NEVADA NATIONAL
NNSS
SECURITY SITES

WE SECURE AMERICA'S FUTURE

Site-Directed Research & Development Annual Report Overview FY 2023

SDRD
SITE-DIRECTED RESEARCH & DEVELOPMENT

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy, the NNSA Office of Defense Programs, and supported by the Site-Directed Research and Development Program. DOE/NV/03624--1933.

How to Read this Report

The SDRD program's annual report for fiscal year (FY) 2023 consists of three parts: the introduction, which includes remarks from both the Chief Scientist and the Program Manager; the program overview, which contains three major sections, Program Description, Program Accomplishments, and Program Value; and individual project report summaries published electronically on the Nevada National Security Sites website, https://nnss.gov/mission/sdrd. Complete technical reports for concluding projects are available from the Office of Scientific and Technical Information (OSTI) or the principal investigator.

On the Cover

Front and back cover: Reconstructed images from project 23-058, "Non-Invasive Spot Size Diagnostic for Linear Induction Accelerators" (E. Scott).
Inside cover: 3D-printed resin from project 23-019, "Additive Manufacturing of Structural and Pixelated/Discriminating Scintillators" (M. Staska).

Staff

SDRD Program Manager	Paul Guss
Editors	Madeline Gauthier, Anne Totten, Kristen Vernon
Design & Layout	Kristen Vernon
Web Design & Production	Kirsten Kellogg, Anne Totten, Kristen Vernon, Obadiah Williams
Management and Support	Michael Baldonado, Beth Burk, Elizabeth Craft, Leslie Esquibel, Matthew Fritz, Edwin Garcia, Lisa Garcia, Emma Gurr, Sally Matthews, Ki Park, Kristen Ruocco

www.nnss.gov

Publication Date: April 2024

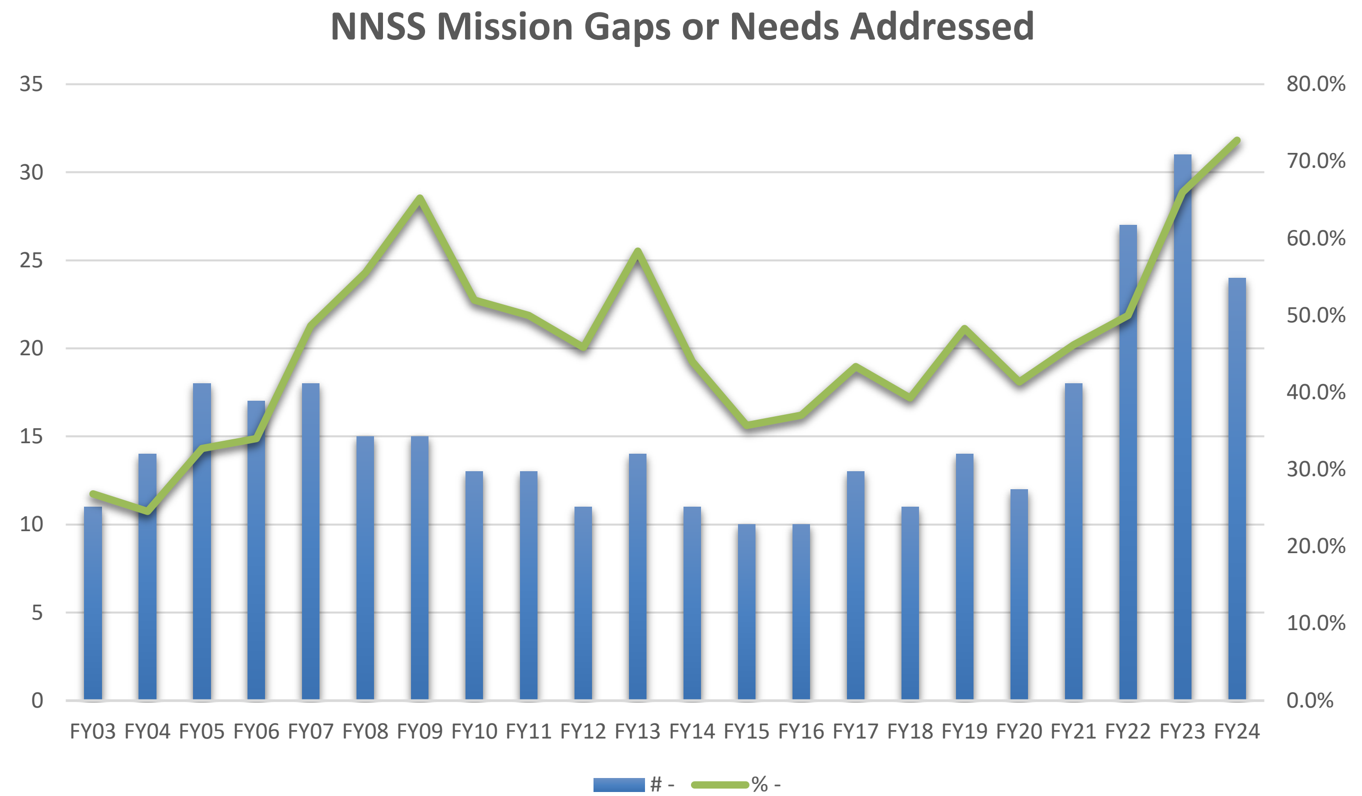
Table of Contents

Letter from the Chief Scientist

SDRD: Supporting the NNSS's Mission and Programs through Innovative R&D

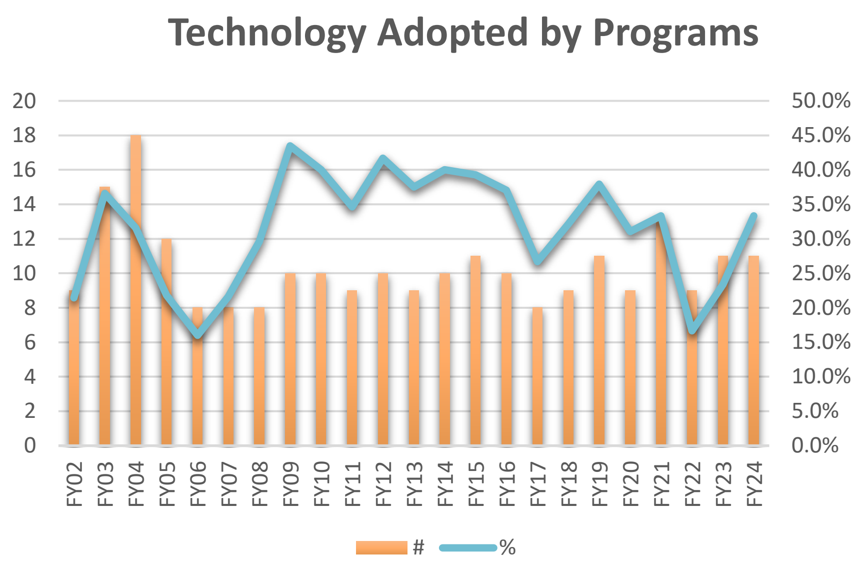
Since its inception in 2002, the Site-Directed Research and Development (SDRD) program has prioritized pursuing research and development (R&D) efforts that address technology needs within the Nevada National Security Site's (NNSS's) unique Programs and mission space. Through its support of high-risk and potentially high-value R&D, the SDRD program develops innovative scientific and engineering solutions, replaces obsolete or aging technologies, and rejuvenates the technical base necessary for peak operations and program readiness at the NNSS.

The NNSS has made great strides in transferring SDRD-developed technologies into programs in recent years. We have seen a consistent increase in the percentages of Program technology needs addressed by SDRD projects (*see chart on this page*) and SDRD technologies adopted by Programs (*see chart on the next page*) ever since our proposal evaluation structure changed to prioritize mission alignment in fiscal year (FY) 2022. With that change, SDRD pre-proposals are now vetted by NNSS Program directors, and are only invited to the full proposal stage if they demonstrate clear and strong alignment with the NNSS's mission.



NNSS Program technology gaps and needs addressed by SDRD Projects, FY03–FY24.

Innovative solutions to complex scientific and technological problems often come to fruition in conditions where calculated risks and learning from mistakes are encouraged, ambition is rewarded, and creativity can thrive. The SDRD program provides such a space for our scientific and technical staff here at the NNSS. Over its 21-year history, SDRD has given rise to many of the essential technologies that the NNSS uses regularly in its stockpile stewardship and global security missions. This year's portfolio of projects promises to continue SDRD's mission of developing technologies that sustain and enhance critical skills and capabilities across the NNSS.



SDRD technologies adopted by Programs, FY02–FY24.

FY 2023's portfolio of projects promises to continue SDRD's mission of developing technologies that sustain and enhance critical skills and capabilities across the NNSS. This year, SDRD's principal investigators (PIs) explored dynamic materials, imaging diagnostics, and autonomous sensing methods; enhanced classified data storage and transfer for subcritical experiments, threat detection, equation of state modeling, and underground event monitoring techniques; improved plasma and radiation modeling codes; embarked on efforts to create new tools for nuclear forensics and non-proliferation science; explored new diagnostic opportunities in stockpile science and experiment collaboration with High Energy Density Programs; and facilitated training efforts for the United States' return to the moon. This is just a small sampling of the innovative research and technologies that were explored and developed this year in SDRD that have a significant impact on the NNSS's programmatic work in stockpile stewardship, global security, and beyond.

José Sinibaldi
Science and Technology Director
& Chief Scientist
Nevada National Security Sites

From the sea to the stars, from nanoparticles to geologic formations, FY 2023's SDRD projects span across scientific, engineering, and technological disciplines and the NNSS programmatic space, injecting innovation into the NNSS's mission space through innovative R&D endeavors.

Kudos to all our PIs on their outstanding work this year!

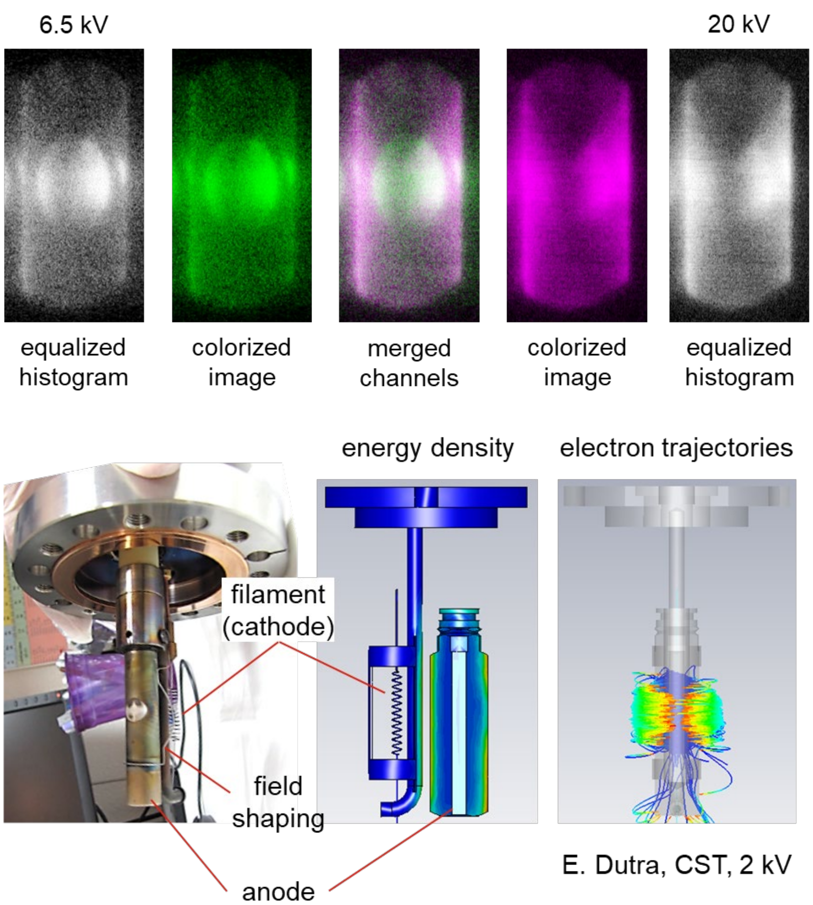
March 2024

Letter from the Program Manager

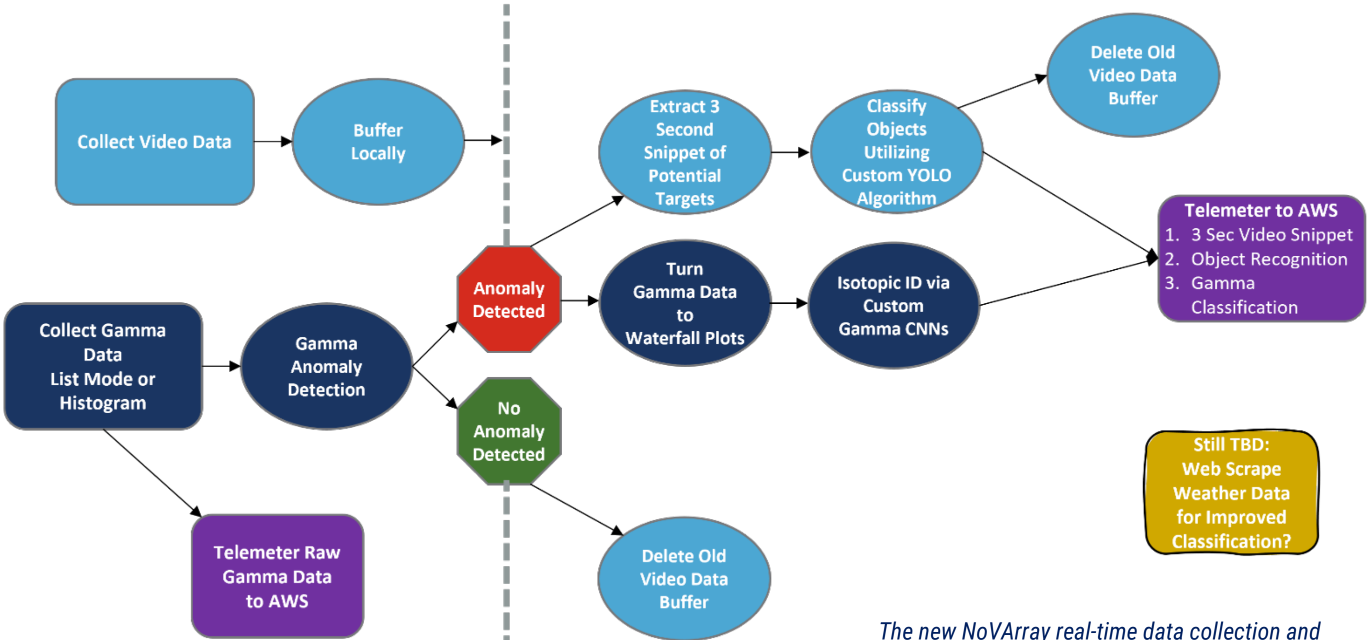
As the principal funding source for internally generated R&D initiatives, the NNSS SDRD Program provides advanced technology to support the broad national security missions of the U.S. Department of Energy (DOE), the National Nuclear Security Administration (NNSA), and other agency programs such as defense and intelligence. Although the program is modeled after the Laboratory-Directed Research and Development (LDRD) program at the national laboratories, it is notably smaller with inherent differences that provide challenges as well as opportunities. The SDRD projects completed over the past twenty-one years span a broad spectrum of technologies and disciplines in the applied sciences. In most cases, the innovations brought to reality would not have reached fruition without funding and support from the SDRD program. In addition to addressing our customers' needs the program offers unique opportunities for our staff to pursue their intellectual interests and serves as an aid in recruitment.

The SDRD program completed an extraordinarily successful year of research and development activities in FY 2023. Forty-seven new projects were selected for funding this year, and fifteen projects started in FY 2021 or FY2022 were brought to conclusion. The total funds expended to operate the entire SDRD program were $15 million, for an average per-project cost of $319,000. Highlights for the year included: programmatic adoption of 11 SDRD-developed technologies; the filing of 6 invention disclosures for innovation evolving from SDRD projects; publication of 5 peer-reviewed journal articles; participation in the DOE LDRD Annual Program Review that was broadly attended by the NNSS, NNSA, and representatives from all 17 DOE Office of Science and NNSA LDRD Programs; peer reviews of all FY 2023 projects; and the successful completion of 47 R&D projects, as presented in this report.

Our partnerships with universities, industry, and our sister institutions within the NNSA build upon our core capabilities and allow us to create innovative solutions to support our mission requirements. Although



"Broadband X-Ray Imager for Spectroscopic Diagnostics" (R. Presura 23-061) confirmed a novel method to obtain multi-monochromatic information using convex curved crystals. Chromatic data (top) and experimental setup (bottom, bottom right courtesy of Eric Dutra).



