Energetic Materials

Strengthening the nuclear deterrent, conventional munitions, and homeland security with new energetic materials and applications.

Introduction

Energetic materials (EM) such as explosives, thermites, propellants, and pyrotechnics are central to Lawrence Livermore National Laboratory's (LLNL's) national security mission. EM are utilized throughout a nuclear weapon and also provide the energy source for most conventional munitions.

LLNL is a Department of Energy/ National Nuclear Security Administration Center of Excellence for the research, development, synthesis, formulation, and characterization of explosives. The primary mission of LLNL's EM Enterprise is to ensure the safety, security, and effectiveness of the U.S. nuclear deterrent.

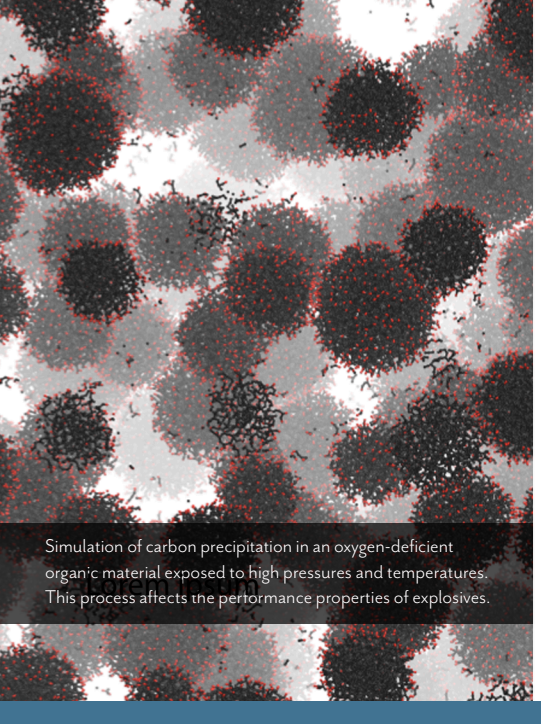
Researchers also apply their expertise to develop solutions for Department of Defense conventional weapons, explore new ways to detect and defeat home-made explosives for the Department of Homeland Security, and develop strategies to counter the threat of improvised explosive devices for nuclear counterterrorism.

Experimental facilities at Livermore's Main Site (Site 200) and remote Site 300 enable research, that, when coupled with high-fidelity modeling and simulation, help advance scientific discovery in EMs.

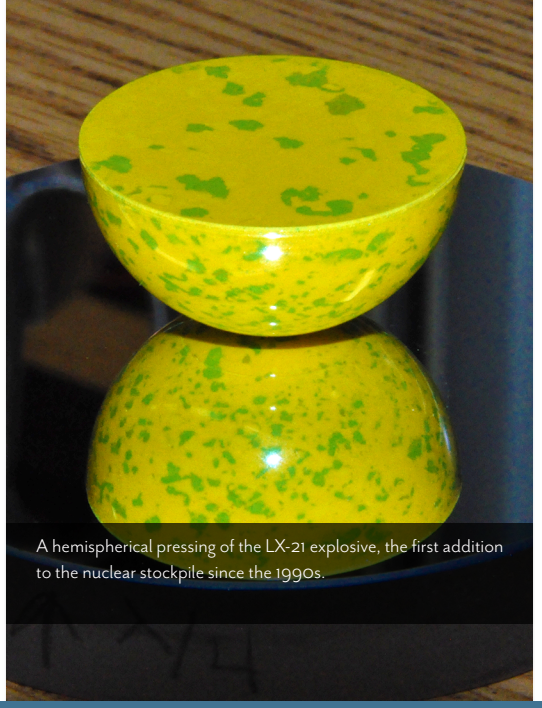
Applications

Ensuring and assessing the nation's nuclear deterrent, countering threats from adversaries, and supporting DOD conventional munitions research requires outstanding inquiry performed by exceptional scientists working at world-class facilities. EM scientists explore the energy released during energetic chemical reactions, the mechanical response, and long-term aging characteristics. Taking advantage of LLNL's family of supercomputers and advanced simulation codes, scientists continually improve EM performance and safety. Objectives for the next decade to more closely apply EM expertise across the Laboratory include:

