to advances that cannot be obtained by existing production development activities.

D. Nuclear Forensics

As defined by the National Technical Nuclear Forensics Center (NTNFC) of the Domestic Nuclear Detection Office (DNDO), "Nuclear forensics is the thorough collection, analysis, and evaluation of radiological and nuclear material in a pre-detonation state and post-detonation radiological or nuclear materials, devices and debris, as well as the immediate effects created by a nuclear detonation. Nuclear forensics conclusions, fused with law enforcement and intelligence information, may support nuclear attribution – the identification of those responsible for planned and actual attacks. A nuclear attribution capability is necessitated by the proliferation of nuclear technology, materials, and the existence of nations and terrorist groups who may attempt to intimidate or defeat the United States and its allies through the coercive or actual use of nuclear or radiological weapons." [14]

The nuclear forensics mission of the U.S. has been divided into what are termed pre-detonation and post-detonation forensics. While the NTNFC is charged with "centralized planning, integration, assessment and stewardship of the nation's nuclear forensics capabilities to ensure a ready, robust and enduring capability in coordination with the federal departments and agencies who have assigned responsibilities for NTNF (National Technical Nuclear Forensics)," it is specifically charged only with the mission "to advance the capability to perform nuclear forensics on nuclear and radiological materials in a pre-detonation (intact) state." [14]

Pre-detonation nuclear forensics involves measurement of all properties of a material that can be used to identify its source or origin, including the means by which it was prepared, processed, and purified. The use of such data in the attribution process relies on the development and understanding of signatures associated with all materials and processes that can provide key information on where, when, and by whom a particular material was produced. The development of signatures requires a deep understanding of all of the processes involved, and, in many cases, requires the development of correlations between minor and trace elemental impurities that might be characteristic of specific processes. With respect to plutonium, for example, the isotopic composition of a sample can be used to limit the range of conditions that could have been used for its manufacture. Knowledge of the various processes by which the plutonium could be separated from the irradiated fuel, and the different chemical materials that could have been used in the separation processes, can lead to further unique or limiting information that can be of great significance in the attribution process.

The nuclear forensics portfolio of TARD is focused on "identifying ways to improve the measurement techniques and methodologies used to determine specific characteristics of material processing history, geographic origins, transport pathways, and intended use," and "improving the evaluation of measured data to compare against models or archived data." [15]

The majority of nuclear forensics programs supported by TARD have been under the ER program and the remainder supported under the ARI program. They have been directed toward computational methodology, analytical developments, and some data acquisition. However, due to budget reductions in FY12, and following consultation with the NTNFC, TARD ended funding for the nuclear forensics portfolio. All projects "are being allowed to finish their current phase and then be placed on hold or ended. Some projects will continue into FY13 and could receive further support depending on funding availability and priority." [15]

DISCUSSION

The nuclear forensics portfolio of TARD [15] is focused on:

- Improvement in measurement techniques and methodologies for determining material characteristics, the processing pathways to which they were subject, and, for establishing history, geologic origin and transport pathways.
- Improving the evaluation of measured data to compare against models or archived data.

In particular, key issues are the development of robust signatures that can give direct information on one or more of the characteristics listed above or which, in combination with other measured properties, significantly limit the range of processes or pathways that must be considered.

During 2012, the nuclear forensics portfolio comprised five exploratory research programs and five academic research initiative programs. Of these, six were associated with analytical methodologies and four were associated with signature development. Of the latter, however, only one was directly concerned with a search for new signatures or correlation of properties.

Assuming improved funding beginning in FY13, TARD expects to concentrate on the following activities, as identified in the Nuclear Defense R&D Roadmap:

- Analytical Methodologies: Improve the performance of analytical techniques by reducing uncertainties through improving instrument efficiencies and thresholds.
- Signature Development: Refine mathematical tools to analyze large and complex sets of data in ways that identify patterns, trends, and degrees of similarity.

TARD will also concentrate on the following Grand Challenges:

- Predictive Signatures: Build a complete "end-to-end" predictive capability that would use modeling and benchmark measurements to assess how the full suite of process steps in the fuel cycle impart or modify material signatures in bulk samples.
- Recent Provenance: Develop ways to trace the recent physical environment where a material sample has been located so as to improve the capability to assess potential locations worldwide that could be the source of the material.

All of the activities noted above are worthy endeavors. While it is unlikely that the Grand Challenges will ever be fully met, there is a pressing need for developing the types of signatures, including recent provenance, which will cover as wide a a range of properties as possible. Signature development in the broad sense appears to us to be of the greatest importance. Whether simple or complex, signature development requires not only a deep understanding of methods, processes, and materials, but also a wide range of experimental data sets from which signatures may be developed or predictive models tested. Improvement in performance of analytical methodologies is always of interest, but significant expenditures should be concentrated on developments for which it is clear or highly likely that the current state-of-the-art is seriously lacking in one or more important property. The Committee cautions against extensive investment in attempting to model the entire nuclear fuel cycle at the expense of increasing the experimental data for reference libraries. Attempting to model the nuclear fuel cycle would, of necessity, include all possible variations in ores and materials and all possible conditions of reactor irradiations. Similarly, expenditures on refinement of mathematical tools should be judged relative to the needs for expenditures on data acquisition.

Observation: At the present time, it is not possible to clearly define the state of our ability to provide complete pre-detonation nuclear forensics information into the attribution process because of the enormity of the general problems that are posed. For any material of interest, one would likely need to understand the origin and processes through which it passed. There is not yet either the extensive library of nuclear materials and their properties or the research needed to uncover robust signatures that are unique to the origin and pathways of all materials. It is likely that the information available in some areas is insufficient even to limit origins and pathways to a narrow range of possibilities.

- **RECOMMENDATION:** TARD should return to funding research and development programs focused on signature identification, understanding of signature transport through the fuel cycle, and detailed experimental measurements on materials of interest in order to develop libraries for comparisons with unknowns and for development of correlations and comparison with model computations that might lead to signature development. [16]

Observation: The separation of the forensics mission into pre-detonation and post-detonation is artificial in many respects. Many methodologies that can be used to good effect are often the same or very similar in both pre- and post-detonation forensics. Many results from materials analysis are useful in both endeavors. If funding interruptions occur, the loss of funding support by a single agency can have significant repercussions on the progress of specific programs of general importance.

- **RECOMMENDATION:** Any artificial divisions that currently exist between the pre- and post-detonation missions should be removed. Joint decisions between relevant agencies should be accomplished to ensure a continuous and well-funded overall program. Centralizing the responsibility for pre- and post-detonation forensics within one government organization may be the best path for securing an enduring and capable nuclear forensic capability for the long term.

As noted above, many of the methodologies used, and results obtained, in pre-detonation nuclear forensics also apply to post-denotation forensics. Thus, research and development in areas such as nuclear and radiochemical analyses and mass spectrometry can benefit both endeavors. In addition, the personnel and equipment that can be used in the research are often the same. Accordingly, with limited resources very close cooperation between the various agencies is required to ensure continuous funding for promising programs and to ensure that weaknesses or needs are identified and managed. The loss of funding support by a single agency can have significant repercussions on the progress of specific programs.

E. Radiation and Neutron Detection

The TARD efforts in radiation detection include the Passive Radiation Detection Portfolio and the Neutron Detection Portfolio. These portfolios are addressed individually below.

PASSIVE RADIATION DETECTION PORTFOLIO

The Passive Radiation Detection Portfolio has as its objective the development of detection systems that provide higher sensitivity and specificity, thereby reducing false or nuisance alarm rates through improved discrimination of threat materials from benign materials and natural background. The portfolio also includes the development of systems that enable stand-off detection of threats.

Novel system approaches are required to provide substantive improvements in the ability to detect, locate, identify, and characterize threats across various Global Nuclear Detection Architecture (GNDA) domains, pathways, and mission areas. Techniques emphasize gamma-ray imaging approaches and enabling technologies, such as sensor fusion and machine vision.