The new NoVArray real-time data collection and analysis workflow for persistent gamma sensors with context (C. Burt, 23-024).

technology partnerships are not new to advanced research and development, they are sometimes viewed as add-on activities, not central parts of an institution's framework. In our case, we have been transforming the culture of partnerships and collaborations for many years now, with SDRD investment driving change. Most of our multidisciplinary SDRD projects have strong university collaborations that provide an advantage by leveraging talent. With these partnerships applied as a force multiplier, we achieve much more than traditional independent research. This is evident in many of the projects in this annual report.

The numerous achievements that this annual program report describes are a tribute to the skill and enthusiasm that principal investigators brought to their individual projects. While many of the R&D efforts drew to successful and natural conclusions, some spawned follow-on work that may lead to further research. The desired result of all SDRD activities is to develop and/or refine technologies that are ultimately implemented by programs. Some of the following project reports clearly identify R&D efforts with those kinds of results. Others, best characterized as feasibility studies, resulted in negative findings—the entirely valid conclusion, often reached in the pursuit of "high-risk" research—that a particular technology is currently impractical. Both types of results help move the NNSS toward a more vital technology base by identifying technologies that can be directly applied to our programmatic mission.

March 2024

Paul Guss
SDRD Program Manager &
Senior Distinguished Member of the Technical Staff
Nevada National Security Sites

Program Description

SDRD Program Mission, Alignment, and Objectives

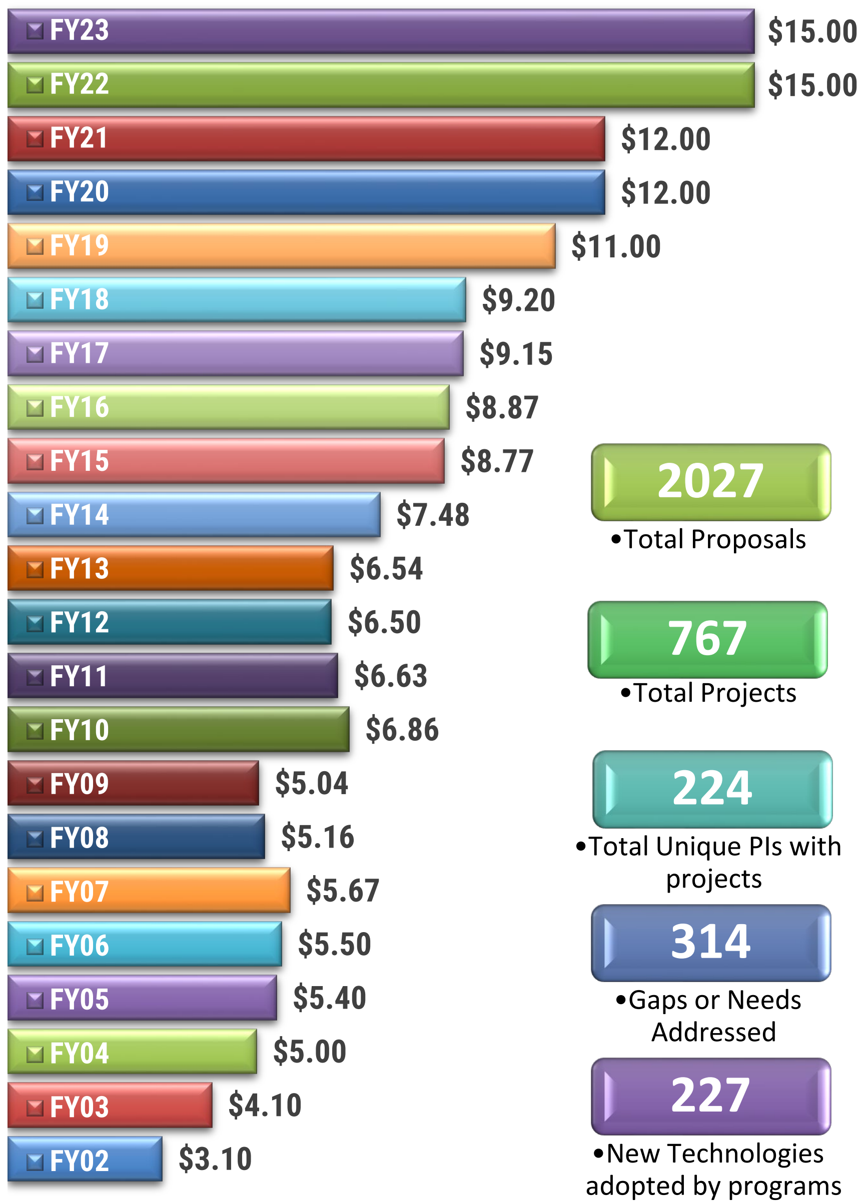
History and Impact

The SDRD program was initiated through Public Law (P.L.) 107-66, "Energy and Water Development Appropriations Act, 2002," Section 310, which grants the NNSA authority to allow the NNSS contractor to conduct an R&D program aimed at supporting innovative and high-risk scientific, engineering, and manufacturing concepts and technologies with potentially high payoff for the nuclear security enterprise.

The program is modeled after the LDRD program, which is conducted in accordance with the guidance provided by U.S. DOE Order 413.2C Chg1, "Laboratory Directed Research and Development," and the supplemental augmenting document "Roles, Responsibilities, and Guidelines for Laboratory Directed Research and Development at the Department of Energy/National Nuclear Security Administration Laboratories." We are also committed to the guiding principles as outlined in the 2019 Strategic Framework for the NNSA Laboratory and Site-Directed Research and Development.

SDRD by the Numbers

FY 2002–FY 2023



P.L. 110-161 (H.R. 2764), "The Consolidated Appropriations Act, 2008," provides that up to 4% of the NNSS site costs may be applied to the SDRD program. In addition, SDRD is an allowable cost within the NNSS management and operating contract and as such is identified in the NNSS contractor accounting system. The program is currently funded at 1.99%. In its first year (2002) the baseline budget was $3.1M, and roughly $15M has been allotted for FY 2024 by the senior management team.

As the illustration on this page shows, SDRD has made a significant impact in the past 21 years, providing over 220 innovative technologies to NNSS programs from 2002 to 2023, a high return on the investment of R&D dollars.

Alignment with the NNSA LDRD/SDRD Strategic Framework

The NNSA laboratories and NNSS R&D programs have five objectives as described in DOE Order 413.2C Chg. 1. They are to:

- maintain the scientific and technical vitality of the laboratories,
- enhance the laboratories' ability to address current and future DOE/NNSA missions,
- foster creativity and stimulate exploration of forefront areas of science and technology,
- serve as a proving ground for new concepts in research and development, and
- support high-risk, potentially high-value research and development.

These objectives underpin the 2019 Strategic Framework for the NNSA Laboratory and Site-Directed Research and Development, a document signed in July 2019 by the three NNSA laboratory directors, Mark Martinez (NNSS President), and Lisa E. Gordon-Hagerty (Under Secretary for Nuclear Security for DOE and NNSA Administrator). This short but key document defines the vision, objectives, and the overarching strategies the R&D programs follow. To quote the Framework, the "NNSA laboratories and NNSS have a shared mission to solve national security challenges by leveraging scientific and engineering excellence." Specifically, the Framework describes how the programs address four important challenges presented in the 2018 Nuclear Posture Review, which are to:

- provide an agile, flexible, and effective nuclear deterrent,
- protect against all weapons of mass destruction threats,
- deter and defend against threats in multiple domains, and
- strengthen our energy and environmental security.

As the Framework also states, "Through their individual strategic planning processes, NNSA laboratories and NNSS use the [R&D] Programs to seed their capability-bases and scientific workforces to prepare for emerging national security challenges, thereby achieving the NNSA mission and supporting the 2018 Nuclear Posture Review."

Mission and Objectives

The SDRD program develops innovative scientific and engineering solutions, replaces obsolete or aging technologies, and rejuvenates the technical base necessary for operations and program readiness at the NNSS. We support high-risk research and potential high-value R&D. Our objectives harmonize with those of the LDRD program, which are:

Mission Agility

Enable agile technical responses to current and future DOE and NNSA mission challenges.

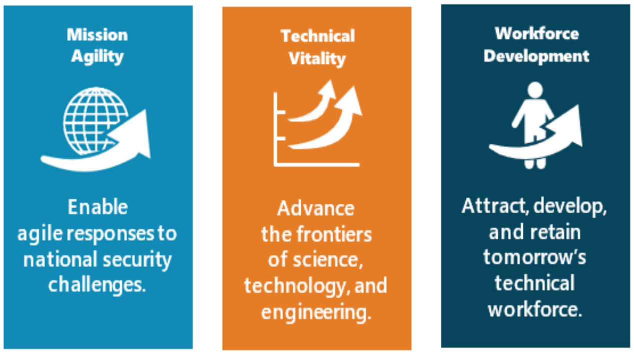
Scientific and Technical Vitality

Advance the frontiers of science, technology, and engineering by serving as a proving ground for new concepts, exploring revolutionary solutions to emerging security challenges, and reducing the risk of technological surprise.

Workforce Development

Recruit, retain, and develop tomorrow's technical workforce in essential areas of expertise critical to mission delivery.

The research projects featured on pages **12-20** are keyed to the three objectives, as indicated by these icons.



SDRD Program Leadership

The senior leadership of Mission Support and Test Services, LLC (MSTS), the management and operating contractor for the NNSS, which includes the president, vice president, and senior program directors, is committed to advancing the contract's R&D goals. Working closely with senior management and the SDRD program manager, the chief scientist ensures the quality of science and technology across the company's multiple programs and missions; advocates translation of research products through technology readiness levels; and plans and directs new scientific concepts and technologies to provide solutions to identified issues to fulfill our mission to the nuclear security enterprise.

The SDRD program manager is a single point of contact for SDRD and is responsible for all practical aspects of the program. The program manager is assisted by the NNSS Science and Technology Thrust Area (STTA) leads and SDRD technology representatives to coordinate technical activities undertaken by local principal investigators (PIs). PIs are responsible for all aspects of technical activities on their projects. They deliver monthly updates, present quarterly reviews, submit final annual reports, and report technical outcomes post-project closure. The SDRD program relies on an external advisory board (EAB) of distinguished individuals from academia, government, and industry to help guide and direct our investments toward the most critical areas of national security science and technology. This board has been instrumental in the success of the program since it was instituted in the mid-2000s.

Program Manager Paul Guss addresses the SDRD FY 2023 Annual Program Review audience including several members of the External Advisory Board (EAB).

Science and Technology Thrust Areas

The NNSS Science and Technology Thrust Areas (STTAs) are a focused long-term technical investment to prepare the NNSS technology capabilities for future NNSA missions and to enhance our ability to respond to future global threats.

The NNSS STTAs consist of seven areas, and each STTA encompasses a specific segment of science and technology conducted at the NNSS. The Radiographic Systems Imaging and Analysis, User-Centered Remote Testing and Operations, Accelerator Beam Science and Target Interactions, and Enabling Technologies for Autonomous Systems and Sensing STTAs were activated in FY 2021 (Phase 1). The Neutron Technologies and Measurements, Dynamic Experiment Diagnostics, and Communications and Computing STTAs were activated during Phase 2. STTA leads or SDRD technology representatives are assigned to lead and support the STTAs. The goals and objectives for the STTAs are to strengthen our technical capabilities in the near term, enhance the readiness of our core competencies in the long term, and make us more agile and adaptable to new global threats.

The STTAs directly align their efforts to support our NNSA and Strategic Partnership Projects missions and are an integral component of the SDRD program. The STTA leads and SDRD technology representatives participate in shaping the program as well as integrating STTA goals with defined strategic initiatives directed to SDRD proposers.

Proposal Cycle and Project Selection

The research undertaken by the SDRD program is inherently staff driven—ideas are submitted annually by staff in response to a call for proposals and these ideas are vetted through a rigorous two-stage review and evaluation process. Proposers are guided by mission needs and other strategic guidance to provide unique solutions to existing and emerging problems. Furthermore, proposers are encouraged to accept higher levels of R&D risk that could nonetheless result in high-reward technological advances that are of immediate benefit to naturally risk-averse programmatic projects.

Call for Proposals

We utilize a two-phase proposal process consisting of a pre-proposal (concept phase) followed by an invited proposal. In the pre-proposal phase, PIs are encouraged to submit ideas in a standardized, succinct format that presents the proposed project's essence and impact. In addition, during the pre-proposal phase, proposers are encouraged to obtain feedback from subject matter experts (SMEs) to refine their ideas. This phase sparks innovation and initiates a feedback loop that extends to the invited proposal phase. Guidance for proposers is provided in two major documents, the Broad Site Announcement (BSA) and the NNSS R&D Technology Needs Assessment. Updated annually, the assessment helps proposers identify and address technology gaps in existing and emerging technologies. The feedback loop also provides specific, useful guidance.

Project Selection

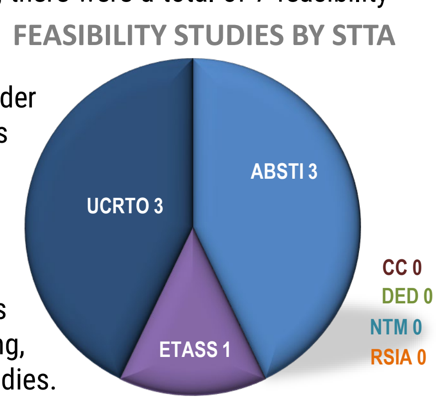
All submitted pre-proposals are evaluated by reviewers. They evaluate how well each pre-proposal addresses the core questions contained in the short pre-proposal form, which is based on the Heilmeier approach to R&D. Additional criteria considered in the evaluation of pre-proposals include their alignment with NNSS's current strategic priorities and focus areas, their potential to drive innovation and promote technological advances needed to meet emerging mission requirements, and their impact on our ability to develop cutting-edge capabilities and to attract and retain top talent for future challenges. Individual pre-proposals are evaluated with a reduced-weighted scoring matrix. The scores are then compiled, and a ranking is determined.

Typically, about 50% of the pre-proposals are promoted to invited proposals. Invited proposals are evaluated according to well-benchmarked and well-established criteria that consist of (1) technical merit, (2) program benefit, (3) probability of success, (4) critical skills, and (5) leverage. Detailed information about these criteria is available for viewing by anyone who has access to the NNSS network. The information is always available via the SDRD program website. In addition, the SDRD program posts an article about these criteria on the company's intranet announcement page every year before the invited proposal phase begins.

The final selection of SDRD investments for the next fiscal year is made and an annual program plan is submitted to the NNSA for concurrence by mid-August.

Feasibility Studies

Several investigative feasibility studies are funded each fiscal year. In FY 2023, there were a total of 7 feasibility studies. These brief studies (three to six months, usually under $100K) focus on topics that may potentially warrant further study and full funding. In the past, successful endeavors, such as broadband laser ranging, began as feasibility studies.



