

NEVADA NATIONAL

**NINSS**

SECURITY SITE

**Site-Directed  
Research & Development  
Annual Report Overview  
FY 2022**

**SDRD**



SITE-DIRECTED RESEARCH & DEVELOPMENT

DOE/NV/03624--1650

# How to Read this Report

The SDRD program's annual report for fiscal year (FY) 2022 consists of three parts: the introduction, which includes remarks from both the Chief Scientist and the Program Manager and a special feature on the 20<sup>th</sup> anniversary of SDRD; 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 Site's website, [www.nnss.gov/pages/programs/sdrd.html](http://www.nnss.gov/pages/programs/sdrd.html). 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:** C3 Launcher from the project "Electromagnetic Launch Modification to C3 Launcher for Increased Velocity" (C. Hawkins 22-068)

**Inside front:** Simulation results from the project "High-Z Semiconductors for h-keV Direct X-Ray Imaging" (C. Leak 22-082).

**Back:** Compilation of previous covers of SDRD Annual Report Overviews from FY 2002–2021.

## Staff

**SDRD Program Manager**

**Editors**

**Design & Layout**

**Web Design & Production**

**Management and Support**

Paul Guss

Kaela Dotson, Kristen Macias, Anne Totten

Kristen Macias

Kirsten Kellogg, Kristen Macias

Michael Baldonado, Elizabeth Craft, Leslie Esquibel, Lisa Garcia, Emma Gurr, Sally Matthews, Ki Park, Kristen Ruocco

[www.nnss.gov](http://www.nnss.gov)

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# Table of Contents

Introduction .....	1
Letter from the Chief Scientist .....	2
Foreword.....	3
SDRD: 20 Years of Innovation .....	3
The Case for SDRD.....	3
Two Milestone Decades.....	4
Program Achievements and Return on Investment .....	4
Annual Meeting in Person.....	8
FY 2022 Annual Report Synopsis.....	8
Special Feature: 20 <sup>th</sup> Anniversary of SDRD .....	9
SDRD: 20 Years of Technology .....	9
Multiplexed Photonic Doppler Velocimetry (MPDV).....	9
Enhanced Dynamic Materials Research (Powder Gun) .....	9
Broadband Laser Ranging (BLR) .....	10
Measurement of Dynamic Melting and Re-Crystallization of Shocked Metals .....	11
Two Bank Dense Plasma Focus Accelerator.....	12
Multi-Path Communication Device (MPCD) .....	12
20 Years of Remarkable PIs: The SDRD MVPI Award.....	14
MVPI 2022 Winner .....	14
MVPI Nominees .....	15
20 Years of SDRD in R&D 100.....	18
Program Overview .....	20
Program Description .....	21
SDRD Program Mission, Alignment, and Objectives.....	21
History and Impact.....	21
Alignment with the NNSA LDRD/SDRD Strategic Framework.....	21
Mission and Objectives .....	22
SDRD Program Leadership .....	23
NNS Science and Technology Thrust Areas.....	23
Proposal Cycle and Project Selection.....	24
Call for Proposals .....	24
Project Selection .....	24

Feasibility Studies.....	24
SDRD Portfolio .....	25
Mission Categories.....	25
Science and Technology Thrust Areas .....	25
Program Accomplishments.....	26
Featured Research .....	26
Accelerator Beam Science and Target Interactions.....	27
Communications and Computing .....	28
Dynamic Experiment Diagnostics.....	29
Enabling Technologies for Autonomous Systems and Sensing.....	31
Neutron Technologies and Measurements .....	33
Radiographic Systems Imaging and Analysis .....	34
User-Centered Remote Testing and Operations.....	36
Program Value .....	38
SDRD Program Performance Metric .....	38
Invention Disclosures and Patents.....	38
Publications.....	38
Technology Transfer .....	38
Technology Needs Addressed.....	39
Postdocs and Interns.....	39
SDRD Impact Stories .....	40
Machine Learning and Artificial Intelligence .....	40
SDRD and University Collaboration.....	42
Appendices.....	43
Appendix A: Mission Support and Test Services-Operated Sites.....	43
Appendix B: Acronyms and Abbreviations.....	44
Appendix C: Acknowledgments .....	48
Appendix D: FY 2022 SDRD Projects .....	48

Prototype ground-based (*previous page*) and air-based (*this page*) detection units from the project “UAV-Based Detection of Methane Emissions through the Use of Micro-Electrical Mechanical Systems” (H. Tarvin 22-086).

# Introduction

# 20 Years of SDRD



SDRD Annual Report covers from 2002-2021.

Site-Directed Research & Development Annual Report Overview FY 2021

# Letter from the Chief Scientist

## ***SDRD: The Key to Meeting NNSA's Current and Future Stockpile Stewardship and Global Security Missions***

As the innovation engine for the Nevada National Security Site (NNSS), the Site-Directed Research and Development (SDRD) program utilizes the full complement of the Nuclear Security Enterprise (NSE), including its research infrastructure, high-performance computing, specialized material production, and many other capabilities, in our pursuit to solve national security challenges. Having access to large- and small-scale research and development (R&D) efforts, associated laboratories, and user facilities is critical to enable our scientific and technical staff to accomplish their mission goals.

Our Science, Technology, and Engineering (ST&E) staff working on SDRD projects partner with NSE laboratories and other institutions to fully leverage competencies that exist elsewhere, and thus we amplify our own abilities to meet NNSA mission requirements and provide solutions with far-reaching impact.

Over the last few years, the SDRD program has made significant progress in aligning its management structure and investment portfolio more closely with areas that directly impact NNSA stockpile stewardship and global security missions, as well as strategic partnership and strategic intelligence partnership programs. We have experienced year over year increase in addressing the various NNSS technology development needs for the NNSA and externally funded NNSS missions. We went from 46% to 50% in FY 2022. This alone showcases a significant impact to the realignment process that started in FY 2020. Moreover, our SDRD project adoption rate into programmatic elements continues to be higher than 30%, which is running closely to two times the average adoption rate across the NSE LDRD/SDRD program.

This alignment enables the program to focus more keenly on seven thrust areas that are critical to the nation's ability to meet current and future nuclear security challenges, namely Radiographic Systems Imaging and Analysis, Neutron Technologies and Measurements, Accelerator Beam Science and Target Interactions, Dynamic Experiment Diagnostics, Enabling Technologies for Autonomous Systems and Sensing, User-Centered Remote Testing and Operations, and Communications and Computing. We believe that this change will enhance our ability to directly support NNSA's Defense Programs, Defense Nuclear Nonproliferation, Nuclear Counterterrorism and Counterproliferation missions, and help ensure the long-term vitality of ST&E advancements at the NNSS.



*José Sinibaldi, Chief Scientist*  
March 2023

The SDRD program aims to enable our ST&E workforce to innovate and advance the ST&E state of the art that will transform us into a next-generation NNSS, become a better partner to NSE laboratories, and enhance our agility in responding to future global threats.

# Foreword

## SDRD: 20 Years of Innovation

This is the 20th anniversary of Congressional authorization of our Site-Directed Research and Development (SDRD) program. During the last 20 years, the SDRD program has grown and matured, becoming an integral part of our technical base. As the primary source for new discovery and innovation, the program has no equal and provides unparalleled return on investment. Our SDRD program allows us to explore and innovate from the “bottom-up” and, coupled with the strategic vision, to create immensely powerful breakthrough and transformative ideas that have real impact for our mission. Many of the breakthroughs are producing technical capabilities much earlier than expected and are contributing directly to our Stockpile Experimentation and Operations, Global Security, and Strategic Partnership Programs in vital and unanticipated ways.

Without the SDRD program, it is difficult to imagine where innovation and breakthroughs would come from for our programs. We see increased value in the surprising and unexpected successes from pursuing high-risk R&D. The morale of our researchers and the successes of programs are only a few of the benefits. The relatively small amount of funding provides tremendous value for programs, our staff, and the overall site mission.



The first 20 years have been filled with many accomplishments, but we are expecting even more in the years to come by challenging our people to take creativity to new levels, aim high, and stay focused on success to ensure the highest return for our nation’s security.

### *The Case for SDRD*

It doesn’t take much insight to quickly perceive how dramatically the geopolitical landscape can engulf planned initiatives. One need only spend a few minutes watching world news to see the remarkable events across the globe that are driven by disparate situations, such as:

- Non-state actors and the threat they present to our nation
- State actors and their motivation to be considered as significant global players (e.g., North Korea)
- Tensions that have been emerging from expansionism in Eastern Europe (e.g., Crimea)
- Continuing nuclear power plant design flaws, risks, and their long-term impacts to the uncontrolled environment (e.g., Three Mile Island, Fukushima, Chernobyl, Ukraine)

These are just a few examples of global conflict that can fundamentally impact initiatives and should, in principle, drive our investment strategies for our Site-Directed Research and Development program. In terms of pressing national interest, we are challenged by new subcritical experiments and integrating them with seismic experiments, as well as achieving an elevated level of efficiency across our major divisions.

Of particular importance to achieving effective implementation is the development of remote technologies as opposed to human-intensive onsite-captured data. From its inception, every organizational element of the NNSS has been addressing and solving complex problems with elegant and implementable solutions. Our diagnostic forte, coupled with our ability to capture and process complex data, has become the norm for most of our programs.

The NNSS, from its beginnings as the Nevada Test Site, has historically conducted large, complex, hazardous, nuclear tests; the can-do approach was a historical tactic that met the urgency of the times. We got it done, and our customers knew we could. In this modern era, however, high thresholds of risk acceptance that were once tolerated have to be seen through a different lens. Our workforce, engaged in increasingly high-hazard activities, is learning and adopting new ways to deliver yet not compromise safety, security, and our environment.

Today we are still an evolving organization; a new generation of leaders is building a stronger foundation to sustain the national security mission. There are core questions to address in optimizing and maximizing our efficacy in devoting resources to fortify a more robust national security posture:

<b>Why: Our Purpose</b> <i>What is our cause? What do we believe?</i>
In an ever-changing world, we protect the nation from ever-changing threats.
<b>How: Our Process</b> <i>Specific actions we take to realize our "Why."</i>
Promote a culture of safety, security, and quality in all we do.
<b>What: The Results</b> <i>What do we do? The result of "Why."</i>
Develop, test, evaluate, and deploy technologies to defeat national and global threats.

Most organizations begin by defining the "What" aspect, whereas high-performance organizations begin from the core principle, the "Why." The NNSS has a bright and ever-changing future filled with challenges and addressing emerging issues from a new perspective. We "can-do" this by coupling innovative ideas in science, technology, and engineering to core principles and modern needs in safety, security, and compliance.

The past two decades have realized a proud and scientifically challenging SDRD Program. SDRD initiatives have reaped phenomenal returns on minor financial investments, and some have been characterized as not only evolutionary but also revolutionary. As we face the unknown future, I am certain that SDRD will continue to lead our effort to produce scientific discoveries across our program in support of national security. SDRD will continue to flourish, paving the path for future mission success.



PI Amber Guckes shares a picture of her MAD detector ("Multilayered Avalanche Diamond Detector for Fast Neutron Applications" 22-024) at the SDRD FY 2022 Annual Meeting held in person once again in Las Vegas, NV.

### **Two Milestone Decades**

This FY 2022 annual report of the SDRD program, the 20th anniversary edition, recognizes two decades of innovative R&D accomplishments in support of the NNSS. The NNSS reflects a diversifying mission, and our R&D program has contributed significantly to shape emerging missions that will continue to evolve. New initiatives in stockpile stewardship science, nonproliferation, and treaty verification and monitoring have had substantial successes in FY 2022, and many more accomplishments are expected. SDRD is the cornerstone on which many of these initiatives rest. Historically supporting our main focus areas, SDRD is also building a solid foundation for new, and non-traditional, emerging national security missions. The program continues its charter to advance science and technology for a broad base of agencies including the U.S. Department of Energy (DOE), Department of Defense (DoD), Department of Homeland Security (DHS), and many others.

### **Program Achievements and Return on Investment**

The examples in our anniversary feature highlight just some of the contributions SDRD has made over the past two decades. In this fiscal year alone, over a quarter of our projects have already developed technologies that were



adopted by direct program areas in stockpile stewardship, nonproliferation, homeland security, and other applications.

The 120 proposals submitted for FY 2022 were diverse; they focused on new interest areas such as intelligence, cyber security, treaty verification, and monitoring activities, as well as our traditional stockpile mission. Ultimately 36 projects were selected. This selection rate of about 1 in 3 is comparable to last year's, and ensures good competition, yet maintains proposers' enthusiasm that their ideas have a reasonable probability for acceptance. In addition, 18 smaller feasibility studies were funded, for a grand total of 54 SDRD projects. Our internal and external peer review system for selecting winning proposals relies on key criteria, which has remained essentially unchanged: high technical innovation, probability of success balanced with technical risk, potential for mission benefit, and alignment with our mission goals to achieve the best possible outcomes.

Developing skills and maturing technologies through SDRD have been vital activities in garnering work through external proposal calls. For instance, seed SDRD projects in five cases from FY 2003 to FY 2020 have resulted in newly funded efforts from the NA-22 directorate of DOE. In one of these cases, an extremely small investment for a 2-month feasibility study on nuclear fuel cycle ontology went on to receive funding for a full 3-year life cycle award from DOE—a first for an SDRD feasibility study. Several million dollars in new funding, equating to a positive return on investment, has been received based on these efforts. In addition, many

proposals and ideas unfunded in recent years are being repurposed into proposals targeting specific, directed applications with other agencies.

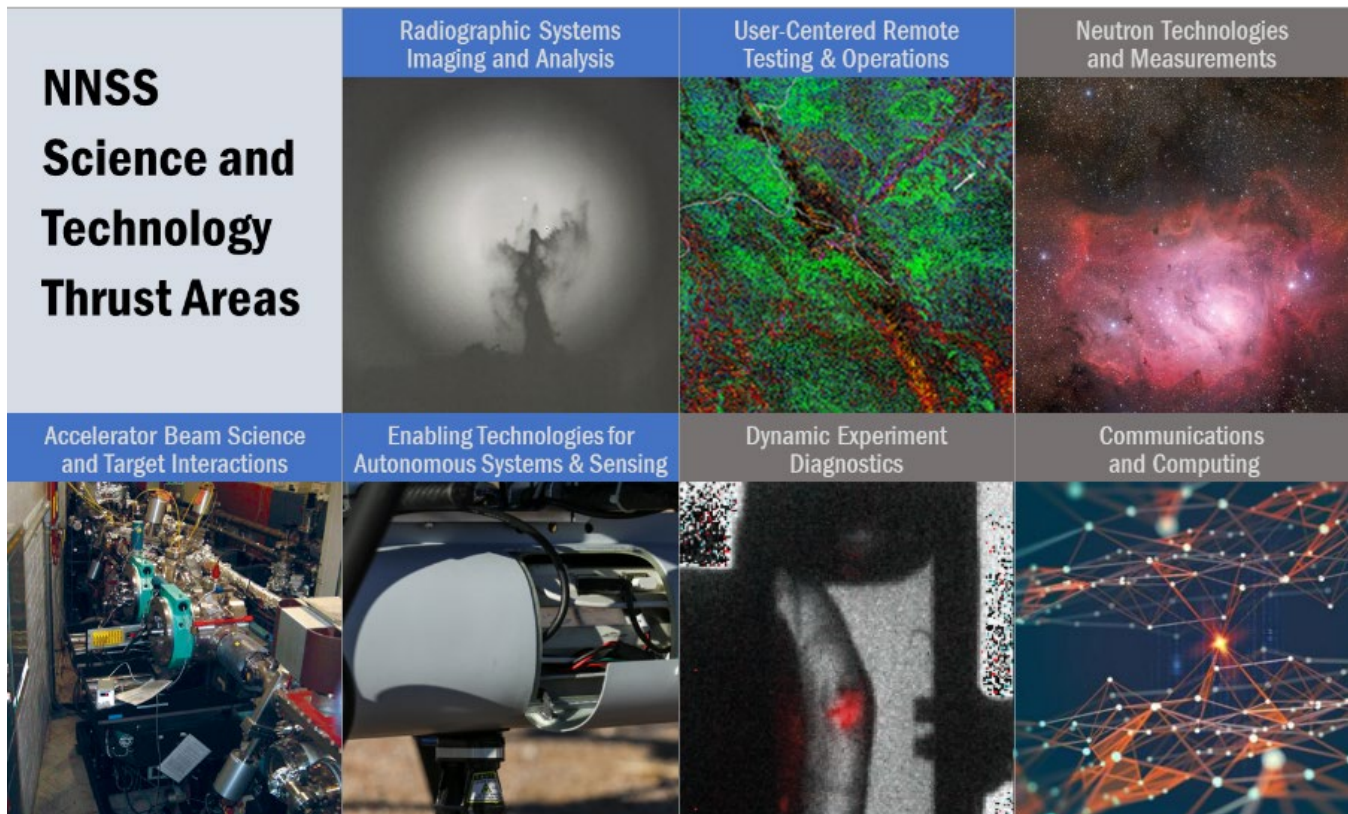
Measures are in place to restore staffing in the most critical areas, which should allow higher SDRD investments in the future and enable us to proceed with enhanced initiatives. For FY 2022, the investment rate was increased to \$15M.

In FY 2022 the SDRD program was better aligned with the new Science and Technology Thrust Areas initiative (our strategic vision for strengthening science and technology at the NNSS). The goal is to enhance or enable new capabilities that will directly impact future NNSA missions and help the National Laboratories to more effectively execute their high hazardous experiments scheduled to take place at the NNSS. In addition, these initiatives seek to enhance university-affiliated research by incentivizing the proposal ranking when university collaborations are present, developing key university relationships leveraging our Outreach program, and acute communication to prospective PIs. This new initiative not only will provide an injection of innovative thinking to our SDRD program, but it will also help us to develop critical skilled workforce pipelines. In April of 2019, we began an enhanced collaboration with the University of Nevada, Reno and Brigham Young University—these continue and are growing for FY 2022. Our longstanding efforts with the University of Nevada, Las Vegas, also continue.

In many cases, we have seen SDRD discoveries migrate to programs, but our assessment shows that heightened focus could deliver more solutions to traditionally difficult areas, such as threat-reduction technologies. The FY 2022 portfolio includes a few projects that met our criteria again in this way. We also believe this may enhance our technology transfer and partnership opportunities. An example is an SDRD-derived Cooperative Research and Development Agreement (CRADA) and new intellectual property (IP) licensing potential opportunities. The impact here is to transfer NNSS scientific and technical innovation from our research program to the commercial sector. Exercising a CRADA helps us to fine-tune our internal technology transfer processes and policies. For instance, this year we are implementing a CRADA with Plumarea Imaging, LLC to perform gas detection work for a Strategic Intelligence Partnership Program (SIPP) that leverages previous SDRD projects “Passive Method to Characterize Atmospheric Turbulence” (M. O'Neill, STL-10-13) and “RGB Wavefront Sensor for Turbulence Mitigation” (M. O'Neill, STL-078-16). This SIPP initiative was enabled by the SDRD investment.



