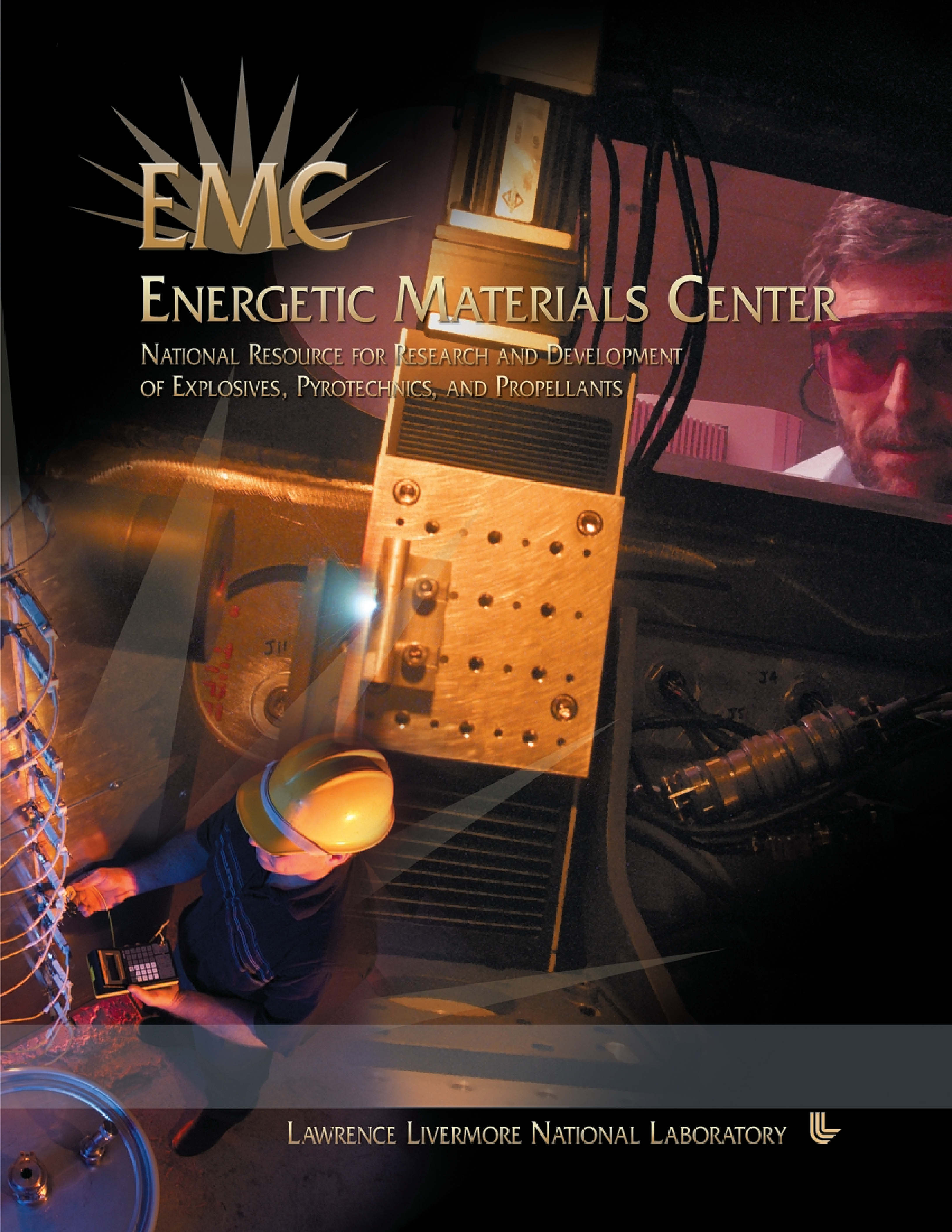
EMC

Energetic Materials Center

National Resource for Research and Development of Explosives, Pyrotechnics, and Propellants



Lawrence Livermore National Laboratory

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Our Focus

Lawrence Livermore's involvement in energetic materials began at its inception in 1952, when the Laboratory instituted a research and development program in high explosives for nuclear weapons. Today, Livermore's high-explosives capabilities, with extensive facilities at the Main Site, Site 300, and at the Nevada Test Site, are the equal of any institution's in the world. The standard of excellence in scientific research ranges from understanding detonation science at the molecular level to predicting structures for exciting new high explosives. The wide range of contributions and capabilities promise significant breakthroughs in the 21st Century.