CURRENT PROJECTS

The current Passive Radiation Detection Portfolio activities include advancements in gamma-ray imaging, sensor fusion/machine vision, and other passive detection approaches. A total of 19 projects, with a combined budget of $7.8M, comprise the FY12 research. This budget is reduced from the FY11 budget of $14.2M, but is commensurate with the overall TARD budget reduction in FY12. The 19 projects include nine ER, eight ARI, two ATD, and no SBIR projects. The two ATD projects represent more than 70% of the FY12 Passive Detection budget. This dominance of the ATD program in FY12 was a significant change from the FY11 portfolio, in which the ATD research was approximately 28% of the budget, and is indicative of the fact that the TARD budget reductions in FY12 came largely from the ER and ARI program elements.

The two ATD projects are continuations of research begun in FY11 and include a second pass at stand-off radiation detection, the Long Range Radiation Detection (LRRD) project, and the Airborne Radiological Enhanced Sensor System (ARES) project, a demonstration of advanced technologies for airborne detection. LRRD incorporates improved algorithms for detection to two of the SORDS ATD systems and provides additional characterization and improvements for the Road Side Tracker (an earlier ER). The objective of these ATDs is to improve detectability and reduce nuisance or false alarms through background characterization algorithms, imaging, sensor fusion, and machine learning.

The ER and ARI projects address a wide range of topics, including new position-sensitive semiconducting detectors; new imaging systems, such as improved Compton imaging, dual neutron-gamma imaging and liquid Xenon imaging; and the application of background characterization, modeling, and situation awareness to improved detection and location of radiological threats.

ACCOMPLISHMENTS

The accomplishments of this portfolio include:

- Completion of Standoff Radiation Detection Systems (SORDS) ATD and Roadside Tracker, with important findings on concept of operations and system performance.
- Target-Linked Radiation Imaging (TLRI) for standoff detection successfully integrated video analytic algorithms with radiation imaging algorithms, and demonstrated real-time motion-compensated imaging with full-size vehicles.
- Initiation of the process to upgrade and obtain the Mobile Imaging and Spectroscopic Threat Identification (MISTI) detection system in order to demonstrate "Nuclear Street View" and to perform systematic radiation background measurements.
- Completion of an Exploratory Research (ER) and Academic Research Initiative (ARI) grant focused on Compton electron tracking.

FY13 PLANS

The Passive Detection Portfolio has the following proposed research efforts:

- ER & ARI: Scientific and engineering approaches for extremely low-cost monitoring for radiological and nuclear threats. Research in this program encompasses new materials integrated with advanced electronics, new detector configurations, and specialized algorithms to greatly improve passive sensing, with emphasis on simultaneously improving detection sensitivity and specificity while minimizing operational burdens associated with employment of these systems.
- ER & ARI: Integrated threat detection with emphasis on data fusion, informatics, and/or novel signature exploitation. Research in this area explores radically new approaches to threat detection. This includes research into new detection system concepts, approaches, and architectures that can support detection of radiation and nuclear threats being transported via general aviation, small maritime craft, and/or across land borders between official points of entry. The capabilities of radiation imaging and modeling of threat detection environments to improve detection are to be examined.
- ATD: Mobile Radiation Imaging and Tracking System (MRITS) will integrate lessons learned from RST, SORDS, TLRI, and LRRD in a single mobile system. This device could be used in multiple applications, such as urban search, long-range monitoring between ports of entry, multi-lane vehicle inspection, mobile replacement for fixed portals, and special event monitoring.

This program is supported by a proposed FY13 budget of $21.7M, a significant increase from $7.8M in FY12. As in FY12, more than 70% of this funding is invested in ATD projects: continuation of the LRRS and the ARES projects as well as the start of the Mobile Radiation Imaging and Tracking System ATD. Most of the remaining increase in funding for FY13 has been allocated to the ER program element.

The anticipated FY13 Continuing Resolution (CR) will impact this proposed plan. TARD has indicated that it will not solicit any new ARI, ER, or ATD proposals until a FY13 budget has been passed. TARD expects a delay of up to five months in the planned release of ER and ARI solicitations and a four-month delay in the release of the MRITS ATD.

Observation: To date, none of the research activities in the Passive Detection Portfolio have advanced beyond the demonstration stage to wide-scale manufacturing and deployment. It is clear that the ATD projects are attempting to develop systems with significantly improved detection capabilities over existing systems. However, these new capabilities will likely require new concepts of operations for the users. TARD has learned this lesson with the LRRD program and has modified its development program to include user operational test events and more feedback from users.

- **RECOMMENDATION:** TARD should work more closely with the user community and the DNDO Product Acquisition Division in developing ATD Concept of Operations and metrics.

Observation: Algorithm developments are being applied to passive detection systems with the expectation and demonstration of improved recognition of threat sources. These developments train the algorithm on the background and its variability over an operational region. In the context of surge deployments, it is not at all clear how well these new algorithms will operate when the training has not been performed in the surge location.

In the design and development of radiation detector systems, the increasing role of "surge" capability should not be overlooked. For example, high-purity germanium (HPGe) detectors are the "gold standard" for gamma-ray spectroscopy, but have characteristics that hinder their rapid deployment. They must be cryogenically cooled, requiring either a bulky Dewar flask of liquid nitrogen or a mechanical cooler. These systems, normally stored at room temperature when not in use, must be at cryogenic temperature for operation. The cool-down period can be as much as eight hours or more, during which the system cannot be used. Also, some alternative semiconductor spectrometers under investigation require a period of hours or days following turn-on before their gain stabilizes sufficiently to allow their practical use. Such delays could be an important disadvantage for some operational scenarios. These considerations add priority to the development of improved semiconductor spectrometers that can operate at room temperature and can also be deployed immediately. One possible alternative is to constantly maintain the detectors in standby with applied voltage while not in use.

- **RECOMMENDATION:** TARD must understand the "surge" concept of operations and assess its impact on the detection systems and capabilities it is developing.

Observation: In one study sponsored by DNDO, the effect of varying energy resolution on the volume of detector required for positive detection of threat objects at a distance was examined. The study concluded that improvements beyond an energy resolution of about 1% (measured at 662 keV) led to only incremental gains. Although this conclusion may be valid for the cases studied, it should be viewed with caution. For the simple case of a weak line source superimposed on a strong continuum background, it can be argued that any improvement in energy resolution will always improve detectability of the corresponding peak in the detector pulse height spectrum.

- **RECOMMENDATION:** Because some scenarios involving large standoff distances involve weak line sources in strong backgrounds, it is important to continue the quest for energy resolution improvements beyond 1% in gamma-ray spectrometer development. To date, high-purity germanium (HPGe) detectors provide the highest standard in energy resolution, ~ 0.3% at 662 keV, but their high cost and cooling requirements inhibit their use in many important applications.

Observation: One branch of remote detection and identification of threat sources is based on passive imaging systems, either for gamma rays or for neutrons. Producing a spatial map of detected sources of radiation within the instrument's field of view extends the available information beyond a simple counting rate or spectroscopy measurement. How useful this additional information is depends on the application. Because passive imaging systems usually sacrifice overall detection efficiency compared with an equivalent non-imaging detector, there can be trade-offs that affect performance. Several immediate benefits of imaging are obvious. If the scenario involves only one or a few point-like sources, then an image will reveal the source directions relative to the detector. Furthermore, the surrounding areas in the image show the background, allowing a quantitative measure of the events due only to the source(s). Subtraction of background is a difficult task for non-imaging sensors, since its contribution can vary substantially from one location to another. Linking an optical image to the corresponding radiation image greatly facilitates the tracking of moving objects, such as a vehicle or boat. Although many of the benefits of imaging are intuitively apparent, a thorough quantitative study of the gains they bring to common scenarios has not yet been demonstrated. However, there is clearly enough potential to justify continuing or increasing support for the refinement of imaging systems for both gamma rays and neutrons.

- **RECOMMENDATION:** TARD should continue the development of detection systems with multi-sensor situation awareness.

Observation: Radiographic imaging systems based on X-ray and gamma ray sources are widely used by Customs and Border Protection (CBP) for imaging the contents of containers and vehicles to screen for contraband and to locate shielding that might conceal a radioactive source. Radiographic imaging and passive radiation detection are highly complementary and when combined, provide a rigorous method for detection of most threats. Since the radiation dose from currently deployed systems is above that allowed for public exposure, such imaging is performed only in secondary screening for alarming or targeted vehicles. The projects supported by TARD and other divisions of DNDO have all been directed at larger, dual-energy systems, whose application regime is the same as currently deployed imaging systems. It would be highly beneficial to develop an imaging system that could be utilized in primary screening on all vehicles currently screened passively. This would require the development of ultra-low dose systems, defined as having background radiation levels of ~1mR per scan, for use in primary screening. Such a system would remove public health as a concern. Some low-dose systems have been studied at National Laboratories, and it would be worthwhile for TARD to support the development of such systems.