**Program Director and Chief Scientist, José Sinibaldi gives opening remarks at the SDRD FY 2022 Annual Meeting in Las Vegas, NV.**



In addition to the initiatives described above, other elements of the program are being enhanced and optimized. As mentioned in a previous plan, we have started implementing the Science and Technology Thrust Areas (STTAs), which will more acutely define NNSS science and technology foundations. The seven STTAs are Accelerator Beam Science and Target Interactions (ABSTI), Communications and Computing (CC), Dynamic Experiment Diagnostics (DED), Enabling Technologies for Autonomous Systems and Sensing (ETASS), Neutron Technologies and Measurements (NTM), Radiographic Systems Imaging and Analysis (RSIA), and User-Centered Remote Testing and Operations (UCRTO) STTAs. Three have been stood up (ETASS, RSIA, and UCRTO), a fourth one is on the verge of completion (ABSTI), and three more are planned for later (CC, DED, and NTM). Similar to other laboratories, these discipline- and capability-based segments of our core competencies will further underwrite how we align SDRD and the investments we make to these areas. We anticipate the FY 2022 call for proposals was optimized with the STTAs and provides a more streamlined approach to S&T investments.

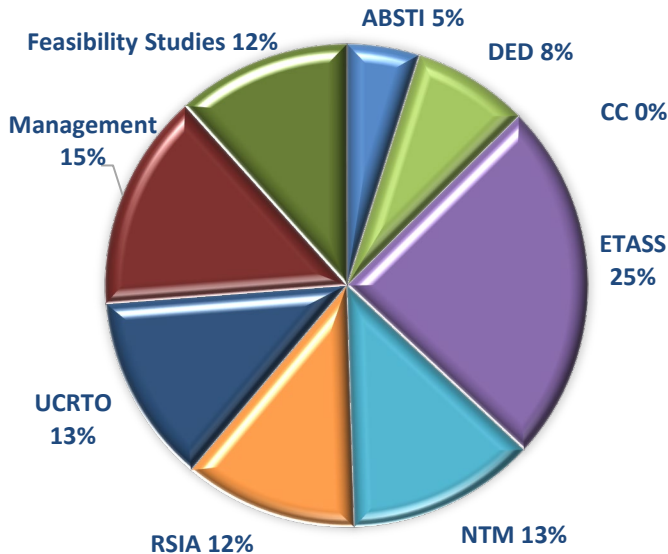
In FY 2022, we again used the Broad Site Announcement (BSA) guidance to announce our proposal call and STTAs. Continuing on the themes suggested by our External Advisory Board (EAB), internal reviews and our near-, mid-,

and long-term strategy goals, we issued revised initiatives based on the STTAs identified by the Program Director/Chief Scientist (PD/CS) and the Executive Leadership Team (ELT). The FY 2022 BSA generated a strong set of submissions in six of the seven areas. Although the CC STTA attracted invited proposals, none ranked high enough to obtain funding—with the exception of one that was pursued at the feasibility study level.

In the past few years, we have placed a strong emphasis on underground event monitoring, and we continued the importance into this proposal year cycle. Multiple strong proposals were submitted along with other closely tied seismic research investigations. In FY 2022 we funded follow-on work (22-017, 22-111, and 22-126, for example). Our efforts in dynamic materials in the extremes, supporting the NNSA laboratories in validation and verification for high-performance computing, is still of strategic importance. Having completed our previous 3-year lifecycle strategic project (LAO-015-18), we plan to explore equation of state (EOS) and dynamic property investigations, such as 22-033, 22-050, 22-51, and 22-120. In the upcoming year, we plan to have three investigations in ABSTI, four investigations in DED, twelve investigations in ETASS, six investigations in NTM, six investigations in RSIA, and eight investigations in UCRTO.

In FY 2022, approximately 5% of the SDRD budget was applied to ABSTI, 8% to DED, 25% to ETASS, 13% to NTM, 12% to RSIA, and 13% to UCRTO.

### PERCENTAGE OF SDRD BUDGET APPLIED TO EACH STTA



As with other LDRD programs, we put an emphasis on high-risk concepts in an effort to encourage PIs to consider bold ideas and embrace high-risk, high payoff. We reinforced this with guidance that “failure is acceptable” in cases where the greater potential exists. In recent years, we have seen a decline in risk taking and we implemented changes to the FY 2022 review committee structure to further enable such ideas. Some improvement was also noted this year with a few extreme ideas submitted. One issue that still remains is the ability to embrace these projects, especially if they fall outside of the traditional NNSA mission space but are still aligned to national security challenges.

We authorized work for several novel exploratory projects, including “Increased Fidelity via Quantum Correlated X-Rays: IF via QCX” (22-160), “Nuclear Thermal Propulsion Borehole Ground Testing” (22-026), and “Performance Monitoring by Simultaneous Sensing of Internal Gas Exchange and Respiration Patterns-Pythia Phase III” (22-083). The first of these three may hold the potential for quantum sensing as a primary future technology that we want to develop, and it is important to understand this technology, which could have immense payoff in other applications. For this study, demonstrating improved imaging via correlated x-rays could lead to a fundamental advance in quantum sensing for the

NNSA. The second study may produce a roadmap and a technology guide for the NNSA to embrace future small modular reactor and nuclear thermal propulsion work, which is increasing in national priority evidenced by new investment commitments by DOE, DARPA, and NASA. The latter work, initiated to evaluate physical performance attributes for the war fighter has application for understanding the level of accuracy and precision needed for COVID-19 detection.

The SDRD program continues to enhance its program elements. The latest effort is establishing STTAs. Although implementing the planned changes to our program structure and proposal review teams has been a positive influence, more will be required. Fresh staff are members of our review team, and they are quickly assuming responsibilities and are becoming more involved with the program. We are actively training and recruiting the next generation of leadership and encouraging increased roles in the strategic planning for SDRD and the future. The addition of the PD/CS to the ELT has been a powerful and positive step forward and helps us to reshape SDRD for tactical relevance and prepare our strategic vision to support future NNSA missions beyond FY 2030 and to enable agile response to future global threats.

We continue to respond to and develop our R&D strategy to provide the most effective solutions to national security



PI Jerry Stevens explains his project “New Methods to Study the Kinetics of Phase Transformation in Shocked Cerium Metal” (22-050) at the SDRD FY 2022 Annual Meeting in Las Vegas, NV.

challenges. This program plan has described our efforts in this regard and is the beginning of more coming enhancements. As we have long noted, global threats are constantly changing and evolving, and the NNSS is unique in its capacity to mitigate, deter, and eliminate these threats. SDRD holds the key to the delivery of innovations needed and provides the best outcomes for our customers, our partners, and the nation.

The NNSS Technology Needs Assessment document continues to be a valuable tool for our proposal submitters and reviewers by providing a roadmap and guidance for technology gaps and challenges facing mission areas. Our directed research emphasis areas for FY 2022 targeted key investment, included nuclear security, information security/assurance, high-energy density physics, integrated experiments, advanced analysis, and IED threat reduction. The needs assessment is developed from a broad base of input from the national security complex including laboratories, NNSA, and other external agencies. Significant revisions were again made last year by enhancing emerging areas and including new lessons derived from the Japan response. The needs assessment itself is in the 18th year of revision, and its utility and effectiveness has improved year to year, plus many trends have been elucidated by the process of updating the assessment.

Total funds expended for the FY 2022 program were approximately \$14 million, a slight increase over last fiscal year. Administrative and management costs, kept to a minimum, are typically less than 15% of the overall budget. Average cost per project for FY 2022 decreased slightly last year to about \$235,000. As demonstrated, this relatively small investment yields considerable return based on the achievements and benefit garnered for our mission and programs.

### ***Annual Meeting in Person***

For the first time since the COVID-19 pandemic, the annual review of projects for the year was held in person in Las Vegas, NV. From September 27<sup>th</sup> to 29<sup>th</sup>, 2022, each PI presented a slideshow of the progress of their work over the past year. Management and PIs got to mingle in person and enjoy the amazing work of their peers. At the end of the week, there were also managerial meetings and the EAB gave their report on their observations and evaluations of both individual projects they found exceptional as well as the state of the SDRD program. Overall, it was an excellent week for SDRD.

### ***FY 2022 Annual Report Synopsis***

The project reports that follow are for activities that occurred from October 2021 through September 2022. The many achievements and challenges described are a testament to the talent and enthusiasm PIs brought to their individual projects. Many of the reports describe R&D efforts that were “successful” in their pursuits and resulted in a positive discovery or technology realization. However, in some cases the result is a “negative” finding; for instance, a technology is currently impractical or out of reach. This can often be viewed erroneously as a “failure,” but is actually a valid outcome in the pursuit of high-risk research that often leads to unforeseen new paths of discovery. As stated before, both types of results advance our knowledge and increase our ability to identify solutions or avoid paths not appropriate for the challenges presented in our pursuits.

In summary, the SDRD program continues to provide an engine of innovation and development that returns multifold to the NNSS mission. Overall, the program has been strengthened by enhanced mission, resources, and increased competitiveness to yield maximum benefit. The 54 projects of FY 2022 exemplify the creativity and ability of a diverse scientific and engineering talent base. The efforts also highlight an impressive capability and resource that can be brought to find solutions to a broad array of technology needs and applications relevant to the NNSS mission and national security.



*Paul Guss, Program Manager*  
March 2023

# Special Feature: 20<sup>th</sup> Anniversary of SDRD

## SDRD: 20 Years of Technology

SDRD's contribution and impact to our core programs is one way we gauge the effectiveness of our R&D investment. Generally, with advanced R&D, some time is required before technologies fully develop and are integrated into our programs. Now, reflecting on two decades of projects, we can claim some major successes; here we highlight six particularly important contributions that have been born out of SDRD investment.

### ***Multiplexed Photonic Doppler Velocimetry (MPDV)*** SDRD Project #: NLV-07-08 PI: Ed Daykin

With the cessation of nuclear testing in the early 1990s and the advent of science-based stockpile stewardship, new diagnostic techniques are constantly being required to assess the safety and performance of the nation's stockpile. The primary methods used to understand materials in extreme conditions are non-nuclear experiments such as subcritical, hydrodynamic, and high-pressure studies. Characterizing materials in these regimes is an active area of research, and the utilization of advanced modeling and simulation has further driven the need for exceptionally precise diagnostics. It is often said that timing is everything, and in the case of SDRD investments in optical velocimetry, this is true literally and figuratively. Optical velocimetry enables the measurement of moving surfaces and as such, directly characterizes fundamentally important shock conditions in materials. Historically, shock wave measurements yielded only a few channels of data. Hydrodynamic tests were even more limited, gathering data with electrical shorting pins at discrete times. SDRD investments over the years resulted in a complete revamping of the traditional velocimetry tool, VISAR (velocity interferometer for any reflector), and greatly improved knowledge of the newer photonic Doppler velocimetry (PDV). Both instruments were improved so much that they began to replace a few of the traditional shorting pins in hydrodynamic tests. In 2010, SDRD breakthroughs in multiplexed PDV (MPDV) achieved by Ed Daykin and his team created a new

paradigm, allowing experiments to be instrumented with hundreds of velocimetry channels with long time records and yielding an unparalleled amount of information obtained. Key to extracting the full capability of MPDV rests on yet another SDRD-based innovation, the compact fiber-optic probe that was studied extensively in the mid-2000s. These key technologies came together at precisely the right time to provide unprecedented capability and, in fact, enabled a new class of subcritical experiments to be conducted. The MPDV developed under SDRD led to a new Stockpile Stewardship paradigm shift for nuclear weapon performance certification at much lower cost and circumventing the need for underground nuclear testing. The led to a >100,000x increase in data, 100x less expense, and the most important data yet obtained to validate nuclear weapon codes and performance. We can now achieve more information in one shot than all previous pre-MPDV subcritical experiments (SCE) combined, which now incorporate SDRD innovations such as PDV and optical "domes" for unprecedented data fidelity. SDRD has led the way to a better, faster, and more economical way of diagnosing nuclear weapon performance and avoid underground testing.



The MPDV team (*back row: M. Teel, A. Diaz; front row: C. Gallegos, C. Perez, E. Daykin*) pictured with the SDRD breakthrough multiplexed photonic Doppler velocimetry system. The MPDV has been used on experiments at Los Alamos National Laboratory as part of a broad collaboration with Lawrence Livermore National Laboratory and the Nevada National Security Site.

### ***Enhanced Dynamic Materials Research (Powder Gun)*** SDRD Project #: LAO-19-15 PI: Robert Hixson

In 2015, we initiated a research program in dynamic materials properties to address some key unresolved shock physics issues. Fundamental shock physics research requires a condition of uniaxial strain to be maintained to be able to

interpret results, and this requires large diameter targets and impactors. To do this we procured a new research-quality propellant launcher, which was installed at the gas launcher and small-scale explosives campus located at the NNS Special Technologies Laboratory (STL). This launcher, with a maximum velocity of 2 km/s, allows us to move dynamic materials research in the direction needed to improve the fundamental physics models used in large hydrodynamic codes routinely used to simulate dynamic events. Specifically, this capability allows research to be done at much higher stress states than previously possible, greatly expanding the region over which fundamental information is available and over which physics models are validated. In FY

2015, we fielded experiments on single-crystal copper using the existing STL launcher; the results helped us to understand the effects of grain structure in metals. Our first experiments performed in collaboration with the California Institute of Technology on their two-stage gas gun allowed us to quantitatively measure the melt curve of tin upon shock release by determining its temperature as a function of shock stress.

**Broadband Laser Ranging (BLR)**

**SDRD Project #: STL-055-16**

**PI: Bruce Marshall**

**SDRD Project #: STL-037-20**

**PI: Brandon La Lone**

**SDRD Project #: SO-001-21**

**PI: Radu Presura**

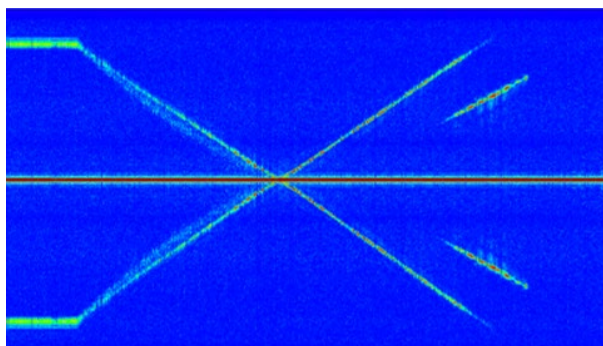


The new propellant launcher, installed in Building 229 at STL, is capable of launching projectiles at 0.5 to 2.5 km/s, which expands the velocity range considerably for shock compression experiments. (Top) Propellant Launcher; (Center) Containment Vessel; (Bottom) Aligning business end of Propellant Launcher in the Containment Vessel.

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 (MPDV) and has been implemented and fielded at numerous NNSA facilities. A close, collaborative working group consisting of subject matter experts from NNS, LLNL and LANL undertook the rapid development and deployment of a complex, mathematically intensive, Broadband Laser Ranging (BLR) software analysis package called the BLR Investigative Tool (BLRIT). BLRIT is a cornerstone of the BLR diagnostic capability and was used to analyze data from subcritical experiments.

This BLR team contributed to the success of fielding BLR for the first time on a U1a experiment. Photon Doppler Velocimetry was a “game changing” diagnostic in measuring the velocity of surfaces for subcritical experiments, and BLR is the next game changer for computing the position of surfaces. This is an essential quantity for weapons codes, and the BLR software team rapidly developed this capability so it could be deployed on the U1a experiment Eurydice. NNS employees have been working feverishly to test, document, and build a 16-Channel Broadband Laser Ranging (BLR) Diagnostic system to be used on Sierra Nevada. This effort required the use of our company’s top talent to assist in the documentation of the project, the testing of components and to help with the custom assembly of the many optical fibers and components needed to complete the construction of the units that make up the entire BLR system. The 1570 nm, 2 mW system was built and delivered to NNS for functional testing and characterization on the C-3 Gas

Gun in preparation for “LAMARK,” the surrogate experiment prior to EDIZA. The BLR project has helped foster existing and new teaming relationship across the complex as well as providing a fantastic opportunity to share optical assembly testing and construction techniques with everyone involved. Nimble series SCE operations include 44 Channels of MPDV and 16 channels of BLR provided and are supported by both LLNL and NNSC scientists to quantify hydrodynamic and Asay window diagnostics.



Interferometric measurements provide position of a surface as a function of time (top). The BLR diagnostic is integrated alongside the MPDV (bottom).

