Question 1. AI Use Case Identifying Information			Question 2. Contact Information for Listed AI Use Case (Note: List the point of contact that will be made available for inter-agency and public inquires)		Question 3. Summary
1A.AI use case name	**1B. Agency with AI use case**	**1C. Office with AI use case**	**2A. Last Name, First Name**	**2B. Email Address**	**Provide a short summary (200 words max) of what the AI does. Include a high-level description of system inputs and outputs.**
Advances in Nuclear Fuel Cycle Nonproliferation, Safeguards, and Security Using an Integrated Data Science Approach	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This research will develop a digital twin of a centrifugal contactor system that receives data from traditional and real time sensors, constructs a digital representation or simulation of the chemical separations component within the nuclear fuel cycle, and performs data analysis through machine learning to determine anomalies, failures, and trends. The research will include the identification and implementation of advanced artificial intelligence, machine learning, and data analysis techniques advised by a team of nuclear safeguards experts.
Development of a multi-sensor data science system used for signature development on solvent extraction processes conducted within Beartooth facility	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop a system that utilizes non-traditional measurement sources such as vibration, acoustics, current, and light, and traditional sources such as flow, and temperature in conjunction with data-based, machine learning techniques that will allow for signal discovery. The goal is to characterize stages within a solvent extraction process can increase target metals recovery, indicate process faults, account for special nuclear material, and inform near real-time decision making.
Scalable Framework of Hybrid Modeling with Anticipatory Control Strategy for Autonomous Operation of Modular and Microreactors	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The goal this research is to develop and validate novel and scalable models to achieve faster-than-real-time prediction and decision-making capabilities. To achieve the project goal of autonomous operation of microreactors, a novel hybrid modeling approach combining both physics-based and artificial intelligence techniques will be developed at the component or sub-system level, integrated with anticipatory control techniques, and scaled. A novel distributed anticipatory control strategy will be developed as part of the scalability analysis to understand the risk of cascading failures when emerging reactors are deployed as part of a full feeder microgrid.
Accelerating and Improving the Reliability of Low Failure Probability Computations to Support the Efficient Safety Evaluation and Deployment of Advanced Reactor Technologies	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will research artificial intelligence enabled Monte Carlo algorithms to significantly reduce the computational burden by reducing the number of finite element evaluations when estimating low failure probabilities. These will be implemented in the Multiphysics Object-Oriented Simulation Environment, which will help the nuclear engineering community to efficiently conduct probabilistic failure analyses and uncertainty quantification studies for the design and optimization of advanced reactor technologies.
Accelerating deployment of nuclear fuels through reduced-order thermo-physical property models and machine learning	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop a novel physics-based tool that combines 1) reduced-order models, 2) machine learning algorithms, 3) fuel performance methods, and 4) state-of-the-art thermal property characterization equipment and irradiated nuclear fuel data sets to accelerate nuclear fuel discovery, development, and deployment. The models will describe thermal conductivity, specific heat, thermal expansion, and self-diffusion coefficients as a function of temperature and irradiation.
Promoting Optimal Sparse Sensing and Sparse Learning for Nuclear Digital Twins	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will address the efficient use of limited experimental data available for nuclear digital twin (NDT) training and demonstration. This involves developing sparse data reconstruction methods and using NDT models to define sensor requirements (location, number, accuracy) for the design of demonstration experiments. NDTs should leverage 1) sparse sensing for identifying optimal locations and the minimal set of required sensors and 2) sparse learning and recovery of full maps of responses of interest for stronger prediction, diagnostics, and prognostics capabilities.

Artificial Intelligence Enhanced Advanced Post Irradiation Examination	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project uses post irradiation examination of uranium-10wt.% zirconium (UZr) metallic fuel as a case study to show how artificial intelligence (AI)-based technology can facilitate and accelerate nuclear fuel development. The approach will 1) revisit the microstructural image and local thermal conductivity data collected from UZr, 2) build a benchmark dataset for the microstructural patterns of irradiated UZr, and 3) train the machine learning and deep learning models to uncover the relationships between micro/nanoscale structure, zirconium phase redistribution, local thermal conductivity, and engineering scale fuel properties.
Secure Millimeter Wave Spectrum Sharing with Autonomous Beam Scheduling	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This approach exploits the millimeter wave beam directionality and utilizes the beam sensing capabilities at end devices to prove that an autonomous radio frequency beam scheduler can support secure 5G spectrum sharing and guarantee optimality for base stations. Measurements and predictive analytics are used to develop the autonomous beam scheduling algorithms. These improvements will benefit mission critical communications and emergency response operations as well as enable secure communication for critical infrastructure without expensive and competitive licensed bands.
