DEFENSE THREAT REDUCTION AGENCY (DTRA)
Small Business Technology Transfer (STTR) Program
STTR 21.B Proposal Instructions

1. INTRODUCTION

The Defense Threat Reduction Agency (DTRA) mission is to enable the DoD, the U.S. Government, and International Partners to counter and deter Weapons of Mass Destruction (WMD – Chemical Biological, Radiological and Nuclear) and Improvised Threat Networks. The DTRA STTR program is consistent with the purpose of the SBIR/STTR Program, i.e., to stimulate a partnership of ideas and technologies between innovative small business concerns and Research Institutions through Federal-funded research or research and development (R/R&D).

The approved FY21.B list of topics solicited for in the Defense Threat Reduction Agency (DTRA) Small Business Technology Transfer (STTR) Program are included in these instructions followed by full topic descriptions. Offerors responding to this Broad Agency Announcement must follow all general instructions provided in the related Department of Defense Program BAA and submit proposals by the date and time listed in the DoD Program BAA. Specific DTRA requirements that add to or deviate from the DoD Program BAA instructions are provided below with references to the appropriate section of the DoD document.

The DTRA Small Business Technology Transfer (STTR) Program is implemented, administered, and managed by the DTRA Program Office. Specific questions pertaining to the administration of the DTRA STTR Program and these proposal preparation instructions should be submitted to:

Mr. Mark Flohr
DTRA SBIR/STTR Program Manager
Mark.D.Flohr.civ@mail.mil
Tel: (571) 616-6066

Defense Threat Reduction Agency
8725 John J. Kingman Road
Stop 6201
Ft. Belvoir, VA 22060-6201

For technical questions about specific topic requirements during the pre-release which begins April 21, 2021 through May 18, 2021 contact the DTRA Technical Point of Contact (TPOC) for that specific topic. To obtain answers to technical questions during the formal BAA open period, visit: https://www.dodsbirsttr.mil.

For questions regarding the DoD SBIR/STTR electronic submission system, contact the DoD SBIR/STTR Help Desk at dodsbirsupport@reisystems.com.

Proposals not conforming to the terms of this announcement will not be considered. DTRA reserves the right to limit awards under any topic, and only those proposals of superior scientific and technical quality as determined by DTRA will be funded. DTRA reserves the right to withdraw from negotiations at any time prior to contract award. The Government may withdraw from negotiations at any time for any reason to include matters of national security (foreign persons, foreign influence or ownership, inability to clear the firm or personnel for security clearances, or other related issues).

Please read the entire DoD announcement and DTRA instructions carefully prior to submitting your proposal as there have been significant updates to the requirements.

The SIBR/STTR Policy Directive is available at:
https://www.sbir.gov/sites/default/files/SBIRSTTR_Policy_Directive_2019.pdf.

2. SMALL BUSINESS ELIGIBILITY REQUIREMENTS

2.1 The Offeror

Each offeror must qualify as a small business at time of award per the Small Business Administration's (SBA) regulations at 13 CFR 121.701-121.705 and certify to this in the Cover Sheet section of the proposal. Those small businesses selected for award will also be required to submit a Funding Agreement Certification document prior to award.

2.2 SBA Company Registry

Per the 2019 SBIR-STTR Policy Directive, all STTR applicants are required to register their firm at SBA's Company Registry prior to submitting a proposal. Upon registering, each firm will receive a unique control ID to be used for submissions at any of the eleven (11) participating agencies in the program. For more information, please visit the SBA's Firm Registration Page: https://www.sbir.gov/user/login/.

2.3 Use of Foreign Nationals, Green Card Holders and Dual Citizens

See the "Foreign Nationals" section of the DoD SBIR Broad Agency Announcement for the definition of a Foreign National (also known as Foreign Persons).