### Measurement of Dynamic Melting and Re-Crystallization of Shocked Metals

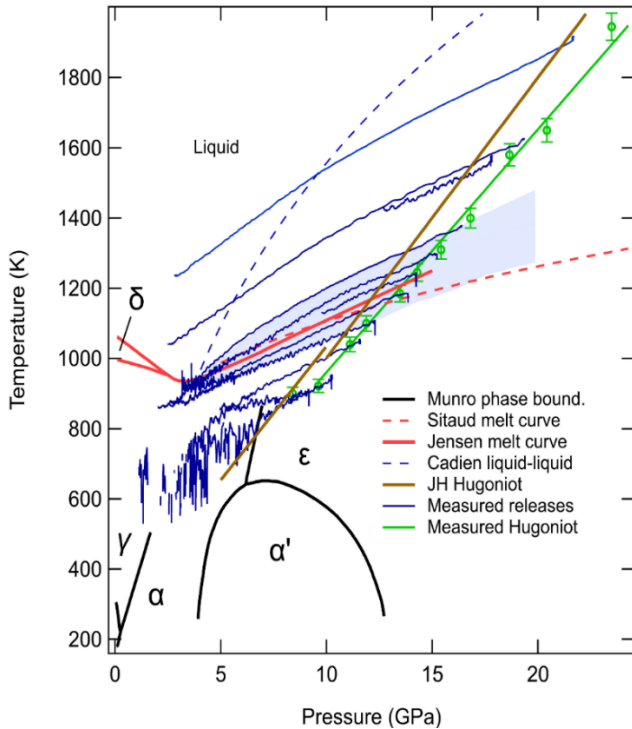
SDRD Project #: 22-033

PI: Jerry Stevens

In addition, recent contributions related to material studies are coming from SDRD projects in dynamic effects conducted at our explosive test facility in Santa Barbara, California. Improved understanding of the equations of state (EOS) of metals under shock conditions is critical to advanced modeling. To fully understand an EOS, it is necessary to measure the temperature of the shocked metal yet obtaining highly accurate measurements has been extremely difficult. SDRD has funded the development of new diagnostics to determine the temperature of a shocked

metal sample from its thermal radiation. This work, led by principal investigators (PIs) D. Turley and G. Stevens and published in articles in the *Journal of Applied Physics* (110 (2011) 103510 and 110 (2011) 093508), has developed methods for using pyrometry to measure the thermal optical emission and small integrating spheres to determine the emissivity of a shocked sample. Study of kinetics of phase transformation in cerium, for instance, led to a phase-transformation detection diagnostic technique. This technique can measure pressure and temperature of an elusive phase boundary off-Hugoniot. The new technique supports actinide experiments at JASPER / LANL TA-55. These diagnostics are now fielded on specialized gas gun experiments at the NNSC to determine the temperature of shocked plutonium. The NNSC captured new data on high-pressure cerium experiments that identify mixed phase regions important to high-fidelity equation of state modeling. These data were obtained using the integrating sphere dynamic temperature technique, developed by prior SDRD projects, which is now a proven, adopted technology used widely by stockpile mission programs. This technique is providing critical data for improved physics models and is the only viable phase transition diagnostic for future subcritical experiments. Recent results and analysis on cerium shock experiments show dynamic data diverging from static data – indicating a mixed phase region (Hixson, R. S., B. M. La Lone, M. D. Staska, G. D. Stevens, W. D. Turley, and L. R. Veaser. 2021. “Temperature measurements in cerium shocked from 8.4 to 23.5 GPa.” *J. Appl. Phys.* **129**, 155106. <https://doi.org/10.1063/5.0043096>.) The isobaric cooling technique is a breakthrough for dynamic mapping of material phase boundaries, and we expect a significant scientific contribution resulting from application of this method to cerium and other materials. A number of benefits from this effort are being realized in the NA-10 Stockpile Stewardship Program. Our method for cerium preparation is being applied to dynamic experiments in support of the Lawrence Livermore National Laboratory Shallow Bubble Collapse project sponsored by DOE Primary Assessment Technology. Also, samples have been prepared and used in collaborative experiments with LANL to assess a novel diagnostic tool to detect trace quantities of shockwave-generated atomic cerium vapor. Finally, the thin film isobaric cooling method is being adapted for future support of LANL Dynamic Material Properties studies.

This particular project was heralded by the EAB as both challenging and important.



Temperature measurements in cerium shocked from 8 to 24 GPa. The isobaric cooling technique may unambiguously pinpoint the incipient melt boundary. Cerium preparation techniques are being used for LLNL Shallow Bubble Collapse and LANL AESOP gun experiments. The NNSS thin film reverse impact technique being adapted for future experiments.

### Two Bank Dense Plasma Focus Accelerator

SDRD Project #: NLV-05-04

PI: Edward Hagen

Exceptionally large dense plasma focus (DPF) fusion neutron sources have greatly expanded the types of neutron-based science that the NNSS supports. To achieve the larger yields required, a large capacitive energy storage and transfer



Dense Plasma Focus technology with a Marx system of two banks with 18 capacitors each

system was designed. The two-bank design successfully passed through engineering review and was mechanically assembled. When completed, the knowledge gained for this bank served as the basis for the design and construction of high-performance DPF fusion photon and neutron sources. These sources represented a significant increase in both the capability and capacity of the existing neutron- and gamma-ray-based core expertise for the NNSS. The DPF can fulfill many roles, including neutron damage studies, interrogation systems, stimulation of fast assemblies of fissionable material, neutron resonance spectroscopy, and neutron imaging and radiography. The DPF assembled under SDRD weigh ~25,000 lb. and yields  $\sim 1.6 \times 10^8$  neutrons/second. This 2004 Two Bank Dense Plasma Focus Accelerator SDRD Project led to Zeus, neutron diagnostic, and various NDSEs performed at the NNSS.



Assembled Marx system, showing scale

### Multi-Path Communication Device (MPCD)

SDRD Project #: RSL-29-05

PI: James Essex

Designed and developed a proof-of-concept Multipath Communication Device (MPCD) for handling field data telemetry. The team created a flexible, centrally configured communications platform. This platform allows static and mobile field-deployed assets to create a most-capable/least-cost configuration, based through one of several commercial or standalone communications mechanisms. This technology is a critical component to the NNSA response to Fukushima, Japan and to Ukraine, for real time monitoring and radiation data transmission about nuclear power facilities.



An unprecedented and devastating natural disaster occurred on March 11, 2011, when the 9.0 magnitude earthquake off the coast of Japan triggered a massive tsunami. The Fukushima Daiichi nuclear power plant was heavily damaged by the ensuing tsunami wave; ultimately, over the course of many months, radioactive materials were discharged into the surrounding landscape and atmosphere. A rapid response, using both environmental monitoring data and computer simulation, was initiated to deal with the contamination and assess the radiological danger. Cooperating with Japanese authorities, the NNSS radiological emergency response teams were put into action and conducted aerial measuring system (AMS) flights over the areas impacted by release of radioactive materials.

Many recent and earlier SDRD projects conducted by our technical staff (many of whom are also members of the response teams) contributed to the ability to deal with the difficult Japan situation. Radiological simulation capabilities used in the absence of live contamination, developed under an FY 2002 SDRD project, have since become integral training tools for the AMS mission and provide a high degree of readiness. Other more recent SDRD projects (FY 2009–2010) sharpened operational expertise and enabled better theoretical understanding and interpretation of the AMS radiological data products. This work allowed DOE's NA-84 Technology Integration Program to develop a suite of tools to quantify aerial radiation data.

An FY 2005 SDRD project resulted in the development of a generation of devices referred to as the Multi-Path Communication Device, or MPCD. The MPCD transmits data in real-time using one of several communication pathways, such as cellular, satellite, and many others. The MPCD technology was embedded in the Search Management Center that was used in the DOE response in Japan. This setup, composed of a small grid of remotely operated detector systems that transmitted sensor data to a remote receiver system, was also first instigated by the SDRD program. As part of our nuclear emergency response mission, our staff work diligently to ensure we can quickly, efficiently, and reliably field sensors all over the world at a moment's notice. The underlying sensors, communications platforms, data management systems, and analytic capabilities are critical to enabling the timely engagement of the DOE's expertise to emerging global security threats.

One example of an SDRD success is the Multi-Path Communication Device. The project produced a prototype that allowed emergency responders to transmit data from

anywhere in the world regardless of impact to communication infrastructure. Since it was initially proposed and awarded in 2005, the program office for Emergency Response (NA-42 then NA-84) has overseen the production of 50 systems in 2007. Then 100 version 2 systems in 2015. The systems are disseminated throughout the RAP emergency response community and serve the RSL-Nellis and RSL-Andrews Consequence Management and Search Teams.

These systems have been deployed to countless Presidential Inaugurations, Super Bowls, National Security Special Events (NSSEs), and other extraordinary events since their creation. These tools, in addition to the technical expertise and capabilities developed under these SDRD projects, played a significant role in the Japan response by providing crucial measurements to ensure the safety of citizens and responders and in handling the aftermath consequences. Modified versions of these capabilities were tailored via an MOU (NASA and NA-84) by the NNSA to support the last Mars Rover Launch and also serve the need for a real-time air monitoring network during an emergency response event. Most recently, 18 radiation sensors were developed for Ukrainian partners during a four-week sprint. A team from the NNSS deployed to Slovakia in late May 2022 to deliver them. All 18 continue to transmit data from critical facilities of interest across Ukraine giving both the NNSA NA-84 emergency response team and our Ukrainian partners situational awareness. That effort can trace its roots back to that critical SDRD investments.



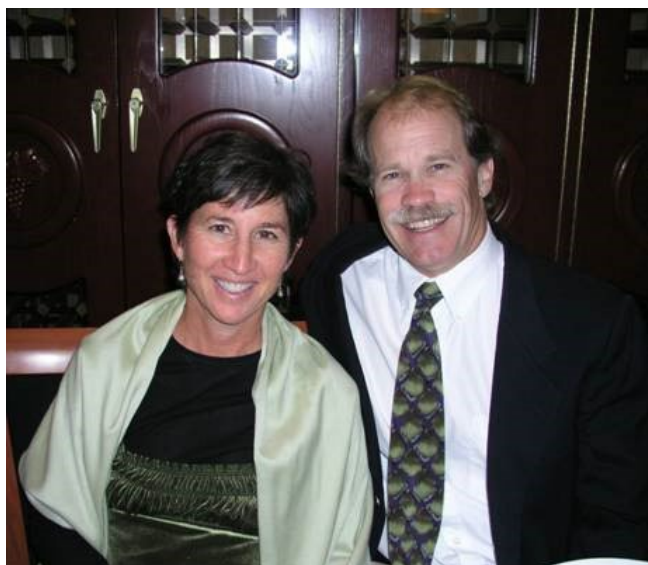
**NNSS PI Michael Reed (back center) providing aerial measurement data analysis for the Japan reactor accident utilizing techniques developed by prior SDRD projects.**

## 20 Years of Remarkable PIs: The SDRD MVPI Award

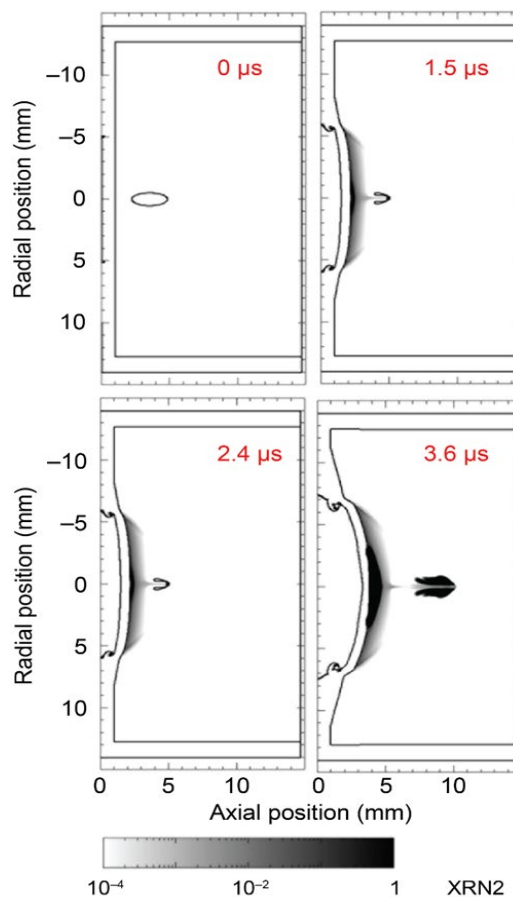
With many exceptional projects going on around the NNS, the S&T Directorate is proud to reinstate the honor of naming SDRD's Most Valuable Principal Investigator (MVPI) in FY 2022. Nominations from around SDRD came from nearly every STTA and reflect our mission to support innovative and high-risk concepts and technologies for the nuclear security enterprise. The MVPI winner and each of the nominated PIs are highlighted with their projects below.

### **MVPI 2022 Winner**

**DALE TURLEY**



Dale Turley is the winner of this year's MVPI award for his project "Study of Bubble Collapse in Optically Transparent High Explosive as a Method to Probe the Detonation Process" (22-052). Dale's project examined what happens to a butane gas bubble when injected into homogeneous explosive nitromethane (NM) revealing the effects of hot-spot formation on the detonation process. While previous studies have examined bubble collapse in NM, this work clearly shows evidence that the detonation process occurs near the bubble collapse and what happens when a detonation shock wave overtakes the butane bubble. This remarkable project already has a manuscript being written for publication and hopes to send its own shockwaves throughout the scientific community. This project was lauded for its "clever experimental setup [and] great visualizations" by the EAB and is highlighted for the Dynamic Experiment Diagnostics STTA on page 29.



**CTH cylindrical simulations of helium bubble collapse and NM reaction (burn without detonation) using the Arrhenius Reactive Burn model.**

Dale received his BS and MS degrees from the University of California at Santa Barbara (UCSB) in chemistry and physical chemistry, respectively. For the last 40 years he has worked as a research scientist and technical manager at a variety of institutions including the UCSB Marine Science Institute, the Clorox pioneering research division and for the DOE/Special Technologies Laboratory. His research endeavors have included optical spectroscopy, surfactant chemistry, applied optics, shock physics and remote sensing. Currently he manages the experimental physics group at the Special Technologies Laboratory. His principal responsibility is the development of diagnostics tools for shock physics experiments and prototype optical sensor systems for a variety of government-sponsored projects. He has authored or co-authored over 100 scientific publications and holds three patents in the field of applied optics and optical spectroscopy.

Kudos to Dale on his innovative and important work! Congratulations on being the FY 2022 MVPI!

## **MVPI Nominees**

### **JOHN DI BENEDETTO, NOMINEE**



John Di Benedetto has been nominated for his work on neutron imaging. His project, “Dual-Use High-Z, High-Cross Section Materials for Neutron Imaging and In Vivo X-Ray-Initiated Cancer Drugs” (22-090), examines the color differentiation between gamma rays and neutrons. The project not only creates a possibility of simplified detectors but has the added benefit of trying to create a highly efficient nitric oxide generator for use in x-ray-initiated cancer drugs. John also had a feasibility study this year, “Growth and Characterization of Novel Scintillation Materials” (22-161), which looked at the feasibility of synthesizing and growing a highly pure, single crystal of lithium gadolinium borate capable of optical up conversion when exposed to neutrons.

John works in Santa Barbara at the Special Technologies Laboratory (STL) and is a Distinguished Member of the Technical Staff. John holds a Ph.D. in Physical Inorganic Chemistry from the University of California Santa Barbara. He has been with the Nevada contract for 31 years and is currently the manager for the Nonproliferation R&D Department at the DOE Special technologies Laboratory (STL). Areas of technical work and expertise include chemistry, laser remote sensing of vegetation and minerals, effluent diagnostics, remote spectroscopy and imaging of trace contaminants by fluorescence, reflectance (hyperspectral) and absorption. His group has designed, built and fielded airborne and hand-held fluorescence imaging instrumentation; FT-IR stack-mounted and long-path spectrometers for trace gas detection at the NNSS; and optical tagging, tracking, and locating materials. Current areas of research include hyperspectral imaging and environmental diagnostics.

### **MICHELLE SCALISE, NOMINEE**



Michelle Scalise has been nominated for her work “Determining the Seismic Hazard of Subsurface Facilities” (22-111). Michelle and her team coupled high-performance computing (HPC) and physics modeling to predict seismic hazard analysis on subsurface facilities. Because U1a is situated close to the Yucca Fault, it created an ideal testbed for applying these techniques that are usually used in predicting seismic ground motion on the surface. This project successfully created a methodology that will improve the accuracy of strong ground motion predictions for both future earthquakes and local chemical explosions which protects our critical infrastructure and helps the NNSS and our mission partners better identify whether an unknown signal is natural or man-made. You can read more about this project in the [FY 2021 SDRD Annual Report](#) where it was highlighted under the UCRTO STTA.

Michelle is a Senior Scientist in the S&T Directorate and the Defense Nuclear Nonproliferation (DNN) program. She received a Bachelor of Science degree in Earth science from the University of California, Santa Barbara, and a PhD in geophysics from University of Nevada, Reno. Michelle’s background is in seismology with a primary focus on ground motion modeling applied to seismic hazard and nuclear explosion monitoring. While pursuing her dissertation, she worked at Lawrence Livermore National Laboratory and the NNSS, utilizing numerical modeling and high-performance computing to simulate ground motion from buried chemical explosions and local earthquakes. Michelle’s SDRD projects have brought physics-based ground motion numerical

modeling and high-performance computing capabilities to the NNSS and established new university partnerships.

Michelle has previously won an NNSS Hot Shot Award for her volunteer work with STEM outreach. She was also honored with the S&T Senior Director's Award in recognition of her unwavering dedication to university STEM outreach and leadership in enabling high performance computing at the NNSS.

#### **BRANDON LA LONE, NOMINEE**



Brandon La Lone was the PI on several exceptional projects this year and was heralded by the EAB for his “interesting experiments” in regard to his SDRD project “Homogenous Detonation of High Explosive by Using Radiation from Shocked Noble Gases for Initiation” (22-120). The researched technique in this project would replace current HE plane-wave lenses, lowering both the complexity and cost of shock-based experiments, as well as allowing access to new more complex shock geometries not currently attainable.

Brandon is a Senior Principal Scientist within the Experimental Physics group at STL. Over the past ten years at the NNSS, he has made significant contributions to dynamic compression science. The STL powder gun platform was developed and brought online under an SDRD project he led in 2017. Since that time, he has been central to the design, construction, execution, and data analysis for over 100 successful experiments using the gun. He codeveloped a very accurate and very high speed optical ranging instrument termed Broadband Laser Ranging (BLR). First demonstrated at STL in 2014, BLR is now extensively used by the National Laboratories in subcritical testing. The most sophisticated of which is a BLR system at the Contained Firing Facility, operated by Lawrence Livermore National

Laboratory, that is capable of measuring position versus time records along 60 different lines of sight, providing the nuclear weapons complex with new data that complements and enhances existing diagnostics. BLR is now one of the main methods for experimentally validating the National Weapons Laboratories' computer simulations of weapon performance.

#### **DANIEL LOWE, NOMINEE**



Daniel Lowe has been nominated for his work on “Cryogenic Deuterium Pellet Injection for Enhanced Neutron Output of a Dense Plasma Focus” (22-004). Though only the first year of this two-year project, the work shows great promise for NLV's Dense Plasma Focus (DPF) machine, Gemini. Coupling this state-of-the-art pellet injector onto Gemini enhances the overall yield of neutrons per shot, continuing our Stockpile Stewardship mission. This novel SDRD also has the added potential of being applied to other DPFs across the NNSS. The EAB praised this project in particular for being interesting and collaborating well with Oak Ridge National Laboratory.

Daniel is a Senior Principal Scientist at NLV as well as a NNSS Lead for the Neutron Diagnosed Subcritical Experiment (NDSE) diagnostic and Lead for the Weapons Effects and Survivability Program. He also serves NA-113 as the Science Executive for Nevada.

Daniel received his BSE in Mechanical Engineering and both his Master's and PhD in Nuclear Engineering all from UNLV. As a PhD, he studied novel isotope production techniques using linear electron beam accelerators. He has developed new analysis tools for Diffusion Tensor Imaging application in MRI machines and leads the DFP R&D teams in Nevada.

*RUSTY TRAINHAM, NOMINEE*



Rusty Trainham was nominated for his work “Radioactive Noble Gases” (22-042) In its second and final year as an SDRD project, Rusty and his team explored Doppler-free laser spectroscopy to detect and quantify isotopic and isomeric abundances of xenon. This novel method creates the potential for increased detection sensitivity over standard spectroscopic techniques that are currently being used.