SDRD Portfolio

Mission Categories

Look for these icons next to project titles to denote which mission category they fall under:

Global Security

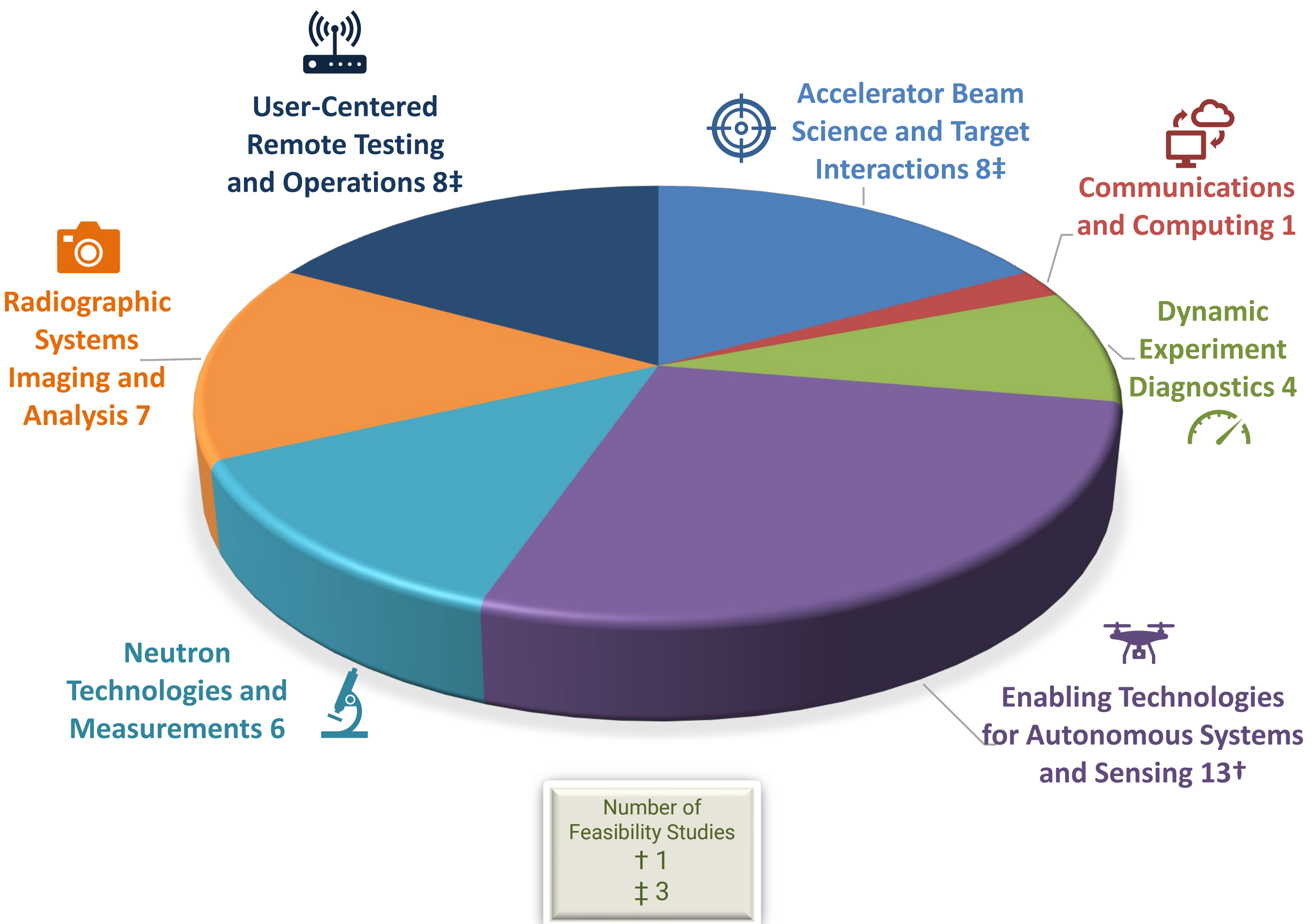
Stockpile Stewardship

The SDRD portfolio falls into two primary mission categories: stockpile stewardship and global security.

Historically, PIs have submitted a nearly equal number of ideas addressing stockpile stewardship and global security issues. Dollars requested in FY 2023 for stockpile stewardship were approximately $5.5 million, while global security requested approximately $6.5 million in funding. In FY 2023, the total amount of funding requested for SDRD was $15M, of which roughly 37 percent was for the stockpile stewardship mission category and about 43 percent was for the global security mission category.

Alignment within Science and Technology Thrust Areas

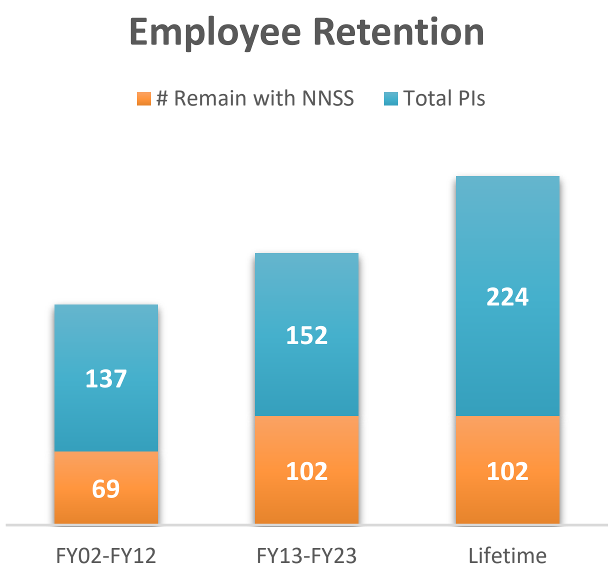
Beginning FY 2021, each funded project is also aligned with one of the seven NNSS STTAs according to its focus. In FY 2023, there were a total of 47 projects, of which 7 were feasibility studies. The pie chart below shows the number of FY 2023 projects that fall into each of the seven thrust areas.



Program Accomplishments

SDRD at a Glance

$15M	$290K	47	21
Total Program Cost	Median Project Size	Total SDRD Projects	New Projects in FY23



Publications	5
Technologies Adopted by Programs	11
Gaps or Needs Addressed	29
Invention Disclosures and Patents	7
Postdocs	4

Featured Research

Interns assist with project 23-009, "Low SNR, High Clutter UAS Detection and Tracking" (I. McKenna). Above: Tristan Richmond (L) and Andrew Song (R). Right: Deanna Koppenjan (L) and Michelle Zimmermann (R).

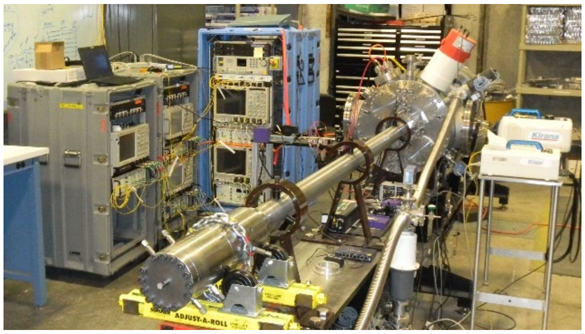
SDRD projects demonstrate a prominent level of ingenuity and innovation each year. Selected highlights of the R&D accomplished in FY 2023 by the SDRD program are presented on the following pages. Summaries of FY 2023 projects can be found on the NNSS website at https://nnss.gov/mission/sdrd and are available on the DOE Office of Scientific and Technical Information website at OSTI.gov. Full reports of concluding projects, including feasibility studies, can be requested from the SDRD Program Office.

Accelerator Beam Science and Target Interactions

Technical Vitality Workforce Development

ABSTI

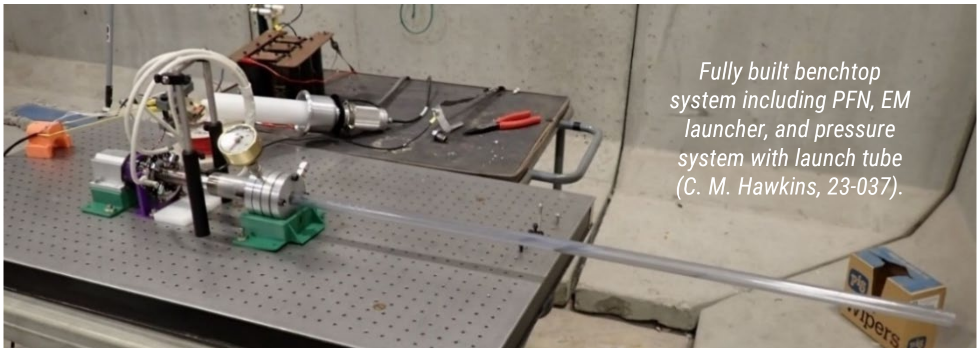
“Electromagnetic Launch Modification to C3 Launcher for Increased Velocity”
M. Cameron Hawkins
23-037



C3 Launcher at the NNSS (M. C. Hawkins, 23-037).

This project is the first step in the development of a novel technology that could lead the Nevada National Security Sites (NNSS) towards a platform that would achieve projectile velocities with pulsed power instead of the explosive hazards (e.g., high explosives) that exist with the current Joint Actinide Shock Physics Experimental Research (JASPER) test facility. Originally, the project began as a collaboration between Kansas City National Security Campus (KCNSC) and the University of Missouri (MU) to develop a full-size system to pair with the C3 Launcher gas gun at the NNSS North Las Vegas facility. However, due to unforeseen circumstances the project was replanned and a series of experiments of a benchtop system were conducted to prove the concept of using pulsed power to drive a piston, which can be used to compress gas to high pressures to accelerate a projectile to high velocities. This benchtop system consisted of three needed subsystems: 1) Pulse Forming Network (PFN), 2) Electromagnetic launcher (EML), and 3) a pressure system to launch a projectile. Simulations and calculations were performed as well as Computer-Aided Design (CAD) models to specify parts, fabricate, and assemble the systems to evaluate each individually and then together as a final unit.

The team was successful in designing and building a system using pulsed power to move a piston forward. The functioning benchtop system will be further developed for use in pulsed power skillset development. More testing will be performed during the next year under programmatic space to assess the final inductor value arrangement, reduce the weight of the piston, add a larger power supply, add the second PFN stage, and add the mechanical system for full system testing. This developed approach has the potential to create a platform able to launch projectiles at high velocities with a quicker, cleaner, and more efficient way to pressurize a chamber of gas.



Fully built benchtop system including PFN, EM launcher, and pressure system with launch tube (C. M. Hawkins, 23-037).

Can Two Pulsed Power Sources of Different Source Impedance Drive the Same Non-Linear Load? Z. Shaw (23-133)

Developing the NNSS Critical Skills in Accelerator Science and Beam Physics, T. Burris (23-137)

Electromagnetic Launch Modification to C3 Launcher for Increased Velocity, C. Hawkins (23-037) ***Featured***

Exploration of an Electron LINAC-Driven Photoneutron Source Based on Scorpius, A. Guckes (23-044)

Feasibility of a Single-Stage Electromagnetic Launcher of High Velocity Projectiles, C. Hawkins (23-121)

Health Assessment and Performance Monitoring of Large Machine Diagnostics, J. Adams (23-003)

Non-Invasive Spot Size Diagnostic for Linear Induction Accelerators, E. Scott (23-058)

Utilizing Machine Learning to Automate Linear Induction Accelerator Beam Tuning, D. Clayton (23-040)

Communications and Computing

Mission Agility · Workforce Development

CC

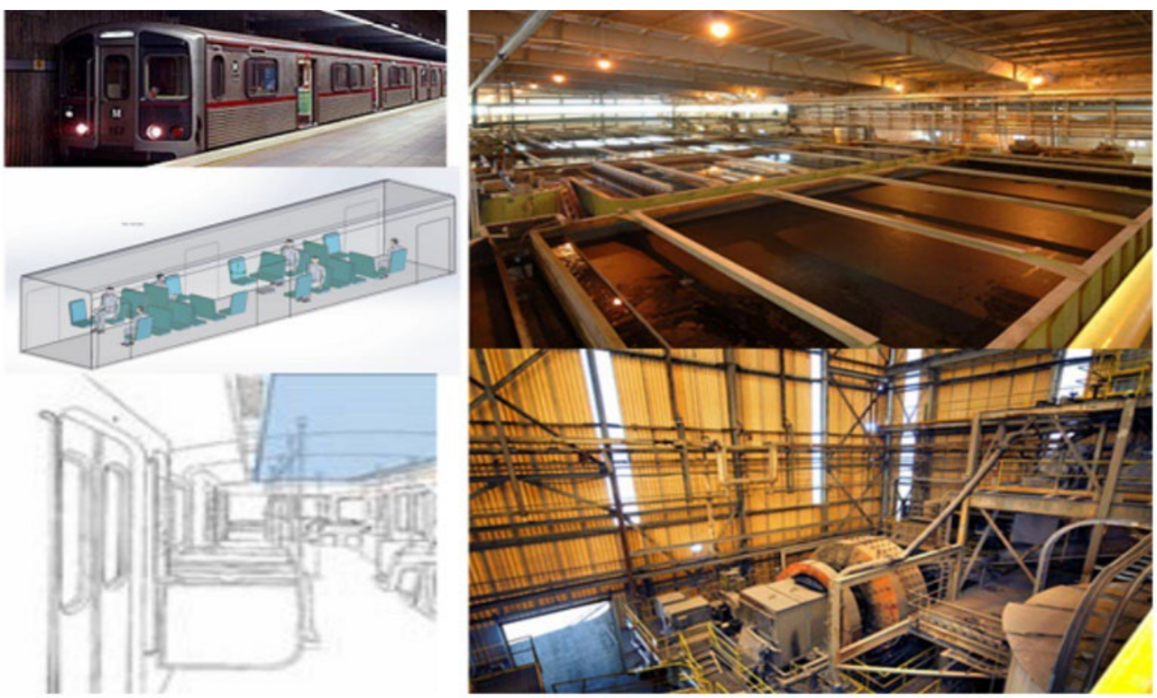
Computational Fluid Dynamic Simulations for Critical Infrastructure (CFD-SCI), S. Breckling (23-016) ***Featured***

"Computational Fluid Dynamic Simulations for Critical Infrastructure (CFD-SCI)"
Sean Breckling
23-016

The goal of this project is to develop new capabilities within the complex to address complicated problems requiring expertise in computational fluid dynamics. There are several established topics of interest to date. One focus is the development of a computational model validating a mitigation technique for situations where gasses or contamination cause insufficient breathable air in occupied spaces common in public transportation (Strategic Partnership Projects (SPP) focus). The second topic is concerned with simulating and characterizing air flow in high hazard chemical production facilities well enough such that an accurate digital twin-type model can be deployed. While these simulation and verification use cases will provide much needed understanding of both vulnerable environments and movement of nonproliferation materials into the environment, a more global result will be developing a core Science & Technology capability for airflow simulation as it applies to our sensing needs.

We are convinced the LESROMs (Large Eddy Simulation – Reduced Order Modelling) are the right approach for our full-scale model. These new techniques couple multiple model reduction methodologies and have shown great promise in literature.

Lessons learned from the first "digital twin" proof-of-concept have guided the construction of our second phase. Incorporating measurement data into the LESROM methodology stands to reduce the number of full numerical simulations required to produce a sufficiently accurate digital twin of the low-speed wind tunnel.



Left: Imagery and model of a Breda 650A passenger railcar. The proposed high flow/low velocity plenum is shown in the bottom left panel. It has not been previously simulated. Right: Two views of a typical drafty building containing chemical extraction tanks (top) and dust generating grinding equipment (bottom). A simplified model of this structure is described as one of the use cases in this proposal. (S. Breckling, 23-016).

Dynamic Experiment Diagnostics

Mission Agility

Technical Vitality

DED

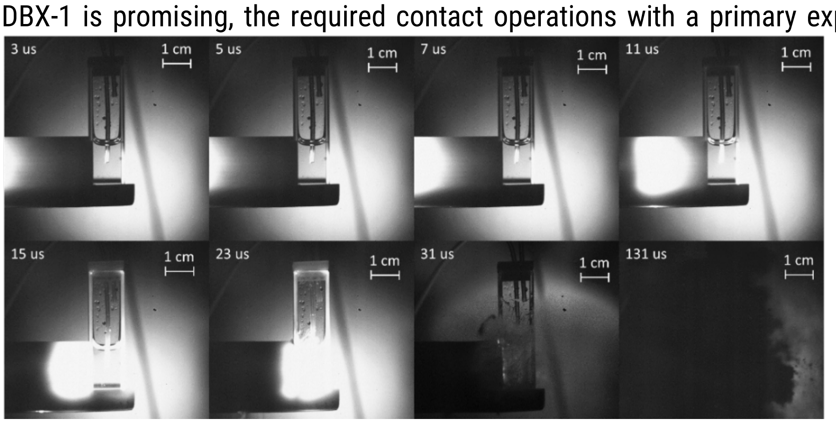
- Direct Measurement of Metal-Hydride Formation during Ejecta Particle Transport in Reactive Gases Using Raman Spectroscopy, J. Mance (23-090)
- Homogenous Detonation of High Explosive by Using Radiation from Shocked Noble Gases for Initiation, T. Myers (23-070), ***Featured***
- Measurement of Dynamic Melting and Re-Crystallization of Shocked Metals, R. J. Scharff (23-060)
- Thermal Transport Detection of Phase Boundaries at Elevated Pressures, G. Stevens (23-022)

"Homogenous Detonation of High Explosive by Using Radiation from Shocked Noble Gases for Initiation"
Thomas Myers
23-070

Thomas Myers presenting at the FY 2023 SDRD Annual Program Review (23-070).