The Stockpile Stewardship Program, managed by the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE), is the centerpiece of Livermore's national security mission. Activities range from assisting NNSA plants in fulfilling the manufacturing mission to understanding the aging of high explosives in the stockpile and predicting their useful lifetime. Today, energetic materials support an even broader base to include Department of Defense (DoD) activities in advanced conventional weapons, rocket and gun propellants, antiterrorist work, demilitarization, and industrial applications of energetic materials.

World-Class Science Meets the Challenge

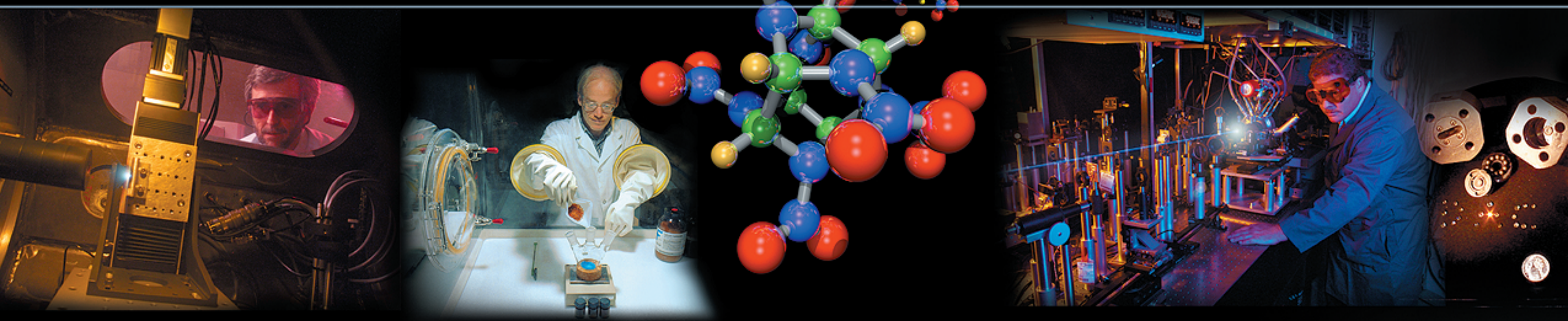
In the study of weapons, a low explosive burns, but a high explosive detonates—a very different phenomenon. An initial shock compresses a high-explosive material, heating it and causing chemical decomposition. The formation of chemical products releases enormous amounts of energy in just billionths of a second. This process sustains the shock wave, which travels at supersonic velocity. All of this happens almost instantaneously to produce a blast of rapidly expanding hot gases.

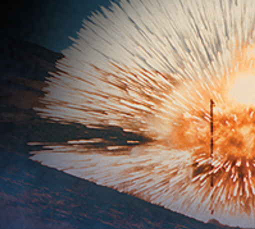
The challenge for scientists who study explosive detonation is knowing—for an event that lasts less than a millionth of a second—the physics of each component over a wide range of pressure densities and temperatures and the way the components interact.

There is always a tradeoff—energy content, safety, and cost—all of which must be addressed to improve energetic materials. The development of molecular modeling techniques now makes it possible to predict many, but not all, relevant material properties through much more fundamental means—a significant improvement over the trial and error approach.

To unravel the mystery of detonation, there's a tradeoff—energy content, safety, and cost—a challenge that our multidisciplinary teams address to improve energetic materials

The Umbrella of Research…





Detonations—Explosive detonation is the most violent form of reaction from energetic materials, and is studied both experimentally and computationally. A Livermore software program called Cheetah simulates a wide variety of detonations, permitting the user to see the calculational results of different formulations without having to mix and test them. Cheetah has become the DoD's preferred code for designing new explosives and, to a lesser extent, propellants and pyrotechnics.