ALL offerors proposing to use foreign nationals, green-card holders, or dual citizens, MUST disclose this information regardless of whether the topic is subject to export control restrictions. Offers must identify any foreign nationals or individuals holding dual citizenship expected to be involved on this project as a direct employee, subcontractor, or consultant. For those individuals, please specify their country of origin, the type of visa or work permit under which they are performing and an explanation of their anticipated level of involvement on this project. You may be asked to provide additional information during negotiations in order to verify the foreign citizen's eligibility to participate on a STTR contract. Supplemental information provided in response to this paragraph will be protected in accordance with the Privacy Act (5 U.S.C. 552a), if applicable, and the Freedom of Information Act (5 U.S.C. 552(b)(6)).

Proposals submitted to export control-restricted topics and/or those with foreign nationals, dual citizens or green card holders listed will be subject to security review during the contract negotiation process (if selected for award). DTRA reserves the right to vet all uncleared individuals involved in the project, regardless of citizenship, who will have access to Controlled Unclassified Information (CUI) such as export-controlled information. If the security review disqualifies a person from participating in the proposed work, the contractor may propose a suitable replacement. In the event a proposed person is found ineligible by the government to

perform proposed work, the contracting officer will advise the offeror of any disqualifications but may not disclose the underlying rationale. In the event a firm is found ineligible to perform proposed work, the contracting officer will advise the offeror of any disqualifications but may not disclose the underlying rationale.

3. EXPORT CONTROL RESTRICTIONS

The International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, will apply to all projects with military or dual-use applications that develop beyond fundamental research, which is basic and applied research ordinarily published and shared broadly within the scientific community. More information is available at https://www.pmddtc.state.gov/ddtc_public.

The technology within some DTRA topics is restricted under export control regulations including the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR). ITAR controls the export and import of listed defense-related material, technical data and services that provide the United States with a critical military advantage. EAR controls military, dual-use and commercial items not listed on the United States Munitions List or any other export control lists. EAR regulates export-controlled items based on user, country, and purpose. The offeror must ensure that their firm complies with all applicable export control regulations.

NOTE: Export control compliance statements found in these proposal instructions are not meant to be all inclusive. They do not remove any liability from the submitter to comply with applicable ITAR or EAR export control restrictions or from informing the Government of any potential export restriction as fundamental research and development efforts proceed.

4. CYBER SECURITY

Any Small Business Concern receiving a STTR award is required to provide adequate security on all covered contractor information systems. Specific security requirements are listed in DFARS 252.204.7012, and compliance is mandatory.

5. PHASE I PROPOSAL GENERAL INFORMATION

5.1 Proposal Evaluation

DTRA will evaluate Phase I proposals using the criteria specified in Section 6.0 of the DoD SSTTR Program BAA during the review and evaluation process. The criteria will be in descending order of importance with technical merit, soundness, and innovation of the proposed approach being the most important, followed by qualifications, and followed by the commercialization potential. With other factors being equal, cost of the proposal may be included in the evaluation. DTRA reserves the right to limit awards under any topic and only proposals considered to be of superior quality will be funded. The Government may withdraw from negotiations at any time for any reason to include matters of national security (foreign persons, foreign influence or ownership, inability to clear the firm or personnel for security

clearances, or other related issues). Phase I contracts are limited to a maximum of $167,500 over a period not to exceed seven months. For clarity, the stated maximum dollar amount is exclusive of the Discretionary Technical and Business Assistance (TABA) that firms may request.

DTRA participates in one DoD STTR BAA each year and anticipates funding two Phase I contracts to small business concerns for each topic.

5.2 DTRA Support Contractors

Select DTRA-employed support contractors may have access to contractor information, technical data or computer software that may be marked as proprietary or otherwise marked with restrictive legends. Each DTRA support contractor performs under a contract that contains organizational conflict of interest provisions and/or includes contractual requirements for nondisclosure of proprietary contractor information or data/software marked with restrictive legends. These contractors require access while providing DTRA such support as advisory and assistance services, contract specialist support, and support of the Defense Threat Reduction Information Analysis Center (DTRIAC). The contractor, by submitting a proposal or entering into this contract, is deemed to have consented to the disclosure of its information to DTRA's support contractors.