This project sought to develop a homogenous explosive drive by combining a shocked xenon light source with a liquid binary explosive mixture. The development of the shocked xenon light source was successful and sustained a blackbody temperature of at least 25,000 K for 15 microseconds but was unable to detonate mixtures of concentrated nitric acid with various organic fuels. While reported to have extreme sensitivity towards shock, impact, and heat, liquid explosive mixtures of nitric acid and fuels failed to detonate even when shocked with a conventional exploding bridgewire detonator. In light of this, other explosives were investigated, and while the conventional secondary explosive pentaerythritol tetranitrate (PETN) could not be optically detonated with a shocked xenon light source, the experimental primary explosive DBX-1 was successfully detonated. However, due to the limitations on contact work with primary explosives, continuation of this success at the Nevada National Security Sites (NNSS) is not possible at this time. Additionally, this project developed several new capabilities that have benefited multiple NA-10, NA-20, and Site-Directed Research and Development (SDRD)-funded projects including an optically/radio frequency (RF) transparent explosive containment vessel and the safety basis to perform high hazard small scale explosive operations.

This project has demonstrated that explosively shocked xenon light sources are capable of outputting tremendous amounts of visible and ultraviolet light from a relatively simple design. This project has also demonstrated that liquid mixtures of nitric acid and organic fuels, while susceptible to deflagration in the presence of weak external stimuli, are not easily detonated when subjected to intense radiation of explosive shock. Through collaboration, the team has demonstrated that our explosively driven xenon light source can be used to optically detonate primary explosives (DBX-1) but could not quite cross the necessary threshold to detonate secondary explosives (PETN). While the success with DBX-1 is promising, the required contact operations with a primary explosive precludes further development at the NNSS, but additional follow-on funding is being pursued by our collaborators who have the proper facilities and knowledge to pursue primary explosives research. However, the explosive containment vessels and the safety basis for performing high hazard small-scale explosives operations at the Special Technologies Laboratory have been integrated into a variety of other NA-10, NA-20, and SDRD-funded projects, enabling a host of new experiments relevant to the NNSS mission.



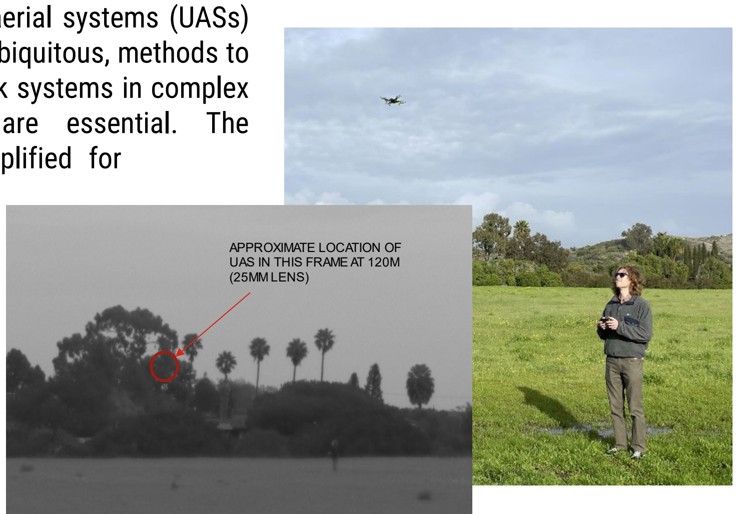
Attempted initiation of a stoichiometric mixture of concentrated nitric acid with nitrobenzene by an explosively shocked xenon light source (T. Myers, 23-070).

Enabling Technologies for Autonomous Systems and Sensing

Mission Agility | Technical Vitality | Workforce Development

"Low SNR, High Clutter UAS Detection and Tracking"
Ian McKenna
23-009

As unmanned aerial systems (UASs) are becoming ubiquitous, methods to detect and track systems in complex environments are essential. The problem is amplified for small vehicles that have low radar cross section (RCS) and little to no visible or infrared signature. This low-cost solution could be added as a subsystem on counter unmanned aerial systems (cUAS) technologies being developed and evaluated at the NNSS. If successful, the completed prototype system will provide an autonomous deployment platform for detection of unmanned systems and can be used to cue countermeasure technologies to mitigate low-observable autonomous threats, critical to the NA-70 physical security mission. The integration of advanced image processing algorithms with current and future state-of-the-art imaging technologies extends current detection capabilities and further enhances our emergency response, nonproliferation, and counter-terrorism capabilities.

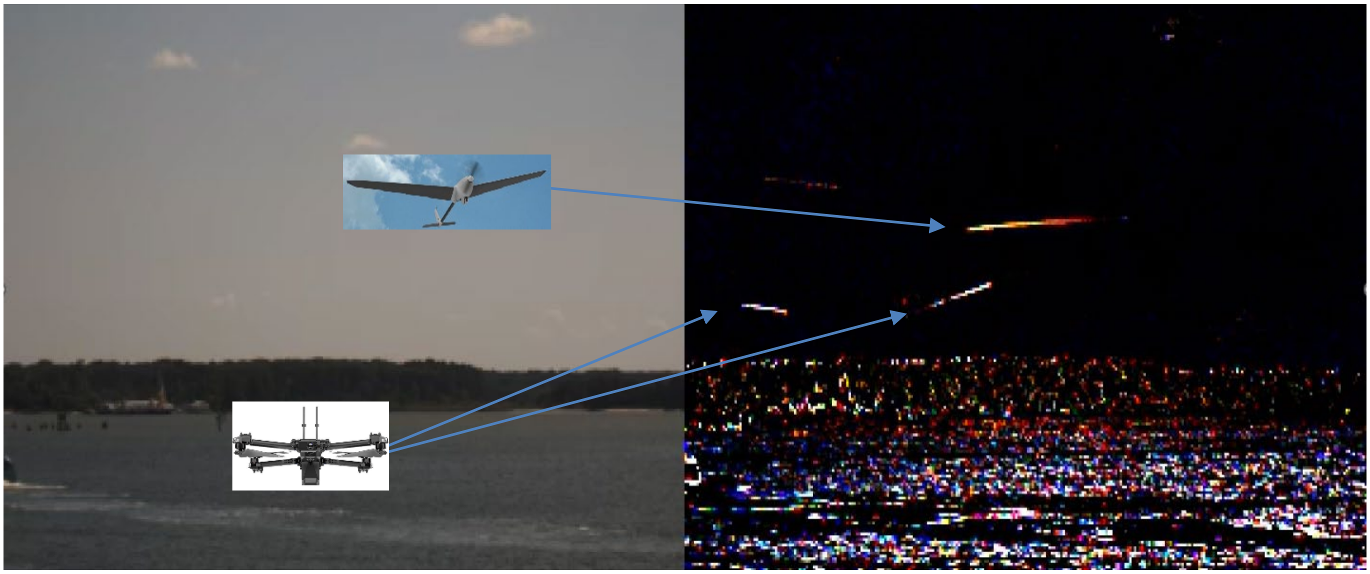


Still frame from 150Hz video stream (left), Tristan Richmond piloting a UAS quadcopter for detection testing (right) (I. McKenna, 23-009).

In previous SDRD work, we proved that atmospheric turbulence was measurable with turbulence enhanced standard video imagery indicating very small changes in air flow are detectable with low cost, commercial off-the-shelf (CMOS) cameras. This project leverages the turbulence enhancement algorithms developed on previous SDRD projects to create a UAS acquisition system using low-cost video cameras and a single board computer (SBC). The turbulence enhancement algorithms not only enhance the turbulence of trails for large UASs, but any variation in intensity associated with the motion of the UAS, even when at very low signal-to-noise ratios (SNRs) sub-resolution targets. The final goal of this SDRD is to have a single camera with associated algorithms. This would allow a full system to be developed with multiple cameras cuing cUASs protecting an area of interest.

ETASS

- Agnostic Modular Payloads for Multi-INT Collection, A. Davies (23-087)
- AR/VR CBRN Solution for Emergency Responders, B. Richardson (23-081)
- Development of a Compact, High-Specificity, Single-Use Sensor/Sampler, D. Baldwin (23-041)
- Low SNR, High Clutter UAS Detection and Tracking, I. McKenna (23-009), ***Featured***
- Mass-Selective Photoionization Detector, M. Manard (23-002)
- Measurements for Combined Gamma Ray and Video Modalities, C. Burt (23-024)
- Microwave Detection through Thin Films, H. Tarvin (23-075)
- Multi-Modal Remote Vibrometer for Infrastructure Interrogation, S. Koppenjan (23-010)
- New Porous Solids for Krypton and Xenon Capture without Cryogenics, M. Morey (23-011)
- Optical Comb Techniques for Hyperfine Spectroscopy, R. Trainham (23-014)
- Robotic System for Radiation Mapping of Dispersal and Point Sources, S. Mukhopadhyay (23-130)
- Spatially Aware Multimodal Directional Radiation Detection Swarms, J. Essex (23-114)
- Surface Gas Sampling Payload for Autonomous Underwater Vehicles, C. Priest (23-034)



Captured frame from Fort Story with Skydio and WingXPand (left), processed image showing black Skydio as being white, vs. the white wings of the WingXPand creating a red enhanced streak (right) (I. McKenna, 23-009).

In early 2023, a member of the research team successfully acquired their Federal Aviation Administration Part 107 certification, allowing for the safe piloting of small UASs to assist in data collection. Early data collections and the addition of a second UAS revealed the variation in contrast of different color UASs against different scene backgrounds. To aid in our parametric studies of object size vs. range vs. platform type (rotary vs. fixed wing) and platform color, we acquired additional lenses and color cameras (1.6, 2.8, and 7.4 MP, color). We collected a large amount of data both at the Special Technologies Laboratory (STL) and at Fort Story on a variety of sizes and types of UASs and background scenes.

We used this collected data to further adapt our algorithms for detection of small UASs as they move across the field of view using standard visible imagery. The detection of the Autel UAS at 2000–3000 feet (0.6–0.9 km) proved the ability to detect sub-resolution (~0.5 pixel) targets.

We modularized and optimized our MATLAB algorithms for speed and for easy conversion to C++ for implementation in an embedded system. We also successfully demonstrated saving data from the Black Fly cameras with the Raspberry Pi 4. In FY 2024, we will prototype in MATLAB the Alert and Display modules.

We have demonstrated the applicability of prior SDRD-developed turbulence enhancement algorithms to detection of small UASs including those that are sub-pixel in size. We collected a large number of relevant datasets to improve and characterize our algorithms. We have modularized these algorithms and began converting these to C++ for implementation in an embedded system.

In FY 2024, we will develop the "Alert" and display modules, which will include an object tracker to determine intent and, ultimately, threat assessment. We will do the needed parametric studies to characterize detected SNR versus system type versus range. As a stretch goal, we will complete the conversion of the MATLAB algorithms to C++ and integrate these modules into a 'main' to demonstrate a real-time embedded single camera system. We will continue to collect data as needed to meet the goals.

Neutron Technologies and Measurements

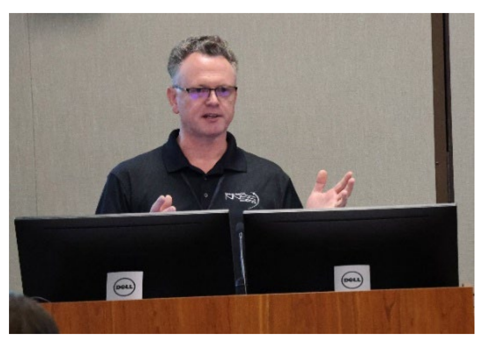
Mission Agility | Workforce Development

"Ultrafast High-Dynamic-Range Photomultiplier Trials"
Robert Buckles
23-119

This project seeks to assemble and assess a future-proof prompt photomultiplier construction based on advanced III-V semiconductor technology. These are the same indium gallium nitride (InGaN)/Aluminum gallium nitride (AlGaN) materials and leveraged industry that have revolutionized UV light-emitting/laser diodes, high-power transistors, and amplifiers over the past decade. These novel wafer level assemblies are manufactured with typical semiconductor processing methods, yet the construction is still quite similar to a classical high-power planar triode/pentode with free-electron transport, just on a very thin scale of photocathode, dynode(s), and anode wafers. Unlike a wire mesh grid, however, we have a crystalline semiconductor mesh of sub-micron epi-layer semiconductor film for complete electronic interactive transport and high gain with the low noise required of a PMT. Ultra-High Vacuum (UHV) processing is typical of both semiconductor processing and PMT construction, and so we retain both aspects in a wafer-bonded package rather than the classic vacuum tube envelope. The very thin structure and high mobility aims at picosecond response required of high energy density experiment applications and linear high dynamic range required of subcritical experiment applications. Our foregoing prototype phototube endeavors are reutilized in a custom vertical wafer assembly process while our university collaboration at the University of Nevada, Las Vegas (UNLV) Nanotechnology Center allows process experimentation and development of a novel foundry-class horizontal process with a larger wafer and the achievement of a Technology Readiness Level (TRL) 5 demonstration.

Top: Wafer Assembly ISO-5/7 cleanroom and vertical assembly apparatus. Bottom: Candidate Dynode and Anode wafers being prepared for assembly (R. Buckles, 23-119).

We have commissioned a modest soft-walled cleanroom for wafer level assembly of a novel PMT concept and are preparing the first such assembly of sapphire/InGaN photocathode with AlGaN multiplier and HR silicon anode. The UHV system to complete the cesium deposition with vertical wafer bonding is also installed in the cleanroom. In early FY 2024, we plan to fully prep the wafer elevator system and commission an atomic-layer deposition cesium oven to begin assembling the wafers. Simultaneously, we expect to complete cesium and indium deposition trials at UNLV to demonstrate a corresponding horizontal process that would occur in a typical foundry.



Robert Buckles presents his project (23-119) at the FY 2023 SDRD Annual Program Review.

NTM

Additive Manufacturing of Structural and Pixelated/Discriminating Scintillators, M. Staska (23-019)

Constraining Physics Models with Complementary PINEX and NUEX Data, J. Clayton (23-110)

Cryogenic Deuterium Pellet Injection for Enhanced Neutron Output of a Dense Plasma Focus, D. Lowe (23-048)

Dual-Use High-Z, High-Cross-Section Materials for Neutron Imaging and In Vivo X-Ray-Initiated Cancer Drugs, J. DiBenedetto (23-107)

Ultrafast High-Dynamic-Range Photomultiplier Trials, R. Buckles (23-119) ***Featured***

Z-Pinch and Laser Ablation-Driven New High-Yield Neutron Source, E. Dutra (23-096)

Radiographic Systems Imaging and Analysis

Mission Agility | Technical Vitality

RSIA

(U) Physics-Informed Deep Learning with Uncertainty Quantification for Weapons Radiography, A. Gonzalez (23-091)

Broadband X-Ray Imager for Spectroscopic Diagnostics, R. Presura (23-061)

High-Z Semiconductors for h-keV Direct X-Ray Imaging, C. Leak (23-088)

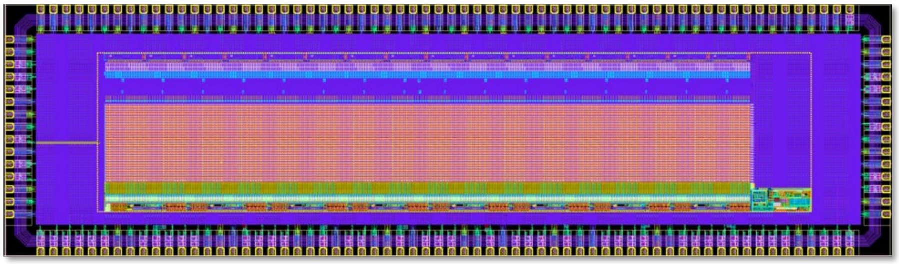
Increased Fidelity via Quantum-Correlated X-Rays: IF via QCX, G. Walker (23-053)

Material Identification in Radiographic Images of Dynamically Formed Metal-Explosive Mixtures by Tuning the X-Ray Source Spectrum Using Multiple Anodes, B. La Lone (23-082)

Novel Photon-Counting Detector Concept for High-Resolution Radiographic Imaging, S. Miller (23-032)

Solid-State Spectrographic Camera for HED and Pyrometry Applications, A. Lewis (23-064) ***Featured***

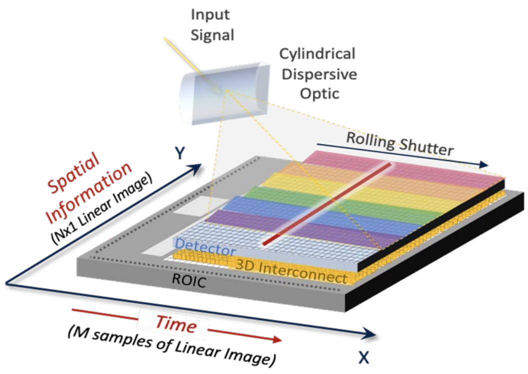
"Solid-State Spectroscopic Camera for HED and Pyrometry Applications"
Amy Lewis
23-064



The ROIC layout was submitted to MESA in May 2023 (A. Lewis, 23-064).

