

DARKSTAR: INVESTIGATING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING APPLICATIONS TO SCIENTIFIC PROBLEMS OF COMPLEX HYDRODYNAMICS, SHOCKWAVE PHYSICS, AND ENERGETIC MATERIALS

LDRD Project DarkStar established foundational research for the potential of artificial intelligence and machine learning to support a wide range of national security missions

LLNL’s Laboratory Directed Research and Development-funded Strategic Initiative Project DarkStar made advancements in controlling material deformation by investigating the scientific problems of complex hydrodynamics, shockwave physics and energetic materials. The purpose of this project was to take the quantum leap from understanding dynamic material response to controlling it. The scientific and technological achievements attained will enable a completely new paradigm for weapons physics and design and advance the U.S. national security posture. Today, foundational methods in surrogate modeling, multimodal anomaly, detection, and explainable reasoning are reusable across mission spaces. Advancements in predicting and controlling instability formation were demonstrated on both high explosive experiments and inertial confinement fusion studies.



LDRD DarkStar Research

The science and technology discoveries made on DarkStar have paved the way for an entirely new approach to solving time-dependent problems through “inverse design” – the idea that complex solutions to challenging problems can be developed directly from a desired final state and AI/ML can be used to find the corresponding initial state.

- AI tools – essentially math and software – are used to solve difficult problems such as controlling explosives and material deformation.
- Darkstar enables a completely new paradigm for weapons physics and design and advances the U.S. national security posture.
- Milestone reached in combining AI with fusion target design using the world’s most powerful supercomputers to automate and accelerate inertial confinement fusion experiments.
- AI use for nuclear deterrence: Multi-Agent Design Assistant (MADA), an outgrowth from Darkstar’s foundational research, is a tool to compress design cycles, explore design spaces, and may help scale up fusion yields with identifying optical conditions.

Programmatic Impact

Project DarkStar contributed to LLNL’s excellence in nuclear weapons science and stockpile stewardship. Because of this project, DOE/NNSA is in possession of world-leading advanced AI technology developed for certain U.S. national security challenges. This breakthrough technology currently enables various NNSA programs and research for Defense Programs and other federal agencies. It advanced LLNL’s leadership in High Energy Density Science, Advanced Materials and Manufacturing, High Explosives Manufacturing and Testing, Nuclear Chemical, and Isotopic Science and Technology, and High-Performance Computing, Simulation, and Data Science.

LDRD Investment

Project #	Project Title	PI	Duration (FY)
21-SI-006	Project DarkStar: Controlling Material Deformation	Jon Belof	2021-2023