Objective-Driven Data Reduction for Scientific Workflows	U.S. Department of Energy	Brookhaven National Laboratory	Byung-Jun, Yoon	byoon@bnl.gov	This project aims to develop theories and algorithms for objective-driven reduction of scientific data in workflows that are composed of various models, including data-driven AI models
The Grid Resilience and Intelligence Platform (GRIP)	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	AI within GRIP is used to develop metrics that quantify the impact of the anticipated weather related extreme events. The platform uses utility data combined with physical models, distribution power solver to infer the potential grid impacts given a major storm.
Open-Source High-Fidelity Aggregate Composite Load Models of Emerging Load Behaviors for Large-Scale Analysis (GMLC 0064)	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	1. Machine learning methods such as cross-correlation, random forest, regression tree and transfer learning are used to estimate the load composition data and motor protection profiles for different climante regions in the Western US 2. Deep learning algorithm is appplied to calibrate the parameters of WECC composite load model to match the responses with detailed feeder model
Big Data Synchrophasor Monitoring and Analytics for Resiliency Tracking (BDSMART)	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
Combinatorial Evaluation of Physical Feature Engineering and Deep Temporal Modeling for Synchrophasor Data at Scale	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
MindSynchro	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
PMU-Based Data Analytics Using Digital Twin Phasor Analytics Software	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
A Robust Event Diagnostic Platform: Integrating Tensor Analytics and Machine Learning Into Real-time Grid Monitoring	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
Discovery of Signatures, Anomalies, and Precursors in Synchrophasor Data with Matrix Profile and Deep Recurrent Neural Networks	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
Machine Learning Guided Operational Intelligence	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.
Robust Learning of Dynamic Interactions for Enhancing Power System Resilience	U.S. Department of Energy	Office of Electricity	Frank, Gregory	gregory.frank@hq.doe.gov	Explore the use of big data, artificial intelligence (AI), and machine learning technology and tools on phasor measurement unit (PMU) data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.

Artificial Intelligence Based Process Control and Optimization for Advanced Manufacturing	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop the capability to intelligently control and optimize advanced manufacturing processes instead of the existing trial and error approach. To achieve this goal, artificial intelligence (AI) based control algorithms will be developed by employing deep reinforcement learning. To reduce the computational expense with advanced manufacturing models, physics-informed reduced order models (ROMs) will be developed. The AI-based control algorithms will employ the ROMs' predictions to adaptively inform processing decisions in a simulation environment.
Smart Contingency Analysis Neural Network for in-depth Power Grid Vulnerability Analyses	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	Typical contingency analysis for a power utility is limited to n-1 due to computational complexity and cost. A machine learning framework and resilience-chaos plots are leveraged to reduce computational expense required to discover, with 90% accuracy, n-2 contingencies by 50%.
Resilient Attack Interceptor for Intelligent Devices	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The Resilient Attack Interceptor for Intelligent Devices approach focuses on developing external monitoring methods to protect industrial internet of things devices by correlating observable physical aspects that are produced naturally and involuntarily during the operational lifecycle with anomalous functionality.
Infrastructure eXpression	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The project developed a framework and process to translate industrial control system features to a machine-readable format for use with automated cyber tools. This research also examined other current and evolving standards for usability with diverse grid architectures that represent a set of variable conditions to establish the foundation for determining where future research should focus and to support improvements to industry standards and architecture designs for machine-learning cyber defense solutions. This project's success can serve as the foundation for prioritizing the next research steps to realize automated threat response, improving the timeliness and fidelity of cyber incident consequence models, and enriching national capabilities to share actionable threat intelligence at machine speed.
Protocol Analytics to enable Forensics of Industrial Control Systems	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The goal of this research is to discover methods and technologies to bridge gaps between the various industrial control systems (ICS) communication protocols and standard Ethernet to enable existing cybersecurity tools defend ICS networks and empower cybersecurity analysts to detect compromise before threat actors can disrupt infrastructure, damage property, and inflict harm. Research focuses on electronic signal analysis of captured communication to determine the protocol, using use machine learning to identify unknown protocols. Findings will be incorporated into a prototype device.
Automated Type and Data Structure Resolution	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This research identified and labeled type and structure data in an automated and scalable way such that the information can be used in other tools and other Reverse Engineering at Scale research areas such as symbolic execution. This was done initially by utilizing heuristic methods and then scaled by adopting a machine learning approach.