High-speed, nanosecond-scale, time-resolved radiance and pyrometry type measurements are essential to characterize advanced high energy density (HED) material tests at Z and the National Ignition Facility (NIF). Traditional streak cameras suffer from poor detector efficiencies, variation in temporal resolution from shot to shot, and limited spectral range and overall sensitivity. A solid-state solution will provide a reliable, cost-effective option with improved performance. The proposed solid-state spectrographic camera will incorporate a complementary metal oxide semiconductor (CMOS) sensor with a novel shutter distribution architecture to create an imager with ~100 ps resolution. A prototype design will be submitted to the Sandia National Laboratories (SNL) Microsystems Engineering, Science and Applications (MESA) foundry as a ride-along to reduce cost and realize a camera in three years.

A solid-state spectrographic camera capability would benefit many programmatic mission priorities in the following areas: HE-driven ejecta temperature measurements for melt equation of state (EOS) of ejecta or bulk materials in dynamic shock tests to inform physics models, HE and detonator performance tests, EOS for insensitive high explosives tests or high-temperature pyrometry on gas gun tests. Dynamic high-temperature measurements currently with traditional streak camera systems are also a critical diagnostic at Z, Omega, and NIF in the HED program.



S4 Concept Timing. The rolling shutter distribution creates a streak-like image (A. Lewis, 23-064).

Streak cameras have been workhorses in the weapons program for underground testing and subcritical experiments, as well as for university research. Very few flexible solid-state solutions exist for the wide variety of streak camera experiments. If successful, this camera design will create a significant opportunity for the Nevada National Security Sites to provide a state-of-the-art diagnostic system tailored to HED experiments.

User-Centered Remote Testing and Operations

Mission Agility
Technical Vitality

“Feasibility of Reoccupying Historic Testbeds for Future Experiments”
Ian Bortins
23-120

We have developed and patented a fieldable platform for remote sensing sensor characterization. This system is known as GETBAGS, short for Gas Effluent Target BAGs.

Ian Bortins presents the GETBAGS project progress at the FY 2023 SDRD Annual Program Review (23-

The GETBAGS system began development in 2016. In a 2021 National Academies of Science Consensus Study Report, recommendations were made to utilize existing testbeds for nonproliferation activities. The release-less feature of GETBAGS suggests that sensor characterization can be done with minimal personnel in shuttered test locations or in areas where open air gas plume releases are impractical, making it a good fit for use at existing testbeds.

Initial deployment of the GETBAGS system as a concept was successful; however, further development was needed. Technical accomplishments that we have made this FY are primarily about making improvements to the GETBAGS system to expand capabilities for our historical testbeds. We are submitting a patent application for our design of the pressure plate system and we have had conversations with commercial vendors.

In the previous work that we have conducted with the GETBAGS system, we have demonstrated that it can be used as a successful target for both aerial and ground-based imagery collection in lieu of an open-air gas release. This year’s work has positioned us well for a leap in progress in the next fiscal year where all of the preparation for system upgrades and work with commercial vendors will come together in demonstrating why this system will be a great asset for our historical testbeds and use in future SDRD projects.

UCRTO

Feasibility of Reoccupying Historic Testbeds for Future Experiments, I. Bortins (23-120) ***Featured***

Fundamental Experiments for Detonation Signature Modeling, C. Kimblin (23-007)

Incorporation of Geologic Data into Centralized Database, D. Smith (23-062)

Increasing Options for Aerial Testbeds to Eliminate Single Aerial Asset Dependence, M. Howard (23-127)

Modernization and Scalability Enhancements for Sub-Nanosecond Accuracy Diagnostic Cross Timing for Use at Current and Future NNSS Testbeds, D. Champion (23-049)

Project Moonshot Soft-Landing Study, B. Eleogram (23-124)

Refinements to the Geological Framework Models, M. Scalise (23-131)

Spatial Spectral Observations from Near and Far, M. Howard (23-095)

SDRD MVPI

With many exceptional projects going on around the NNSS, the S&T Directorate is proud to continue the honor of naming SDRD's Most Valuable Principal Investigator (MVPI) in FY 2023. Each year, one principal investigator (PI) who has excelled in his or her area of research receives special recognition through the MVPI award. Nominations from around SDRD came from nearly every STTA and reflect our mission to support innovative and high-risk concepts and technologies for the nuclear security enterprise. The MVPI winner and each of the nominated PIs are highlighted with their projects below.

Hilary Tarvin
2023 MVPI Winner

Hilary Tarvin is the MVPI for FY 2023!

Her FY 2023 SDRD project, "Microwave Detection through Thin Films" (23-075), sought a low-cost solution to measuring potentially harmful levels of microwaves. During her work with the U.S. Air Force, she noticed aircraft mechanics and personnel could be exposed to microwaves at unknown levels. Although measuring microwaves is not new, electronic detectors are often costly and cumbersome for implementation in a large workforce. Hilary and her team are working to create a low-cost, low-SWaP microwave detector that could be worn on someone's person while working.

In the first year of the project, the prototype detectors were successful at achieving the minimum wattage and exposure time requirements. Now entering the second year, the project aims to expand the detection range and investigate methods to quantify the microwave exposure.

This innovation holds the potential to improve the safety envelope of workforce personnel and exemplifies the goals and purpose of SDRD. As one reviewer commented, "*she really produced and demonstrated how SDRD can really achieve success in a short amount of time*."

Hilary M. Tarvin, M.S., *Remote Sensing Laboratory, Nellis*, received her B.S. from the United States Air Force Academy in Materials Chemistry and her M.S. from the Colorado School of Mines in Materials Science. She spent eight years in the Air Force maintaining fighter aircraft with a focus on counter Russian air policing and fifth generation test and development. She later returned to teach both core chemistry and weapons chemistry at her alma mater, the US Air Force Academy, and then joined the Special Programs Department at the Remote Sensing Laboratory in Nevada in 2021. Since then, she has worked on a number of projects including nonproliferation efforts in both the uranium and weaponization portfolios.

Congratulations to Hilary on her MVPI award! We look forward to the completion of this and future innovations she will bring to SDRD at the NNSS.

Runners Up

The following PIs were also considered for this year's MVPI award. Below is a short description of the PIs and the projects that earned them their nominations.

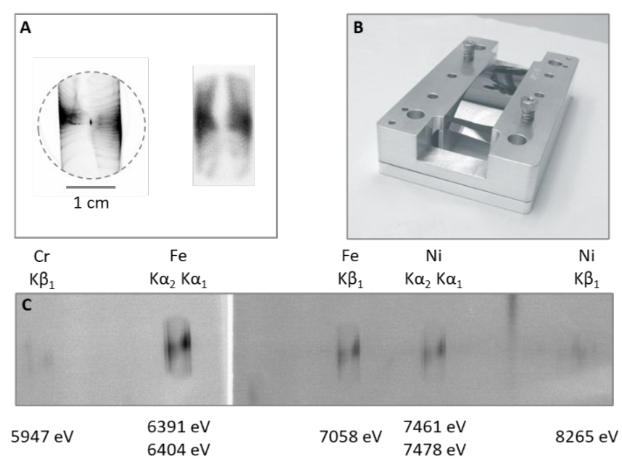
John DiBenedetto
Nominee

John DiBenedetto received an MVPI nomination for his SDRD project "Dual Use High-Z, High-Cross-Section Materials for Neutron Imaging and In-Vivo X-Ray Initiated Cancer Drugs" (23-017). Differences in gamma/neutron energy deposition can generate differences in emission color. Successful scintillation may lead to a neutron imager in a follow-up SDRD. If x-ray scintillation can be coupled to reactive compounds, a new class of cancer drugs based on x-ray photodynamic therapy will be created. These same scintillators may act as sensitizers to drive in-vivo nitric oxide production when functionalized with organometallics materials.

Dr. John DiBenedetto, *Special Technologies Laboratory*, is a Distinguished Member of the Technical Staff and the former manager of the Nonproliferation Department at the NNSS STL. His current research is focused on radiological and chemical signatures related to threats against the Homeland. Most recent activities have included ground-based hyperspectral imaging for trace detection, validation techniques for airborne sensors, and the development of novel scintillation materials. Under his leadership, the Nonproliferation Department became well known for their optical work in laser fluorescence remote sensing, field-ready effluent diagnostics, tagging, tracking, and locating, and optical ground truth. Since joining the NNSA as a researcher, Dr. DiBenedetto's focus has been on remote spectroscopy and imaging of trace contaminants by fluorescence (solids), reflectance (solids), Raman (solids), and absorption (gases). Remote sensing research has included the conceptualization, design, and deployment of airborne and hand-held fluorescence imaging instrumentation (LIFI), portable ground-based hyperspectral imagers, optical spectroscopy of vegetation and uranium oxides, the design of fluorescence imaging systems for forensic signatures, and the design and development of optical blood reagents. He developed diagnostics for calibrating effluent plumes from chemical sources at NNSS resulting in the development of ruggedized, stack-mounted Fourier Transform Infrared Spectrometers used to calibrate effluent concentrations at the aperture of the release stacks used for testing remote detection systems. Other trace detection projects have incorporated multiple techniques such as reflectance, polarization, microscopy, and Raman and infrared spectroscopy.

Radu Presura
Nominee

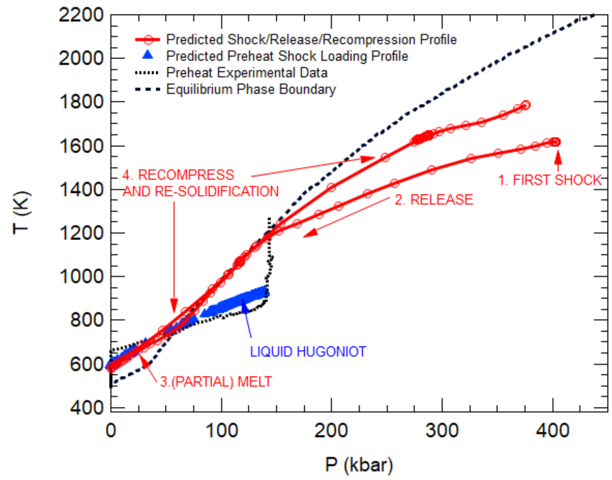
Radu Presura was nominated for MVPI for his SDRD project, "Broadband X-Ray Imager for Spectroscopic Diagnostics" (23-061). This work provides spectra that enable, in principle, 2D space-resolved plasma diagnostics, e.g., maps of plasma density and



A. Two images of Henke x-ray sources obtained with 50 μm (left) and 50-μm (right) pinholes. B. Si crystal mounted in the 5" bending fixture. C. Spectrum of the radiation from a Henke source with stainless steel anode (R. Presura, 23-061).

temperature. Reviewers were very impressed with Radu's work on multiple levels. They noted that "*Radu's work stood out with noticeable advancements in spectroscopy*," had "*innovative research with impressive results*," and resulted in "*five conference presentations and posters*." One reviewer sang his praises over his additional work with the internship program: "*Most impressive is his project integration and mentoring with multiple interns over a few months' time. His last intern won presentation of the year for the NNSS group of summer interns*."

Dr. Radu Presura, *Sandia Operations*, joined the NNSS in 2016, after serving for over 15 years on the research faculty in the Physics Department at the University of Nevada, Reno. His research has focused on high energy density plasma generation, applications, and diagnostics. He has mentored several postdoctoral scholars and graduate students and has co-authored over 60 publications in peer-reviewed journals. Radu holds Ph.D., masters, and undergraduate degrees in physics from the University of Bucharest, Romania. Currently, he is a Principal Scientist at the Sandia Office, where he works on x-ray diagnostics for experiments on the Z Facility.



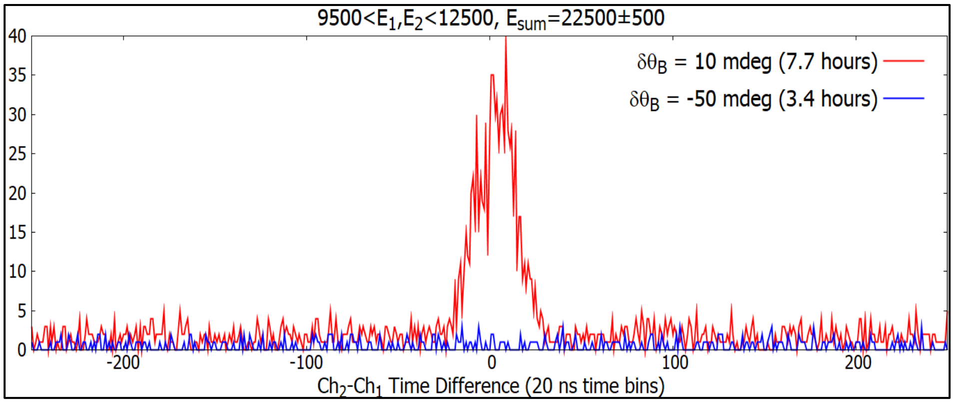
NNSS developed phase/temperature diagnostic demonstrates that phase change kinetic pathways depend on initial starting conditions of the material (R. J. Scharff, 23-060).

Robert J. Scharff (Jason) Nominee

Robert J. Scharff (Jason) has been nominated for MVPI for his work on "Measurement of Dynamic Melting and Re-Crystallization of Shocked Metals" (23-060). Reviewers were impressed with this project and observed that "*the diagnostic techniques can be rapidly adapted to TA-55 and JASPER to provide accurate and time resolved temperature and pressure data for determining phase transition dynamics. This will more than likely be the preferred diagnostic tool to directly measure the phase behavior of SNM at TA-55, JASPER, and PULSE*."

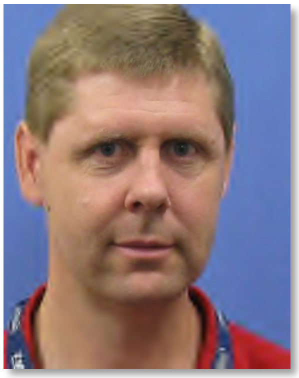
Accurate simulation of the dynamic trajectory of a nuclear primary critically relies on high-fidelity models of the equation of state and constitutive properties of plutonium and relevant materials. Of particular importance to the nuclear weapons design agencies is the accurate measurement of the temperature of weapons relevant materials subjected to high strain-rate compressive and tensile loading conditions. The reason being that the locations of solid-solid and solid-liquid phase boundaries are critical components to the equation of state model, whose accuracy is seminally important to nuclear weapon design and certification. As such, NNSS scientists have engaged in the development and testing of diagnostic tools to directly measure the phase and temperature of dynamically loaded materials. This project advances a recently developed NNSS phase and temperature diagnostic using simultaneous radiance and reflectance spectroscopy for use in ever more complex dynamic loading conditions that are important to the nuclear weapons design agencies.

Dr. Robert J. Scharff (**Jason**), *Special Technologies Laboratory*, joined the NNSS in 2017 as a full-time staff member at LAO. Jason provides advanced technical leadership to NNSS shock physics and diagnostic instrumentation teams. He received a Ph.D. in Chemical Physics from The University of Texas at Austin in 2005. He was a Los Alamos National Laboratory (LANL) Postdoctoral Research Associate (2005-2008) prior to his full conversion to the LANL technical staff (2008-2017). As a research scientist, Jason’s professional work spans multiple disciplines that include nuclear weapons physics; fundamental and applied research in the chemistry and physics of energetic materials; shock wave physics of metals and porous materials; program development through internal and external proposal writing; and principal investigator for programmatic projects. He has 40+ peer-reviewed publications with 1000+ citations in numerous research areas that include high explosives chemistry, shock and detonation physics, materials science, optical spectroscopy, and quantum chemistry. Jason’s current research focus at the NNSS is in shock wave compression science, particularly in the areas of equations of state development for metals, phase transition kinetics, and dynamic strength model development.



Histogram of events vs. time difference between the two Vortex detectors. No peak for the -50 mdeg data is expected since down conversion is not possible for a negative crystal rotation (G. Walker, 23-053).

Gary Walker
Nominee



Gary Walker has been nominated for his project “Increased Fidelity via Quantum Correlated X-Rays: IF via QCX” (23-053). This work found a very clear signal and a 10x higher coincident rate, unambiguously demonstrating the production of correlated pairs at 11 keV. A paper describing the measurements and results has been submitted to the journal *Results in Physics* for publication.