Performance—We must understand the detonation performance of energetic materials—the conditions under which energy is released, how much energy is released, and the rate at which it is released—to effectively apply these materials to practical problems. We combine an experimental program focused on high-fidelity measurements of detonation performance with a modeling program in which existing detonation models are improved and new models are developed.

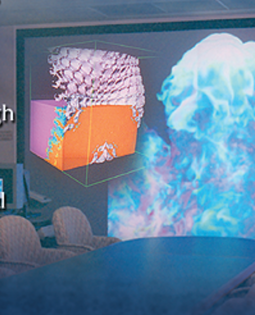
Safety—The very high destructive power of energetic materials places a premium on all aspects of their safety, during manufacture, transportation, storage, handling, and deployment. Much of Lawrence Livermore's high-explosives work involves determining the sensitivity of existing high explosives and propellants to accidents such as handling or shipping events or fire and deliberate attack.

Experimental Capabilities—The general experimental approach at LLNL is to perform relatively few experiments under carefully controlled conditions, with each experiment having sufficient number of high-resolution diagnostics to give an accurate representation of the details of the outcome. Explosives experiments may be considered in two categories – material characterization where the explosive is not expected to react, and performance or safety testing where the explosive is driven to violent reaction or detonation.

Diagnostics—The Livermore emphasis on high-resolution measurements has led to the application, and in some cases development, of many high-speed diagnostics. These must function in highly dynamic environments with nanosecond time resolution, pressure measurement of hundreds of thousands of atmospheres, and temperature measurements of several thousand degrees.

Computer Simulations—The Laboratory has the fastest computers in the world. ASCI makes it possible to computationally simulate, visualize, and analyze what happens to each of a nuclear weapon's components—a critical step in simulating an entire nuclear weapon's explosion in three dimensions.

Theory and Modeling Capabilities—Explosives function through chemical reactions, and application of modern chemical theories enhances the Livermore explosives program. Calculations are being applied to analyze the reaction pathways and kinetics during the first few picoseconds of a detonation, a time so short that it cannot be experimentally characterized. Modeling assists in design of experiments, helps to understand experimental results, and ultimately leads to a predictive capability for performance and safety.



Stockpile Surveillance—Any weapon in the U.S. nuclear arsenal, if ever deployed, must work exactly as intended. To provide assurance the stockpile quality is maintained, a team develops diagnostic tests that are performed on the high explosives in the stockpile weapons.

Material Aging—The performance and safety properties of explosives may change over time, as chemical or physical mechanisms result in alterations such as addition of new chemical species, modification of particle morphology or binder structure, and increase in internal defects in explosive crystals or at the interface of crystal and binder. Experimental characterization of aging signatures and their effects are combined with modeling of aging reactions and simulation of aging effects to gain an understanding of the age-related behavior of these materials.

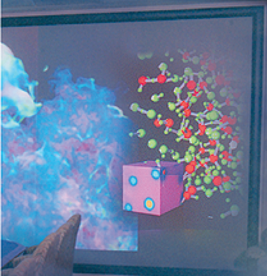
...MULTIDISCIPLINARY TEAMS MAKE IT HAPPEN

Livermore researchers have studied and synthesized high explosives for decades because they are an integral element of every nuclear weapon. Under the EMC umbrella, their work encompasses a wide range of basic research and programmatic activities. Researchers combine breakthrough computer simulation codes, state-of-the-art experimental diagnostics, and a culture in which theoretical, synthesis, and experimental chemists and physicists work alongside each other.

Creation of New Materials—Synthesis of new explosive molecules and formulation of energetic ingredients into new explosives is a cornerstone of our explosives program. The goals of improved performance and improved safety drive these activities. In addition, the growing use of small high-value systems allows the application of some innovative explosives that might not be suitable from safety or cost considerations for use in large systems; for some of these applications, high performance is the key.