The following are, at present, the prime contractors anticipated to access such documentation: Cherokee Nation Strategic Programs, LLC (contract specialist support), Kent, Campa, and Kate, Inc. (contract closeout support), Engility Corporation (a company under SAIC, Inc), (advisory and assistance services), Quanterion Solutions, Inc. (DTRIAC), Kforce Government Solutions, Inc. (financial/accounting support), and CACI (contract writing system administration). This list is not all-inclusive (e.g., subcontractors) and is subject to change.

6. PHASE I PROPOSAL SUBMITTAL

Detailed guidance on registering in DSIP and using DSIP to submit a proposal can be found at https://www.dodsbirsttr.mil/submissions/learning-support/training-materials. If the proposal status is "In Progress" or "Ready to Certify" it will NOT be considered submitted, even if all volumes are added prior to the BAA close date. The proposer may modify all proposal volumes prior to the BAA close date.

Although signatures are not required on the electronic forms at the time of submission the proposal must be certified electronically by the corporate official for it to be considered submitted. If the proposal is selected for award, the DoD Component program will contact the proposer for signatures at the time of award.

Proposals addressing the topics will be accepted for consideration if received no later than the specified closing hour and date in the DoD Announcement The Agency requires your entire proposal to be submitted electronically through the DoD Submission Web site https://www.dodsbirsttr.mil/submissions/. A hardcopy is NOT required and will not be accepted. Hand or electronic signature on the proposal is also NOT required.

Proposals are required to be submitted in Portable Document Format (PDF), and it is the responsibility of submitters to ensure any PDF conversion is accurate and does not cause the Technical Volume portion of the proposal to exceed the 20-page limit. **Any pages submitted beyond the 20-page limit, will not be read or evaluated.** If you experience problems uploading a proposal, email the DoD SBIR/STTR Help Desk at: dodsbirsupport@reisystems.com

MAXIMUM PHASE I PAGE LIMIT FOR DTRA IS 20 PAGES FOR VOLUME 2, TECHNICAL VOLUME

DTRA's objective for the Phase I effort is to determine the merit and technical feasibility of the concept. The contract period of performance for Phase I shall be seven (7) months (approx. 6 months technical work plus 1 month final report preparation) and the award shall not exceed $167,500. A list of topics currently eligible for proposal submission is included in these instructions, followed by full topic descriptions.

Animal and Human Research

Companies should plan carefully for research involving animal or human subjects, biological agents, etc. (see Sections 4.7 - 4.9 in the DoD Program Announcement). The few months available for a Phase I effort may preclude plans including these elements unless coordinated before a contract is awarded.

Profit or Fee on Travel Costs

Travel shall not be a profit or fee bearing cost element.

7. DECISION and NOTIFICATION

DTRA has a single Evaluation Authority (EA) for all proposals received under this solicitation. The EA either selects or rejects Phase I and Phase II proposals based upon the results of the review and evaluation process plus other considerations including limitation of funds, and investment balance across all the DTRA topics in the solicitation. To provide this balance, a lower rated proposal in one topic could be selected over a higher rated proposal in a different topic. DTRA reserves the right to select all, some, or none of the proposals in a particular topic.

Following the EA decision, the DTRA SBIR/STTR office will release notification e-mails for each accepted or rejected offer. E-mails will be sent to the addresses provided for the Principal Investigator and Corporate Official. Offerors may request a debriefing of the evaluation of their not selected proposal and should submit this request via email to: DTRA.belvoir.re.mbx.sbir@mail,mil and include "STTR 21.B / Topic XX Debriefing Request" in the subject line. Debriefings are provided to help improve the offeror's potential response to future solicitations. Debriefings do not represent an opportunity to revise or rebut the EA decision.