- **RECOMMENDATION:** TARD should support an effort to develop an ultra-low dose radiography system, where "low dose" is defined as a background radiation level for primary screening of ~1mR per scan.

Observation: One area of detector development not currently supported by TARD involves improvements to the currently deployed polyvinyl toluene (PVT) detector materials. While other divisions of DNDO may be modestly funding some efforts in this area, there are substantial research and development improvements that could be made, both in the materials and algorithms. The reality is that the bulk of the radiation interdiction capability of the U.S. will continue to be based upon PVT for the foreseeable future. Developments should be supported starting at the basic materials level to improve efficiency and resolution of PVT, and to understand the observed aging effects that are unique to the operational environments for instruments deployed by DNDO. While more than a dozen algorithms have been proposed for improving PVT-based systems, no systematic study has been conducted of the benefits and shortcomings of the proposed methods. Such a study should be performed.

- **RECOMMENDATION:** TARD should support a significant effort to enhance the capability of PVT-based detectors and better understand the impact of environmental effects on performance.

NEUTRON DETECTION PORTFOLIO

OBJECTIVE

The current Neutron Detection Portfolio has the mission to provide detection, identification, and location of neutron sources with improved efficiency, gamma ray rejection, size, power, voltage, robustness, and cost. This includes development of near- and long-term alternatives to ^{3}He for portal, backpack, handheld, and personal applications; development and characterization of materials with dual gamma-neutron detection; and investigation of the benefits of fast versus thermal detection capabilities. The near-term focus of the program has been to provide replacements for portal-sized ^{3}He detector systems. That has been accomplished.

CURRENT PROJECTS

Current projects include efforts for radiation portal monitor alternatives to ^{3}He (projects ended in FY12), alternatives to ^{3}He for hand-held detectors and backpacks, compact detectors (small solid state devices), and fast neutron detectors. A total of 26 projects with a combined budget of $4.1M comprise the FY12 research. This budget is reduced from the FY11 budget of $7.8M but is commensurate with the overall TARD budget reduction in FY12. The 26 projects include ten ER, seven ARI, nine SBIR, and no ATD projects.

The major emphasis of the FY12 program has been on technology for portal-sized neutron detection systems as replacements for current ^{3}He detectors. Six projects were investigating a wide array of technologies: $^{6}LiF/ZnS(Ag)$/wavelength shifting fiber designs, ^{10}B-coated straw proportional counters, GEM avalanche detectors, nanoparticle-based planar pixelated detector, planar multi-layer tiled ^{10}B-coated electrode detector, and planar multi-wire ^{6}Li-foil proportional counter. The $^{6}LiF/ZnS$ (Ag) and ^{10}B-coated straw designs are now successfully being commercialized. The other technologies need more development and testing.

The medium-sized neutron detection systems—backpacks and handhelds—are the next priority for ^{3}He replacement. The neutron portfolio currently supports five projects in this area. Technologies investigated here include $^{6}LiF/ZnS(Ag)$/wavelength shifting fiber designs, $^{10}B/Gd$ doped microchannel plate detectors, Cs_2LiYBr_6 (CLYB) scintillators, and systems utilizing Cs_2LiYBr_6:Ce (CLYC) scintillator in support of the ARMD ATD program. A key consideration in these systems is gamma-neutron discrimination.

Eight other projects in the portfolio address the development of compact, semiconductor detectors for low-power, wearable detection units. Materials under study include B_2Se_3, $LiInSe_2$, B_6P, hexagonal BN, and 3-D structured ^{10}B-filled silicon diodes.

Fast neutron detection is addressed in seven additional projects focused on fast, high-count rate, large-area detectors for Active Interrogation environments with high gamma backgrounds. Consequently, large areas, gamma-blindness or good pulse shape discrimination, and capture-gated operation are key performance metrics.

ACCOMPLISHMENTS

The portal-sized ^3He alternative detector systems have been successfully commercialized. Non-^3He RPM panel replacements are now available. Consequently, all ER and SBIR activities in portal-sized detectors are ending this year.

The ER low-volume production of CLYC that provides dual neutron and gamma detection provided a continuing source of detectors for the ARMD ATD program.

FY13 PLANS

The Neutron Detection Portfolio has the following planned activities:

- No future activities are planned addressing ^3He replacements for radiation portal monitors. The focus will be on cost-effective, smaller-sized form factors to include backpacks, handhelds, and personal detector applications.
- Test campaign activities will continue in 2013 with the Government Sponsored Backpack, Handheld, and Vehicle Mounted (GBHVM) Neutron Detection Replacement Program Government Independent Test Campaign.
- The first ATD under this portfolio will be initiated in FY 2013 on a Portable Advanced Neutron Detector (PAND). The objective of this ATD is to develop a small, modular device for portable applications, either handheld or wearable, with potential to replace ^3He tubes in commercially available detectors.

The proposed FY13 budget for the neutron portfolio is $9.0M, $5.0M of which is allocated to the PAND ATD project. The ER and ARI program elements continue at approximately the FY12 allocation.

The anticipated FY13 Continuing Resolution (CR) will impact this proposed plan. TARD has indicated that it will not solicit any new ARI, ER, or ATD proposals until the FY13 budget has been passed. TARD expects a delay of up to five months in the planned release of ER and ARI solicitations, and the CR will result in a one-month delay in the planned release of the PAND ATD.

OBSERVATIONS

The neutron detection portfolio is appropriately redirecting its activities toward alternatives to ^3He for smaller systems, since the radiation portal monitor requirement for alternatives has been addressed by the collective effort of the community. The projects in the ARI and ER areas are addressing a wide range of alternative approaches. It is unclear whether the proposed PAND ATD will have an outcome that, if too narrowly focused, will be of benefit beyond what the industry can currently deliver.

This concludes discussion of the six TARD focus areas: shielded nuclear material detection; algorithms and modeling; materials; forensics; radiation detection; and, neutron detection.

Appendix

A. Review methodology

In early CY2012, the Transformational and Applied Research Directorate (TARD) of the Domestic Nuclear Detection Office (DNDO) approached the American Physical Society (APS) about providing a technical review of the TARD research program and possible new directions. The APS Panel on Public Affairs (POPA) is the component of the Society that conducts studies and creates reports on areas of science that overlap the public interest. POPA agreed to participate in the review and suggested that the Institute of Electrical and Electronics Engineers (IEEE) and its Nuclear and Plasma Sciences Society (NPSS) be included to provide a broader range of expertise. The review was conducted by a team of scientists and engineers from both the APS and the IEEE.

COMMITTEE MEMBERSHIP

Robert Borchers	Maui High Performance Computing Center
Jill Dahlburg	Naval Research Laboratory
John Donnelly	District of Columbia, Fire & EMS
Adam Isles	The Chertoff Group
Neil Johnson	Naval Research Laboratory
Glenn Knoll	University of Michigan
Richard Kouzes	Pacific Northwest National Laboratory
Richard Lanza	Massachusetts Institute of Technology
Anthony Lavietes	International Atomic Energy Agency and IEEE Lead
James Lund	Sandia National Laboratories
Stanley Prussin	University of California, Berkeley
James Trebes	Lawrence Livermore National Laboratory and APS Lead

Additional APS staff participating in the review included:

Francis Slakey	Associate Director of Public Affairs
Jodi Lieberman	Senior Government Relations Specialist
Jeanette Russo	POPA Studies Administration Specialist

REVIEW PROCESS

The process was executed through the following sequence of events:

- A subset of the Committee members attending two nuclear detection conferences to accumulate relevant background information from TARD ARI project presentations
- Conducting two focused workshops with the full Committee
- Conducting focused analysis by individuals and small groups of Committee members

The conferences attended were the IEEE 2012 Symposium on Radiation Measurements and Applications in Oakland, CA, May 14-17, 2012, and the 5th Annual Academic Research Initiative Grantees Conference in Leesburg, VA, July 23-25, 2012. These conferences enabled committee members to see a wide range of relevant R&D sponsored by DNDO, TARD, and other organizations. This also allowed committee members to meet with and talk with a number of active researchers and get their perspectives on multiple issues, and on possible R&D future paths.