Insensitive Materials—the development of less sensitive high explosives have significantly improved the safety and survivability of munitions, weapons, and personnel. TATB, for instance, is virtually invulnerable to significant energy release in plane crashes, fires, and explosions or to deliberate attack with small fire arms.

Simulants—produced in molding powders, clay, emulsion gel and other forms popular among terrorists are used by airport guards, canine units and other security forces to train for explosives detection.



Femtosecond Laser—to safely dispose of munitions containing high explosives and other hazardous materials, it is necessary to gain access to the interior of the munition so that the contents may be removed without danger of detonation. The advantage of using a femtosecond laser for cutting is that the cutting process transfers virtually no heat to the material that is being cut and produces almost no waste. The femtosecond laser pulse will cut anything—metals and explosives, aerogel, ceramics, and diamonds. This is also being examined for demilitarizing chemical weapons.

Laboratory Explosives Reference Guide—a database that is available to Government users to provide a wide-spectrum of information that supports the efforts of the NNSA/DOE and DoD.

State-of-the-art facilities—capabilities that range from laboratory-scale experimental purposes to full-scale production and testing

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State-of-the-Art Facilities

High Explosives Application Facility (HEAF)

High Explosives Application Facility (HEAF)—a center with well-integrated teams of experimental scientists and engineers, theoretical and computational scientists, and support staff that address nearly all aspects of high explosives:

— Research, development, and testing—from molecular simulation developed for stockpile certification to the beginning of detonation;

— Material characterization work to determine physical, chemical, mechanical and thermal properties; small-scale safety properties; thermal stability and decomposition rates; and deflagration rates at high pressures and temperatures; and

— Performance and safety tests—detonating up to 10 kilograms of explosive in firing tanks equipped with many high-speed diagnostics.

Contained Firing Facility (CFF)

Contained Firing Facility (CFF)—Livermore's Site 300 facility to test larger quantities of explosives up to 60 kilograms, using high-speed, sophisticated diagnostics such as high-speed optics and x-ray radiography.

Big Explosives Experimental Facility (BEEF)

Big Explosives Experimental Facility (BEEF)—NNSA's/DOE's hydrodynamic testing facility at the Nevada Test Site where large explosives experiments are performed to test thousands of kilograms of explosives, safely.

Forensic Science Center (FSC)

Forensic Science Center (FSC)—The development and production of weapons of mass destruction—whether nuclear, chemical, or biological—generate a variety of unique chemical species and materials. The FSC provides advanced research and development capabilities to apply to problems of concern to the NNSA/DOE, law enforcement, and the intelligence communities. The FSC utilizes state-of-the-art methods and instrumentation to analyze high priority samples of all types. The results of these analyses provide insight to support investigations and to aid policymakers concerned with issues of national and international security (including nonproliferation, nuclear smuggling, and counter-terrorism). Highlights include:

— Field-Portable Instrumentation—Highly sensitive analytical capabilities for the characterization of CW and explosives in the field (including a portable kit with digital imaging capabilities).

— Solid Phase Microextraction Absorbents—This novel sample collection technology utilizes hair-sized fibers to safely and efficiently capture organic vapors. We have provided the FBI and first responders with field kits for the safe collection of chemical warfare (CW) agents in the field.

— Advanced Trace Analytical Protocol Development—New technologies to collect, isolate and identify trace levels of target species. Such analysis methods have been developed for CW compounds, explosives, illicit drugs and other chemical signatures of interest to the intelligence community.