For selected offers, DTRA will initiate contracting actions that if successfully completed will result in contract award. DTRA Phase I awards are issued as fixed-price purchase orders with a maximum period of performance of seven-months. DTRA may complete Phase I awards without additional negotiations by the contracting officer or without opportunity for revision for proposals that are reasonable and complete.

8. PHASE II PROPOSAL GUIDELINES

8.1 Phase II Proposal Introduction

Small business concerns awarded a Phase I contract are permitted to submit a Phase II proposal for evaluation and potential award selection. The Phase II proposals are best submitted no later than (NLT) 30 days AFTER the end of the 7 month Phase I period of performance.

All STTR Phase II awards made on topics from solicitations prior to FY13 will be conducted in accordance with the procedures specified in those solicitations.

DTRA is not responsible for any money expended by the proposer prior to contract award.

DTRA has established a **40-page limitation** for the Technical Volume submitted in response to its topics. This does not include the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site), or the Cost Volume, or the Company Commercialization Report. The Technical Volume includes, but is not limited to: table of contents, pages left blank, references and letters of support, appendices, key personnel biographical information, and all attachments.

Further details on the due date, content, and submission requirements of the Phase II proposal will be provided either in the Phase I award or by subsequent notification.

8.2 Phase II Proposal Instructions

Each Phase II proposal must be submitted through the DoD STTRSBIR Submission Web site by the deadline as specified in the Phase II Proposal Guidelines, or in the Phase I award or subsequent notification. Each proposal submission must contain a Proposal Cover Sheet, Technical Volume, Cost Volume, a Company Commercialization Report (see Sections 5.4.c.and 5.5 of the BAA Announcement), Volume 5, and Volume 6. The format should be similar to Phase I proposal except the Phase II Technical Proposal is limited to 40 pages. The Commercialization Strategy Volume should more specific than was required for Phase I.

As instructed in Section 5.4.e of the DoD STTR Program BAA, the CCR is generated by the **submission website based on information provided by you through the "Company** Commercialization Report" tool.

8.3 Commercialization Strategy

See Section 7.3 of the DoD STTR 21.B BAA.

8.4 Phase II Evaluation Criteria

Phase II proposals will be reviewed for overall merit based upon the criteria in Section 7.0 of this Broad Agency Announcement and will be similar to the Phase I process.

8.5 Profit or Fee on Travel Costs

Travel shall not be a profit or fee bearing cost element.

9. PUBLIC RELEASE OF AWARD INFORMATION

If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released via the Internet. Therefore, do not include proprietary or classified information in these sections. For examples of past publicly released DoD SBIR/STTR Phase I and II awards, visit https://www.dodsbirsttr.mil.

10. PROTESTS

Service of Protest (Sept 2006)

(a) Protests, as defined in section 33.101 of the Federal Acquisition Regulation, that are filed directly with an agency, and copies of any protests that are filed with the Government Accountability Office (GAO), shall be served on the Contracting Officer (addressed to Mr. Herbert Thompson, Contracting Officer, as follows) by obtaining written and dated acknowledgement of receipt from (if mailed letter) Defense Threat Reduction Agency, ATTN: AL-AC (Mr. Herbert Thompson), 1680 Texas Street, SE, Kirtland AFB, NM 87117. If Federal Express is used for the transmittal, the appropriate address is: Defense Threat Reduction Agency, ATTN: AL-AC (Mr. Herbert Thompson), 8151 Griffin Avenue, SE, Building 20414, Kirtland AFB, NM 87117-5669.

(b) The copy of any protest shall be received in the office designated above within one day of filing a protest with the GAO.