Discussions on interagency coordination were held by various committee members with representatives from DTRA, DNDO, and NNSA. Additionally, discussions on multiple topics were held with GAO.

The Committee held two workshops to generate detailed insights into the TARD research program. The first workshop took place at DNDO headquarters and consisted of one day of detailed briefings presented by DNDO personnel. Topics included an overview of the DNDO organization and the missions and functions of its components, including TARD. These briefings were followed by a review of TARD research and development programs, including potential new directions for fiscal year 2013. Immediately following this workshop, a second half-day classified overview of the Global Nuclear Detection Architecture was provided to the Committee. A key aspect of TARD's mission is to develop technical solutions to address gaps and needs of the GNDA. A comprehensive understanding of the GNDA is essential for understanding how well TARD translates GNDA requirements into programs and projects.

After this workshop, the Committee split into 2-3 person groups to review the TARD components in more detail and to consider future possible directions. This activity was followed by a second workshop, held at the National Conference Center in Leesburg, VA, that focused on the current TARD research programs. The workshop included a number of invited speakers who presented material on topics that contributed to future areas of research and issues affecting TARD. The topics included:

1. Detection of shielded nuclear materials
2. Information science
3. Operational constraints
4. Radiation detection at the U.S. borders
5. Nuclear terrorism deterrence
6. Surge concepts
7. Forensics
8. Interagency coordination

Funding for the review was provided by the APS, the IEEE, and by some of the Committee members' home organizations. The meeting room at the National Conference Center was provided by DNDO as an extension of the ARI Conference.

REVIEW PROCESS TIMELINE

February 3, 2012	DNDO TARD requests APS POPA conduct review. APS POPA National Security sub-committee begins creating proposal for review
April 12, 2012	APS POPA approves conducting review
April 19, 2012	IEEE NPSS approves conducting review
May13-17, 2012	Multiple APS/IEEE Study Committee Members attend IEEE Symposium on Radiation Measurements and Applications Conference to review multiple DNDO TARD funded project presentations
May 29-30, 2012	DNDO TARD provides initial briefings, including overview of DNDO, GNDA, and the current TARD R&D portfolios
July 23-25, 2012	Multiple APS/IEEE Study Committee Members attend DNDO/NSF Academic Research Initiatives Conference to review multiple DNDO TARD funded project presentations
July 26-27, 2012	APS/IEEE conducts discussion session with DNDO TARD on current and proposed R&D activities and on possible new areas of R&D
August-September	APS/IEEE creates review report
October 1, 2012	Draft Review report submitted to DNDO for comment and to APS and IEEE for review and approval

WORKSHOP AGENDAS

The first workshop was an introductory meeting for the APS and IEEE study panel on the Domestic Nuclear Detection Office Research and Development Strategy, held at DNDO Headquarters. The agenda for the first workshop was as follows:

Agenda for May 29, 2012

8:30-9:00	**Check-In**	**Washington**
9:00-9:10	**Welcome/Introductions**	**Rynes**
9:10-9:20	**Director's Priorities**	**Stern**
9:20-9:40	**APS / IEEE Study Overview**	**Trebes**

Part One: DNDO Deep Dive

9:40-10:00	**DNDO Overview**	**Koeppel**
10:00-10:30	**Architecture and Planning Directorate (APD)** *Global Nuclear Detection Architecture (GNDA) Overview*	**Bernard**
10:30-10:45	**Break**	
10:45-11:00	**National Technical Nuclear Forensics Center (NTNFC)**	**Ulicny**
11:00-11:15	**Systems Engineering and Evaluation Directorate (SEED)**	**Wright**
11:15-11:30	**Red Teaming and Net Assessments (RTNA)**	**Oliphant**
11:30-11:45	**Operations Support Directorate (OSD)**	**Magrino**
11:45-12:00	**Product Acquisition and Deployment Directorate (PADD)**	**Pardue**
12:00-1:00	**Lunch**	

Part Two: R&D Overview

1:00-1:30	**Transformation and Applied Research Directorate**	**Rynes**
1:30-3:00	**Advanced Technology Demonstrations (ATD)**	
	1. Advance Radiation Monitoring Device (ARMD)	*Kuhn*
	2. Long Range Radiation Detection (LRRD)	*Vojtech*
	3. Airborne Radiological Extrasensory System (ARES)	*Kuhn*
	4. Intelligent Radiation Sensing System (IRSS)	*Ashenfelter*
	5. Shielded Nuclear Alarm Resolution (SNAR)	*Moon*
	6. Nuclear and Radiological Imaging Platform (NRIP)	*Rynes*
	7. Future ATDs	*Kuhn*

3:00-3:15	**Break**	
3:15-4:45	**Research Portfolios**	
	8. Materials Development and Supporting Technology	*Janos*
	9. Neutron Detection Including He-3 Replacements	*Giles*
	10. Radiation Detection Techniques	*Wrobel*
	11. Shielded Threat Detection Techniques	*Moon*
	12. Algorithms and Modeling	*Ashenfelter*
	13. Nuclear Forensics	*Jankowski*
	14. Future R&D	*Wrobel*
4:45-5:00	**Wrap-up**	

WORKSHOP AGENDAS

The second workshop was a two-day meeting for the full Study Committee, held at the National Conference Center in Leesburg, VA. The agenda for the second workshop was:

APS-IEEE DNDO Study Committee, Workshop II: Leesburg, VA – National Conference Center

July 26, 2012

8:00-8:15 AM	**Introduction – Study Charge** *James Trebes, Study Co-Chair*
8:15-9:30 AM	**Round Table Discussion with Transformation & Applied Research Directorate (TARD) Staff** *James Trebes, Study Co-Chair* *John Donnelly, Study Committee Member* *Joel Rynes, Acting Assistant Director, TARD, Domestic Nuclear Detection Office (DNDO)*
9:45-12:00 PM	**SME Special Talks** **"What's Hard about Detecting and Identifying Shielded Fissionable Material?"** *Dennis Slaughter, Study Committee Member* **Shielded Threat Detection Portfolio Review: Current & Planned Portfolio** *Namdoo Moon, Program Manager, SBIR, DNDO* **Discussion** *Richard Kouzes, Richard Lanza, Stan Prussin, Study Committee Members* **Learning to Understand Nuclear Threat** *Artur Dubrawski, Carnegie Mellon*
1:00-3:30 PM	**SME Special Talks, continued…** **Algorithms/Modeling Portfolio Review: Current & Planned Portfolio** *Tim Ashenfelter, Program Manager, TARD, DNDO* **Discussion** *Robert Borchers, Richard Kouzes,Study Committee Members* **Operational Constraints** *Ira Reese, U.S. Customs and Border Protection (CBP)* **DTRA/NNSA/TARD Coordination** *David Beach, National Nuclear Security Administration*
3:45-5:30 PM	**SME Special Talks, continued…** **Radiation Detection at Borders** *Richard Kouzes, Study Committee Member* **Neutron Detection Portfolio Review: Current & Planned Portfolio** *Alan Janos, Program Manager, DNDO*

Discussion
Richard Kouzes, James Lund, Study Committee Members

6:30- 8:15 PM	**SME Special Talks, continued…**	
	Material Portfolio Review: Current & Planned Portfolio *Alan Janos, Program Manager, DNDO*	
	Discussion *Glenn Knoll, Study Committee Member* *Anthony Lavietes, Study Co-Chair*	
	Nuclear Counterterrorism and Deterrence *Rob Allen, LLNL*	
8:15-8:45 PM	**Washington Round-up** *Ms. Jodi Lieberman, American Physical Society*	