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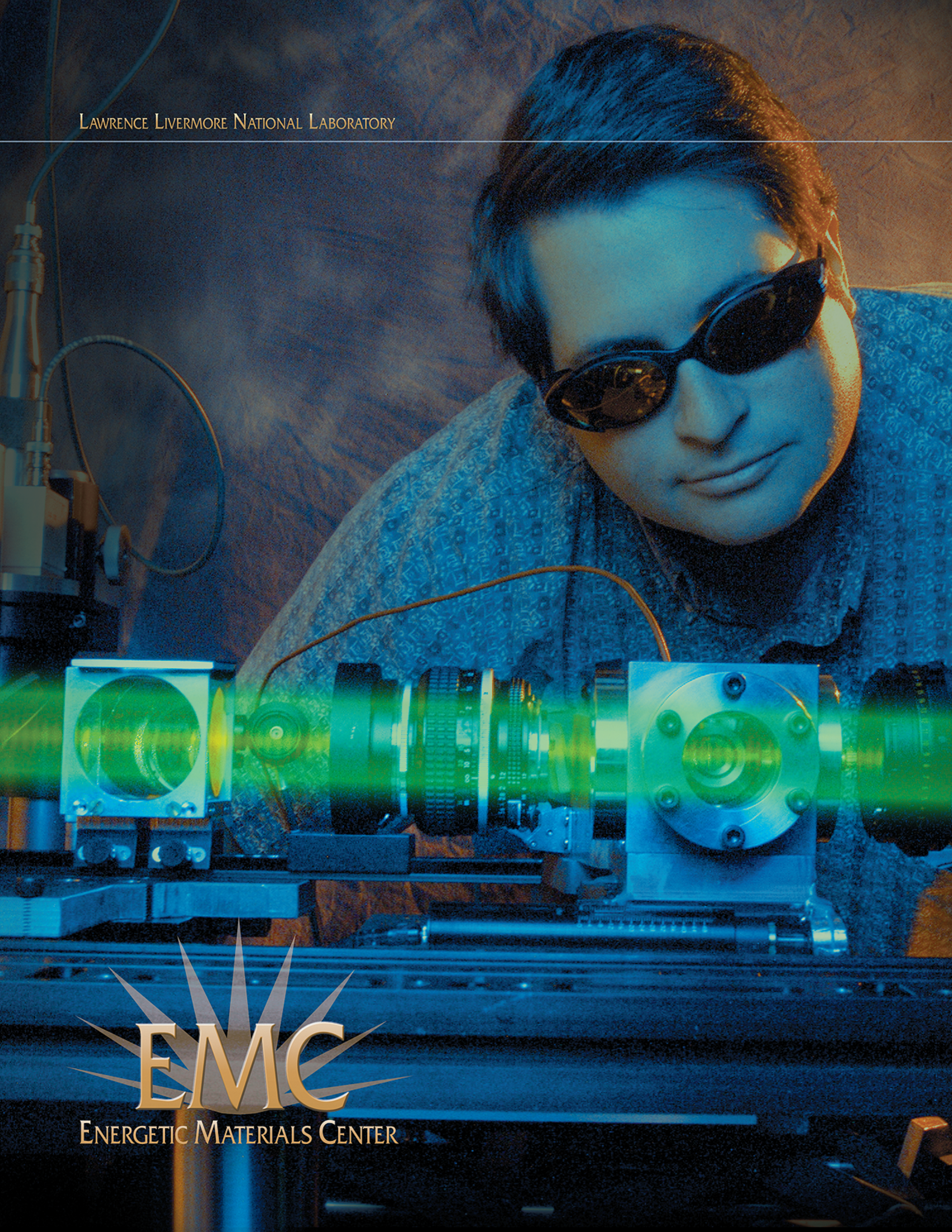

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Capabilities Highlights

- Complex theory-guided simulations of a wide-variety of detonations and explosions
- Combine high-fidelity measurements and high-resolution modeling to maximize productivity and performance
- Determine the sensitivity of existing high explosives and propellants to accidents—handling, shipping, fire, or deliberate attack
- Emphasize high-resolution experiments using high-speed diagnostics:
  - —Flash radiography
  - —Laser velocimetry
  - —High-speed streak and frame cameras
  - —Streak spectrometry
  - —Embedded particle and pressure gauges
  - —Detonation calorimetry
- First principles quantum mechanical calculations
- Molecular dynamic simulations
- Develop new computer codes to understand reaction chemistry, heat flow, mechanics, and equations-of-state of reactants, intermediates and products
- Provide advanced research capabilities in the field of detection and forensic science
- Surveillance