- **Qualification Science:** Continue evolving advanced certification and qualification of explosives with next-generation theory and modeling, coupled to quantification of uncertainties and state-of-the-art experiments using advanced diagnostics.
- **Safety:** Science-informed safety basis enables rapid new explosive and process adoption.
- **Material Aging and Compatibility:** Age-aware performance models incorporating the latest data science are integrated into LLNL's code framework.
- **Manufacturing Modernization and Material Development:** Novel components and manufacturing technologies for high explosives (HE) are routinely transitioned to production in response to new requirements.
- **World-Class Facilities:**
  - High Explosives Applications Facility extension: integrates new technologies.
  - Site 300 Energetic Materials Development Enclave Campus: synthesizes, formulates, manufactures, tests, and transitions HE to production.
  - Contained Firing Facility: houses hydrodynamic experiments up to 60 kg.
  - Engineering Test Complex: ensures the lifetime of systems.
  - Forensic Science Center: supports ultratrace chemical analysis of explosive materials and decomposition products for weapon and global security programs.



Simulation of carbon precipitation in an oxygen-deficient organic material exposed to high pressures and temperatures. This process affects the performance properties of explosives.



A hemispherical pressing of the LX-21 explosive, the first addition to the nuclear stockpile since the 1990s.

Staff at the recently commissioned Facility for the Advanced Manufacturing of Energetics (FAME) at LLNL's Site 300. This facility applies modern HE solutions to NNSA needs.

Accomplishments

LLNL scientists have developed numerous new energetic materials (EMs), especially high explosives (HES), experimental techniques for their characterization, and computational models (e.g., Cheetah and ALE3D) to predict their behavior. These advancements form much of the scientific basis for the modern EM R&D community. EMs developed by LLNL are used by Livermore and Los Alamos nuclear weapon programs, and the Department of Defense (DOD) uses LLNL explosives, initiation systems, and models for their unique weapon designs. Accomplishments from the EM team include:

- LLNL invented and implemented the Mechanical Safing and Arming Device (MSAD) which prevents accidental or unintended detonation of a nuclear warhead.
- Developing LX-21 , the first new explosive to enter the stockpile without underground testing. LX-21 is based on the LLM-105 explosive molecule, invented by LLNL.
- Using pioneering additive manufacturing for complex, multi-material, explosive components resulting in three LLNL patents on the technology.
- Leading the remanufacturing of critical IHEs for W80-4 and W87-1 LEPs. LLNL researchers identified key production parameters and LLNL's Forensic Science Center developed chemical analysis protocols.
- Mitigating the risk of high-consequence subsea drilling operations (i.e. Deepwater Horizon), LLNL designed a linear shaped charge array for Shell Oil Company to sever a drill collar on-command.
- Predicting effects of material aging on explosives' performance and improving assessments of weapon service life through groundbreaking capabilities.
- Obtaining never-before-captured high-resolution data in the reaction zone of a detonating HE through research at DOE user facilities.
- Identifying new explosive threats to Homeland Security by using advanced x-ray, dual-energy, and computed tomography processing.
- Patented E.L.I.T.E.™ (Easy Livermore Inspection Test for Explosives) system for first-responders uses chemical reactions to quickly detect explosives.

The Future

Looking ahead, LLNL will continue to support Energetic Materials research and development for advanced conventional weapons, rocket and gun propellants, homeland security, demilitarization, and industrial applications of energetic materials.

In direct support of the Laboratory's mission, the program will uphold high confidence in the safety, security, reliability, and effectiveness of EMs used in our nation's nuclear deterrent.

Researchers will attain program goals, transform our enterprise, develop relevant capabilities, and advance the science, technology, and engineering of EMs.

LLNL maintains a steadfast commitment to the Laboratory's national security partners. This includes addressing the needs of the Department of Homeland Security and its Transportation Security administration while countering the threat of nuclear proliferation.

LLNL-MI-857181
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 13, 2023