July 27, 2012

8:00-8:15 AM	**Introduction – Logistics** *Anthony Lavietes, Study Co-Chair*
8:15-9:00 AM	**Uncertainty, Deterrence, Risk, Conops, Surge 1** *Mitchell Woodring, Senior Scientist, Detection Systems Group, National Security Directorate PNNL*
9:00-10:00 AM	**Nuclear Forensics: Considerations for Success** *Stephen LaMont, Chief Scientist Office of Intelligence, Nuclear Materials Information Program (NMIP), U.S. Department of Energy*
10:15-12:00 PM	**Nuclear Forensics Portfolio Review: Current & Planned Portfolio** *Bill Uliciny, Rich Vjtech, TARD, DNDO*
	Discussion *Jill Dahlburg, Stan Prussin, Study Committee Members*
12:45-1:45 PM	**Radiation Detection Techniques: Current & Planned Portfolio** *Austin Kuhn, Rich Vjtech, TARD, DNDO*
	Discussion *Neil Johnson, Glenn Knoll, Study Committee Members*
1:45-2:30 PM	**Conclusion** *Richard Lanza, James Lund, Study Committee Members*
2:30 –	**Study Committee Postmortem** *Logistics of report writing, deadlines, discuss key conclusions*

KEY DOCUMENTS

The following list of documents were provided by DNDO TARD and used extensively by the Committee:

- All TARD presentations at the workshops
- Nuclear Defense Research and Development Roadmap, Fiscal Years 2013-2017, Executive Office of the President, National Science and Technology Council, April 2012
- Department of Homeland Security Global Nuclear Detection Architecture Implementation Plan, Fiscal Year 2012 Report to Congress, April 23, 2012
- Global Nuclear Architecture Strategic Plan 2010
- Memorandum of Understanding Among the Domestic Nuclear Detection Office, the National Nuclear Security Administration, the Defense Threat Reduction Agency, and the Office of the Associate Director of National Intelligence for Science and Technology on the Coordination of National Nuclear Detection Research and Development Programs, June 20, 2007

B. Review General Topic: Domestic Nuclear Detection Office (DNDO)

The Domestic Nuclear Detection Office (DNDO) was established by National Security Presidential Directive NSPD-43/ Homeland Security Presidential Directive HSPD-14 on April 15, 2005.

DNDO PRIMARY TASKING

Primarily, DNDO was tasked to serve as "the primary entity in the United States Government to further develop, acquire, and support the deployment of an enhanced domestic system to detect and report on attempts to import, process, store, transport, develop, or use an unauthorized nuclear explosive device, fissile material, or radiological material in the United States, and improve that system over time." [16]

DNDO is comprised of the following directorates:

1. ***Architecture and Plans Directorate***— Determines gaps and vulnerabilities in the existing global nuclear detection architecture, then formulates recommendations and plans to develop an enhanced architecture.
2. ***Product Acquisition & Deployment Directorate***— Carries out the engineering development, production, developmental logistics, procurement, and deployment of current and next-generation nuclear detection systems.
3. ***Transformational & Applied Research Directorate***— Conducts, supports, coordinates, and encourages an aggressive, long-term research and development program to address significant architectural and technical challenges unresolved by R&D efforts on the near horizon.
4. ***Operations Support Directorate***— Develops the information sharing and analytical tools necessary to create a fully integrated operating environment. Residing within the Operations Support Directorate is the Joint Analysis Center, which is an interagency coordination and reporting mechanism and central monitoring point for the GNDA.
5. ***Systems Engineering & Evaluation Directorate***— Ensures that DNDO proposes

sound technical solutions and thoroughly understands systems performance and potential vulnerabilities prior to deploying those technologies.

6. ***Red Team & Net Assessments***— Independently assesses the operational performance of planned and deployed capabilities, including technologies, procedures, and protocols.

National Technical Nuclear Forensics Center (Part of DNDO)—Provides national-level stewardship, centralized planning, and integration for an enduring national technical nuclear forensics capability.

The risk of nuclear terrorism was a focus of the U.S. Government long before DNDO's establishment. The International Atomic Energy Agency (IAEA) documented more than a dozen incidents involving the illicit trafficking of highly enriched uranium (HEU) and Plutonium between 1993 and 2006 [17]. The break-up of the former Soviet Union and resulting concerns that nuclear material and related expertise might fall into the wrong hands precipitated a number of programs designed to address the nuclear materials trafficking threat. In the ten years leading up to DNDO's establishment, Congress appropriated approximately $800 million for radiation detection equipment and training to border security personnel in the U.S. and overseas. [18] In particular, the Department of Energy established a Second Line of Defense Program to deploy radiation detection equipment in the former Soviet Union, as well as a companion program to focus on the risk of nuclear material smuggling through major foreign ports.

The September 11th attacks in 2001 highlighted the asymmetric nature of the international terrorist threat, and the National Commission On Terrorist Attacks Upon the United States (the 9/11 Commission) warned that "the greatest danger of another catastrophic attack in the United States will materialize if the world's most dangerous terrorists acquire the world's most dangerous weapons [19]." Moreover, the 2004 revelation of Pakistani nuclear scientist A.Q. Khan's proliferation activities showed how rogue nuclear weapons expertise could be leveraged, for the right price, as a shortcut to developing a nuclear bomb. Finally, the U.S. intelligence community developed information that al-Qa'ida had established contact, albeit limited, with Pakistani scientists who discussed development of nuclear devices [20].

In this context, questions arose about both the effectiveness of "current state" nuclear detection technology and the degree of coordination across relevant agencies. For example, the 2004 Defense Science Board Task Force on Preventing and Defending Against a Clandestine Nuclear Attack highlighted the limitations of current state technology in identifying HEU, particularly when shielded [21]. With respect to coordination across agencies, the Government Accountability Office found individual agencies were pursuing their own nuclear detection programs, both domestically and internationally, without fully leveraging expertise in different parts of the government [18].

For a nuclear explosive device, fissile material, or radiological material to be smuggled successfully into the U.S., such material would have to travel on one of a number of different potential pathways, each presenting a different degree of detection complexity. On any given day, U.S. Customs & Border Protection (CBP) processes almost 65,000 truck, rail, and sea containers crossing U.S. borders, and balancing an effective inspection regime with facilitation of legitimate commerce is a key CBP imperative [22]. The global supply chain represented both an obvious avenue to exploit for nuclear smuggling purposes and a significant target in its own right, and it became an early focus of detection technology. It was, however, also recognized that other avenues (such as general aviation, small maritime craft, and surreptitious land border crossings between a port of entry) also represented potential, and perhaps more likely, pathways [23]. Moreover, depending on the pathway in question, the opportunity for detection varied by agency, as each had its own standard operating procedures and constraints.

The establishment of DNDO followed an extended dialogue within the U.S. Government about how the government could most effectively push the limits of science and technology in detecting the presence of smuggled nuclear material, and how the many different agencies with equities in the effort could be organized most effectively to detect nuclear smuggling [24]. A review of agency authorities, end-users, and functional practicalities led to a decision that a coordinating office should be located in the newly-established Department of Homeland Security (DHS), which housed both operational agencies like CBP, the U.S. Coast Guard, and the Transportation Security Administration (TSA), as well as the Science & Technology Directorate, which had already commenced work on developing next-generation nuclear detection technologies.

When DNDO first was created, it was recognized that resources must be prioritized based on an umbrella architecture anchored in an assessment of the nation's existing capabilities and matched against the threat. Accordingly, HSPD 14 tasked DNDO with developing an "enhanced global nuclear detection architecture" (GNDA), in coordination with the Departments of State, Defense, Energy, and Justice. The following year, the SAFE Port Act not only provided formal statutory authorization for DNDO but also gave DNDO statutory authority to develop the GNDA and implement the domestic portion [25].

The Global Nuclear Detection Architecture (GNDA) is an integrated system of radiation detection equipment and interdiction activities to combat nuclear smuggling in foreign countries and at the border and within the U.S. [3]. It is a multi-layered, international system that includes border protection, maritime inspection, at-sea interdiction, port-of-departure screening, security of radioactive sources, and materials protection, control, and accountability. Key aspects include situational awareness, threat assessment, information analysis, quality assurance, information integration, law enforcement, intelligence, technical reachback, and forensics [26]. In the last few years, GNDA has significantly broadened in scope to include flexible, mobile, agile components that include intelligence-cued surges [27]20. This inclusion of a more mobile, agile capability is intended to provide detection and deterrence capability over a broad range of pathways beyond such primary pathways as ports, airports, and border-crossing highways.