Standoff capability to determine mission-critical attributes of enclosed targets has been a crucial and long-standing need within the response community. This information is vital to inform critical decisions, reduce risk, and achieve mission success. Gary’s team undertook an investigation into x- ray quantum imaging techniques to enhance the imaging of targets of interest to NNSS. Quantum imaging offers numerous practical advantages at visible wavelengths, including improvement in RADAR/LIDAR, sub shot-noise imaging, improved imaging in turbulence or diffuse samples, and imaging at extremely low illumination levels. In the last decade quantum light sources at x-ray wavelengths have been demonstrated, with some work suggesting the benefits of quantum imaging may be realized in the x-ray regime. These exciting developments may be directly applicable to improving standoff imaging and to penetrate and 'see through' materials for national security applications.

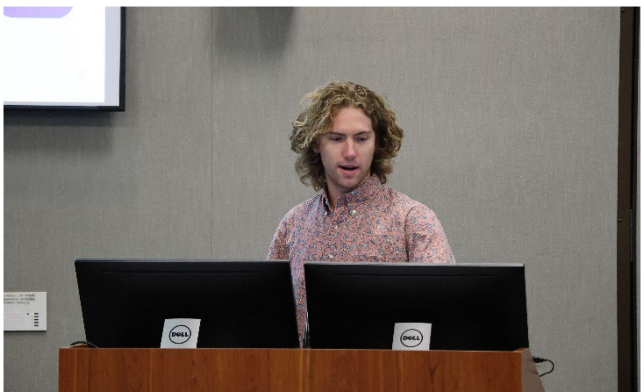
Gary Walker, *Remote Sensing Laboratory, Nellis*, earned a Ph.D. in physics from the University of Utah studying gamma-ray astronomy. Following three years as a postdoc at LANL in the same field, he joined the NNSS in 2008. His work at the Remote Sensing Laboratory, Nellis has necessarily covered a broad range of topics, including supporting numerous government tests at the Radiological/Nuclear Countermeasures Test and Evaluation Complex, gamma-ray spectroscopy, measurement of transient RF sources, infrasound and overpressure measurements, x-ray safety studies in support of the Nuclear Emergency Support Team, and quantum-correlated x-rays.

Honorable Mentions

The following PIs and their projects were also considered during the nomination period.

Ian Bortins and **John DiBenedetto** for *Feasibility of Reoccupying Historic Testbeds for Future Experiments* (23-120). Featured on page 20.

Amy Lewis for *Solid-State Spectroscopic Camera for HED and Pyrometry Applications* (23-064). Featured on page 19.



Tristan Richmond presents at the FY 2023 SDRD Annual Program Review (I. McKenna, 23-062).

Ian McKenna for *Low SNR, High Clutter UAS Detection and Tracking* (23-009). Featured on page 16.

Mark Morey for *New Porous Solids for Krypton and Xenon Capture without Cryogenics* (23-011).

Devon Smith and **Andrew Miller** for *Incorporation of Geologic Data into Centralized Database* (23-062).

Devon Smith presents at the FY 2023 SDRD Annual Program Review (23-062).

Synthesized Metal Organic Framework (M. Morey, 23-011).

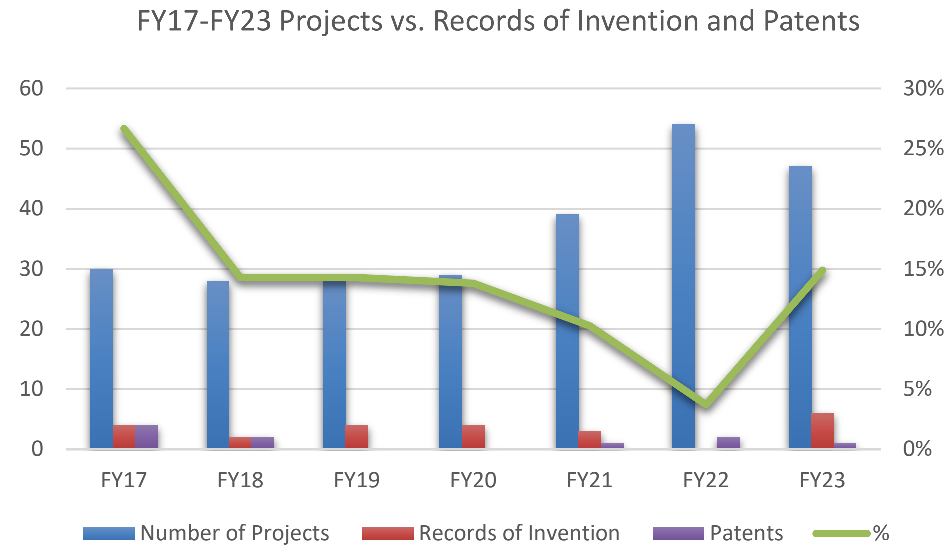
Program Value

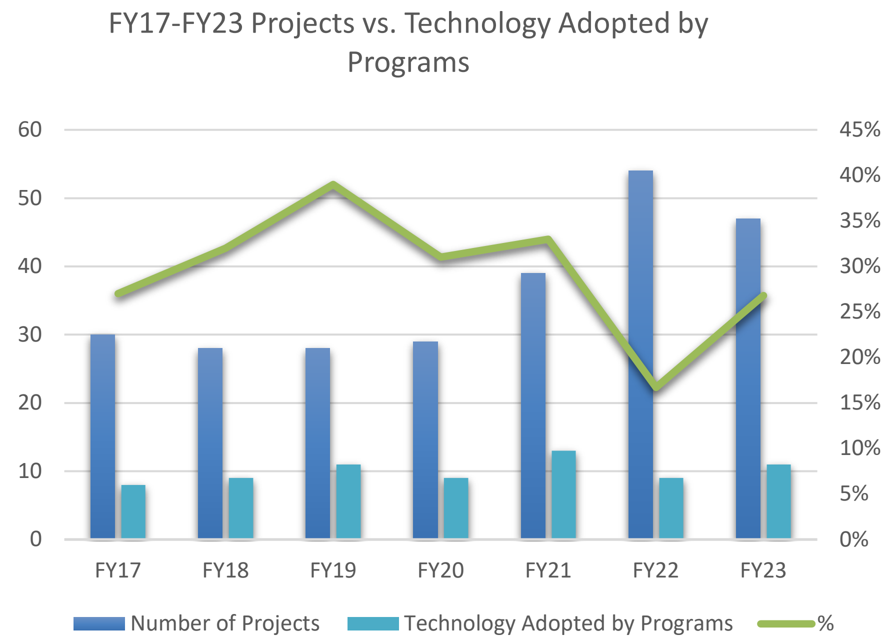
SDRD Program Performance Metrics

SDRD Program Performance Metrics: FY 2017 to FY 2023							
Metric	FY17	FY18	FY19	FY20	FY21	FY22	**FY23**
Number of Projects	30	28	28	29	39	54	**47**
Records of Invention	4	2	4	4	3	0	**6**
	13%	7%	14%	14%	8%	0%	**11%**
Patents	4	2	0	0	1	2	**1**
Technology Adopted by Programs	8	9	11	9	13	9	**11**
	27%	32%	39%	31%	33%	17%	**27%**
Gap or Need Addressed	13	11	14	12	18	27	**29**
	43%	39%	50%	41%	46%	50%	**71%**
Emerging Area and Special Opportunity	5	6	3	6	18	11	**9**
	17%	21%	39%	21%	46%	20%	**22%**
Journal Publications	8	8	10	24	21	16	**5**
Postdocs	1	2	2	2	12	4	**4**

Records of Invention and Patents

When new and novel ideas are realized in SDRD projects, PIs are invited to submit a Record of Invention detailing and protecting their intellectual property. Patents are then pursued when appropriate. In FY 2023, a total of six Records of Invention were filed, and one of those resulted in a Patent filing. With these six, SDRD accounted for two-thirds of all Records of Invention submitted by the NNSS in FY 2023.



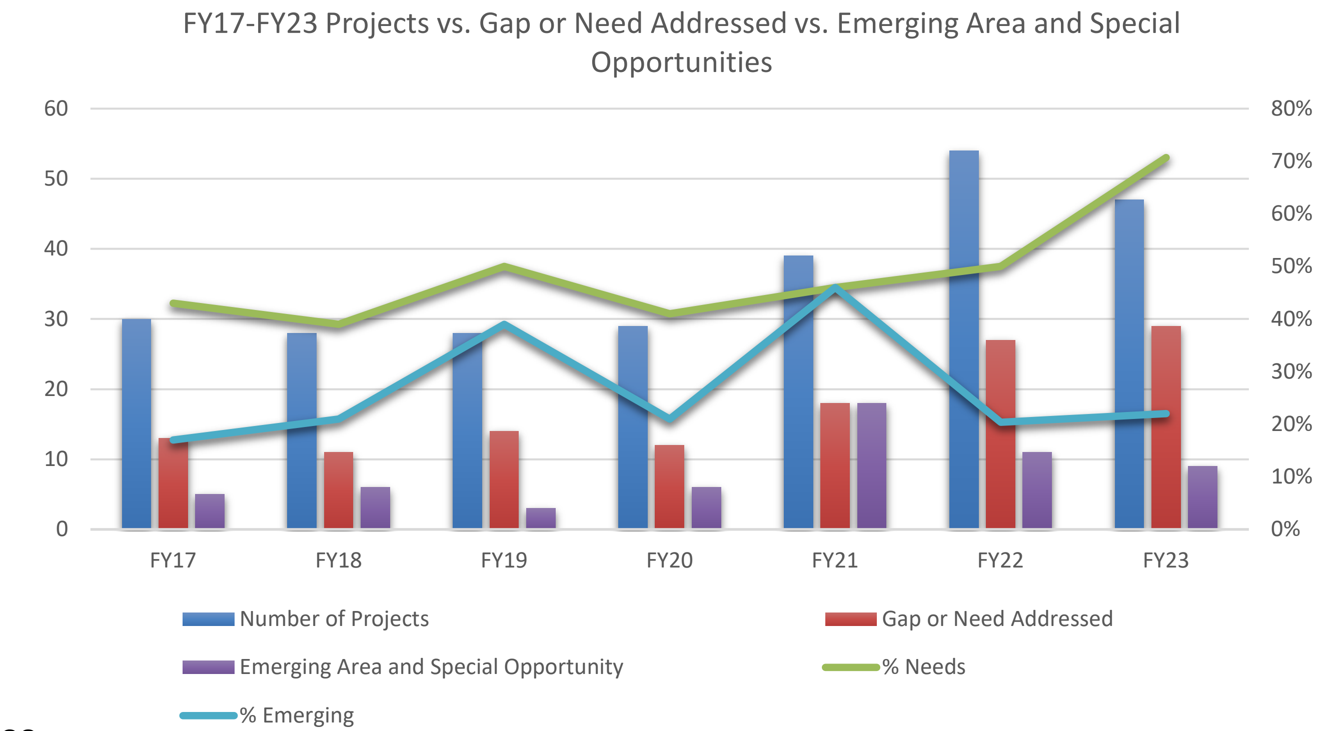


Technology Adopted by Programs

Anticipating needs and providing technology solutions are the cornerstones of the SDRD program, and migrating SDRD-developed technology into programs is a key metric for SDRD program success. In FY 2023, 11 SDRD technologies were adopted by Programs, a rate of nearly 27%.

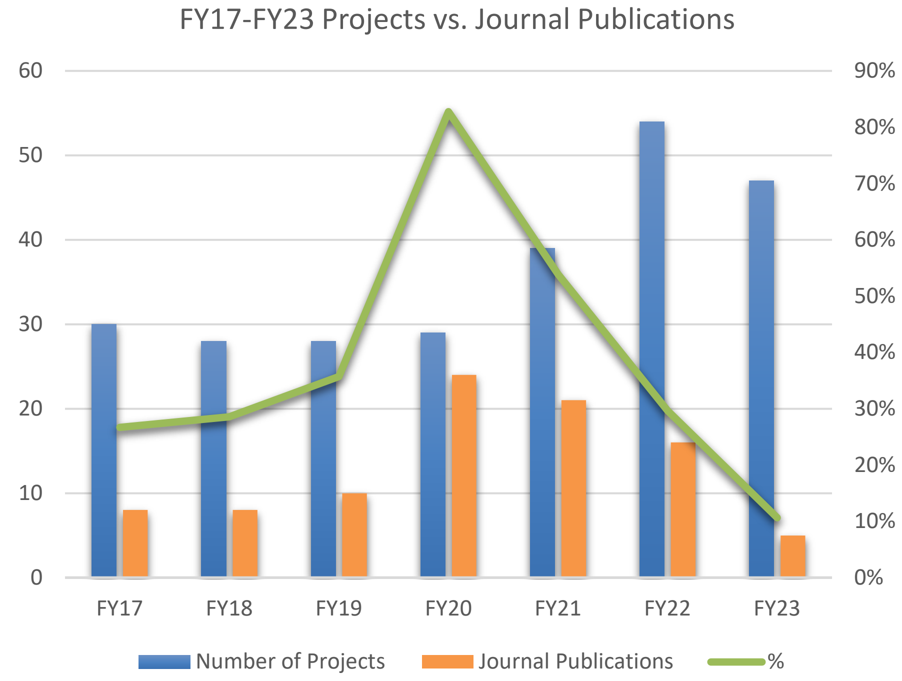
Technology Needs Addressed

Each year, the NNSS creates a Needs Assessment document to guide potential PIs in what mission needs are known and anticipated. The SDRD proposal process evaluates how closely the preproposals align with these mission needs. For FY 2023, over 70% of the projects funded were directly addressing one of these identified needs. Emerging Areas and Special Opportunities are those that, while not historically under SDRD, fulfill a nationally identified priority. In FY 2023, SDRD had 9 such projects representing 22% of the portfolio.



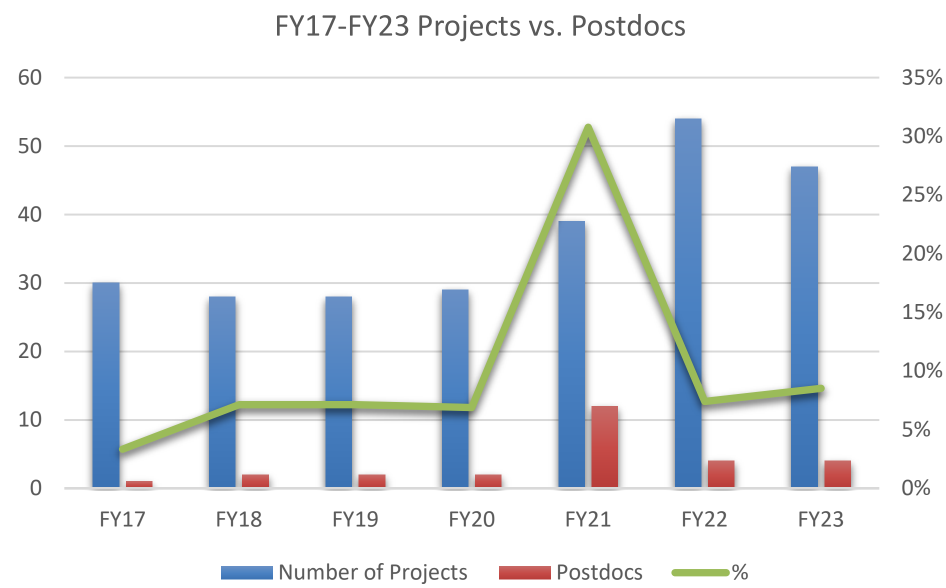
Publications

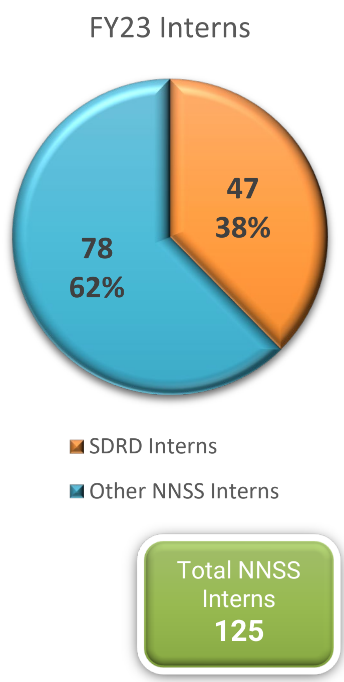
Publications in peer-reviewed journals showcase the various scientific and technical achievements of our PIs. SDRD had five publications for FY 2023 including prestigious peer-reviewed journals such as the *Journal of Applied Physics*, *Communications: Physics*, and *Spectrochimica Acta Part B: Atomic Spectroscopy*, as well as in the proceedings of SPIE, the International Society for Optics and Photonics, in the Hard X-Ray, Gamma-Ray, and Neutron Detector Physics category.