(End of provision)

DTRA 21.B Phase I Topic Index

DTRA21B-001	Synthetic Aperture Radar (SAR) Image Generation Data Augmentation (SIGDA)
DTRA21B-002	Numerics-Informed Neural Networks (NINNs)
DTRA21B-003	Mathematical models to build multi-radiation detector algorithms

DTRA21B-001 TITLE: Synthetic Aperture Radar (SAR) Image Generation Data Augmentation (SIGDA)

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning

TECHNOLOGY AREA(S): Battlespace; Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a method to produce synthetic SAR data for augmentation into Artificial Intelligence (AI) Automatic Target Recognition (ATR) algorithms and assess improvement compared to current methods. Leverage existing radiative transfer models (RTMs) within the research community to create phased history as well as radar images from which specific features can be exploited for use in current ATR algorithms. Explore the use of state of the art artificial intelligence (AI) methods such as the Generative Adversarial Network (GAN) in producing realizable synthetic SAR data in conjunction with RTM results to further improve ATR training.

DESCRIPTION: Current Standard Operating Procedures (SOPs) for SAR image analysis consists of manual processes that are labor intensive. SAR analysis currently requires a trained analyst with years of experience to accurately classify targets in a scene. Analysts cannot keep up with the amount of captured data that needs to be processed which has spawned attempts to push human capabilities [1]. The sheer volume of data from desperate systems produces a situation in which reviewing all collected imagery becomes an impossibility for the Intelligence Communities (ICs). Specifically for the Counter Weapons of Mass Destruction (CWMD) mission, foreign governments purposely take actions, such as moving locations and the use of remote sites that make it difficult for analysts to identify objects of interest. AI automated solutions have been proposed as a force multiplier with the potential to significantly increase the amount of actionable intelligence an analyst can produce [2]. Despite the promise that AI presents to the SAR analysis problem, training data for ATR algorithms is scarce.

AI algorithms must first be trained on existing data in order to process and make classifications on new data. Finding quality data that meets the end goal of the algorithm is often the Achilles heel of ATR systems. Moreover, the training data must incorporate all possible aspects of the target, viewpoint, and scene making the task of creating a training set difficult and cumbersome. Images are often translated, rotated, cropped, and noise added in various ways to capture possibilities. However, creating such a dataset for SAR imagery on desired military targets is even more difficult, cost prohibitive, and impractical with the very limited available data.

Instead, the use of RTMs for the creation of synthetic data has shown promise for ATR algorithms on other sensor modalities and can be extended to SAR [3].

A number of RTMs that have SAR capability already exist and should be further developed for the SAR synthetic data augmentation problem. Some of these models include RaySAR [4] CohRas [5], SARViz [6], and DIRSIG [7]. These systems were originally created with engineering studies in mind, for instance, sensor specifications, target characteristics, environmental conditions, platform properties, and so forth. Generally, RTMs are based on statistical ray-tracing techniques into a 3d scene description to predict at sensor radiance contributions from scene components. Scene descriptions can contain detailed information such as surface Bidirectional Reflectance Distribution Functions (BRDFs), textures, and spectral dependencies. Environmental conditions such as atmospheric propagations are also often incorporated with the use of models such as MODTRAN [8]. Sensor and antenna specifications such as power, frequency, and gain pattern are important parameters that are included for robust simulations. With the ability to create physically realizable SAR data, RTM outputs are well suited to solve the lack of training data problem for SAR ATR algorithms.

ATR algorithms are aimed at solving the classification problem of objects in a scene. Convolution Neural Networks (CNNs) have become the most common method for difficult classification problems, and have proven to be highly effective due to their ability to hone in on local features in the vector space. CNNs are comprised of layered connections of convolutions with learned filters that enable neighboring semantic meanings, making it an ideal choice for image classification. A number of CNNs have been developed for the SAR classification problem with promising accuracy but often lack sufficient datasets [2] [9] [10].