In implementing the GNDA, DNDO has:

- Delivered a Strategic Plan for the GNDA in 2010
- Finalized a follow-on GNDA implementation plan in 2012 that identifies funding dedicated to plan objectives and monitoring mechanisms to assess progress toward those objectives
- Completed a classified comprehensive analysis that compares the GNDA capabilities with the expected capabilities of adversaries who may wish to smuggle nuclear material into the U.S. [3]. Although the GAO complained that "it remains difficult to identify priorities" from the GNDA Implementation Plan, it also acknowledged that the above-referenced classified analysis could be used to set priorities within the GNDA.

DNDO ADDITIONAL TASKING

Given the limitations of current state technology, DNDO was also tasked in Homeland Security Presidential Directive HSPD-14 with conducting "an aggressive, expedited, evolutionary, and transformational program of research and development efforts ." In this respect, DNDO proceeded on two fronts.

1. First, through its Product Acquisition and Deployment Directorate (PADD), DNDO sought to drive what was originally hoped to be a near-term boost in surmounting detection challenges (such as those identified in the 2004 Defense Science Board report) through investments in both passive imaging systems and, to address shielding-related gaps, active radiography systems [28] . Passive imaging advances in particular were intended to improve the ability to detect nuclear material, both through direct detection improvements and false alarm reductions that would have enabled systems to be set to higher sensitivity levels. While DNDO would develop and acquire new systems, the end users and maintainers of such systems would be in different components of DHS – Customs and Border Protection, Coast Guard, and Transportation Security Administration – or state and local law enforcement and regulatory agencies.

Both passive and active programs were the subject of numerous Congressional hearings and GAO audits, and neither has survived in its original form. In addition to initial concerns over the adequacy of testing and cost-benefit analysis, the lack of considered end-user buy-in appears, based on GAO commentary and Executive Branch testimony, to have been a key issuestumbling block in both programs [3, 4]. Based on its experience with both programs, DNDO also announced last year that it would adopt a "Commercial First" approach whereby DNDO will engage first with the private sector for non-developmental, commercially available solutions, and only move to a government-sponsored and managed development effort if necessary.

2. Second, to achieve longer-term transformational objectives, the Transformational & Applied Research Directorate (TARD) was established within DNDO. TARD's self-described mission is to develop break-through technologies that will have a dramatic impact on capabilities to detect nuclear threats through an aggressive and expedited research and development (R&D) program. The Directorate's objectives include addressing GNDA gaps through improvements in performance, cost, and operational burden of detectors and systems. By design, its programs include industry, federal security (NOTE: 'federal security' is the appropriate phrase, cf, e.g., [https://www.ida.org/upload/stpi/pdfs/p-4916-final-12-12-12.pdf] (IDA's Nov 2012 Study of Facilities & Infrastructure Planning, Prioritization, and Assessment at Federal Security Laboratories.) laboratories laboratories, and academia. TARD also coordinates with related R&D organizations in other agencies, in particular the Department of Energy's National Nuclear Security Administration and the Defense Threat Reduction Agency. In addition, TARD has as an explicit objective the transition of successful technologies to system development, acquisition, and deployment or commercialization.

To accomplish these objectives, TARD's staff and programs are focused on four areas:

1. The Exploratory Research Program (ERP), which sponsors investigations to show feasibility through proof of concept demonstrations for identified GNDA gaps. Development of transformational nuclear detection technology is also included in this area. The funding mechanism emphasizes low technical readiness level investigations and proof of concept demonstrations. The Exploratory Research Program currently supports 30 projects with a total budget of $13.6 million. This is down from 64 projects and a budget of $48.1 million in 2011. The proposed budget for 2013 is $44.5 million.

2. The Small Business Innovative Research (SBIR) Program, which seeks to use small businesses to meet R&D needs and increase private sector commercialization. The SBIR portfolio budget and its 2013 projection were not available for this report. The SBIR program supported 21 projects in 2012.

3. The Academic Research Initiative (ARI), which funds academic exploratory and basic research to stimulate many radiation detection sectors, is carried out in partnership with the National Science Foundation (NSF). TARD-funded academic projects are also intended to help create the next generation of scientists and engineers needed to advance the field of radiation detection. The ARI budget was $18.2 million in 2011. This dropped to $5.2 million for 2012. The proposed 2013 ARI budget would increase to $8.8 million.

4. The Advanced Technology Demonstration (ATD) program, which builds on technology concepts previously demonstrated under the Exploratory Research Program (ERP), or equivalent. ATD objectives are to develop and characterize technology in a simulated operational environment to generate performance data for cost-benefit decisions in order to transition to commercial system development and acquisition. The ATD budget was $30 million in 2011. This dropped to $21.2 million in 2012. The proposed 2013 ATD budget would increase to $30.6 million.

KEY TECHNICAL CHALLENGES FOR TARD ARE:

- ***Cost-effective equipment*** with sufficient performance to ensure widespread deployment
- ***Enhanced wide area search*** in a variety of scenarios, including urban and highly cluttered environments
- Monitoring along ***challenging GNDA pathways***, including general aviation, small vessels, and areas between ports of entry
- ***Detection of special nuclear material (SNM)***, even when heavily shielded [29].

TARD has developed a broader set of technical objectives to address the Grand Challenges. These technical objectives include:

- Gamma-ray detection ***materials*** with improved resolution and room-temperature operation that are environmentally rugged and producible in large volume at low cost.
- Neutron detection materials to provide an ***alternative to*** ^{3}He, and support both passive and active sensing of SNM.
- Passive detection systems with higher sensitivity and ***specificity*** that can discriminate threat materials
- Increased ***stand-off*** detection of threats through both passive and active systems.
- Low-dose active portal systems, including radiography, which can automatically detect nuclear and radiological threats and concealment methods such as ***shielding***.
- ***Highly mobile*** active systems for surge and intelligence driven applications.
- Advanced localization and tracking systems through autonomous, directional, imaging, and/or networked systems that enable ***wide area search*** and monitoring.
- ***Algorithms*** and data fusion for enhanced detection, localization, and identification for both passive and active systems.
- Accurate ***modeling*** and simulation capabilities of RN detection systems to aid in their development, testing, and employment. 37

C. Study Charge

POPA STUDY TITLE:

Technical Review of the proposed long term R&D plan for the Transformational and Applied Research Directorate of the Domestic Nuclear Detection Organization

POPA PROPOSER

James Trebes
L-210
Lawrence Livermore National Laboratory
Livermore, CA
94551 trebes1@llnl.gov
925-423-7413

POPA TOPICAL AREA

National Security

OBJECTIVE

The Transformational and Applied Research Directorate (TAR) of the Department of Homeland Security (DHS) Domestic Nuclear Detection Organization (DNDO) has requested POPA review their proposed R&D path forward over the next 10 years. This review will provide comments about the DHS/DNDO long-term R&D plan and vision for the next 10 years. To ensure the presence of a broad range of expertise, POPA is teaming with the IEEE Nuclear and Plasma Society and its Radiation and Instrumentation Steering Committee. The IEEE team members bring significant engineering, systems, and operational experience to the review. The goal will be to produce a POPA report produced and published jointly with IEEE describing the outcome of the review. This report will be used by DNDO for evaluating their current program. Because the report will be made publically available, it could be used by Congress, the Administration and others to answer questions about the DNDO and TAR technical direction.

OPPORTUNITY

DNDO has received significant Congressional scrutiny in the last few years with several GAO reports that have been critical of major DNDO technical efforts. In partial response, DNDO and TAR are trying to determine the best path forward over the next 10 years for their R&D program. They are reaching out to us for help. This review presents the APS the opportunity to significantly impact this path and to ensure a highly credible R&D program at TAR.

The detection of nuclear weapons and ensuring nuclear security have long been areas of concern for the American Physical Society. Some of its members conduct much of the research that goes into the detection of nuclear weapons and have many of the key capabilities required for these efforts.

APPROACH

The APS Panel on Public Affairs (POPA) and the IEEE Radiation and Instrumentation Steering Committee will jointly conduct the review. The review will have a series of activities culminating with a two-day workshop.

A workshop steering committee will be formed to help organize and facilitate the workshop. The committee will include representatives from APS, IEEE and other organizations as appropriate. To prevent any perceived or actual conflicts of interest, members of the steering committee cannot be principal investigators funded by DNDO.

The steering committee led by POPA's James Trebes will create the workshop participant invitation list, determine the detailed workshop format, and oversee the workshop.