Dr. Trainham has been at the Special Technologies Laboratory (STL) since the year 2000, working primarily on nonproliferation projects. He holds a PhD in Physics from the University of Virginia, and his educational background is in experimental atomic, molecular, and optical physics, but he also has experience in nuclear, chemical, and accelerator physics. He has published articles on atomic spectroscopy, nuclear spectroscopy, and hyperfine structure. Since arriving at STL he has designed and constructed a negative ion accelerator, ion traps, and portable field diagnostics for optical and nuclear radiation detection. For the past three years he has been directing a project on sensor development for unmanned aerial vehicles. Prior to joining STL he was the principal investigator for the multi-ampere neutral beams (MANTIS) injection test stand at the Tore Supra Tokamak in Cadarache, France.

*REAGAN TURLEY, NOMINEE*



As another PI with multiple projects, Reagan Turley was also recognized by the EAB for his projects “Biochemical Patterns of Life at NNS Explosive Testing Sites” (22-157) and “Re-Purposing Old Seismic Data to Calibrate Nuclear Test Monitoring Sites in Sparse Seismic Regions” (22-107). The first project examined former explosive sites at the NNS to determine the impact that those experiments had on the local flora and fauna which can, in turn, inform verification teams as to the type of development activity that might be occurring there. The second project leveraged archived seismic data to improve subsurface characterization and earth model development to support nuclear explosion monitoring capabilities. Both projects help strengthen the nuclear nonproliferation mission of the NSE.

Reagan is a Senior Scientist at the NNS and is on-site most of the time. He received his bachelor’s degree from BYU and his PhD from the University of Texas at El Paso, both in chemistry. After being a Graduate Fellow at the Pacific Northwest National Laboratory (PNNL), Reagan joined MSTs in 2021. He is an avid climber and is officially an authorized climber/rescuer.

## 20 Years of SDRD in R&D 100

The R&D 100 awards are one of the many ways that an R&D program like SDRD can measure success. Established in 1963, the R&D 100 awards showcase the top new technological achievements and commercially available products of the last year. These prestigious awards are given out each year to the top 100 new and available technologies as determined by the R&D World magazine. The awards ceremony is a black-tie affair, and the winners range from Fortune 500 companies to national laboratories to academic institutions. Submissions are competitive and only those technologies and products that are the most innovative and groundbreaking make the final cut. The NNSC is honored to be able to boast 10 different winners and finalists since 2009.

The SDRD program generated R&D 100 award entries on high-speed imaging and other technologies relevant to national security issues during its first two decades. Many projects that the NNSC submits to the prestigious R&D 100 awards get their start as SDRD projects. From feasibility studies to exploratory research, SDRDs allow scientists and engineers to engage in innovative research and technology

in global security and stockpile stewardship. All five of the NNSC projects that were finalists or winners since 2017 have their roots in SDRD. In fact, our most recent winner, the “X-Ray Polarizing Beam Splitter (XRPBS)” project, began as an SDRD in 2018.



Of all these innovative projects, six began as SDRD projects, making SDRD the largest contributor to R&D 100 success for the NNSC.

### NNSC R&D 100 Winners and Finalists

Year	Project Title	R&D 100 Status
2020	“X-Ray Polarizing Beam Splitter (XRPBS)”	Winner
2020	“The Aerial Reconnoiter Using Unmanned Systems (ICARUS)”	Finalist
2019	“Flacon Plasma Focus”	Finalist
2018	“Silicon Strip Cosmic Muon Detector”	Winner
2017	“Geometrically Enhanced Photocathodes”	Winner
2015	“Argus Fisheye Probe”	Finalist
2013	“Nuclear Energy in Space” (KiloPower project with LANL)	Winner
2012	“Multiplexed Photonic Doppler Velocimeter (PDV)”	Winner
2010	“Faster than the Speed of Sound” (Movies of eXtreme Imaging Experiments (MOXIE) project with LANL)	Winner
2009	“In Shocking Conditions, Holograms Come Through” (High-Resolution UV Holography Lens project)	Winner

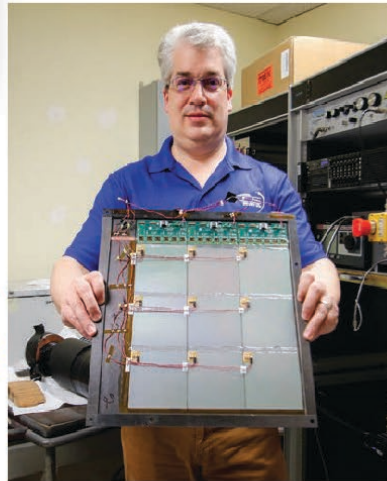


**2012 Winner**  
**Multiplexed Photonic Doppler Velocimeter**  
Ed Daykin, Sonny Gonzalez, Araceli Rutkowski, Carlos Perez



**2017 Winner**  
**Geometrically Enhanced Photocathodes**  
Kathy Opachich

**2018 Winner**  
**Silicon Strip Cosmic Muon Detector**  
Andrew Green, David Schwellenbach



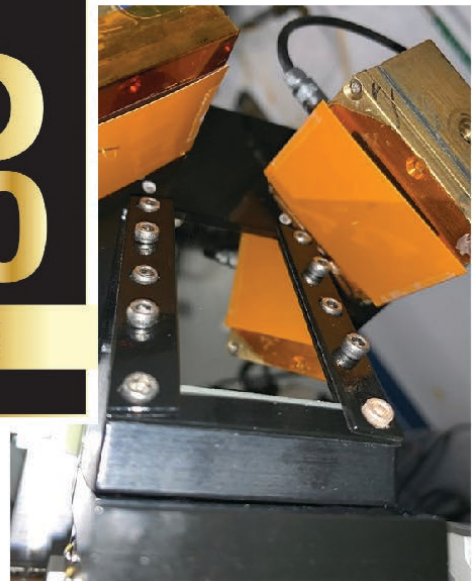
**2019 Finalist**  
**Falcon Portable Dense Plasma Focus**  
Brady Gall



**2020 Finalist**  
**Intelligent Consequence Control by Aerial Reconnoiter Using Unmanned Systems (ICARUS)**  
Paul Guss, Manuel Manard, Rusty Trainham



**2020 Winner**  
**X-Ray Polarizing Beam Splitter (XRPBS)**  
Radu Presura





## Program Overview

# Program Description, Accomplishments, and Value



# Program Description

## SDRD Program Mission, Alignment, and Objectives

### History and Impact

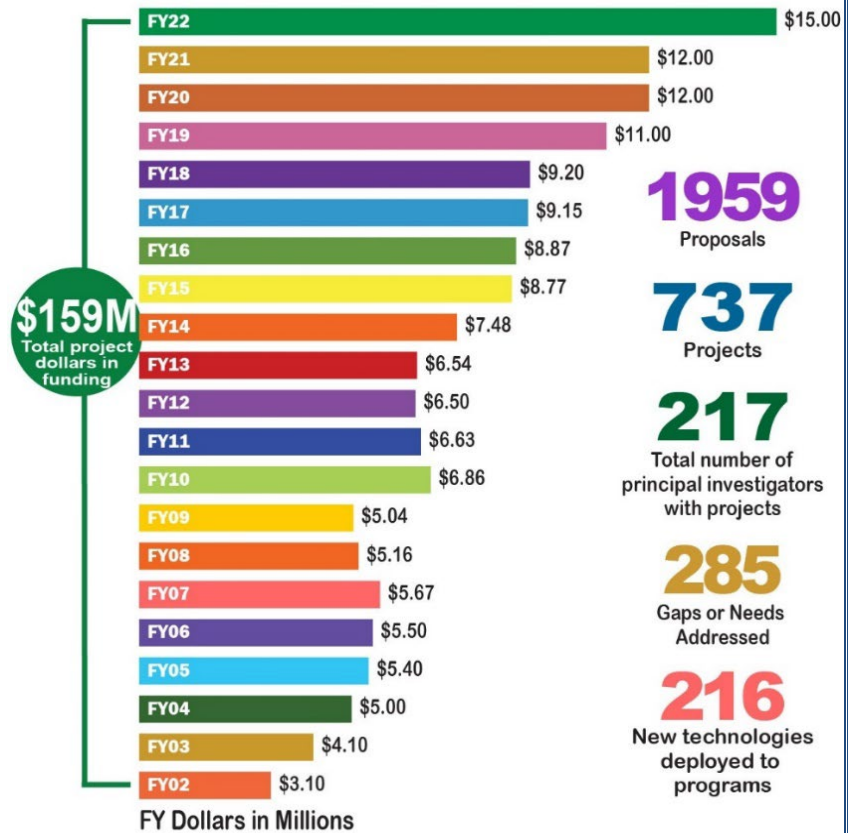
The Site-Directed Research and Development (SDRD) program was initiated through Public Law (P.L.) 107-66, "Energy and Water Development Appropriations Act, 2002," Section 310, which grants the NNSA authority to allow the NNSC contractor to conduct an R&D program aimed at supporting innovative and high-risk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

The program is modeled after the Laboratory Directed Research and Development (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.

P.L. 110-161 (H.R. 2764), "The Consolidated Appropriations Act, 2008," provides that up to 4% of the NNSC site costs may be applied to the SDRD program. In addition, SDRD is an allowable cost within the NNSC management and operating contract and as such is identified in the NNSC contractor accounting system. The program is currently funded at 2.33%. In its first year (2002) the baseline budget was \$3.1M, and roughly \$15M has been allotted for FY 2023 by the senior management team.

As the illustration on this page shows, SDRD has made a significant impact in the past 20 years, providing over 216 innovative technologies to NNSC programs from 2002 to 2022, a high return on the investment of R&D dollars.

## NNSC Site-Directed R&D BY THE NUMBERS FY2002–2022



### Alignment with the NNSA LDRD/SDRD Strategic Framework

The NNSA laboratories and NNSC R&D programs have five objectives as described in DOE Order 413.2C. 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 (NNSA 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 page 27–37 are keyed to the three objectives, as indicated by these icons.

**Mission Agility**

Enable agile responses to national security challenges.

**Technical Vitality**

Advance the frontiers of science, technology, and engineering.

**Workforce Development**

Attract, develop, and retain tomorrow’s technical workforce.

## SDRD Program Leadership

The senior leadership of Mission Support and Test Services, LLC (MSTS), the management and operating contractor for the NNSC, 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 NNSC Science and Technology Thrust Area (STTA) leads and SDRD technology representatives (see below) 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 of distinguished individuals from academia, government, and industry to help guide and direct our investments toward the most important 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.

### NNSC Science and Technology Thrust Areas

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

The NNSC STTAs consist of seven areas, and each STTA encompasses a specific segment of science and technology conducted at the NNSC. 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 are set to be 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.

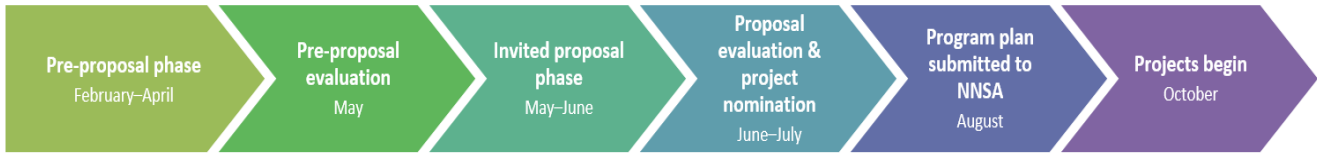
The STTAs directly align their efforts to support our NNSC and Strategic Partnership Projects missions and are an integral component of the SDRD program. The STTA leads and SDRD technology representatives are involved in shaping the program as well as integrating STTA goals with defined strategic initiatives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

### NNSC Science and Technology Thrust Areas

	<b>Radiographic Systems Imaging and Analysis</b>
	<b>User-Centered Remote Testing &amp; Operations</b>
	Neutron Technologies and Measurements
	<b>Accelerator Beam Science and Target Interactions</b>
	<b>Enabling Technologies for Autonomous Systems &amp; Sensing</b>
	Dynamic Experiment Diagnostics
	Communications and Computing

Activation of the seven STTAs will occur in two phases; those shaded in blue become active in FY 2021 (in conjunction with the FY 2022 call for proposals), followed by the others shaded in grey.

# 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 NNSC Technology Needs Assessment for R&D. 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

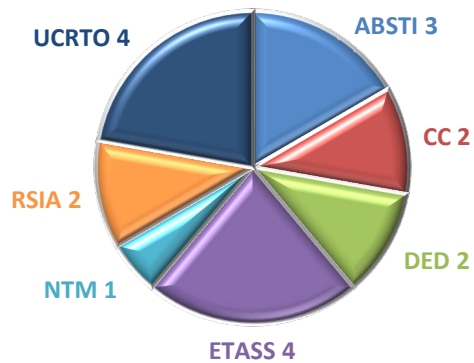
All submitted pre-proposals are evaluated by reviewers. They evaluate how well each pre-proposal addresses the core questions contained in the short pre-proposal form, which is based on the Heilmeyer approach to R&D. Additional criteria considered in the evaluation of pre-proposals include their alignment with NNSC’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 NNSC 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 BY STTA



## Feasibility Studies

Several investigative feasibility studies are funded each fiscal year. In FY 2022, there were a total of 18 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 (see [FY 2020 SDRD Annual Report Overview](#), pp. 24–25), began as feasibility studies.

# SDRD Portfolio

## Mission Categories

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

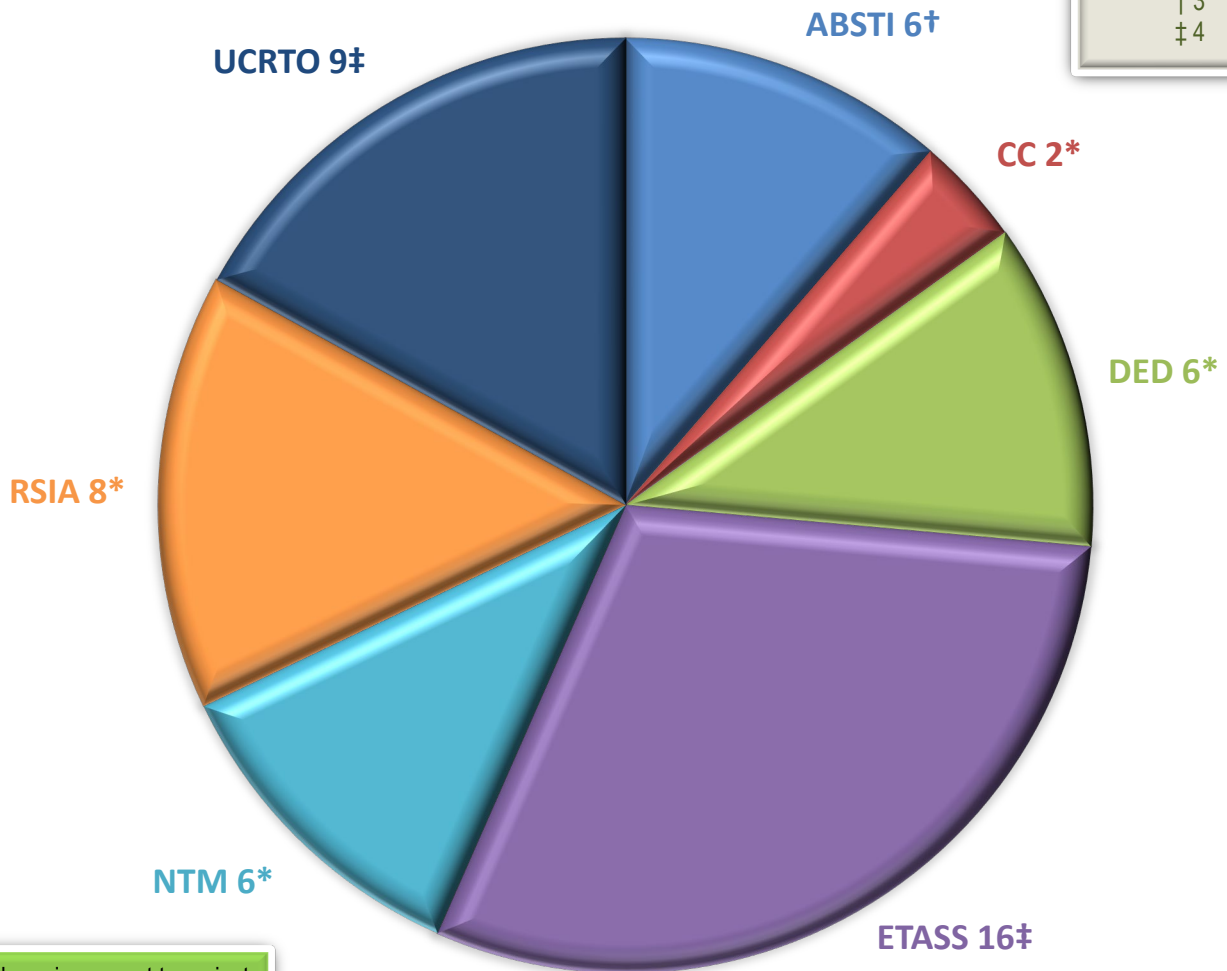
Historically, PIs have submitted a nearly equal number of ideas addressing stockpile stewardship and global security issues. Dollars requested over the past five years to stockpile stewardship were approximately \$27.3M, while global security requested approximately \$25M in funding. In FY 2022, the total amount of funding requested for SDRD was

approximately \$15M, of which about 51 percent was for the stockpile stewardship mission category and about 49 percent for the global security mission category.

## 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 2022, there were a total of 54 projects, of which 18 were feasibility studies. The pie chart below shows the number of FY 2022 projects that fall into each of the seven thrust areas.

NUMBER OF PROJECTS BY STTA



Number of Feasibility Studies

- \* 2
- † 3
- ‡ 4

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

- Global Security
- Stockpile Stewardship

# Program Accomplishments

## FY 2022 SDRD Statistics at a Glance

**\$15.0M**

Total Program Cost

**\$234K**

Median Project Size

**54**

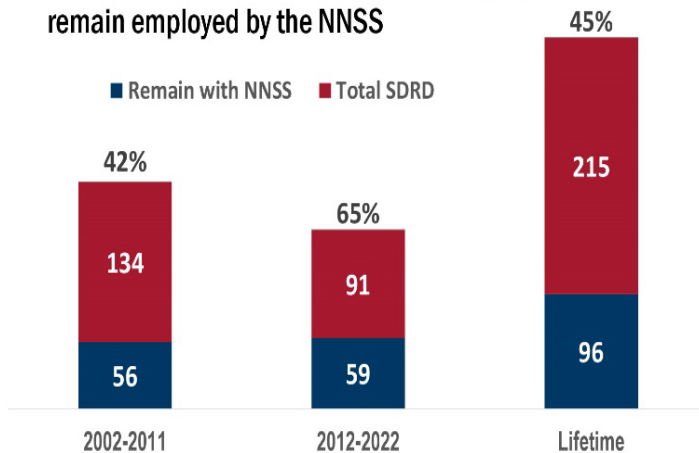
Total SDRD Projects

**12**

New Projects FY22

### Employee Retention & SDRD

Since 2012, 65% of PIs who had SDRD projects remain employed by the NNSS



Publications 16

Technologies Adopted by Programs 9

Gaps or Needs Addressed 27

Invention Disclosures and Patents 2

Postdocs and Interns 14

### Featured Research

SDRD projects demonstrate a high level of ingenuity and innovation each year. Selected highlights of the R&D accomplished in FY 2022 by the SDRD program are presented on the following pages. Summaries of all FY 2022 projects can be found on the NNSS website at [www.nnss.gov/pages/programs/sdrd.html](http://www.nnss.gov/pages/programs/sdrd.html). Full reports of all concluding projects and feasibility studies are available on the DOE Office of Scientific and Technical Information website at OSTI.gov.