Signal Decomposition for Intrusion Detection in Reliability Assessment in Cyber Resilience	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The objective of this project is to research, assess, and implement machine learning and artificial intelligence and physics-based algorithms for signal decomposition and provide a straightforward framework wherein an anomaly detection algorithm can be trained on existing expected data and then used for false data injection detection. An advanced library for signal decomposition and analysis will be developed that allows combining machine learning and artificial intelligence algorithms and high-fidelity model comparisons for greatly improved false data injection detection. This library will facilitate online and posteriori analysis of digital signals for the purpose of detecting potential malicious tampering in physical processes.
Advanced Machine Learning-based Fifth Generation Network Attack Detection System	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The project goal is to prove that enhancing attack detection via innovative machine learning and artificial intelligence techniques into the fifth generation (5G) cellular network can help to secure mission-critical applications, such as automated vehicles and drones, connected health, emergency response operations, and other mission-critical devices that either are or will be connected to the 5G cellular network.
Red Teaming Artificial Intelligence	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This research will advance the state of the art for red team security assessment of machine learning and artificial intelligence systems by providing methods for the reverse engineering, exploitation, risk assessment and vulnerability remediation. The insights gained from the explorations into vulnerability assessment research will proactively address critical gaps in the cybersecurity community's understanding of these systems and can be used to create appropriate risk evaluation metrics and provide best practices for inclusion into consequence-driven cyber-informed engineering.

Unattended Operation through Digital Twin Innovations	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The team hypothesizes that artificial intelligence can predict events using the integrated data from test bed sensors and physics-based models. A second hypothesis is that integrating software and artificial intelligence with sensor data from a test bed will lead to a framework for future digital twins. The team will train artificial intelligence models to determine what attributes are most important for enabling intelligent autonomous control and will determine best practices for digital twin cybersecurity.
Secure and Resilient Machine Learning System for Detecting Fifth Generation (5G) Attacks including Zero-Day Attacks	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will implement an advanced machine learning based 5G attack detection system that can achieve high classification speed (10k packets per second) with high accuracy (90% or greater) as well as address a vulnerability to zero-day attacks (90% accuracy against real zero-day attacks recorded by Amazon Web Services) using field programmable gate array based deep autoencoders.
Automated Malware Analysis Via Dynamic Sandboxes	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The goal of this project is to develop an analysis framework enabled by dynamic sandboxes that allows for automated analysis, provides non-existing core capabilities to analyze industrial control system malware, and outputs to a format that is machine readable and an industry standard in sharing threat information. This will enable further analysis efforts via machine learning and provide a foundational platform that would allow for timely, automated analysis of malware samples.
Interdependent Infrastructure Systems Resilience Analysis for Enhanced Microreactor Power Grid Penetration	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop machine learning enabled integrated resource planning methodologies to help quantify key resilience elements across integrated energy systems and their vulnerabilities to threats and hazards. This includes the ability to accurately analyze and visualize a region's critical infrastructure systems ability to sustain impacts, maintain critical functionality, recover from disruptive events. This advanced decision support capability can improve our understanding of these complex relationships and help predict the potential impacts that microreactors and distributed energy resources have on the reliability and resiliency of our energy systems.
Adaptive Fingerprinting of Control System Devices through Generative Adversarial Networks	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project focuses on the reduction of manual labor and operational cost required for training an electromagnetic (EM)-based anomaly detection system for legacy industrial control systems devices and Industrial Internet of Things. This research would enable EM-based intrusion detection systems to be deployed to protect legacy control systems.
Support Vector Analysis for Computational Risk Assessment, Decision-Making, and Vulnerability Discovery in Complex Systems	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project addressed limitations in current probabilistic risk assessment (PRA) by combining a support vector machine and PRA software to auto-detect system design vulnerabilities and find previously unseen issues, reduce human error, and reduce human costs. This method does not require training data that would only be available in the event of system or subsystem failures.
Deep Reinforcement Learning and Decision Analytics for Integrated Energy Systems	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop a novel deep reinforcement learning approach that can manage distributed or tightly coupled multi-agent systems utilizing deep neural networks for automatic system representation, modeling, and end-to-end learning. This new control method will enable complex, nonlinear system optimization over timescales from milliseconds to months.
Nuclear-Renewable-Storage Digital Twin: Enhancing Design, Dispatch, and Cyber Response of Integrated Energy Systems	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop a learning-based and digital twin enabled modeling and simulation framework for economic and resilient real-time decision-making of physics-informed integrated energy systems (IES) operation. High-fidelity physics models will be linked with large-scale grid monitoring data to provide real-time updates of IES states, predictive control systems, and optimized power dispatch solutions. Learning-based algorithms will make real-time decisions upon detection of component contingencies caused by climate-induced or man-made extreme events, such as cyber-attacks or extreme weather, thereby mitigating their impacts through appropriate counter measures.