One of the most recent studies on the creation of synthetic SAR data for augmentation into ATR algorithms looked at processing RTM visible imagery into SAR like imagery by using a GAN [11]. Although the study showed that important features were missing in the GAN produced synthetic imagery required to improve ATR accuracy, the researchers proposed that instead, RTMs should produce the SAR data directly, and a GAN then could be used to improve the realism of the SAR image.

PHASE I: An in depth literature review comparing current SAR Radiative Transfer Models, data sets, and ATR algorithms is first required to understand the state of the art. An understanding of the advantages and disadvantages of the different available RTMs as well as their availability for use in this effort will be determined. An RTM will then be chosen, acquired, and used to produce synthetic SAR data, both phased history as well as imagery. SAR datasets will also be researched that contain objects of interest, one example being MSTAR [12]. An ATR algorithm will be chosen based on literature review results and availability. The ATR algorithm will be trained with the “off the shelf” data set and tested for accuracy. Training data will then be augmented from synthetically generated SAR data. Metrics, such as precision and recall will tracked to measure the increase in ATR performance with data augmentation. Deliver model, all software, data, and reports on the effort.

PHASE II: Build upon lessons learned from phase I, pursuing efforts that show promise in SAR data augmentation. Research AI methods to enhance synthetic imagery such as usage of GAN

algorithms. Implement AI and other synthetic imagery enhancements and test ATR improvements as a result of the enhancements. Produce TRL level 6 system by incorporating models into operational analytical tools and performing a technology demonstration. Metrics, such as precision and recall will be tracked to measure the increase in ATR performance with data augmentation. Deliver the system, model, all software, data, and reports on the effort.

PHASE III DUAL USE APPLICATIONS: Finalize and commercialize software for use by customers (e.g. government, satellite companies, etc.). Although additional funding may be provided through DoD sources, the awardee should look to other public or private sector funding sources for assistance with transition and commercialization.

REFERENCES:

1. R. A. McKinley, L. McIntire, N. Bridges, C. Goodyear, N. B. Bangera and M. P. Weisend, "Acceleration of image analyst training with trascranial direct current stimulation," Behavioral Neuroscience, vol. 127, no. 6, p. 936, 2013. ;
2. C. Coman, "A deep learning sar target classification experiment on mstar dataset," in International Radar Symposium, Bonn, Germany, 2018. ;
3. R. Kemker, C. Salvaggio and C. Kanan, "Algorithms for semantic segmentation of multispectral remote sensing imagery using deep learning," ISPRS journal of photogrammetry and remote sensing, no. 145, pp. 60-77, 2018. ;
4. S. Auer, R. Bamler and P. Reinartz, "RaySAR-3D SAR simulator: Now open source," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2016. ;
5. H. Hammer, K. Hoffmann and K. Schulz, "On the classification of passenger cars in airborne SAR images using simulated training data and a convolutional neural network. Image and Signal Processing for Remote Sensing XXIV," International Society for Optics and Photonics, vol. 10789, 2018. ;
6. M. Gupta, V. Malhotra, B. Shah, S. Prakash, A. Sharma and B. Kartikeyan, "RISAT-1 SAR HRS Mode Data Quality Evaluation," IGARSS IEEE International Geoscience and Remote Sensing Symposium, 2019. ;
7. M. Gartley, A. Goodenough, S. Brown and R. Kauffman, "A comparison of spatial sampling techniques enabling first principles modeling of a synthetic aperture RADAR imaging platform," in SPIE Defense, Security, and Sensing, Orlando, FL, 2010. ;
8. A. Berk, L. Bernstein and D. C., "MODTRAN: A moderate resolution model for LOWTRAN.," Spectral Sciences Inc., Burlington, MA, 1987. ;
9. H. S. Pannu and A. Malhi, "Deep learning-based explainable target classification for synthetic aperture radar images," in 13th International Conference on Huan System Interaction IEEE, Tokyo, Japan, 2020. ;
10. E. G. john, "Convolutional Neural Networks For Feature Extraction and Authomated Target Recognition in Synthetic Aperture Radar Images," Naval Postgraduate School, Monterey, CA, 2020. ;
11. J. Slover, "Synthetic Aperture Radar Simulation by Electro Optical to SAR Transformation Using Generative Adversarial Network," Rochester Institute of Technology, Rochester, NY, 2020. ;
12. T. D. Ross, W. Steven, V. J. Velten, J. C. Mossing and M. L. Bryant, "Standard SAR ATR evaluation experimetns using the MSTAR public release data set," in Algorithms for Sythetic Aperture Radar Imagery V. , Orlando, FL, 1998. ;