Steven Koppenjan and team test their “Multimodal Remote Vibrometer for Infrastructure Interrogation” (22-087)

# Accelerator Beam Science and Target Interactions

## “Utilizing Machine Learning to Automate Linear Induction Accelerator Beam Tuning”

Daniel Clayton  
22-068  
Year 1 of 2

Sorting algorithms are being applied to historical Dual Axis Radiographic Hydrodynamic Test (DARHT) Axis 2 accelerator data to search for abnormal conditions within the large dataset. These algorithms will then be applied to accelerator data in real time to predict machine component failure.



Historical pulsed power data from Axis 2 of the DARHT facility were compiled, and a shared, secure computational workspace was created on the DARHT computer network to access this data and to write analysis code in a version-controlled, collaborative environment. Code was written to access this data and apply different clustering algorithms with a GUI interface. One particular clustering algorithm, spectral

clustering, has proven the most robust for this analysis.

Initial results are promising, but much work remains. The spectral clustering parameters must be optimized, and any abnormal accelerator conditions identified, then the algorithm needs to be applied to new data. Additionally, algorithms will be developed to include beam monitor data to cluster beam tune parameters, to be used for automated beam tuning routines.

**Mission Impact:** Component failures do happen from time to time during routine operation of linear induction accelerators (LIAs) used for radiography. An unexpected failure occurring during a hydrodynamic or subcritical experiment would be catastrophic, causing a loss of data on a valuable experiment. The pulsed power datasets collected from LIA operations are vast, and small abnormalities typically go unnoticed by human eyes. Using clustering algorithms to predict machine failure and to identify the failing component before it happens, operators could replace parts before a catastrophic failure leads to loss of data.

### ABSTI

Desorbed Ion Mitigation for Linear Induction Accelerators, *Z. Shaw (22-165), Feasibility Study*

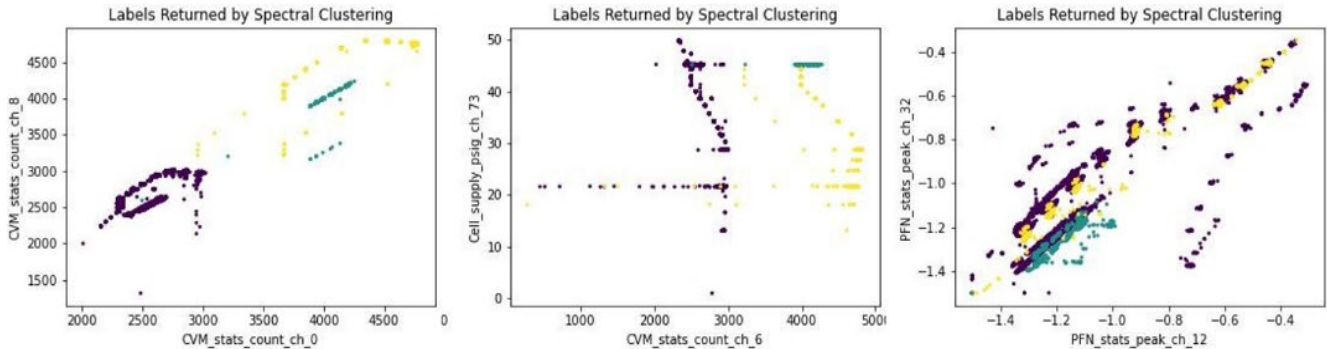
Electromagnetic Launch Modifications to C3 Launcher for Increased Velocity, *C. M. Hawkins (22-037)*

Health Assessment and Performance Monitoring of Large Machine Diagnostics, *M. Howard (22-119)*

Magnetic Tune Optimization in XTR, *E. Scott (22-171), Feasibility Study*

Noninvasive Spot Size Diagnostic for Linear Induction Accelerators, *M. Weller (22-162), Feasibility Study*

Utilizing Machine Learning to Automate Linear Induction Accelerator Beam Tuning, *D. Clayton (22-068) [Featured]*



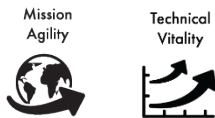
DARHT pulsed power data sorted into three clusters (highlighted with different colors). Each plot is a 2D projection of a dataset with thousands of variables.

# Communications and Computing

## “LiFi for Limited Area and Underground Wireless Communication”

Brian Sanders  
22-106  
Feasibility Study

*The feasibility and compatibility of using LiFi in the NNS network infrastructure is evaluated in this study. LiFi is a wireless communication technology that uses light waves instead of the radio spectrum. LiFi is capable of transmitting data over light at high speeds using visible light or infrared light. LiFi is mostly used in areas where wireless is a must-have and where the use of traditional radio systems reliant on radio frequency (RF) is not available or not allowed.*



The goal of the LiFi Feasibility Study was to demonstrate proof-of-concept use cases with the light-based line-of-sight communication medium (not susceptible to RF tapping) as the



LiFi component Trulifi 6002



LiFi component Trulifi 6014

primary communications links in the Limited Areas or environmentally challenging locations without physical copper wires or fiber-optic cables. Based on our successful preliminary test and evaluation of the LiFi system and components, we have determined that LiFi is a viable technology for use in the NNS network infrastructure.

In order to evaluate the LiFi system performance in more realistic field use cases at the NNS Enterprise facilities for our internal and external customers/projects, we recommend close coordination with the NNS Cyber Security Department and the Spectrum Management Office to ensure that there are no cybersecurity concerns and/or frequency spectrum management conflicts.

Currently wireless communication is restricted or prohibited in certain areas. LiFi is a solution that can offer alternative network support where wired and wireless RF communication may not be allowed or is restricted. This technology can provide a secure wireless network connectivity option that is not utilizing traditional RF

CC

LiFi for Limited Area and Underground Wireless Communications, B. Sanders (22-106), Feasibility Study [Featured]

SWITCH/NNS Proof of Concept Data Communications, C. Priest (22-167), Feasibility Study

network connectivity in certain situations.

**Mission Impact:** This technology can benefit the mission by facilitating wireless network connectivity in areas where traditional wireless connectivity is limited or restricted. This can also be used in situations where wired connectivity is not a practical option. This technology can provide additional connectivity options and flexibility to our customers.



LiFi component Trulifi 6016

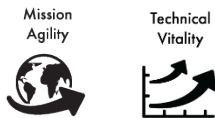


# Dynamic Experiment Diagnostics

## “Imaging of Bubble Collapse Effects in Optically Transparent High Explosive as a Method to Study the Detonation Process”

Dale Turley  
22-051  
Year 3 of 3

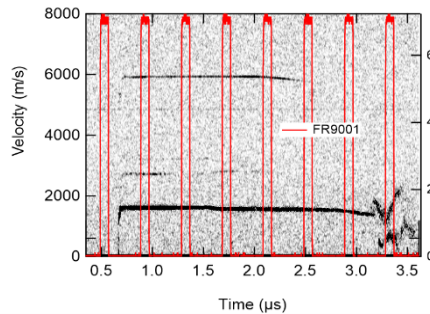
We used dynamic imaging and other techniques (velocimetry, radiometry, and spectroscopy) to investigate the processes leading to detonation in a homogeneous liquid explosive. By adding a gas bubble and observing its collapse caused by a shock wave propagating in the explosive, we were able to study the effect of “hot spot” formation during the early stages of the initiation process, furthering our understanding of explosive detonation.



Hot spots can affect the reactive flow and rate at which some chemical reactions occur during the onset of detonation; however, the detailed contribution of hot spots to initiation of

### The Four Combination Conditions of Shocked NM

	Bubble	No Bubble
Detonation	Bubble; Detonation	No Bubble; Detonation
No Detonation	Bubble; No Detonation	No Bubble; No Detonation



### Apparent velocity spectrogram.

detonation is still not well understood. Our goal is to develop methods to investigate effects of hot spots on detonation mechanisms in explosives and apply experimental results to detonation simulation models. Because polymer-bonded explosive (PBX) is optically opaque, we selected nitromethane (NM), a transparent liquid explosive, for our studies.

In a series of dynamic experiments, we were able to measure four important conditions of shocked NM: NM with and without a bubble, and with and without detonation. With our suite of measurement tools and this experimental approach, we were able to demonstrate the effect of a collapsing bubble on the explosive detonation process.

We investigated the incipient processes of detonation by studying shock-induced bubble collapse in NM. In this study, we quantified the effects of bubble collapse and peak input stress on the detonation process. We measured the time-resolved formation of hot spots and associated radiance temperatures and their effects on detonation using

## DED

High Pressure Strength of Materials by Measuring Tamped Richtmyer-Meshkov Instability Growth, *B. La Lone (22-124), Feasibility Study, [Classified]*

Homogeneous Detonation of High Explosive by Using Radiation from Shocked Noble Gases for Initiation, *B. La Lone (22-120)*

Imaging of Bubble Collapse Effects in Optically Transparent High Explosive as a Method to Study the Detonation Process, *W. Turley (22-051) [Featured]*

Low-Cost High-Speed Camera for Actinide Vessel Experiments, *E. Larson (22-170)*

Measurement of Dynamic Melting and Re-Crystallization of Shocked Metals, *R. Scharff (22-033)*

New Methods to Study the Kinetics of Phase Transformation in Shocked Cerium Metal, *G. Stevens (22-050)*

dynamic imaging, radiance, spectroscopy, and velocimetry measurements. Visible imaging identified distinct spatial features of detonation and, most importantly, the formation of a detonation wave. The simultaneous measurement of the

emitted radiance and the time-resolved shock and detonation velocities shows temporal features well correlated with the detonation signature in the images. The signatures of detonation occurred significantly earlier in time when gas bubbles were present.

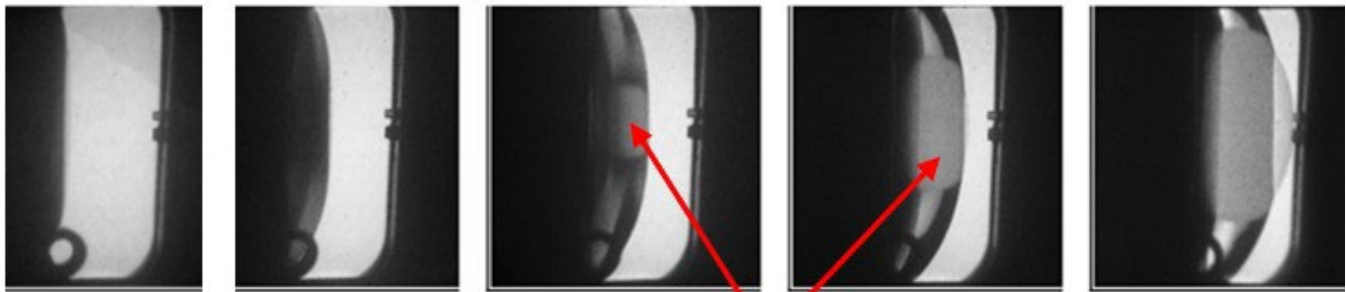
Using a butane bubble, we multi-diagnosed the phenomena of void-collapse and its influence on the detonation process. This process underlies many complex detonation models currently employed by the

DOE, and, prior to our work, scant experimental evidence of hot spot behavior was published.

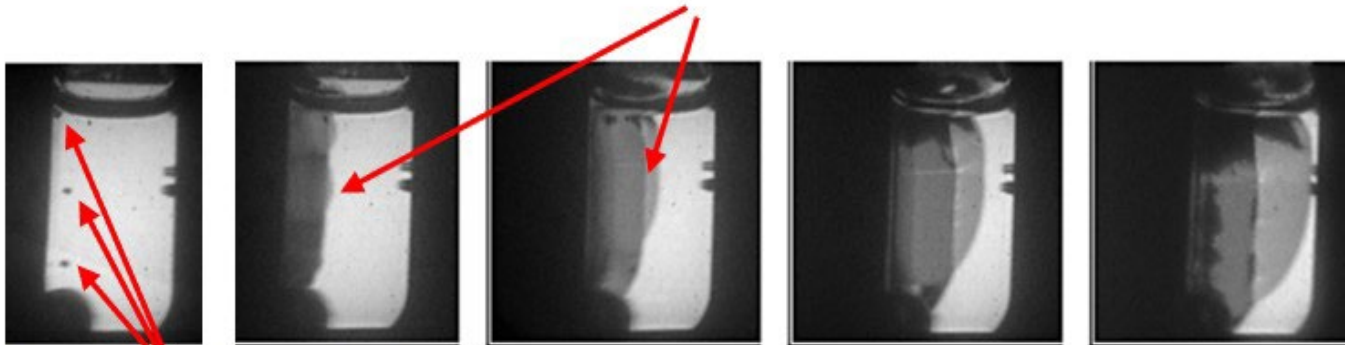
**Mission Impact:** Hydrodynamic codes can model the localized energy increase caused by collapse of a void in an explosive and can provide insight into the effects of individual hot spots on detonation. Dynamic imaging of shock and detonation waves and hot spots can contribute to the understanding of wave dynamics and

the fundamentals of the detonation process. Such measurements could be extremely useful in the understanding of reactive flow in the high explosive detonation burn process. Further understanding and control of hot spot densities can help tailor designs for high explosive detonation sensitivity and improve the predictive capability for sensitivity and initiation characteristics.

### No bubbles, 8.6 GPa



Onset of detonation



### Butane bubbles, 8.7 GPa

Comparison of images captured (package window  $1 \times 2$  cm) for shocked and detonating NM without (*top row*) and with butane bubbles (*bottom row*) at an input stress of 8.6–8.7 GPa. The shock wave is moving from left to right in the images. Camera intra-frame times and integration times are  $\sim 400$  ns and  $\sim 100$  ns, respectively. Images show that the bubbles sensitize the explosive and cause detonation to occur earlier compared to the neat NM and at the location of the collapsed bubbles.

# Enabling Technologies for Autonomous Systems and Sensing

## “Spatially Aware Multi-Modal Directional Radiation Detector Swarms”

James Essex  
22-134  
Year 1 of 3

*This project is exploring spatially aware platforms that combine inputs from multiple sensors to estimate detector measurement locations, enabling protocols for radiation data exchange between sensors, and developing methods to optimize source detection and localization.*



**Simultaneous Localization and Mapping (SLAM) algorithm using an RGB-Depth camera to determine position of operator and sensor in XYZ space. The correlated XYZ and radiation detector measurements can be used to predict the location of a radiation source.**

All existing radiation detection systems utilize alarming algorithms that are temporal, and the localization of a potential threat currently requires manual methods and operator skill. If alerted using existing systems, the operator can rotate using body shielding to affect count rate or use a finder mode with tones that increase as the count rate increases. In access-restricted environments, it is not currently possible to locate a source without long dwells using sophisticated and expensive instrumentation. These methods are slow and error-prone, require post-processing, or, in some tactical situations, are not practical or safe.

In the first year of this effort, we tested spatial sensing capabilities and developed the software layer to map relative positions of devices into a common local coordinate system. This effort is novel because all previous radiation anomaly detection efforts have focused solely on detector

response and have not been capable of exploiting precise spatial coordinates of each measurement or angular indications from a multi-detector system. In addition to increasing the sensitivity of anomaly detection, we will develop algorithms for determining optimal data for inclusion into existing localization algorithms. Our approach to this effort will be to utilize similar methods to those used with the HoloLens (Essex et al. 2018), but we will adapt the spatial sensing to the new Inertial Measurement Unit, the RGB-Depth camera-based Simultaneous Localization and Mapping (SLAM) algorithm, and Ultra-Wide Band modules with new modular gamma and neutron detectors.

## ETASS

Agnostic Modular Payloads for Multi-INT Collection, *A. Davies (22-114)*

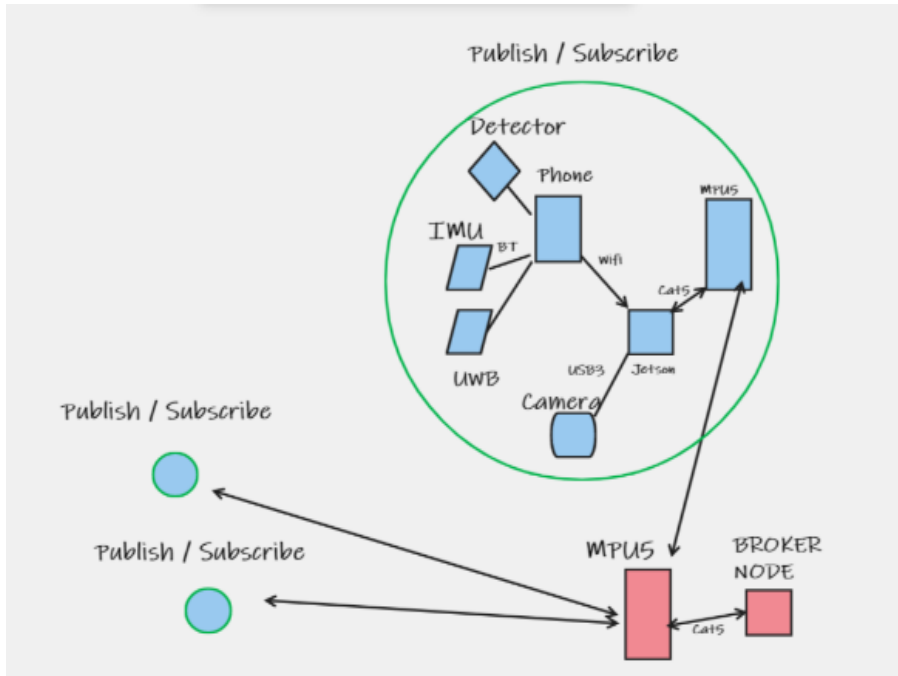
AR/VR CBRN Solution for Emergency Responders, *B. Richardson (22-117)*

Deploying Isotope Identification Machine Learning Models to Edge and Detector Systems, *G. Dean (22-142)*

Electronics Integrity, *L. Drake (22-164), Feasibility Study*

Enhancing Deep Cavity Detection Using Orthogonal Measurement Techniques, *M. Howard (22-074)*

High-Density Energy Storage and Harvesting Technologies for Portable Systems, *K. Lee (22-169), Feasibility Study*



The hardware architecture and data pathways of the detector swarm from each component of the system.

