LA-UR-17-27382

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Title:	The Mesoscale Science of the Matter-Radiation Interactions in Extremes (MaRIE) project
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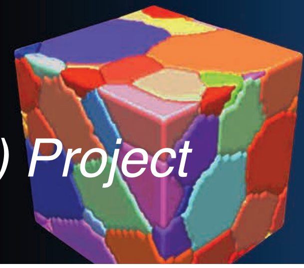
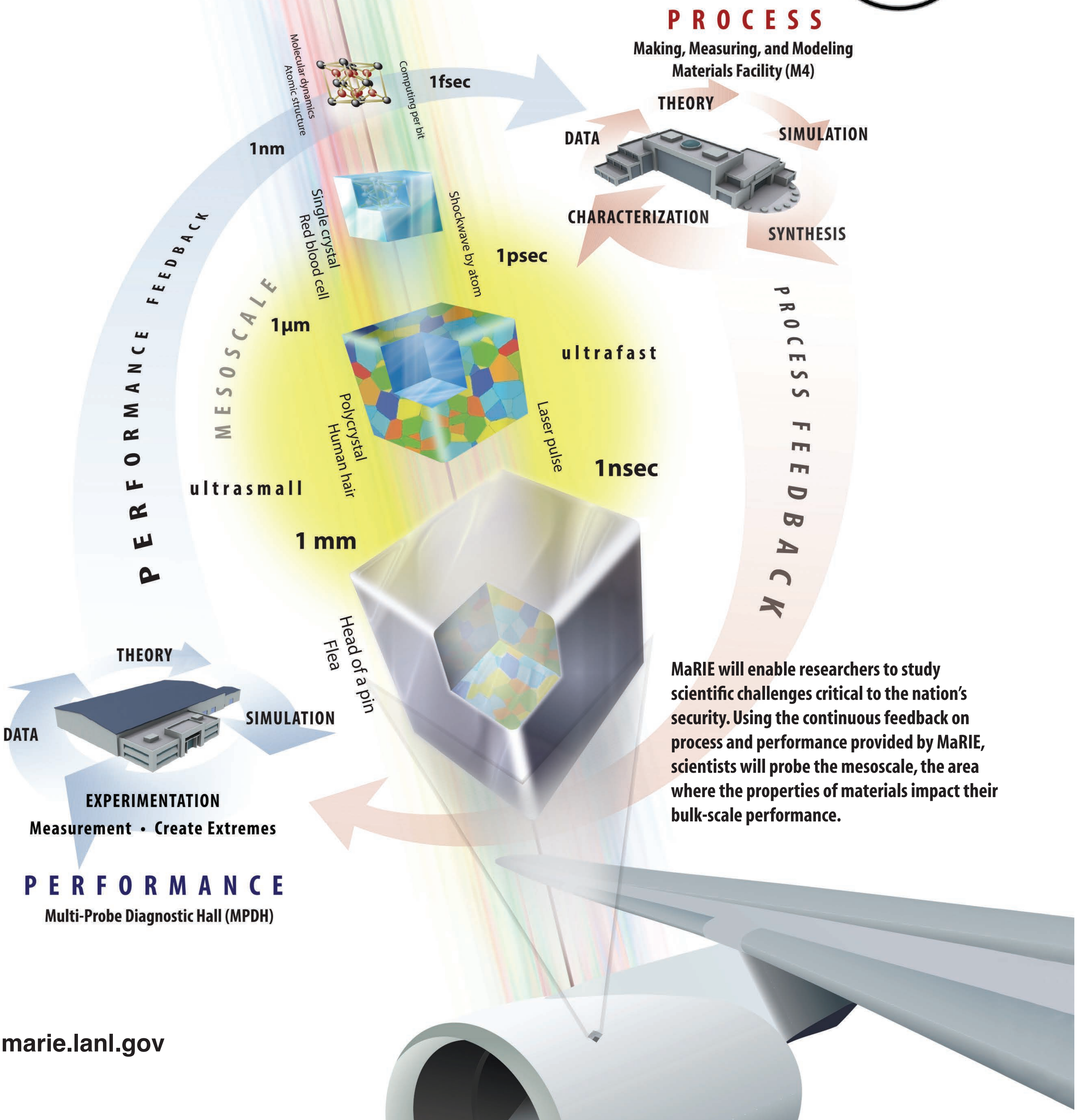
Intended for:	Brochure
Issued:	2017-08-17

The Mesocale Science of the
Matter-Radiation Interactions in Extremes (MaRIE) Project



Revolutionizing materials in extremes

MaRIE will combine theory, experiment, and simulation, using real-time feedback to achieve transformational material advances in extreme environments.



MaRIE will enable researchers to study scientific challenges critical to the nation's security. Using the continuous feedback on process and performance provided by MaRIE, scientists will probe the mesoscale, the area where the properties of materials impact their bulk-scale performance.

marie.lanl.gov

The Case for the

Matter-Radiation Interactions in Extremes (MaRIE) Project

For more than 20 years the science and engineering capabilities of the nation's Stockpile Stewardship Program have allowed the United States to sustain a safe, secure, and effective nuclear deterrent. Most of the problems identified within the nuclear stockpile are related to its aging materials. MaRIE will advance this record of excellence in addressing such materials problems.