Postdocs and Interns

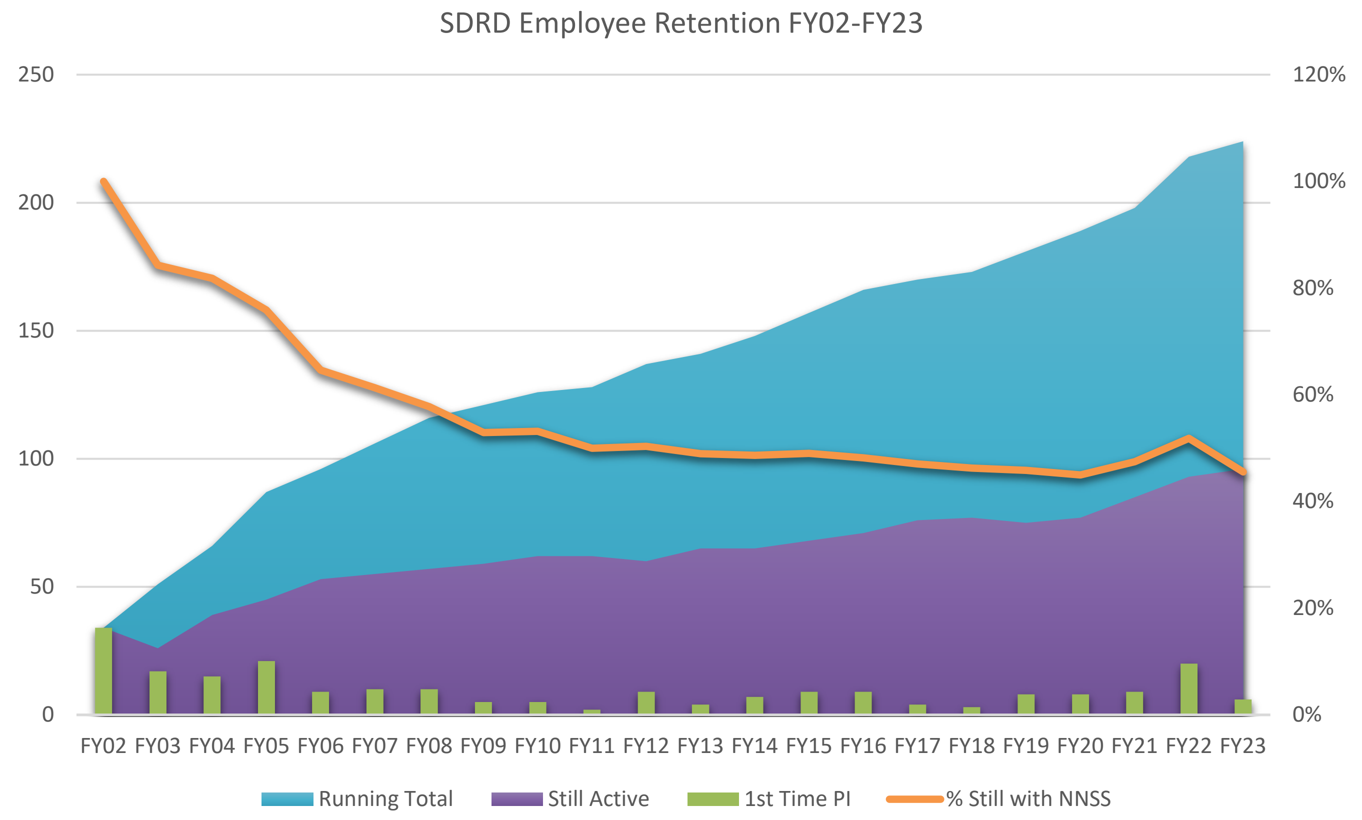
Early Career Employees are essential to bringing in new perspectives and innovative ideas. The SDRD program had 4 postdocs in FY 2023 and 47 interns, which accounted for 37.6% of the total number of interns at the NNSS.





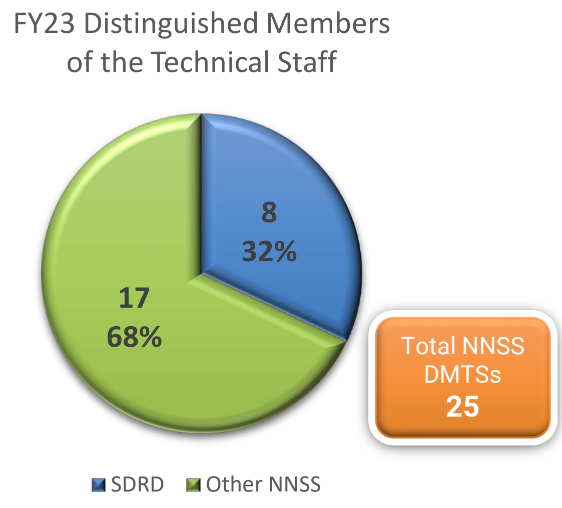
Employee Retention and the NNSS

Employee conversion and retention reveals the desirability to work at the NNSS. SDRD has brought on 224 unique PIs over the last 21 years and has retained 102 for an overall retention rate of 46%.



The Top 2%: Distinguished Members of the Technical Staff

The NNSS recognizes the lifetime achievements of its most seasoned scientists and engineers through a promotion to the title of Distinguished Member of the Technical Staff (DMTS). DMTSs are recognized by the NNSS as authoritative sources of information as they provide strategic direction to senior management as well as mentorship to early- and mid-career staff. Of 25 DMTSs currently at the NNSS, 8 are active participants in SDRD.

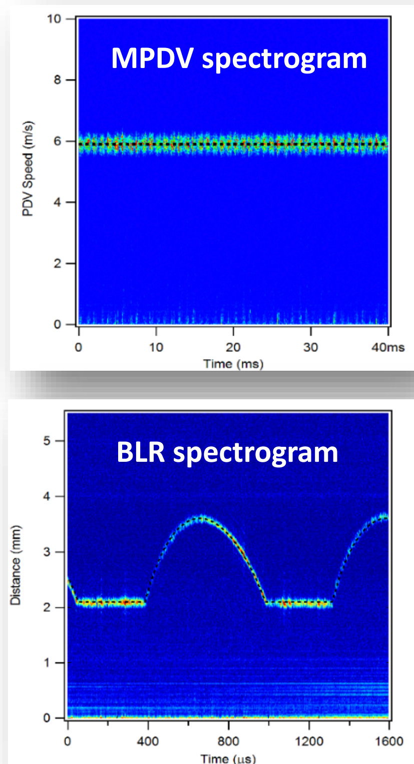


SDRD Impact Stories

Broadband Laser Ranging (BLR)

The Next Level of Dynamic Material Diagnostics

Traditional velocimetry that is routinely implemented in shock physics experiments does not always return a reliable position of a moving surface. A repetitive broadband laser pulse reflected off a surface is interfered with a reference, giving an interferometric measure of position as a function of time. This new diagnostic is integrated alongside traditional velocimetry and has been implemented and fielded at numerous NNSA facilities.

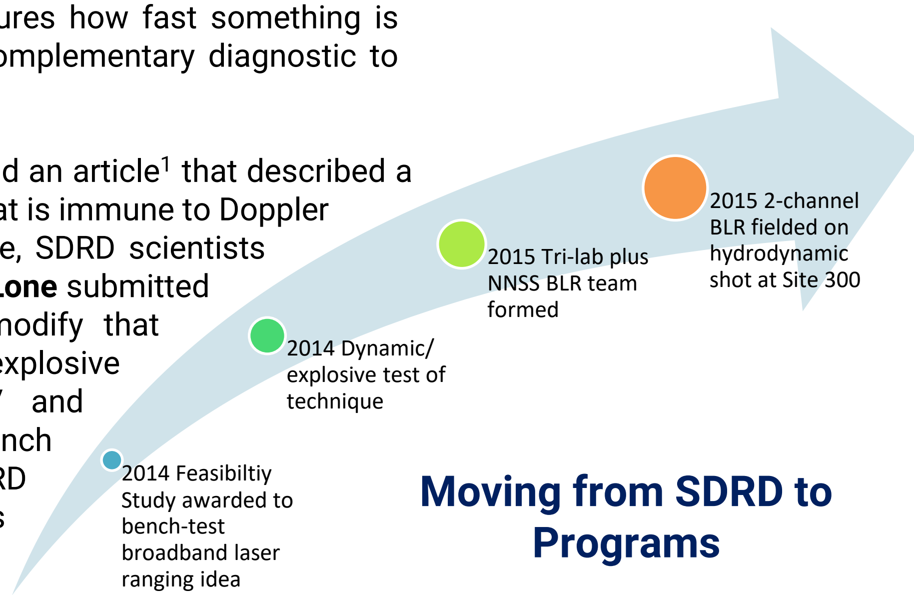


Comparison of the output of the MPDV diagnostic (top) against the output of the BLR diagnostic (bottom).

Broadband Laser Ranging (BLR) is a diagnostic intended to measure the position of rapidly moving surfaces in combination with optical velocimetry. The diagnostic uses spectral interferometry to measure distance by mapping femtosecond laser pulses to the time domain via chromatic dispersion within the fiber-optic architecture.

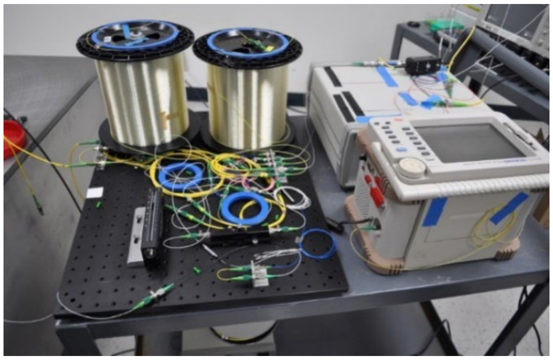
Velocimetry measurements in shock physics experiments previously relied on technology such as the fiber pin dome implemented at Lawrence Livermore National Laboratory. These pins provide one position and one arrival time for every pin on the device. Multiplexed photonic Doppler velocimetry (MPDV) is an optical system that provides continuous velocity records along discreet directions but does not necessarily give positions. Because MPDV measures how fast something is moving and not where it is, a complementary diagnostic to measure distance was needed.

In April of 2014, researchers found an article[1] that described a technique for dynamic ranging that is immune to Doppler shift. Starting with that technique, SDRD scientists **Bruce Marshall** and **Brandon La Lone** submitted an SDRD feasibility study to modify that diagnostic for use on explosive experiments by adding MPDV and extending the full range. The bench test proved viable and further SDRD projects were borne out of this



Moving from SDRD to Programs

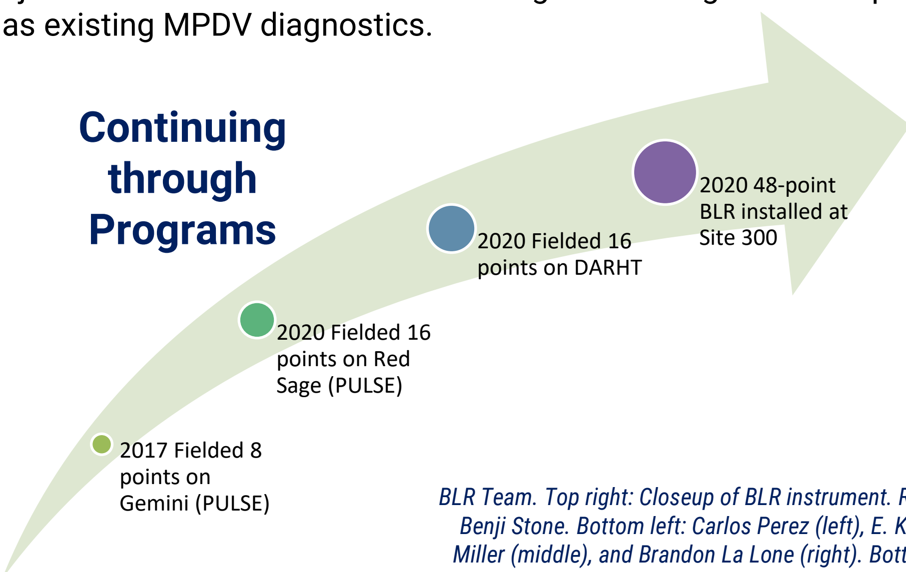
[1]H. Xia and C. Zhang, Optics Express **18**, 4118 (2010).



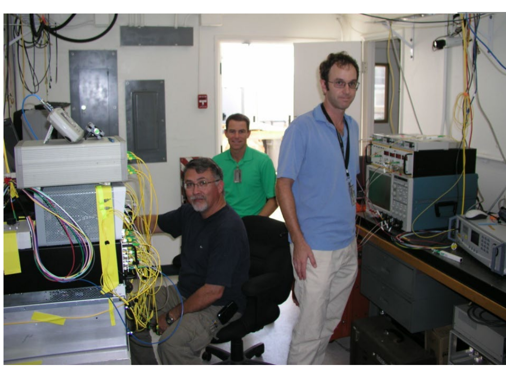
Early BLR prototype.

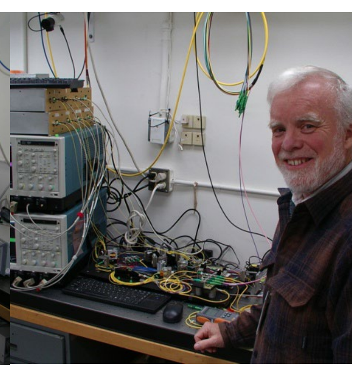
newly developed diagnostic. An SDRD project in FY 2020 by Brandon, **Matt Staska**, **Ben Valencia**, **Gerald Stevens**, and **Rick Allison**, along with **Ricky Chau** (Lawrence Livermore National Laboratory) and **Dan Dolan** (SNL), as well as an FY 2021 SDRD project by **Radu Presura**, **Matthew Wallace**, **Showera Haque**, **Padrick Beggs**, **Robert Heeter**, **James Heinmiller**, and **Isiah Pohl**, with **Patrick Lake** and **Ming Wu** (SNL) stemmed directly from the original 2014 work on BLR.

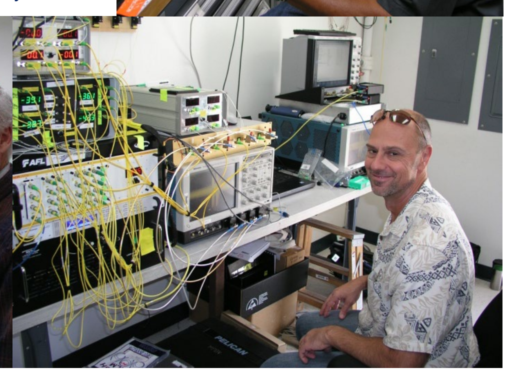
Since its inception, BLR has been fielded throughout the NNSS, notably in 2020 at Site 300 with a 48-point BLR, at DARHT [Dual Axis Radiographic Hydrodynamic Test facility] with 16 points, and at PULSE with 16 points. Currently, BLR can determine position every 10 to 80 ns with ~10 μm accuracy and with ~100 μm accuracy for two-surface resolution. The current range of BLR is approximately 150 mm with no upper limits yet found. Multiple positions can be resolved simultaneously including fragments and clouds of ejecta. The BLR also has the advantage of sharing the same probe as existing MPDV diagnostics.

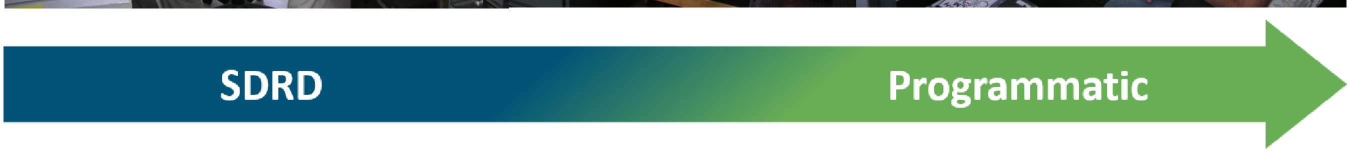


BLR Team. Top right: Closeup of BLR instrument. Right: Benji Stone. Bottom left: Carlos Perez (left), E. Kirk Miller (middle), and Brandon La Lone (right). Bottom middle: Bruce Marshall. Bottom right: Ed Daykin.