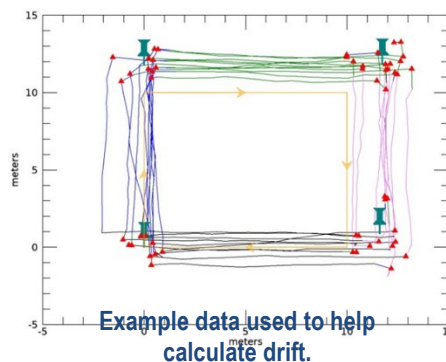
In the second year of this effort, we will continue to optimize pedestrian-based spatial awareness technologies and sensor fusion algorithms, and tune localization solutions using both gamma and neutron directional detection systems. Several data collection campaigns will be executed in a variety of environments that represent the spectrum of operational conditions of interest (i.e., static environments too crowded with people). These tests will characterize the performance of the spatial awareness suite to enable error estimates associated with localization.

**Mission Impact:** The development of this technology represents: 1) a practical solution to mapping radiation measurements in GPS-denied environments, and 2) the potential to equip current overt radiological search teams with a capability to localize a radiation source. This could enable the discovery of potential threat sources in rooms or buildings without access, such as apartment complexes, office

spaces, or high-rises, and reduce the time to find potential threats in large venues such as warehouses, parking garages, or maritime container ships.

#### Reference

Essex, J., C. Okada, A. Podovich, M. Reed, A. Guild-Bingham, D. Haber. 2018. "Adaptive Source Localization Using Augmented Reality." In *FY 2018 Site-Directed Research and Development Annual Report*, 85–90. Las Vegas, Nevada: Mission Support and Test Services, LLC.



## ETASS (cont.)

Measurements for Combined Gamma Ray and Video Modalities, *P. Mendoza (22-022)* ●

Micro-Ion Traps for Real-Time Chemical Analysis in Harsh Environments, *M. Manard (22-003)* ●

Multimodal Remote Vibrometer for Infrastructure Interrogation, *S. Koppelman (22-087)* ●

New Porous Solids for Krypton and Xenon Capture without Cryogenics, *M. Morey (22-030)* ●

Passive Detection of UAS Using Turbulence-Enhanced Imagery, *I. McKenna (22-088), Feasibility Study* ●

Performance Monitoring by Simultaneous Sensing of Internal Gas Exchange and Respiration Patterns—Pythia Phase III, *E. Stassinis (22-083)* ●

Radioactive Noble Gas Detection, *R. Trainham (22-042)* ●

Spatially Aware Multimodal Directional Radiation Detection Swarms, *J. Essex (22-134) [Featured]* ●

SWIR LED-Based Dual Comb Spectroscopy for High Value Gas Detection, *D. Baldwin (22-061)* ●

UAV-Based Detection of Methane Emissions through the Use of Micro-Electrical Mechanical Systems, *H. Tarvin (22-086), Feasibility Study* ●

# Neutron Technologies and Measurements

## “Detector Wall Research for Fast Gamma Signal Detection in Neutron-Diagnosed Subcritical Experiment Applications”

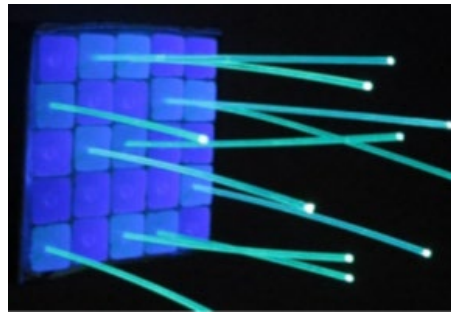
Stuart Baker  
22-045  
Year 3 of 3

This project pursued a new gamma radiation detection method with evaluation of a detector concept designed for ultra-high sensitivity along with fast (ns) time response. The intended application is high accuracy measurement of a pulsed gamma signal produced in Neutron-Diagnosed Subcritical Experiment (NDSE) tests.



The NDSE testing platform capability is the next generation of instrumentation for subcritical nuclear weapon testing being planned for the Zeus testbed in the U1a facility. A large area detector with sufficient collection efficiency is needed to provide an accurate measurement of the gamma-ray flux produced in the NDSE test. Our need for high gamma sensitivity led us to test a detector with an array of smaller scintillator cells coupled to a small fast photomultiplier tube (PMT).

Tests were first performed on a small format prototype detector. This detector proved to be highly sensitive while maintaining fast time response. Detector response was measured in PMT signal to be approximately 20 times more voltage per scintillator area and volume over the large area NDSE baseline prototype. Also, to be comparable to the baseline detector wall pixel, the scintillator area



Detector assembly of the small format prototype detector. Figure shows 25, 1 mm scintillator cells illuminated with UV light with the wavelength shifting fibers extending out of the cells.

dimensions must be scaled up to provide relative statistical detection efficiency measurements.

To produce a detector on the scale of the baseline pixel, we scaled up the dimensions of the design. Three detector configurations were then tested and showed that the smaller format detector configuration proved to be approximately 10 times more sensitive than the larger format detector.

The small format detector is shown to be highly sensitive for MeV gamma radiation detection with good time response. The small format detector scheme proved to be highly efficient and could prove to be highly useful for certain x-ray and gamma signal monitoring, as well as neutron time-of-flight.

The large format detector tested was limited in sensitivity with poor optical collection efficiency that would need to be remedied for further pursuit of a scaled up large area on the order of the NDSE detector wall.

**Mission Impact:** NDSE tests planned

## NTM

Constraining Physics Models with Complementary PINEX and NUEX Data, *J. Clayton (22-053)* [Classified]

Cryogenic Deuterium Pellet Injection for Enhanced Neutron Output of a Dense Plasma Focus, *D. Lowe (22-004)*

Detector Wall Research for Fast Gamma Signal Detection in Neutron-Diagnosed Subcritical Experiment Applications, *S. Baker (22-045)* [Featured]

Dual-Use High-Z, High-Cross-Section Materials for Neutron Imaging and In Vivo X-Ray-Initiated Cancer Drugs, *J. Di Benedetto (22-090)*

Growth and Characterization of Novel Scintillation Materials, *J. Di Benedetto (22-161)*

Multilayered Avalanche Diamond Detector for Fast Neutron Applications, *A. Guckes (22-024)*

Z-Pinch and Laser Ablation-Driven New High-Yield Neutron Source, *E. Dutra (22-052)*

for U1a with measurement of dynamic reactivity to infer criticality are essential to inform the accuracy of predictive models and dynamic performance of device design. Gamma time profile measurement accuracy is crucial for determining the nuclear reactivity and criticality of NDSE tests.

# Radiographic Systems Imaging and Analysis

## “Fast Methods for Geometric Inference in Limited-Angle Tomography”

Sean Breckling  
22-137  
Year 3 of 3

We are developing and implementing novel techniques to accurately quantify 3D volumetric density from an extremely limited number of x-ray projection images. This work was motivated, in part, by open questions regarding uncertainties inherent in assuming a perfect radial symmetry of hydrodynamic dynamic scenes.



Single and extremely few-view (EFV) x-ray imaging modalities are the most common techniques used to reconstruct data from dynamic experiments. In the single-view reconstructions, it is assumed that the 3D volumetric density of the target region enjoys a perfect radial symmetry; however, data rarely support this assumption. This condition makes us question how much 3D geometric information is available in imaging applications where as few as one or two projection angles are recorded. We suspect that recent developments in EFV tomographic reconstruction techniques stand to improve our analyses and our uncertainty quantification capability.

The standard model for regularized computer tomography (CT) reconstruction seeks to reconstruct a volume  $u$  which minimizes a loss function of the form via numerical optimization.

$$Loss(u) = \frac{\lambda}{2} \|Au - d\|_2^2 + R(u)$$

Equation 1: Generalized cost model corresponding to the tomographic reconstruction problem.

The operator  $A$  is the forward projection model,  $d$  is the radiography data, and  $R(u)$  is a non-negative regularization penalty. In year three, we developed new capabilities to solve Equation 1, when the forward model is in one of the three of the following forms:

$$A = \begin{bmatrix} P_1 \\ \vdots \\ P_k \end{bmatrix}, [P], \text{ or } \mathcal{A},$$

where operators  $P$  denote classic Radon projection operators from a single k-indexed vantage point. The operator  $M$  also denotes the Radon transform, but specifically from the momentum diagnostic's vantage. Lastly,  $\mathcal{A}$  specifies the axially symmetric transform.

During the summer months, several numerical optimization approaches were used to solve the EFV model, with two views in the Cygnus configuration and the DARHT configuration.

The Jovial series at the NNS's Special Technologies Laboratory's *Boom Box*, provided an opportunity to combine well-characterized radiography of a hydrodynamic scene with a momentum diagnostic capable of measuring mass in ranges that span much of the material seen in the radiographic field of view. It is presumed and cross-verified using PDV that the bulk of the mass is contained within the surface near the front of the wave. However, from the perspective of the radiography, seen in

## RSIA

(U) Physics-Informed Deep Learning with Uncertainty Quantification for Weapons Radiography, A. Gonzalez (22-019)

Broadband X-Ray Imager for Spectroscopic Diagnostics, R. Presura (22-123)

Develop a Tolerance System for the CODE V Monte Carlo Tolerancing Module that Uses Manufacturing Data as Input for the Required Probability Distribution Functions, M. Kaufman (22-168)

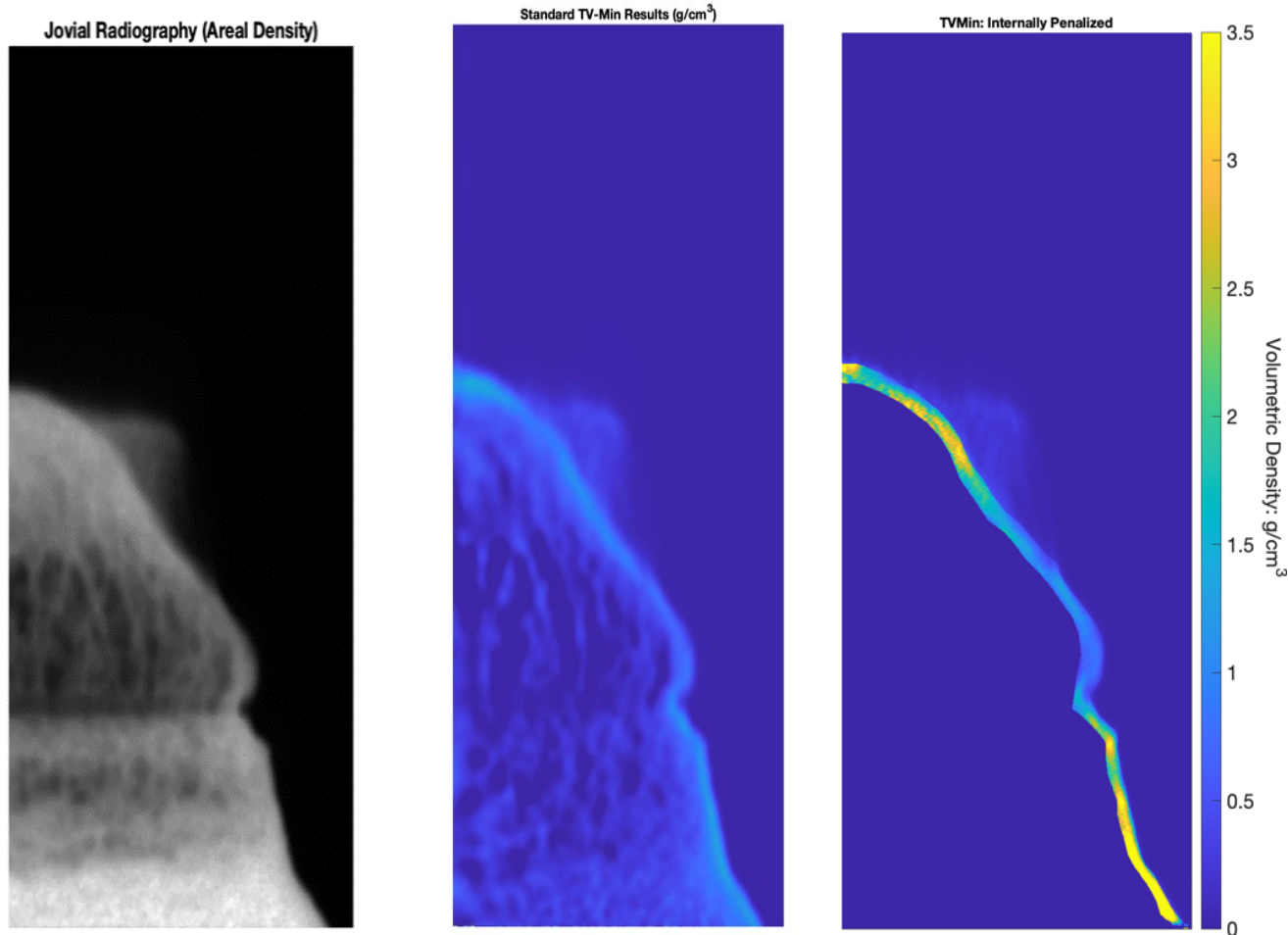
Fast Methods for Geometric Inference in Limited-Angle Tomography, S. Breckling (22-137) [Featured]

High-Z Semiconductors for h-keV Direct X-Ray Imaging, C. Leak (22-082)

Increased Fidelity via Quantum-Correlated X-Rays: IF via QCX, G. Walker (22-160)

Limits of Bulk-Material Property Calculations for X-Ray Opacity of Tungsten-Loaded Composite Materials, K. Miller (22-166), Feasibility Study

Solid-State Spectrographic Camera for HED and Pyrometry Applications, A. Lewis (22-064)



Comparison between projection radiography (*left*), unmodified, single-view reconstruction (*center*) and one with additional penalties  $R(u)$  applied to the numerical optimization procedure (*right*). Original Jovial image courtesy of Jerry Stevens.

the figure, we see striations on the surface of the propelled coupon surface. The standard axial symmetry model used in single-view reconstruction methods will fail to correctly place volumetric density at that surface region, instead filling up much of the internal bubble with errant mass.

Among the numerous methods explored during FY 2022, we developed two alternative approaches to solving Equation 1 when an operator of type  $\mathcal{A}$  is presumed by amending the regularization penalty with additional terms. More analysis will be required before this prototype technique is ready for publication or

deployment on NNSS testbeds.

**Mission Impact:** The largest success of the FY22 period spurred from the arrival of the combined Jovial radiography and Asay window velocimetry data. This sparked a substantial modelling effort during half of FY22. Given the novelty of the measurement configuration, the reconstruction modeling efforts were high-risk, but have proven to be a fruitful avenue for both a brand-new analytical capability, and new mathematics. This work will continue development under the Nimble series.

The semi-blind deconvolution technique explored in FY21 through

mid-year FY22 has proven quite fruitful. This image restoration methodology has been effective at estimating the so-called “Monty Wood” blurring kernel without the need for a rollbar in the field of view. A publishable report on this work, coauthored by Sean Breckling and Malena Español at ASU, is also in a mature preprint stage. Analysts working on the Stockpile Stewardship Data Analysis (SSDA) program will likely explore an extension of this work to produce anode spot reconstructions using a similar statistical learning strategy. Such a tool would represent a substantial new capability at any pulse-powered X-ray imaging testbed.

# User-Centered Remote Testing and Operations

## “Dynamic Sub-Micron Particulate Behavior in Turbulent Media” ●

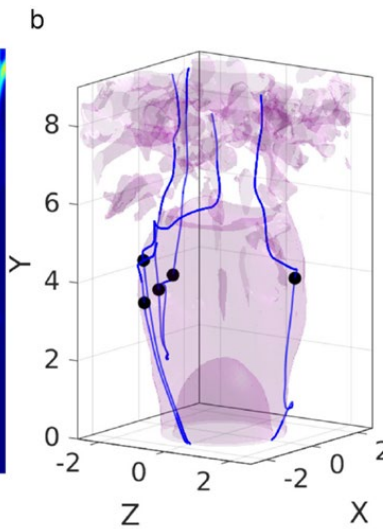
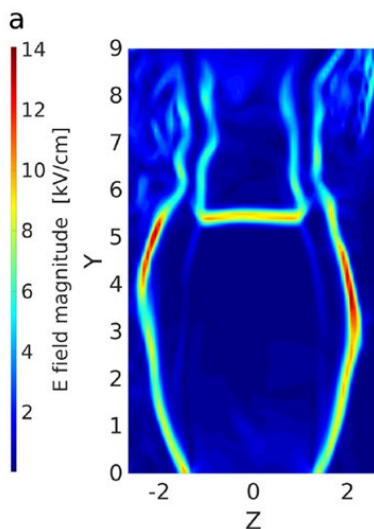
Clare Kimblin  
22-046  
Year 3 of 3

To investigate RF and charge associated with turbulently mixed carbon particles and so inform modeling of large-scale detonation signatures, we have performed three types of novel experiments using new experimental platforms. In doing so we have captured conditions which favor streamer formation with shocked diamond powder, demonstrated that triboelectrically charged carbon detonation particles (CDPs) produce RF emissions, and have confirmed that CDPs produced within .5 ms following a detonation are charged.



Particulates form nearly instantly following a detonation and can provide clues as to the high explosive (HE) device that produced them. Carbon

soot and metal/oxide particulates are thought to influence real time RF emissions, and particulates collected post-event serve as long lasting forensic evidence. To inform modeling of detonation signatures associated with particulates, we have performed low technology readiness level (TRL), controlled experiments using platforms designed to interrogate aspects of HE detonation signature production. Using these, we determined conditions and C allotropes that favor production of RF emissions, tested the theory that CDPs produce significant RF emissions, and explored charge on DPs produced within 1 ms following a detonation. To determine whether RF emissions were more prominent with a soot producing HE formulation vs. one which was oxygen balanced, we compared RF emissions from a fuel rich HE formulation, known to produce a significant amount of graphitic soot, to RF from an oxygen balanced nitromethane formulation. Preliminary results indicate that in the first millisecond following detonation, the fuel rich formulation yielded more RF pulses.



Model electric field with magnitude proportional to the velocity gradient (a) and simulated electrical discharge paths, black dots indicate points of maximum ionization. They are seen to originate in the rarefaction region (b).