KEYWORDS: Synthetic Aperture Radar (SAR), Automatic Target Recognition (ATR), Artificial Intelligence (AI), Convolution Neural Network (CNN), Radiative Transfer Model (RTM), Synthetic Imagery

DTRA21B-002 TITLE: Numerics-Informed Neural Networks (NINNs)

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning

TECHNOLOGY AREA(S): Chem Bio Defense; Information Systems

OBJECTIVE: DTRA has a need to perform high-fidelity CFD modeling of agent defeat phenomenology and associated test and evaluation activities in order to quantify and increase the accuracy of hazard source predictions for counter weapons of mass destruction (C-WMD) defeat and deny tactics. These simulations are technically and computationally challenging due to the long-time duration of interest (weapon detonation through stabilization of plume), the stochastic nature of fragmentation and turbulent mixing phenomena, the temperature dependency of thermal neutralization mechanisms, and the relatively stiff chemical kinetics models. The objective of this topic is to improve the computational efficiency of the chemical kinetics models for chemical weapon agents and simulants by investigating and developing Numerics-Informed Neural Networks (NINNs). This topic explores the premise that simply using the residual of the PDE as in Physics-Informed Neural Networks (PINNs) is not optimal. One might instead use directly the numerical schemes which are employed to integrate the PDEs in time. This leads naturally to numerics-informed neural nets (NINNs).

DESCRIPTION: The last decade has seen a tremendous amount of activity and developments in the field of deep neural networks (DNNs). When trying to apply these to physics governed by partial differential equations (PDEs), traditional DNNs have been ‘supplemented' or ‘informed’ with the underlying physics, leading to physics-informed neural nets (PINNs).
This topic explores the premise that simply using the residual of the PDE (as in PINNs) is not optimal. One might instead directly use the numerical schemes which are employed to integrate the PDEs in time. This leads naturally to Numerics-Informed Neural Networks (NINNs).

To leverage the ongoing research momentum in Artificial Intelligence and Machine Learning, DTRA seeks innovative ideas for replacing the PDE residuals used for PINNs by the discrete time stepping increments of numerical integrators.
Phase I development must demonstrate a NINN approach for local residuals (e.g., chemically reacting flows) and non-local residuals (e.g., PDEs with spatial derivatives). The new techniques should then be compared to PINNs and traditional DNNs. Phase II development will further optimize the NINN approach to extend the range of applicability to other problems.

PHASE I: Define and develop NINNs for chemical reactions (CHEM-NINNs). Define and develop NINNs for PDEs with spatial derivatives. Investigate and validate NINNs and CHEM-NINNs by comparison of results with traditional DNNs and PINNs.

PHASE II: Further develop, test and optimize the NINN approach to extend the range of applicability. Demonstrate use of NINNs on High Performance Computing (HPC) systems. Perform detailed comparisons with high-fidelity Computational Fluid Dynamics (CFD), Computational Chemistry application codes and observational data, to quantify speed and

accuracy of the NINNs and CHEM-NINNs. Generalize and document for pre-commercial release.

PHASE III DUAL USE APPLICATIONS: In addition to implementing further improvements that would enhance use of the developed product by the sponsoring office, identify and exploit features that would be attractive for commercial or other private sector HPC applications. The software developed for use in DTRA's very demanding application codes will be well suited, once refined, for use on more general HPC workloads. Investigate commercialization avenues that could include other government agencies, national labs, research institutes, and defense contractors. Develop a plan to enable successful technology transition at the end of this phase.