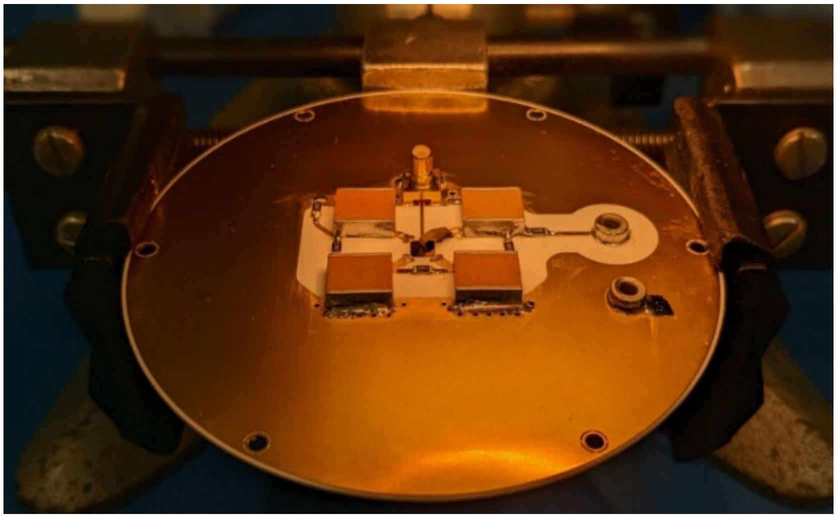


SDRD Programmatic

Multi-Layered Avalanche Diamond (MAD) Detector

MAD about Radiation Detection

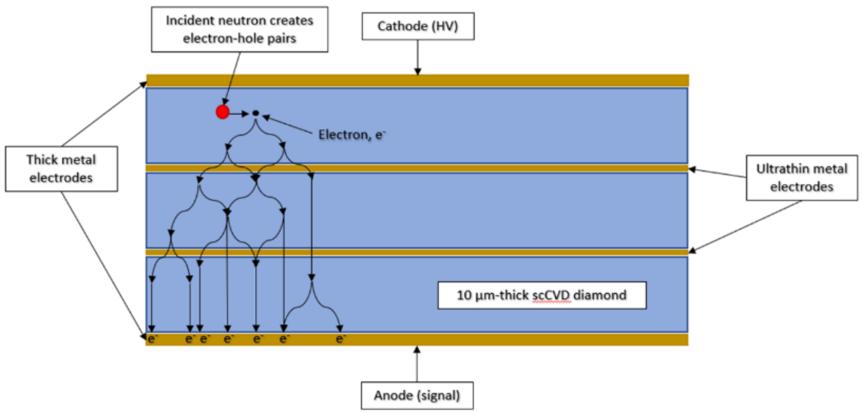
NDSE work at the NNSS requires accurate and timely measurements of the pulsed neutron source. The novel MAD detector utilizes the avalanche effect in diamond to achieve multiplicative gain for faster, smaller, and more efficient neutron measurements. The work originally funded by SDRD has since been developed into designs that are currently being incorporated into NNSS Programs.



Experimental 4-layer Gen 1 MAD Detector prototype.

SDRD Program researchers, **Amber Guckes**, **Robert Buckles**, **J. Andrew Green**, and **Adam Wolverton**, in collaboration with Applied Diamond, Inc., developed a multi-layered avalanche diamond (MAD) detector suitable for radiation detection applications. High gamma ray rejection and intrinsic detection efficiency are requirements important to the success of high-flux neutron source experiments across the DOE complex. MAD detector research and development focused on the measurement of the pulsed neutron source used in the Neutron Diagnosed Subcritical Experiment (NDSE) project at the NNSS. The use of diamond for prompt neutron detection is currently used at Area-11 at the NNSS and provides a high-bandwidth, clean signal to experimenters.

Diamond can efficiently detect neutrons and reject gamma ray interactions, a quality important to high-flux neutron source experiments. The main drawback is the small amplitude of the signal measured, but this can be improved with an increase in gain. The idea of the MAD Detector stemmed from research exploring the effect of thin single-crystal chemical vapor deposition (scCVD) diamond. The SDRD program funded research to further explore the avalanche effect in metalized thin scCVD samples to see if it could be harnessed to build a device that has inherent multiplicative gain. By using thin diamond layers, the MAD detector takes advantage of the intrinsic avalanche and atomic properties of scCVD diamond to yield a novel fast neutron detector with inherent gain, improved detection efficiency compared to a single layer, and a small footprint. The desired avalanche effect was observed at electric fields greater than 30 $\frac{\mathrm{V}}{\mu\mathrm{m}}$ on diamond samples as thin as 5 μm across.



Neutrons interact in the scCVD Diamond resulting in the creation of electron-hole pairs. These electrons are accelerated with high electric field across the thin diamond stack and causes avalanche through impact ionization.

The beginning of this project was truly exploratory in characterizing the effect of diamond thickness, patterning of metallization layers, and different passivation materials. Once the desired materials, thickness, and patterning were determined, a few conceptual designs were chosen to be fabricated and assembled. The design that was pursued utilized the concept of a vertical stack of thin diamond layers. These layers had increasing potential, which would apply field from one layer to the next. Keeping the diamond and metallization layers thin allows for electrons created from the avalanche process to transport through the diamond layers and induce additional avalanche events through the stack.

In FY 2023, the MAD detector became entirely funded by programs and multiplicative gain was achieved in the first iteration of the design. This achievement signifies successful movement of a technology from an idea in the SDRD program to programmatic adoption. Currently the team is moving towards an improved design that will streamline the bonding and assembly process to package this detector as a product to be used in future designs for experiments around the complex. This project has achieved success outside of SDRD as well in having publications, copyright assertion for records of invention, and an R&D 100 award submission.

MAD Detector team members at the University of Delaware. From left to right: Robert Buckles, Kaleab Ayalew, Amber Guckes, and Adam Wolverton.

Acknowledgments

Welcome to the SDRD FY 2023 Annual Program Review!

SDRD requires a talented team of individuals to ensure success from year to year. Without their support, none of this would be possible.

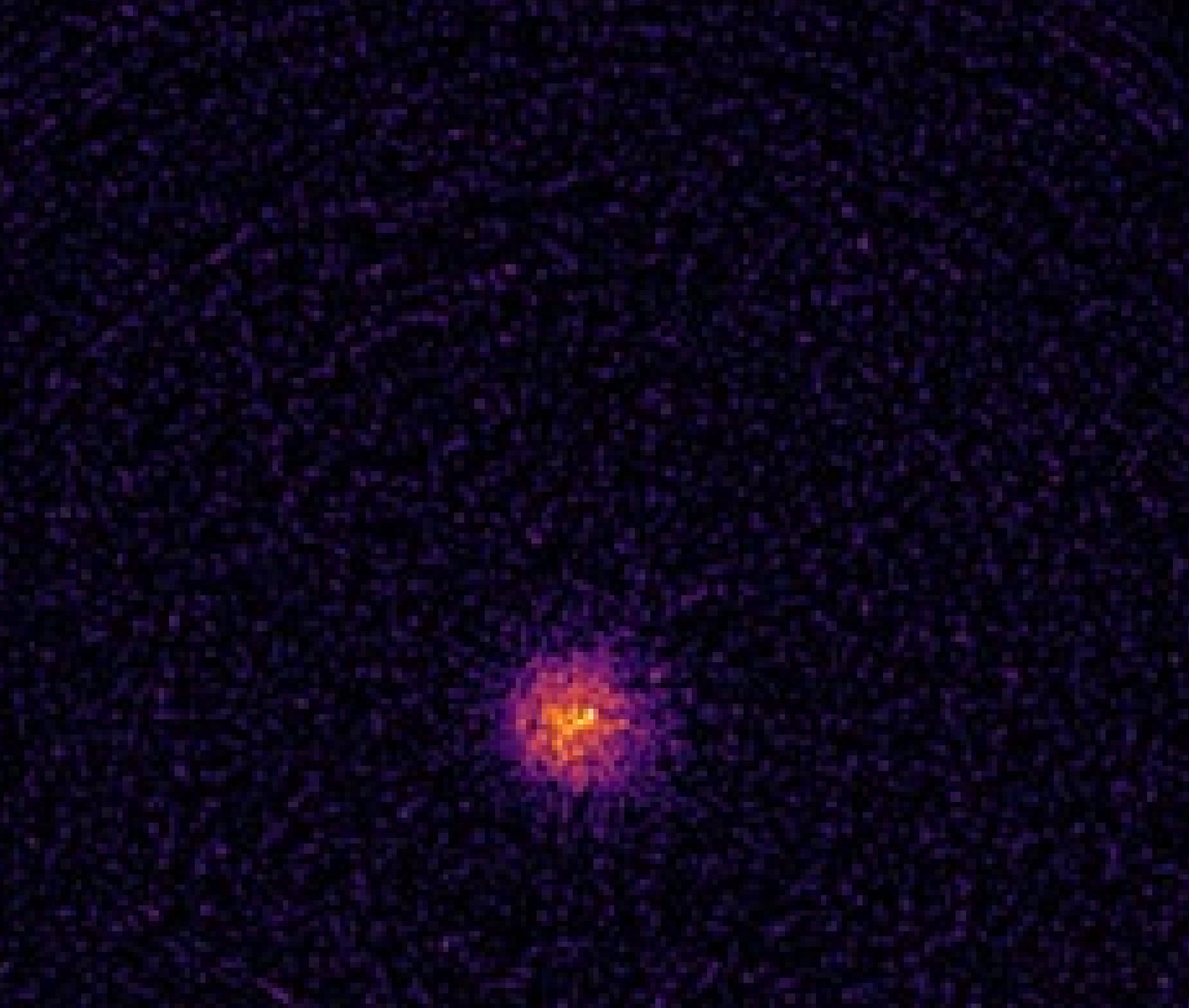
Special acknowledgment and appreciation go to **Kristen Vernon, Anne Totten**, and **Madeline Gauthier** for technical communications and compiling, editing, and publishing this report; to Kristen Vernon for providing document design; to **Leslie Esquibel**, **Emma Gurr**, **Sally Matthews**, **Kristen Ruocco**, and **Luke Rocha** for project management and cost accounting efforts; to **Michael Baldonado** for information system support; to **Elizabeth Davis**, **Eduardo Morales**, **Sandy Young**, and **Stacey Duffy** for financial data reporting; to **José Sinibaldi** and **Larry Franks** for technical guidance and support; and to our SDRD technology representatives, SDRD site representatives, and technical review committee: **Stuart Baker**, **Kirk Miller**, **Cleat Zeiler**, **Bruce Dunham**, **Trevor Burris-Mog**, **Daniel Champion**, **Daniel Lowe**, **Edward Daykin**, **Jerry Stevens**, **Marylesa Howard**, **Eric Dutra**, **Amy Lewis**, **Matthew Wallace**, **Scott Suchyta**, **Cameron Hawkins**, **Daniel Frayer**, **Brandon La Lone**, **Dan Clayton**, **Radu Presura**, **Sanjoy Mukhopadhyay**, **James Essex**, and **Rusty Trainham**. And, finally, special thanks to members of our External Advisory Board, **Ryan Camacho**, **Larry Franks**, **Carl Ekdahl**, **Damon Giovanielli**, **Maurice Sheppard**, **Ralph Schneider**, and **Gerry Yonas**, who graciously give their time and supply ongoing, valuable recommendations.

Paul Guss
SDRD Program Manager
March 2024

Photos from the FY 2023 SDRD Annual Program Review. Clockwise from top left: Agenda; Director José Sinibaldi, PI Michelle Scalise (23-131); J. Andrew Green presenting for PI Amber Guckes (23-044); PI Sanjoy Mukhopadhyay (23-130); PI Cameron Hawkins (23-037 & 23-121); Audience members including PIs, EAB members, and project contributors.

List of All Projects for FY23

(U) Physics-Informed Deep Learning with Uncertainty Quantification for Weapons Radiography, A. Gonzalez (23-091)
Additive Manufacturing of Structural and Pixelated/ Discriminating Scintillators, M. Staska (23-019)
Agnostic Modular Payloads for Multi-INT Collection, A. Davies (23-087)
AR/VR for CBRN Solution for Emergency Responders, B. Richardson (23-081)
Broadband X-Ray Imager for Spectroscopic Diagnostics, R. Presura (23-061)
Can Two Pulsed Power Sources of Different Source Impedance Drive the Same Non-Linear Load? Z. Shaw (23-133)
Computational Fluid Dynamic Simulations for Critical Infrastructure (CFD-SCI), S. Breckling (23-016)
Constraining Physics Models with Complementary PINEX and NUEX Data, J. Clayton (23-110)
Cryogenic Deuterium Pellet Injection for Enhanced Neutron Output of a Dense Plasma Focus, D. Lowe (23-048)
Developing the NNSS Critical Skills in Accelerator Science and Beam Physics, T. Burris (23-137)
Development of a Compact, High-Specificity, Single-Use Sensor/Sampler, D. Baldwin (23-041)
Direct Measurement of Metal-Hydride Formation during Ejecta Particle Transport in Reactive Gases Using Raman Spectroscopy, J. Mance (23-090)
Dual-Use High-Z, High-Cross-Section Materials for Neutron Imaging and In Vivo X-Ray-Initiated Cancer Drugs, J. DiBenedetto (23-017)
Electromagnetic Launch Modification to C3 Launcher for Increased Velocity, C. Hawkins (23-037)
Exploration of an Electron-Driven Photoneutron Source Based on Scorpius, A. Guckes (23-044)
Feasibility of a Single-Stage Electromagnetic Launcher of High Velocity Projectiles, C. Hawkins (23-121)
Feasibility of Reoccupying Historic Testbeds for Future Experiments, I. Bortins (23-120)
Fundamental Experiments for Detonation Signature Modeling, C. Kimblin (23-007)
Health Assessment and Performance Monitoring of Large Machine Diagnostics, J. Adams (23-003)
High-Z Semiconductors for h-keV Direct X-Ray Imaging, C. Leak (23-088)
Homogeneous Detonation of High Explosive by Using Radiation from Shocked Noble Gases for Initiation, T. Myers (23-070)
Incorporation of Geological Data into Centralized Database, D. Smith (23-062)
Increased Fidelity via Quantum-Correlated X-Rays: IF via QCX, G. Walker (23-053)
Increasing Options for Aerial Testbeds to Eliminate Single Aerial Asst Dependence, M. Howard (23-127)
Low SNR, High Clutter UAS Detection and Tracking, I. McKenna (23-009)
Mass-Selective Photoionization Detector, M. Manard (23-002)
Material Identification in Radiographic Images of Dynamically Formed Metal-Explosive Mixtures by Tuning the X-Ray Source Spectrum Using Multiple Anodes, B. La Lone (23-082)
Measurements for Combined Gamma Ray and Video Modalities, C. Burt (23-024)
Measurements of Dynamic Melting and Re-Crystallization of Shocked Metals, R.J. Scharff (23-060)
Microwave Detection through Thin Films, H. Tarvin (23-075)
Modernization and Scalability Enhancements for Sub-Nanosecond Accuracy Diagnostic Cross Timing for Use at Current and Future NNSS Testbeds, D. Champion (23-049)
Multi-Modal Remote Vibrometer for Infrastructure Interrogation, S. Koppenjan (23-010)
New Porous Solids for Krypton and Xenon Capture without Cryogenics, M. Morey (23-011)
Non-Invasive Sport Size Diagnostic for Linear Induction Accelerators, E. Scott (23-058)
Novel Photon-Counting Detector Concept for High-Resolution Radiographic Imaging, S. Miller (23-032)
Optical Comb Techniques for Hyperfine Spectroscopy, R. Trainham (23-014)
Project Moonshot Soft-Landing Study, B. Eleogram (23-124)
Refinements to the Geological Framework Models, M. Scalise (23-131)
Robotic System for Radiation Mapping of Dispersal and Point Sources, S. Mukhopadhyay (23-130)
Solid-State Spectrographic Camera for HED and Pyrometry Applications, A. Lewis (23-064)
Spatial Spectral Observations from Near and Far, M. Howard (23-095)
Spatially Aware Multimodal Directional Radiation Detection Swarms, J. Essex (23-114)
Surface Gas Sampling Payload for Autonomous Underwater Vehicles, C. Priest (23-034)
Thermal Transport Detection of Phase Boundaries at Elevated Pressures, G. Stevens (23-022)
Ultrafast High-Dynamic-Range Photomultiplier Trials, R. Buckles (23-119)
Utilizing Machine Learning to Automate Linear Induction Accelerator Beam Tuning, D. Clayton (23-040)
Z-Pinch and Laser Ablation-Driven New High-Yield Neutron Source, E. Dutra (23-096)



SDRD

SITE-DIRECTED RESEARCH & DEVELOPMENT