## UCRTO

Biochemical Patterns of Life at NNSS Explosive Testing Sites, *R. Turley (22-157)* ●

Classified Data Analytics, *S. Kamath (22-048), Feasibility Study* ●

Determining the Seismic Hazard of Subsurface Facilities, *M. Scalise (22-111)* ●

Dynamic Submicron Particulate Behavior in Turbulent Media, *C. Kimblin (22-046)* [Featured] ●

Fuel Fabrication in Support of Nuclear Thermal Propulsion and Advanced Nuclear Reactor Technologies, *T. Lewis III (22-163), Feasibility Study* ●

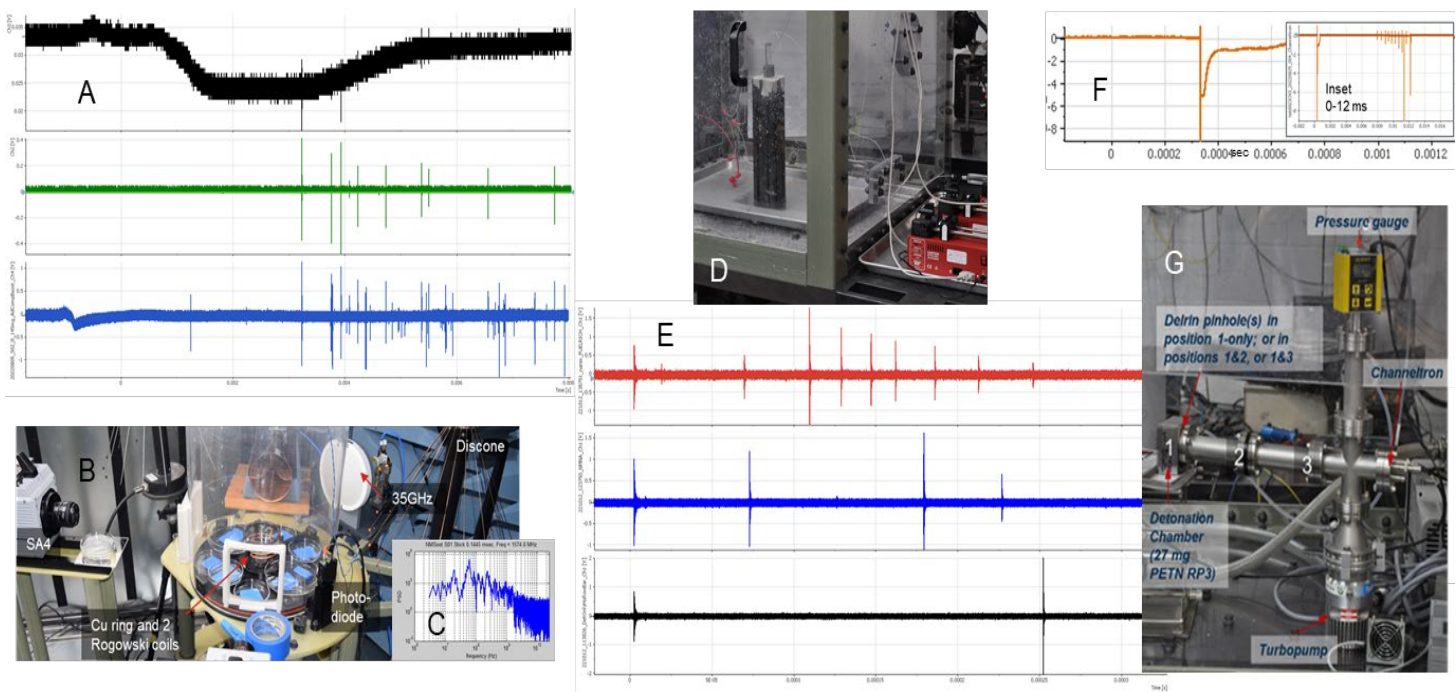
Indirect Measurement of Underground Facility Expansion/Extent through the Multimodal Use of Cyber Metadata (Traceroutes) and Physics-Informed Models Applied to Pre-Post Digital Surface Mapping, *D. Champion (22-126)* ●

Nuclear Thermal Propulsion Borehole Ground Testing Validation, *C. G. Rosaire (22-026), Feasibility Study* ●

Product Development to Support NASA’s Artemis Program and Astronaut Training, *B. Eleogram (22-031), Feasibility Study* ●

Re-Purposing Old Seismic Data to Calibrate Nuclear Test Monitoring Sites in Sparse Seismic Regions, *R. Turley (22-107)* ●





**Results from Shock tube experiment with CompB detonation soot showing raw photodiode (PD) (black trace). Drop in PD signal indicates release of soot, pulses coincide with antenna signals and are more pronounced after FFT of PD. Upper Rogowski internal antenna, (green trace), Active Discone antenna (blue trace) (A). Photo of shock tube with diagnostics (B). FFT from soot release indicating 1-4 GHz emission with soot on 1-18 GHz frequency antenna (C). Photo showing set-up for nitromethane soot studies with automated syringe pumps to the right of the PC boom box (D). Results indicating more RF emissions observed with fuel rich detonation (red trace) vs. oxygen balanced (blue trace); RP-80 detonator only (black trace) (E). Results indicating detection of burst of ions (F) following RP-3 detonation in vacuum tight chamber shown in (G).**

Using platforms, diagnostics and an analysis code developed under this SDRD we have investigated the effect that triboelectric charging has on prompt emissions from known particulates. We observe significantly more RF and optical emissions with electrically insulating diamond relative to with conductive graphite and detonation soots but have demonstrated that CompB and TNT detonation soots produce RF and concurrent light emissions when ejected from the AI shock tube. More RF emissions are also produced following detonation of a fuel rich HE formulation, vs. using a detonator alone, and vs. an oxygen balanced formulation. These results suggest that triboelectric charging of detonation soots is an important mechanism for the production of RF in a soot rich

detonation. Using a CEM and small detonation we have demonstrated that charged particles are produced from the detonation of PETN, and that making a TOF MS measurement, within a ms of detonation, will be feasible (under STL-007-23).

**Mission Impact:** This work provides new NNSS capabilities in the form of experimental platforms, diagnostics, and analysis code. The particulate shock tube permits verification of optical as well as hydrodynamic and electrostatic models (as described in Von der Linden et al.). Using the shock tube and PC boom-box, we have demonstrated that triboelectric charging of carbonaceous soot is an important mechanism for RF generation, though the role of the metal support requires more

investigation. In FY23 the shock tube and the PC boom box will be used to perform small scale experiments in support of 3 non-proliferation projects. In addition to providing platforms for small-scale experiments, the two platforms also permit testing of diagnostics and analysis techniques prior to fielding equipment at large scale tests. The Data Analysis code, first developed to analyze RF and high-speed camera imagery from the shock tube, is now being leveraged by multiple projects for field data analysis. Finally, we have also demonstrated that measurement of m/z for detonation particles produced directly from a detonation will be feasible and will continue this investigation under STL-007-23.

# Program Value

The SDRD program uses quantifiable metrics to track the performance of our R&D investment from year to year. Metrics such as intellectual property, technology transfer to our programs, addressing R&D needs and requirements, and publications are some of the most common types of measurable outcomes. We also consider the importance of other factors, such as follow-on programmatic or external funding received, new methods developed that effectively reduce costs, and overall enhanced staff capabilities. These are further indicators of innovation productivity and are also a direct measure of investment return. SDRD provides our staff with opportunities to explore and exercise creative motivations that ultimately lead to new knowledge and realized technologies.

## SDRD Program Performance Metric

### *Invention Disclosures and Patents*

Invention disclosures are the first step in our intellectual property pursuit and are often followed by patent applications when deemed appropriate. SDRD has generated well over half of all inventions disclosed company-wide since FY 2002.

	FY18	FY19	FY20	FY21	FY22
Number of Projects	28	29	29	39	54
Invention Disclosures and Patents	4	4	4	4	2
	14%	14%	14%	10%	4%

Since FY 2016 about one-third of our projects have generated new invention disclosures, which is a reasonably high ratio given that projects can vary widely from basic concept, low technical readiness to much higher more applied development efforts. In fact, our programs benefit from a high rate of technology utilization precisely due to this diverse project mix.

### *Publications*

Publications are another indicator of R&D output and provide an

	FY18	FY19	FY20	FY21	FY22
Journal Publications	8	10	24	21	16

archival record of the investments made, which are then available to the broader scientific and technical community. We place a strong emphasis on high-quality, high-impact journal publications. We generally expect about half of all SDRD projects will publish in a given year.

### *Technology Transfer*

Approximately one in three SDRD projects produce technology that is subsequently adopted by a direct NNSC program. The ratio of needs addressed to total projects is also indicative of a trend that aligns efforts strategically with the NNSC

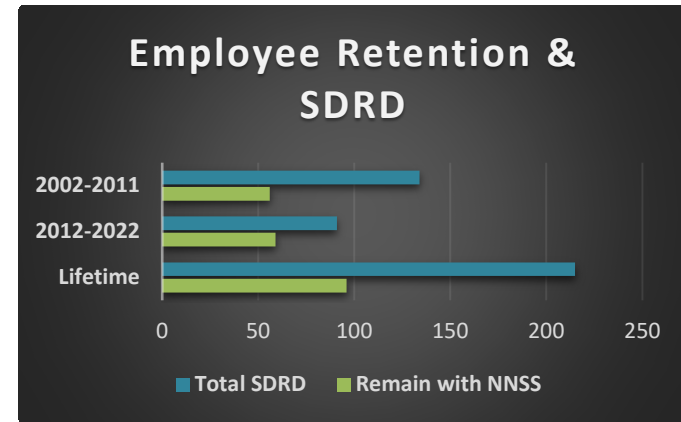
	FY18	FY19	FY20	FY21	FY22
Number of Projects	28	29	29	39	54
Technology Adopted by Programs	9	11	9	13	9
	32%	38%	31%	33%	17%

mission. The program strives to effectively contribute new technology into key programmatic efforts as quickly as possible. New strategic efforts are also providing greater emphasis on forward-looking needs efficiently coupled with long-term visionary goals.

### Technology Needs Addressed

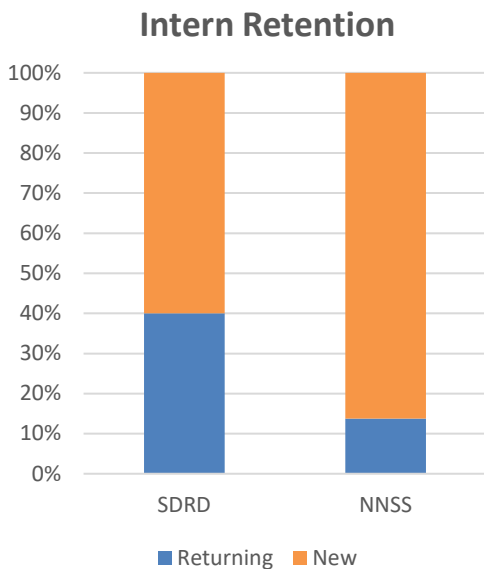
The NNSS technology needs assessment document includes guidance regarding technology gaps and challenges facing mission areas. Our directed research emphasis areas this year targeted key investment needs, including nuclear security, information security/assurance, high energy density physics diagnostics, integrated experiments, advanced analysis, and safeguarded energy. The NNSS Technology Needs Assessment for R&D is developed from a broad base of input from the national security complex, including laboratories, NNSA, and other external agencies, and it is updated annually. In addition to the assessment, at the beginning of each year's proposal call, we issue a Broad Site Announcement that contains detailed information on strategic initiatives in our directed research areas. A number of projects, but still a small percentage, are targeting emerging fields and new initiatives intended to incorporate higher risk; these projects explore opportunities for enhanced mission outside of traditional NNSS areas of expertise.

	FY18	FY19	FY20	FY21	FY22
Number of Projects	28	29	29	39	54
Gap or Need Addressed	11	14	12	18	27
	39%	48%	41%	46%	50%
Emerging Area and Special Opportunity Effort*	6	3	6	18	11
	21%	10%	21%	46%	20%



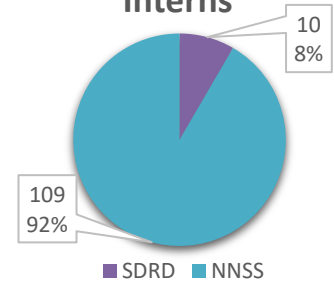
### Postdocs and Interns

The SDRD program welcomed its first postdoctoral PI in 2015. Since then, it has attracted numerous postdocs and interns. The contribution of these early-career scientists is significant. The program continues to enjoy the contributions of this group, having converted most to full-time staff. Since 2012, 65% of staff who participated in the SDRD program remain in the workforce, and from 2002 until the present 45% have been retained.

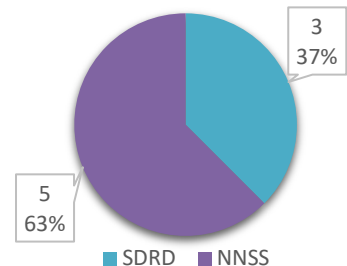


In FY 2022, SDRD supported a total of 10 interns. SDRD projects that were funded at over \$250K financed a minimum of one intern and those over \$350K financed two or more. SDRD also hosted 3 of the 5 interns from the NNSS Minority Serving Institution Partnership Program (MSIPP), further strengthening the mission to create a STEM pipeline between universities and the NNSS. The retention rate for interns in SDRD in FY 2022 was 40%, vastly higher than the overall NNSS intern retention rate. SDRD continues to be a source of innovation and interest for early career scientists and other STEM professionals.

### Total Number of Interns



### MSIPP Interns



# SDRD Impact Stories



The long-term value of SDRD is demonstrated by projects whose benefits to the NNSA's mission and then to the program emerge over many years. An SDRD project's lifespan may be only one to three years long, but research that is subsequently adopted by programs and funded by programmatic dollars can mature and provide the basis for long-lasting technologies. Following the evolution of our SDRD projects over five or more years demonstrates how our initial R&D investments yield a high return of programmatic capability. Several SDRD projects have contributed to Machine Learning and Artificial Intelligence programmatic efforts over the years as detailed by Bruce Dunham below. Following that is a look at another indicator of our long-term success: our university partnerships.

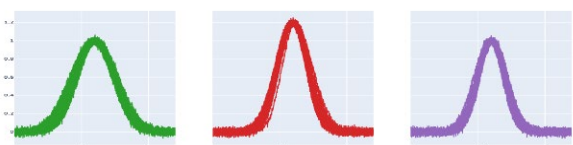
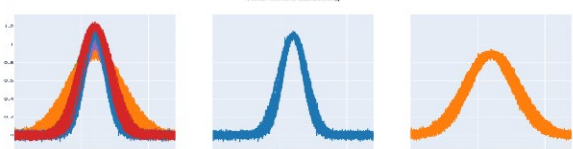
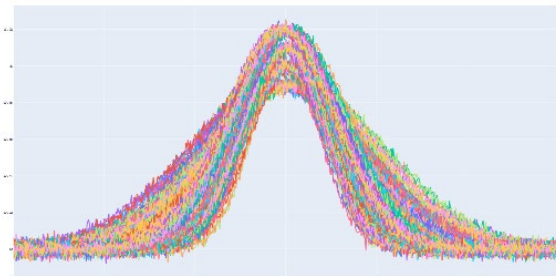
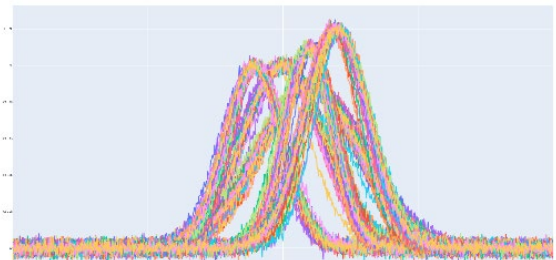
## Machine Learning and Artificial Intelligence *Written by Bruce Dunham*



The application of modern machine learning (ML) techniques to sub-critical experiments and related sources, like Cygnus and Scorpius, is a relatively new field of study at NNSA. Using ML can help to improve machine reliability, enhance performance, and potentially increase the number of experiments we can perform. The main areas we are studying now are anomaly detection/prognostics, digital twins, and uncertainly quantification, using SDRD funding to launch these efforts.

The first topic of importance is anomaly detection and prognostics. The sources for subcritical experiments are complicated devices with many thousands to millions of components and controls points, too many for anyone to monitor in a meaningful way. We have highly trained operations staff, but they cannot possibly monitor every signal nor predict when a component will fail. The concept is to use ML techniques to learn how systems behave under normal conditions and the continuously monitor them for anomalies that indicate a pending failure. One of our SDRD projects (led by Jesse Adams) is investigating how to monitor capacitors in the Cygnus pulsed power system by incorporating new diagnostics that will allow them to collect data to feed into ML algorithms. Eventually, the system will be able to tell the operators when there is a potential problem, so they can fix it before losing a shot.