An important part of the advance effort will be the creation of key questions and issues to be resolved during the workshop. The DNDO will brief the steering committee on current capabilities and needs, long-term goals and the proposed R&D path forward prior to the workshop. The steering committee will use the briefing as the basis for the creation of key questions and issues to be addressed during the workshop. These questions and issues will be assigned, in advance, to selected teams of workshop participants so that these teams can undertake a more detailed investigation into these questions and perform the requisite analyses. Possible issues for consideration include: key operational constraints and their effects on R&D plans, leveraging and coordination of R&D with other Federal agencies, translation plans for R&D to operational capabilities, methods for identifying, including, gaps and requirements, and exploiting new S&T as it develops worldwide. The results of these examinations will form the basis for leading discussion sessions in the workshop. The briefing by DNDO will take place in mid to late April if possible.

Steering committee members and invited participants will be invited (but not funded) to attend the

IEEE Symposium on Radiation Measurements and Applications (SORMA) WEST in Oakland, California May 14-17th. During the symposium, nearly 50% of R&D funded by TAR will be presented. .

On July 23-25, POPA, DNDO, and IEEE will then jointly host a 2-day workshop, timed to coincide with the DNDO-sponsored Academic Research Initiative (ARI)[1] Grantees Conference at the National Conference Center in Lansdowne, Virginia. This workshop will be composed of DNDO personnel and a wide range of nuclear detection experts selected from across Academia, Government, the National Labs, and Industry. Expertise in detection, systems, operations, and policy will be included. We anticipate having approximately 35 total participants. Combining with the ARI Conference allows POPA/IEEE review participants to hear about other DNDO-funded TAR projects. It will also save on travel costs and time as some of the ARI conference participants will also participate in the APS/IEEE workshop. Some of the workshop participants are already DNDO reviewers and will be funded separately by DNDO to attend.

At the workshop, DNDO/TAR will brief the workshop participants on current capabilities and limitations, long-term needs and requirements, and the proposed long term R&D plan and vision for the next 10 years. Then each group pre-assigned a topic will report out their results to the workshop and carry on a discussion of those results. The discussion will be open to the entire workshop. The workshop will work through each of the questions and issues in turn. Each group with a pre- assigned topic will have a person taking notes on the discussion.

At the end of the first day new questions or issues that need to be discussed can be brought forward and groups formed to provide some analysis for the next day.

After the conclusion of the workshop, a report committee composed of APS and IEEE participants will generate a report reviewing the proposed TAR S&T strategy and proposed path forward. The report will be based on the written summaries and the results of further discussions by APS and IEEE report committee members. A draft report will be provided to DNDO/TAR for comments about possible technical corrections to the subject matter. The APS/POPA and IEEE will have final editorial control, and the report will not be available as a DNDO discussion aid or for release until the APS POPA and IEEE approve the report text as final. The APS and the IEEE, after using their existing internal approval processes, will then jointly publish the workshop report and provide copies to all participants.

PARTICIPANTS

The participants will span the full range of government, industry, academia, and national laboratories. Expertise will include detector science and engineering, systems analysis, policy, and operations. Committee members were recommended by POPA and IEEE key participants.

The draft steering committee currently consists of:

Dahlburg, Jill	NRL
Davis, Jay	Hertz Foundation
Donnelly, John	DC Fire Department
Isles, Adam	The Chertoff Group
Johnson, Neil	NRL
Knoll, Glenn	U. of Michigan
Kouzes, Dick	PNNL
Lanza, Richard	MIT
Larson, Ray	SLAC
Lavietes, Tony	IAEA
Perrone, Cosmo	LA/Long Beach Port Security (former)
Prussin, Stan	U. C. Berkeley
Schwitters, Roy	U. of Texas
Trebes, Jim	LLNL

1 The DNDO/TAR Academic Research Initiative (ARI) is a joint National Science Foundation and DNDO program established through a formal Memorandum of Understanding in January 2007 to conduct basic andlong-term research to stimulate innovation across many radiation detection sectors while augmenting the ER pgoram and supporting the DNDO research goals. The ARI is also aimed at developing and training the next generation of researchers in nuclear detection technology.

Staff Advisors:	Jodi Lieberman Francis Slakey

This committee may change somewhat as people schedules and availability change. If a person is not available someone of comparable capability and experience will be invited to join.

The full list of workshop participants has not yet been developed.

DELIVERABLES

Formation of steering committee	now
Initial briefing by DNDO/TAR	late April, early May
Investigation of key issues	July 23
Workshop	July 26, 27
Draft report to DNDO/TAR	mid to late September
Draft report to POPA	October 5 – POPA meeting
Final report	after approval and any required revisions
Publication	after all approvals

NOTE: The IEEE approval process calendar needs to be added.

DURATION AND FUNDING

The duration will be less than one year with a goal of final report completed before end of 2012. Funding will be $25K from POPA, $25K from IEEE, with the workshop site funded by DNDO. The POPA and IEEE funding will be used to pay travel and per diem for the workshop participants. This level of funding is currently being reviewed.

KEY ISSUES

The review will take place on an aggressive schedule in order to utilize existing meeting venues and to assist DNDO by providing comments about the DHS/DNDO long-term R&D plan and vision for the next 10 years. This schedule is complicated by teaming with the IEEE. They have their own independent approval and funding process. It appears to be running about 2 weeks behind the APS, but there is no certainty of outcome to the process. DNDO is aware of all this. We will inform DNDO in writing that meeting the aggressive schedule is a "best effort" and not a certain deliverable. DNDO is also aware that an actionable POPA/IEEE report must go through approval processes that will take the time it takes. These processes are critical for quality assurance. DNDO will also receive this condition in writing.

The IEEE participation is not certain. At the moment they are working through their approval process and a favorable outcome is expected. If IEEE decides not to participate the original plan will now be unaffordable. The back up plan is to reduce the size of the steering committee by 4 and to have a subset of workshop participants attend the ARI review. This subset will report out to the APS/IEEE workshop. Additionally we will utilize DNDO-funded ARI reviewers and we can add a few people to this list. DNDO has agreed to this.

D. Study Committee Bios

Anthony D. Lavietes, Study Committee Co-Chair; International Atomic Energy Agency (IAEA)
Tony Lavietes is a researcher with the IAEA's Department of Safeguards. He specializes in electrical engineering. As a member of the Institute of Electrical and Electronics Engineers (IEEE), Tony serves as Committee Chairman of Nuclear & Plasma Sciences Society's Radiation Instrumentation Technical Committee (RITC) whose purpose is to promote the development and applications of radiation detectors.

James Trebes, Study Committee Co-Chair; Lawrence Livermore National Laboratory (LLNL)
Jim Trebes is currently the Physics Division Leader at LLNL's Physical and Life Sciences Directorate. The Physics Division conducts frontier physics research and development in optical and x-ray science, detectors, accelerators, lasers, space, and fusion.

Robert Borchers, Maui High Performance Computing Center (MHPCC)
Bob Borchers is the Chief Technology Officer at the MHPCC at the University of Hawaii, specializing in various aspects of high performance computing.

Jill Dahlburg, Naval Research Laboratory (NRL)
Jill Dahlburg has been Superintendent of the Space Science Division at the NRL since 2007. In this position she serves as Science/Technical expert to the Department of the Navy (DON)/ Department of Defense (DoD), other government, and international fora on a broad-spectrum RDT&E program in solar-terrestrial physics, astrophysics, upper/middle atmospheric science, and astronomy. Jill was the Senior Scientist for Science Applications at NRL from 2003 – 2007.

John Donnelly, District of Columbia Fire & EMS
John Donnelly is the Deputy Fire Chief at DC Fire and EMS and is also an Adjunct Professor at the University of the District of Columbia. He specializes in homeland security and emergency preparedness.

Adam Isles, The Chertoff Group
Adam Isles is the Managing Director at The Chertoff Group, focusing on security risk management, domestic and international border security, and cyber security. Prior to The Chertoff Group, Adam worked at Raytheon Company as Director of Strategy and Policy Consulting for homeland security. He also served as Deputy Chief of Staff at the U.S. Department of Homeland Security.