The Benefits

LLNL's energetic materials research and development is meeting critical needs of the United States—the NNSA's/DOE's and DoD's national defense and security requirements, the Federal Aviation Agency's explosive detection efforts, and many industries, including mining, oil exploration, and automobile. The continuing demand drives a search for better theoretical models of the behavior of energetic materials, new materials, and an improved diagnostic capability to measure the complex chemical and hydrodynamic processes in energetic materials.

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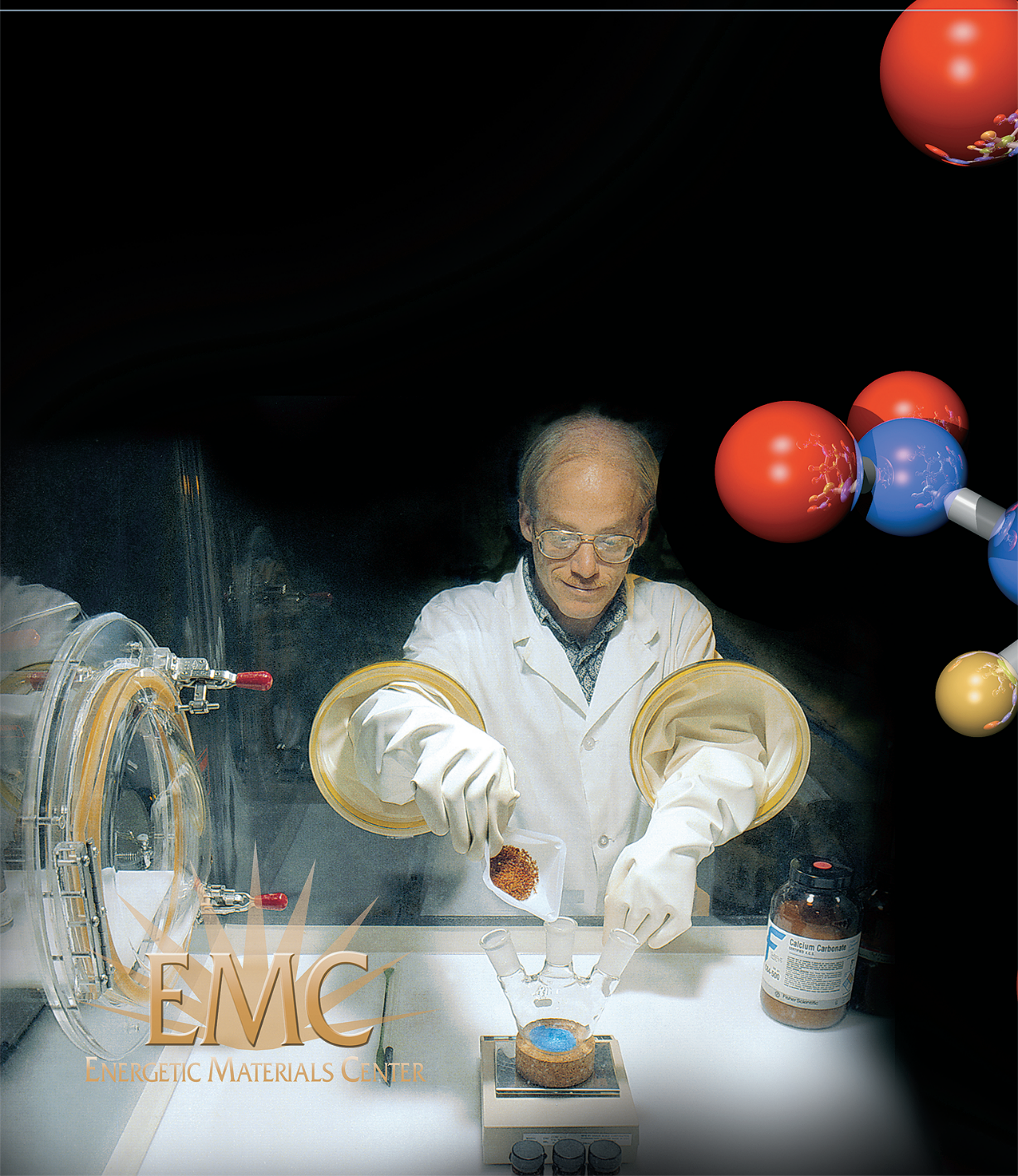