MaRIE provides the ability for control of both performance and production of materials vital to national security missions.

The National Nuclear Security Administration (NNSA) requires the ability to understand and test how material structures, defects, and interfaces determine performance in extreme environments such as in nuclear weapons. To do this, MaRIE will be an x-ray source that is laser-like and brilliant with very flexible and fast pulses to see at weapons-relevant time scales, and with high enough energy to study critical materials.

The Department of Energy (DOE) has determined there is a mission need for MaRIE to deliver this capability. MaRIE can use some of the existing infrastructure of the Los Alamos Neutron Science Center (LANSCE) and its accelerator capability. MaRIE will be built as a strategic partnership of DOE national laboratories and university collaborators.

There is an urgent need for accelerated delivery of integrated materials solutions to the nuclear deterrent and other national security missions.

The nation must annually assess whether the aging stockpile will continue to work as designed. These assessments (performance, reliability, safety, and security) are increasingly reliant on detailed scientific understanding of material properties. MaRIE will provide NNSA with more rigorous science-based approaches to manufacturing and certification supporting a more responsive, agile enterprise for U.S. stockpile needs and meet new security challenges in the nonproliferation and counter proliferation contexts.

The United States must prepare for an uncertain future.

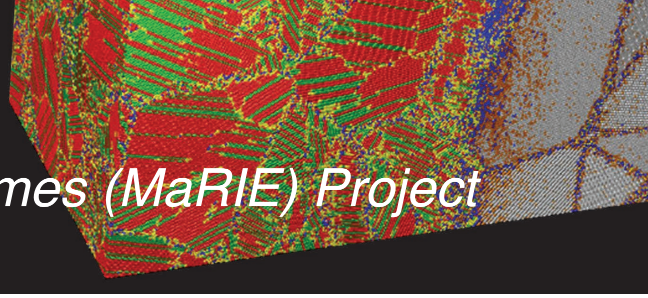
National security in the 21st century requires state-of-the-art computing platforms as well as experimental facilities like MaRIE to generate data to inform models and challenge the computations. Addressing current and new threats will require higher fidelity and resolution models, which in turn will require greatly increased computing capacity. Exascale computing for materials needs experimental data at that high fidelity and resolution at scale. Together, MaRIE and exascale computing allow more accurate calculations of component manufacturing processes and weapon safety and performance, enabling more rapid and confident deployment of new parts and systems.

We need to ensure U.S. technological superiority and advantages.

Basic research provides the greatest potential for fundamentally new ways of creating technological advances with national security and economic implications. Materials innovations have been at the core of the majority of big technological advances since the start of the industrial revolution. MaRIE will provide a comprehensive materials discovery facility with a unique capability to address the control of strategic materials at a middle (mesoscale) of material structure, the scale recognized as a major science grand challenge.

A skilled workforce is crucial for U.S. national security.

MaRIE will transform our ability to compete for intellectual capital and signal to the international community, allies, and adversaries that the nation's best and brightest are prepared to solve any national security challenge.



The Misson Need for the
Matter-Radiation Interactions in Extremes (MaRIE) Project