Automated Infrastructure & Dependency Detection via Satellite Imagery and Dependency Profiles	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	Computer vision, a broad set of techniques for training statistical models and neural networks to process images, has advanced substantially in recent years. Applying these capabilities to satellite imagery can improve critical infrastructure analysis and interdependency data build-outs. Combining advanced computer vision techniques, a functional taxonomic approach to critical infrastructure, and the unique geo-spatial and dependency datasets the research team developed can produce innovative and state-of-the-art image processing results that advance abilities to secure and defend national critical infrastructure.

Accelerated Nuclear Materials and Fuel Qualification by Adopting a First to Failure Approach	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	Physics-based multi-scale modeling was coupled with deep, recursive, and transfer learning approaches to accelerate nuclear materials research and qualification of high-entropy alloys. Applying AI to combinatorial-based materials research enables subsequent analysis to focus on a limited number of candidates predicted to have the necessary materials properties for the application.
Evaluating thermal properties of advanced materials	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	The standard thermal diffusivity measurement technique laser flash is enhanced by modifying the traditional experimental set up and analyzing results with a machine learning based tool that includes a finite element model, a least-squares fitting algorithm and experimental data treatment algorithms. This tool helps elucidate thermo-physical properties of a material from a single laser flash measurement.
Spectral Observation Convolutional Neural Network	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project developed method to analyze collected radiation spectra using advanced, scalable deep learning by combining spectroscopic expertise with high performance computing. Sophisticated deep learning can overcome the weaknesses of existing spectroscopic techniques and enhance the value of difficult measurements. This method was trained, tested, and operated on the International Space Station's Spaceborne Computer-2 supercomputer, returning zero errors over the course of 100 training hours. This demonstrated performance autonomously in far-edge, low-wattage computing situations and in hazardous radiological environments where interference can cause errors.
Passive Strain Measurements for Experiments in Radiation Environments	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will develop passive instrumentation to determine permanent strains induced by irradiation and extract critical parameters using modeling and simulation as well as machine learning algorithms. An irradiation experiment will be conducted that will benefit from engineered anisotropic materials and characterize the directional deformation in response to neutron radiation. The results of the experiment will be incorporated into the model so that the material response can be predicted for future uses as a probe material.
Machine Learning Interatomic Potentials for Radiation Damage and Physical Properties in Model Fluorite Systems	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This project will use machine learning interatomic potentials to study the influence of radiation damage on physical properties of calcium fluoride and uranium dioxide. Electron irradiation experiments and thermal conductivity measurements will be performed to validate the effectiveness of the developed potentials. The high throughput capability of this method will become an important combinatorial materials science tool for developing and qualifying new nuclear fuels.
Data-driven failure diagnosis and prognosis of solid-state ceramic membrane reactor under harsh conditions using deep learning technology with internal voltage sensors	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This research will investigate in situ the effects of different components on the degradation behavior in a solid-state ceramic membrane reactor by embedding sensors that will collect current and impedance data during operation. Artificial intelligence will be used to understand the large amounts of data and predict reactor failure under harsh operating conditions.
Tailoring the Properties of Multiphase Materials Through the Use of Correlative Microscopy and Machine Learning	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This research uses state-of-the-art machine learning (ML) techniques in a new and novel manner to identify and correlate the critical microstructural features in a multiphase alloy that exhibits high strength and fracture toughness. Experimental data will be used to train a convolutional neural network (CNN) in a semi-supervised environment to identify key microstructural features and correlate those features with the strength and toughness. The resulting machine learning tool can be trained for additional microstructural features, different alloys, and/or target mechanical properties.
Microstructurally-driven Framework for Optimization of In-core Materials	U.S. Department of Energy	Idaho National Laboratory	Kerman, Mitchell C.	mitchell.kerman@inl.gov	This research will develop a methodology that relies on mechanism-informed machine learning models, rapid ion irradiation and creep testing techniques, and advanced characterization coupled with automated image analysis to enable reactor developers to quickly understand the complex linkage between alloy composition, thermomechanical processing, the resulting microstructure, and swelling and creep behavior. This project will (1) develop and demonstrate a high-potential methodology for rapid development of future in-core materials and (2) provide critically important information on alloy design for optimized swelling and creep behavior to the advanced reactor development community.