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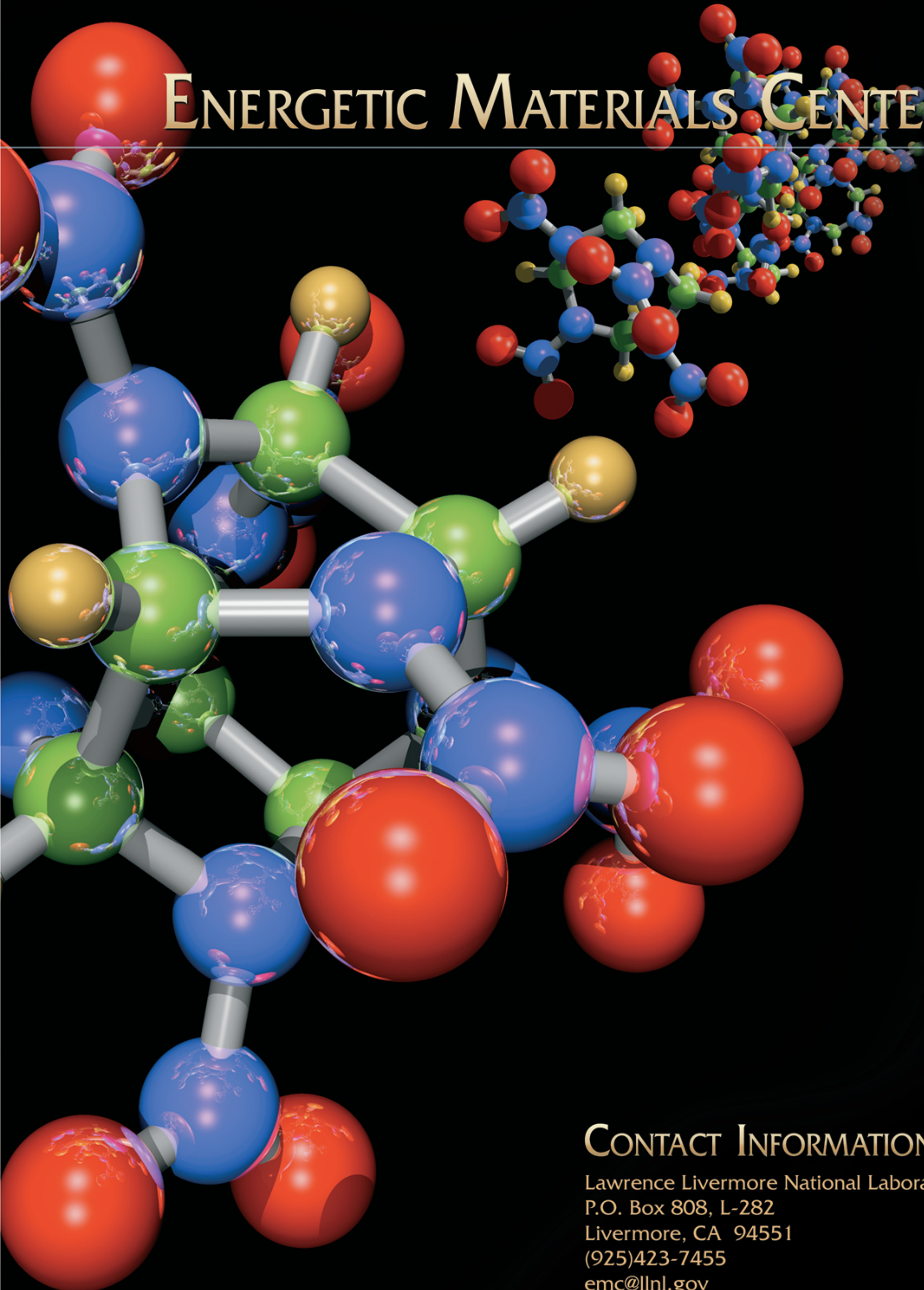