Neil Johnson, Naval Research Laboratory (NRL)
Neil Johnson is the Head of the High Energy Space Environment Branch in NRL's Space Science Division and is the Deputy Principal Investigator for Instrument/Observatory Operations for the Large Area Telescope (LAT) on Fermi. He specializes in the detection and study of high energy signatures in astrophysical objects as well as terrestrial and near earth environments.

Glenn Knoll, University of Michigan
Glenn Knoll is Professor Emeritus of Nuclear Engineering & Radiological Sciences at the University of Michigan. He specializes and is interested in detection and spectroscopy of ionizing radiation, gamma ray imaging for medical and other applications, three dimensional position sensing in gamma ray spectroscopy, and neutron detection and imaging.

Richard Kouzes, Pacific Northwest National Laboratory
Richard Kouzes is a Laboratory Fellow at PNNL, working in the areas of neutrino science, homeland security, non-proliferation, and computational applications. His work on homeland security has been for the development and deployment of radioactive material interdiction equipment at U.S. borders, and for three years he was the Principal Investigator and Technical Lead for the U.S. Customs and Border Protection's Radiation Portal Monitor Project.

Richard Lanza, Massachusetts Institute of Technology
Richard Lanza is a Senior Research Scientist in the MIT Department of Nuclear Science and Engineering. His interests are primarily in the area of application of nuclear techniques and development of instrumentation to problems in materials science, medicine and national security. He has been active in in development of new imaging methods for nuclear medicine and also in the problem of detection of illicit materials such as explosives, contraband, and special nuclear materials.

James Lund, Sandia National Laboratory
Jim Lund is Senior Manager of Security Systems Engineering at Sandia. Jim's research has included work on neutron scatter cameras able to detect radiation from greater distances and through more shielding. His expertise is in semiconductor material science, detector design, and application of detection and imaging devices and systems.

Stanley Prussin, University of California, Berkeley
Stan Prussin is a Professor of Nuclear Engineering at UC Berkeley. His areas of expertise include fission product behavior in nuclear fuels, radiation detection, and radio and nuclear chemistry and applications. His research interests are in the areas of low energy nuclear physics and chemistry, the use of nuclear methods and instrumentation for solution of applied problems, with current emphasis on nuclear security and nuclear forensics.

ACKNOWLEDGEMENTS

The Study Committee wishes to thank Dr. Joel Rynes, Director of TARD, and the entire TARD staff for their assistance in making this review possible. They provided substantial information requiring significant preparation, and freely participated in numerous discussions covering the full range of TARD and nuclear counter-terrorism issues. The Committee also wishes to thank Jeanette Russo of the American Physical Society and Kaye Washington of TARD for setting up our workshops and arranging for numerous side meetings and conference calls. Additionally, the Study Committee would like to thank the numerous invited participants in the workshop who provided valuable insights into the many research achievements and also the issues facing TARD, and who offered a host of beneficial, useful suggestions for the TARD research program.

REFERENCES

[1] "Department of Homeland Security Global Nuclear Detection Architecture Implementation Plan, Fiscal Year 2012 Report to Congress," 23 April 2012.

[2] R. Schwitters and et al, "Domestic Nuclear Surge Operations," January 2012.

[3] "Combating Nuclear Smuggling: DHS has Developed Plans for Its Global Nuclear Detection Architecture, but Challenges Remain in Deploying Equipment," US Goverment Accountability Office, 2012.

[4] "Combating Nuclear Smuggling: DHS has Developed a Strategic Plan for Its Global Nuclear Detection Architecture, but Challenges Remain in Deploying Equipment," US Government Accountability Office, 2011.

[5] "Congressional Transcript: House Homeland Security Subcommittee on Cybersecurity, Infrastructure Protection and Security Technologies Holds Hearing on Nuclear Detection Strategy," Congressional Quarterly, 26 July 2012.

[6] N. Moon, "Shielded Threat Detection Techniques (Shielded SNM) Research Portfolio," 29 May 2012.

[7] C. Hagmann and J. Pruet, "Photon production through multi-step processes important in nuclear fluorescence experiments," Nuclear Instruments and Methods in Physics Research, vol. B259, p. 895, 2007.

[8] W. Bertozzi, S. Korbly, R. Ledoux and W. Park, "Nuclear resonance fluorescence and effective Z determination applied to detection and imaging of special nuclear material, explosives, toxic substances and contraband," Nuclear Instruments and Methods in Physics Research, vol. B261, pp. 331-336, 2007.

[9] R. Schwitters and et al, "Domestic Nuclear Surge Operations," January 2012.

[10] S. Labov and et al, "Foundations for Improvements to Passive Detection Systems -Final Report," Lawrence Livermore National Laboratory, 8 October 2004.

[11] R. Runkle, D. Chichester and J. Scott, "Rattling nucleons: New developments in active interrogation of special nuclear material," Nuclear Instruments and Methods in Physics Research, vol. A663, pp. 75-95, 2012.

[12] "Shielded Nuclear Alarm Resolution (SNAR) Advanced Technology Demonstration (ATD)," DNDO TARD.

[13] "TARD Comprehensive 2012.pdf," DNDO TARD, 2012.

[14] "National Technical Nuclear Forensics Center," [Online]. Available: http://www.dhs.gov/national-technical-nuclear-forensics-center.

[15] K. Jankowski, "Nuclear Forensics Research Portfolio," 29 May 2012.

[16] "Compilation of Homeland Security Presidential Directives, Prepared for Use of the Committee on Homeland Security of the House of Representatives," January 2008, pp. 81-82. [Online]. Available: http://www.gpo.gov/fdsys/pkg/CPRT-110HPRT39618/pdf/CPRT-110HPRT39618.pdf.

[17] "IAEA Illicit Trafficking Database," [Online]. Available: http://www.iaea.org/NewsCenter/Features/RadSources/PDF/fact_figures2006.pdf; http://www.iaea.org/NewsCenter/Focus/NuclearSecurity/pdf/heu-pu_1993-2006.pdf.

[18] "Combating Nuclear Smuggling: Efforts to Deploy Radiation Detection Equipment in the United States and Overseas," 2005. [Online]. Available: http://www.gao.gov/assets/120/111799.pdf.

[19] "The 9/11 Commission Report," 22 July 2004, p. 380. [Online]. Available: http://govinfo.library.unt.edu/911/report/911Report_Ch12.pdf.

[20] "Report of the Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction," 31 March 2005, p. 272. [Online]. Available: http://govinfo.library.unt.edu/wmd/report/wmd_report.pdf.

[21] "Report of the Defense Science Board Task Force on Preventing and Defending Against a Clandestine Nuclear Attack," June 2004, p. 28. [Online]. Available: http://www.acq.osd.mil/dsb/reports/ADA429042.pdf.

[22] "On a Typical Day in Fiscal Year 2011," [Online]. Available: http://www.cbp.gov/linkhandler/cgov/about/accomplish/typical_day_fy11.ctt/typical_day_fy11.pdf.

[23] "Remarks by Homeland Security Michael Chertoff at the Center for Strategic and International Studies on Aviation Security Measures," 18 November 2008. [Online]. Available: http://csis.org/files/media/csis/events/081117_transcript_chertoff.pdf.

[24] "Lawmakers Cut U.S. Nuclear Detection Office Funding (interview with Jonah Czerwinski)," 4 August 2006. [Online]. Available: http://intelligence-summit.blogspot.com/2006/08/lawmakers-cut-us-nuclear-detection.html.

[25] "Security and Accountability for Every Port Act of 2006," Pub.L., 13 October 2006, § 501.

[26] R. Connelly, Global Nuclear Detection Architecture, 2009, DNDO presentation.

[27] W. Stern, Testimony before House Committee on Homeland Security, Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies, 2011.

[28] V. Oxford, Detecting Nuclear Weapons and Radiological Materials: How Effective Is Available Technology?, DNDO, Opening Statement Before House Homeland Security Committee Hearing, 2005.

[29] J. Rynes, Transformational and Applied Research Directorate Overview Briefing for the APS/IEEE DNDO R&D Study Committee, 2012.

[30] R. Vojtech, "Nuclear Forensics Research Portfolio: Overview Brief for the APS/IEEE DNDO R&D Study Committee," 27 July 2012.

[31] S. LaMont, Nuclear Forensics: Introduction and Considerations for Success, APS-IEEE DNDO Study Committee, 27 July 2012.