REFERENCES:

[1] Shin, Yeonjong , On the Convergence of Physics Informed Neural Networks for Linear Second-Order Elliptic and Parabolic Type PDEs},Communications in Computational Physics
https://arxiv.org/pdf/2004.01806 ;

[2] M Raissi, P Perdikaris, GE Karniadakis, Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations Journal of Computational Physics, 2019
https://www.osti.gov/servlets/purl/1595805 ;

[3] Harbir Antil, Ratna Khatri, Rainald Löhner, Deepanshu Verma, Fractional Deep Neural Network via Constrained Optimization
https://arxiv.org/pdf/2004.00719 ;

[4] Lars Ruthotto, E. Haber, Journal of Mathematical Imaging and Vision 2019 Deep Neural Networks motivated by Partial Differential Equations
https://arxiv.org/pdf/1804.04272 ;

KEYWORDS: High Performance Computing; HPC; Artificial Intelligence; Neural Networks; Deep Learning; Physics; Partial Differential Equations

DTRA21B-003 TITLE: Mathematical models to build multi-radiation detector algorithms

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning

TECHNOLOGY AREA(S): Nuclear; Sensors

OBJECTIVE: Develop flexible radiation algorithms deployed across battlefield networks to enable the linking of multiple detector variants and fusing of raw detector outputs into usable information.

DESCRIPTION: Often, multiple detectors, and multiple detector variants are deployed to characterize a complex scene (i.e. stationary detectors, handheld radioisotope devices, vehicle-mounted detectors, and backpack detectors) within 1 square kilometer. This topic seeks to develop flexible radiation detection algorithms leveraging proven mathematical data models that would sit either at a node for multiple detectors or at a command center that fuses raw detector outputs into useable information. Multiple data types are included in this deployment modality: gross gamma/neutron counts, gamma spectral data, GPS data, etc. Advances in big data theory, machine learning, and artificial intelligence have yielded new mathematical models that could be applied to multiple radiation detection sensors to fuse data in a way that novel algorithms may analyze the overall data input, instead of discrete sensor data. The intent of this topics is to leverage these new mathematical principals and models to decrease time to localize and characterize radiological signature anomalies in a complex scene by leveraging data from all radiation detector types. This would serve to better protect warfighters by reducing mission times and provide commanders better mission radiological characterization for the overall scene.

PHASE I: Identification of multi-radiation detector algorithms and demonstrate their potential to improve the identification, characterization, and/or localization of a radioactive source in a complex scene as compared to the singular detector algorithm. Multiple candidate algorithms shall be down selected for further development in Phase II. Demonstrate pathways for meeting the Phase II performance goals through feasibility studies at the end of Phase I.

PHASE II: Demonstrate enhanced identification, characterization and/or localization of radioactive sources with the multi-detector algorithm that fuses data (gamma and neutron radiation outputs, and GPS location/time) from disparate ground based and mobile detector types. Demonstrate improved performance of the multi-detector algorithm over single-system algorithms. The algorithm should support the integration of additional new detector types.

PHASE III DUAL USE APPLICATIONS: Field demonstration in radiation environment with users deploying multiple and varied radiation detectors linked via communications to a network node in which the algorithm receives detector outputs. The algorithm must conduct scene characterization in real-time as operators move through a complex environment with disparate detector modalities. The multi-system algorithm will be directly compared to legacy single-system algorithms to assess impact on mission. Develop commercialization and transition plan to DoD end users.

REFERENCES:

1. Information Fusion Volume 57, May 2020, Pages 115-129; https://doi.org/10.1016/j.inffus.2019.12.001 ;
2. Joint Pub 3-11 ;

KEYWORDS: RN Detection, Algorithm