CONTACT INFORMATION:

Lawrence Livermore National Laboratory
P.O. Box 808, L-282
Livermore, CA 94551
(925)423-7455
emc@llnl.gov

National Nuclear Security Administration

DISCLAIMER

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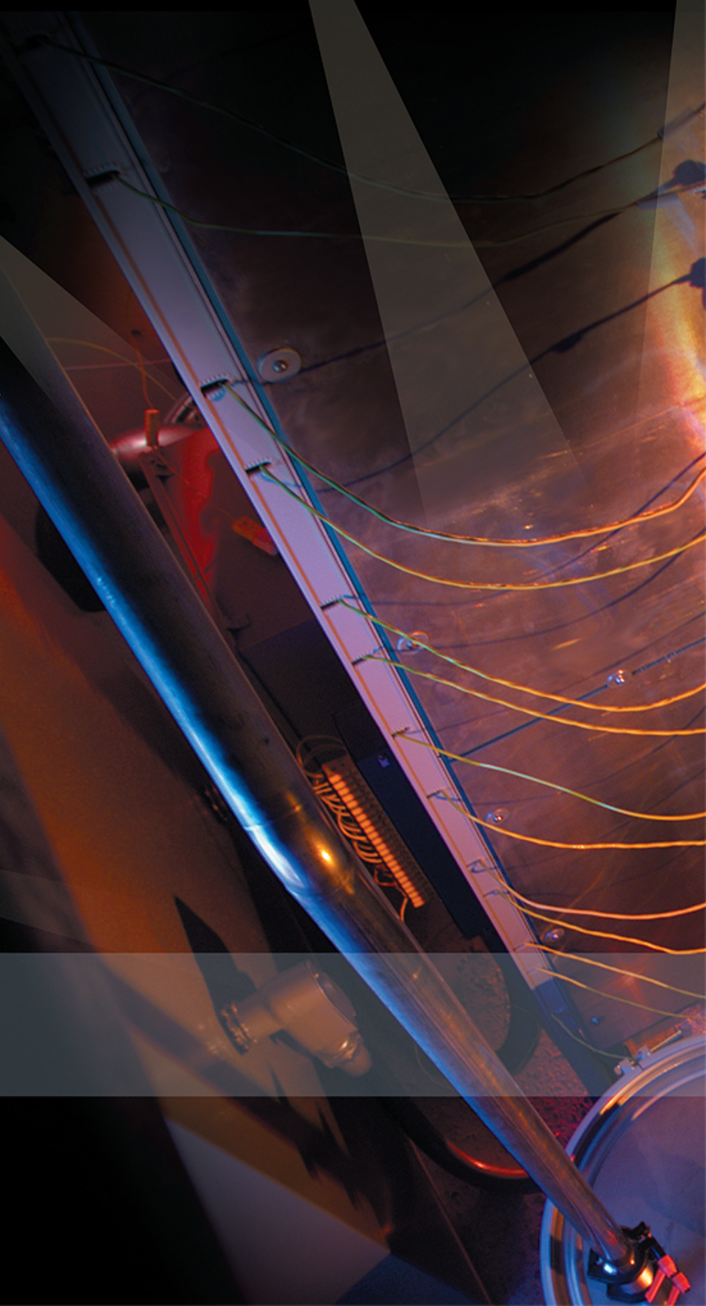

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