The second ML topic that is getting a lot of attention these days is Digital Twin (DT), formerly known as surrogate modeling. Computer simulations are very powerful and are used to design complex

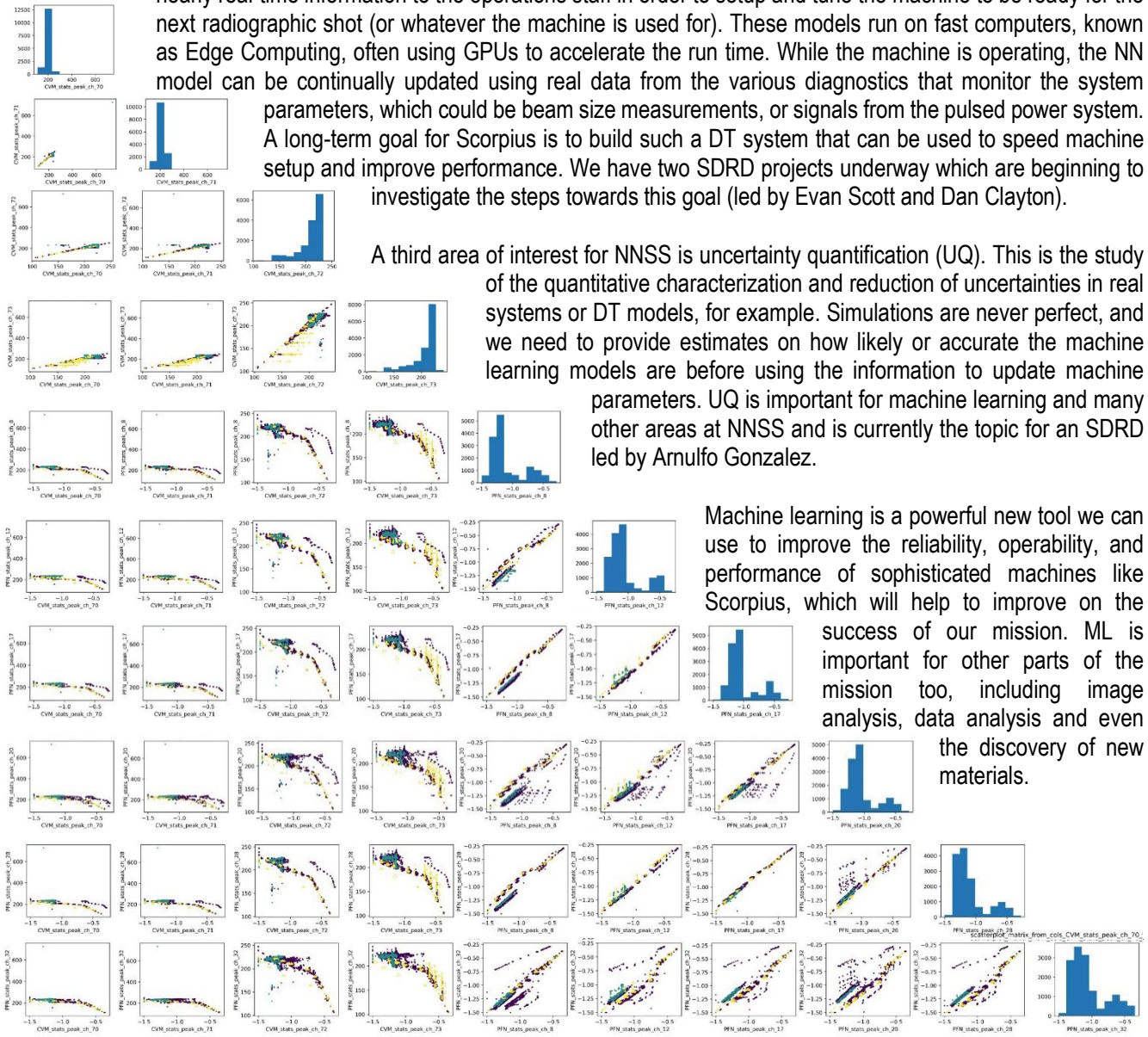


Jesse Adams "Health Assessment and Performance Monitoring of Large Machine Diagnostics" (22-003)

machines like Scorpis, but these simulations can take many hours to run, even on a supercomputer. The idea behind DT is to use a combination of real data and simulated data to generate a fast-executing neural network (NN) model that can provide nearly real-time information to the operations staff in order to setup and tune the machine to be ready for the next radiographic shot (or whatever the machine is used for). These models run on fast computers, known as Edge Computing, often using GPUs to accelerate the run time. While the machine is operating, the NN model can be continually updated using real data from the various diagnostics that monitor the system parameters, which could be beam size measurements, or signals from the pulsed power system. A long-term goal for Scorpis is to build such a DT system that can be used to speed machine setup and improve performance. We have two SDRD projects underway which are beginning to investigate the steps towards this goal (led by Evan Scott and Dan Clayton).

A third area of interest for NNSS is uncertainty quantification (UQ). This is the study of the quantitative characterization and reduction of uncertainties in real systems or DT models, for example. Simulations are never perfect, and we need to provide estimates on how likely or accurate the machine learning models are before using the information to update machine parameters. UQ is important for machine learning and many other areas at NNSS and is currently the topic for an SDRD led by Arnulfo Gonzalez.

Machine learning is a powerful new tool we can use to improve the reliability, operability, and performance of sophisticated machines like Scorpis, which will help to improve on the success of our mission. ML is important for other parts of the mission too, including image analysis, data analysis and even the discovery of new materials.



Dan Clayton “Utilizing Machine Learning to Automate Linear Induction Accelerator Beam Tuning” (22-068)



## SDRD and University Collaboration

Workforce  
Development



The SDRD program collaborates with a variety of companies, national laboratories, and universities to complete projects at the highest level. Our university partnerships are especially critical to not only our current projects and programs, but also our continued mission to build the future of technology and innovation across the enterprise. In FY 2022, SDRD partnered with over 30 other

entities including the 11 prestigious universities shown on this page.

By collaborating with universities, SDRD creates strong connections, relationships, and bonds with the rising talent of early career scientists and engineers. While working with SDRD, university interns gain access to cutting-edge projects, increase their real-world knowledge, and bolster their interest in what the NNSS does, thus strengthening the STEM university to

NNSS pipeline. Including the MSIPP participants, SDRD was able to host a total of 10 interns in FY 2022 making up 8% of the total number of interns that worked at the NNSS.

The SDRD program is proud to be able to support interns while building our relationships with the academic community and to continue being a leader in technology while injecting innovation across the NNSS.

UC SANTA BARBARA



TEXAS A&M  
UNIVERSITY.



Colorado  
State  
University

BYU  
BRIGHAM YOUNG  
UNIVERSITY

ASU<sup>®</sup>  
ARIZONA STATE  
UNIVERSITY



University of Nevada, Reno



THE UNIVERSITY  
OF ARIZONA

UNIVERSITY OF  
OREGON

UNLV  
UNIVERSITY OF NEVADA LAS VEGAS



University of Missouri

# Appendices

## Appendix A: Mission Support and Test Services-Operated Sites

**Livermore Operations (LO)**  
**P.O. Box 2710**  
**Livermore, California 94551-2710**

**Nevada National Security Site (NNSS)**  
**P.O. Box 98521**  
**Las Vegas, Nevada 89193-8521**

**New Mexico Operations (NMO)**  
**Los Alamos and Sandia Offices**  
**182 East Gate Drive**  
**Los Alamos, New Mexico 87544**

**North Las Vegas (NLV)**  
**P.O. Box 98521**  
**Las Vegas, Nevada 89193-8521**

**Remote Sensing Laboratory-Andrews (RSL-A)**  
**Andrews Air Force Base**  
**P.O. Box 380**  
**Suitland, Maryland 20752-0380**

**Remote Sensing Laboratory-Nellis (RSL-N)**  
**Nellis Air Force Base**  
**P.O. Box 98521**  
**Las Vegas, Nevada 89193-8521**

**Special Technologies Laboratory (STL)**  
**5520 Ekwil Street**  
**Santa Barbara, California 93111-2352**

## Appendix B: Acronyms and Abbreviations

### #

1D	one-dimensional
2D	two-dimensional
3D	three-dimensional

### A

ABSTI	Accelerator Beam Science and Target Interactions (STTA)
ADMM	Alternating-Direction Method of Multipliers
Ag	silver
AI	artificial intelligence
Al	aluminum
AMS	aerial measuring system
AR	augmented reality
ASU	Arizona State University

### B

BLR	Broad Laser Ranging
BLRIT	Broad Laser Ranging Investigative Tool
BSA	Broad Site Announcement
BYU	Brigham Young University

### C

CBRN	chemical, biological
CC	Communications and Computing (STTA)
CDP	carbon detonation particle
CEM	Channeltron electron multiplier
CRADA	Cooperative Research and Development Agreement
CS	Chief Scientist
CT	computer tomography

### D

DARHT	Dual Axis Radiographic Hydrodynamic Test (facility at LANL)
DARPA	Defense Advanced Research Projects Agency
DED	Dynamic Experiment Diagnostics (STTA)
DHS	U.S. Department of Homeland Security
DNN	Defense Nuclear Nonproliferation
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DPF	dense plasma focus
DT	Digital Twin

### E

EAB	External Advisory Board
EFV	extreme-few view
ELT	Executive Leadership Team
EOS	equation of state
ETASS	Enabling Technologies for Autonomous Systems and Sensing (STTA)

### F

FFT	fast Fourier transform
FY	fiscal year



**G**

GHz gigahertz  
 GPa gigapascal  
 GPU graphical processing unit

**H**

HE high explosive  
 HED high energy density  
 High-Z high atomic number  
 HPC high performance computing

**I**

IED improvised explosive device  
 IF increased fidelity  
 IP intellectual property

**J**

JASPER Joint Actinide Shock Physics Experimental Research (facility)

**K**

keV kilo electron volt  
 km kilometer

**L**

LANL Los Alamos National Laboratory  
 LDRD Laboratory-Directed Research and Development  
 LED light-emitting diode  
 LIA linear induction accelerator  
 LiFi wireless communication technology  
 LLNL Lawrence Livermore National Laboratory  
 LO Livermore Operations (MSTS)

**M**

ML machine learning  
 mm millimeter  
 MOU Memorandum of Understanding  
 MPCD multi-path communication device  
 MPVD multiplexed photon Doppler velocimetry  
 ms millisecond  
 MSIPP Minority Serving Institution Partnership Program  
 MSTS Mission Support and Test Services, LLC  
 MVPI Most Valuable Principal Investigator  
 mW milliwatt  
 m/z mass to charge (ratio used in spectroscopy)

**N**

NA-10 DOE Defense Programs  
 NA-22 Office of DNN Research and Development  
 NA-84 Office of Nuclear Incident Response  
 NASA National Aeronautics and Space Administration  
 NDSE neutron diagnosed subcritical experiment  
 NLV North Las Vegas (MSTS)  
 nm nanometer  
 NMO New Mexico Operations (Los Alamos and Sandia) (MSTS)

NN	neural network
NNSA	National Nuclear Security Administration (DOE)
NNSS	Nevada National Security Site
NM	nitromethane
NSE	Nuclear Security Enterprise
NSSE	National Security Special Event
NTM	Neutron Technologies and Measurements (STTA)
NTS	Nevada Test Site
NUEX	NeUtron EXperiment
<b>O</b>	
OSTI	Office of Scientific and Technical Information
<b>P</b>	
PC	polycarbonate
PD	photodiode
	Program Director
PDV	photon Doppler velocimetry
PETN	pentaerythritol tetranitrate
PI	principal investigator
PINEX	PINhole EXperiment
PL	Public Law
PNNL	Pacific Northwest National Laboratory
<b>Q</b>	
QCX	quantum-correlated x-rays
<b>R</b>	
R&D	research and development
RAP	Radiological Assistance Program
RF	radio frequency
RSIA	Radiographic Systems Imaging and Analysis (STTA)
RSL	Remote Sensing Laboratory
RSL-A	Remote Sensing Laboratory-Andrews (MSTS)
RSL-N	Remote Sensing Laboratory-Nellis (MSTS)
<b>S</b>	
s	second
S&T	Science and Technology (MSTS Directorate)
SCE	subcritical experiment
SDRD	Site-Directed Research and Development
SIPP	Strategic Intelligence Partnership Program
SLAM	Simultaneous Localization and Mapping (algorithm)
SMC	Search Management Center
SME	subject matter expert
SNL	Sandia National Laboratory
SSDA	Stockpile Stewardship Data Analysis
ST&E	Science, Technology, and Engineering
STEM	science, technology, engineering, and mathematics
STL	Special Technologies Laboratory (MSTS)
STTA	Science and Technology Thrust Area
SWIR	shortwave infrared

## **T**

TA  
TNT  
TOF

test area  
trinitrotoluene  
time of flight

## **U**

UAS  
UAV  
UCRTO  
UCSB  
UNLV  
UNR  
UQ

unmanned aircraft system  
unmanned aerial vehicle  
User-Centered Remote Testing and Operations (STTA)  
University of California, Santa Barbara  
University of Nevada, Las Vegas  
University of Nevada, Reno  
uncertainty quantification

## **V**

VISAR  
VR

velocity interferometer for any reflector  
virtual reality

## **W**

## **X**

XRPBS

X-Ray Polarizing Beam Splitter

## **Y**

## **Z**

Z  
Z-pinch

atomic number (see also High-Z)  
zeta pinch (type of plasma confinement system)

## Appendix C: Acknowledgments

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

Finally, as we mark our 20th annual report, I want to gratefully acknowledge the tremendous support by the multiple individuals and teams that make SDRD successful year after year. My sincere gratitude goes out to Kristen Macias, Anne Totten, and Kaela Dotson for compiling, editing, and publishing this report; to Leslie Esquibel for her valuable efforts in cost accounting of FY 2022 projects and significant project management support; to Emma Gurr and Sally Matthews for compiling the financial data for congressionally mandated reporting requirements; to Michael Baldonado for vast website and project tally assistance; to Larry Franks for exceedingly valuable technical guidance; and to SDRD Technology Representatives and review committee, Stuart Baker, Kirk Miller, Cleat Zeiler, Bruce Dunham, Radu Presura, Dan Clayton, Eric Dutra, Andrew Davies, Ki Park, Marylesa Howard, and Jerry Stevens. Again, I offer my sincerest appreciation for your dedication and fortitude to ensure another phenomenally successful year of R&D in support of the NNSS!

## Appendix D: FY 2022 SDRD Projects

[www.nnss.gov/pages/programs/sdrd.html](http://www.nnss.gov/pages/programs/sdrd.html)

- |  |   |
|--|---|
| (U) Physics-Informed Deep Learning with Uncertainty Quantification for Weapons Radiography, A. Gonzalez (22-019)                   | Develop a Tolerance System for the CODE V Monte Carlo Tolerancing Module that Uses Manufacturing Data as Input for the Required Probability Distribution Functions, M. Kaufman (22-168) |
| Agnostic Modular Payloads for Multi-INT Collection, A. Davies (22-114)   | Dual-Use High-Z, High-Cross-Section Materials for Neutron Imaging and In Vivo X-Ray-Initiated Cancer Drugs, J. Di Benedetto (22-090)  |
| AR/VR CBRN Solution for Emergency Responders, B. Richardson (22-117)   | Dynamic Submicron Particulate Behavior in Turbulent Media, C. Kimblin (22-046)  |
| Biochemical Patterns of Life at NNSS Explosive Testing Sites, R. Turley (22-157)   | Electromagnetic Launch Modifications to C3 Launcher for Increased Velocity, C. M. Hawkins (22-037)  |
| Broadband X-Ray Imager for Spectroscopic Diagnostics, R. Presura (22-123)  | Electronics Integrity, L. Drake (22-164), Feasibility Study   |
| Classified Data Analytics, S. Kamath (22-048), Feasibility Study   | Enhancing Deep Cavity Detection Using Orthogonal Measurement Techniques, M. Howard (22-074)   |
| Constraining Physics Models with Complementary PINEX and NUEX Data, J. Clayton (22-053)  | Fast Methods for Geometric Inference in Limited-Angle Tomography, S. Breckling (22-137)   |
| Cryogenic Deuterium Pellet Injection for Enhanced Neutron Output of a Dense Plasma Focus, D. Lowe (22-004)                         | Fuel Fabrication in Support of Nuclear Thermal Propulsion and Advanced Nuclear Reactor Technologies, T. Lewis III (22-163), Feasibility Study   |
| Deploying Isotope Identification Machine Learning Models to Edge and Detector Systems, G. Dean (22-142)                            | Growth and Characterization of Novel Scintillation Materials, J. Di Benedetto (22-161)  |
| Desorbed Ion Mitigation for Linear Induction Accelerators, Z. Shaw (22-165), Feasibility Study                                     | Health Assessment and Performance Monitoring of Large Machine Diagnostics, M. Howard (22-119)   |
| Detector Wall Research for Fast Gamma Signal Detection in Neutron-Diagnosed Subcritical Experiment Applications, S. Baker (22-045) |   |
| Determining the Seismic Hazard of Subsurface Facilities, M. Scalise (22-111)   |   |

This page and next: More cobalt squarate from the project “New Porous Solids for Krypton and Xenon Capture without Cryogenics” (M. Morey 22-030).

- High Pressure Strength of Materials by Measuring Tamped Richtmyer-Meshkov Instability Growth, B. La Lone (22-124), Feasibility Study
- High-Density Energy Storage and Harvesting Technologies for Portable Systems, K. Lee (22-169), Feasibility Study
- High-Z Semiconductors for h-keV Direct X-Ray Imaging, C. Leak (22-082)
- Homogeneous Detonation of High Explosive by Using Radiation from Shocked Noble Gases for Initiation, B. La Lone (22-120)
- Imaging of Bubble Collapse Effects in Optically Transparent High Explosive as a Method to Study the Detonation Process, W. Turley (22-051)
- Increased Fidelity via Quantum-Correlated X-Rays: IF via QCX, G. Walker (22-160)
- Indirect Measurement of Underground Facility Expansion/Extent through the Multimodal Use of Cyber Metadata (Traceroutes) and Physics-Informed Models Applied to Pre-Post Digital Surface Mapping, D. Champion (22-126)
- LiFi for Limited Area and Underground Wireless Communications, B. Sanders (22-106), Feasibility Study
- Limits of Bulk-Material Property Calculations for X-Ray Opacity of Tungsten-Loaded Composite Materials, K. Miller (22-166), Feasibility Study
- Low-Cost High-Speed Camera for Actinide Vessel Experiments, E. Larson (22-170)
- Magnetic Tune Optimization in XTR, E. Scott (22-171), Feasibility Study
- Measurement of Dynamic Melting and Re-Crystallization of Shocked Metals, R. Scharff (22-033)
- Measurements for Combined Gamma Ray and Video Modalities, P. Mendoza (22-022)
- Micro-Ion Traps for Real-Time Chemical Analysis in Harsh Environments, M. Manard (22-003)
- Multilayered Avalanche Diamond Detector for Fast Neutron Applications, A. Guckes (22-024)
- Multimodal Remote Vibrometer for Infrastructure Interrogation, S. Koppenjan (22-087)
- New Methods to Study the Kinetics of Phase Transformation in Shocked Cerium Metal, G. Stevens (22-050)
- New Porous Solids for Krypton and Xenon Capture without Cryogenics, M. Morey (22-030)
- Noninvasive Spot Size Diagnostic for Linear Induction Accelerators, M. Weller (22-162), Feasibility Study
- Nuclear Thermal Propulsion Borehole Ground Testing Validation, C. G. Rosaire (22-026), Feasibility Study
- Passive Detection of UAS Using Turbulence-Enhanced Imagery, I. McKenna (22-088), Feasibility Study
- Performance Monitoring by Simultaneous Sensing of Internal Gas Exchange and Respiration Patterns—Pythia Phase III, E. Stassinis (22-083)
- Product Development to Support NASA's Artemis Program and Astronaut Training, B. Eleogram (22-031), Feasibility Study
- Radioactive Noble Gas Detection, R. Trainham (22-042)
- Re-Purposing Old Seismic Data to Calibrate Nuclear Test Monitoring Sites in Sparse Seismic Regions, R. Turley (22-107)
- Solid-State Spectrographic Camera for HED and Pyrometry Applications, A. Lewis (22-064)
- Spatially Aware Multimodal Directional Radiation Detection Swarms, J. Essex (22-134)
- SWIR LED-Based Dual Comb Spectroscopy for High Value Gas Detection, D. Baldwin (22-061)
- SWITCH/NNSS Proof of Concept Data Communications, C. Priest (22-167), Feasibility Study
- UAV-Based Detection of Methane Emissions through the Use of Micro-Electrical Mechanical Systems, H. Tarvin (22-086), Feasibility Study
- Utilizing Machine Learning to Automate Linear Induction Accelerator Beam Tuning, D. Clayton (22-068)
- Z-Pinch and Laser Ablation-Driven New High-Yield Neutron Source, E. Dutra (22-052)