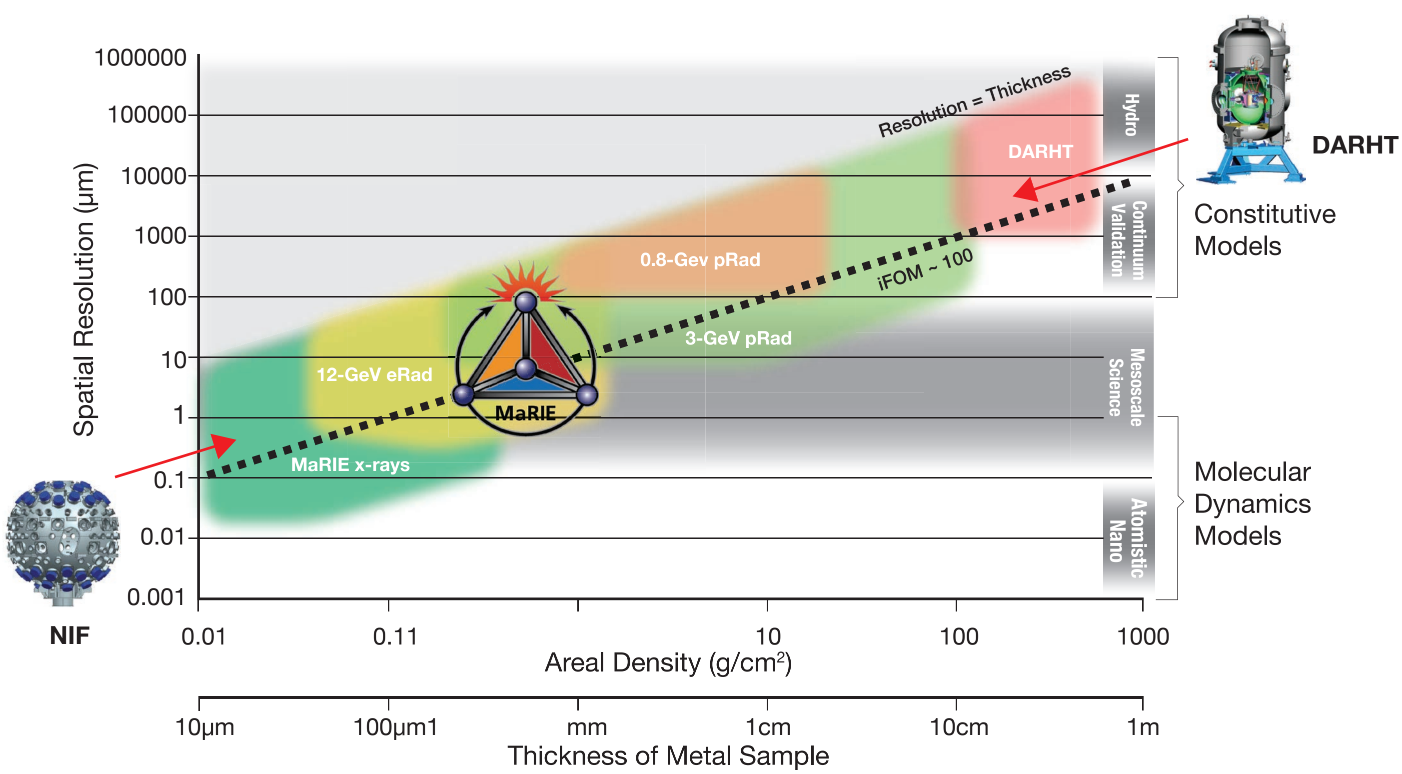
The nation does stockpile stewardship to provide predictive capabilities for weapons performance in the absence of nuclear testing. To date there is a "knowledge gap" for science tools for stockpile stewardship between the atomic scale of materials—addressed by facilities such as the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory and the Z Pulsed Power Facility operated by Sandia National Laboratories—and the integral scale addressed by the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos and the U1a complex at the Nevada National Security Site.

Los Alamos proposes to build a coherent, brilliant x-ray source with energy and repetition rate characteristics uniquely matched to address materials performance challenges associated with the National Nuclear Security Administration's mission.

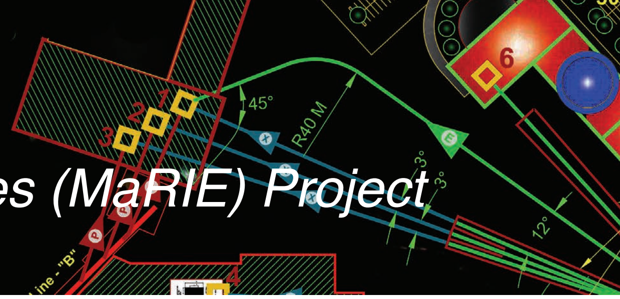
The MaRIE (for Matter-Radiation Interactions in Extremes) capability is designed to address several aspects of materials behavior under extreme conditions. In particular the proposed capabilities will help characterize the behavior of interfaces, defects, and microstructure between the spatial scales of atomic structures and those of the engineering continuum. The role microstructure plays in affecting a material's macroscopic engineering properties—such as strength, stability under heat and pressure, elasticity, and durability in use over time—is well recognized.

MaRIE will deliver the ability to offer time-dependent control of material processes, structures, and properties during manufacture and production. Experimental characterization will be complemented by capabilities in synthesis and fabrication and will be combined with advanced theory, modeling, and computational tools.

MaRIE uses material samples that allow resolution of mesoscale science. MaRIE is positioned to deliver critical stockpile science data, filling a "knowledge gap" between existing facilities such as the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory and the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos.



The Facility Concept of the
Matter-Radiation Interactions in Extremes (MaRIE) Project



MaRIE will provide researchers with the ability to

- create flexible and reduced-cost stockpile materials options for the nuclear weapons complex through accelerated qualification, certification, and assessment, including advanced/additive manufacturing opportunities;
- probe real-time materials response at length scales providing the linkage between materials defects, interfaces, and nonequilibrium structures and performance (the “mesoscale”);
- subject samples to extreme environments and use imaging and diffractive scattering from multiple probes at multiple spatial and time scales to connect models to product performance;
- reduce the uncertainty of physics-based predictions of performance, thus providing sufficient confidence for the material over the life cycle of the system;
- leverage the efforts of exascale computing to validate and calibrate reduced-order models used in advanced codes; predict and control behavior from materials and devices to manufacturing processes; and
- recruit and retain future generations of nuclear weapons stewards.

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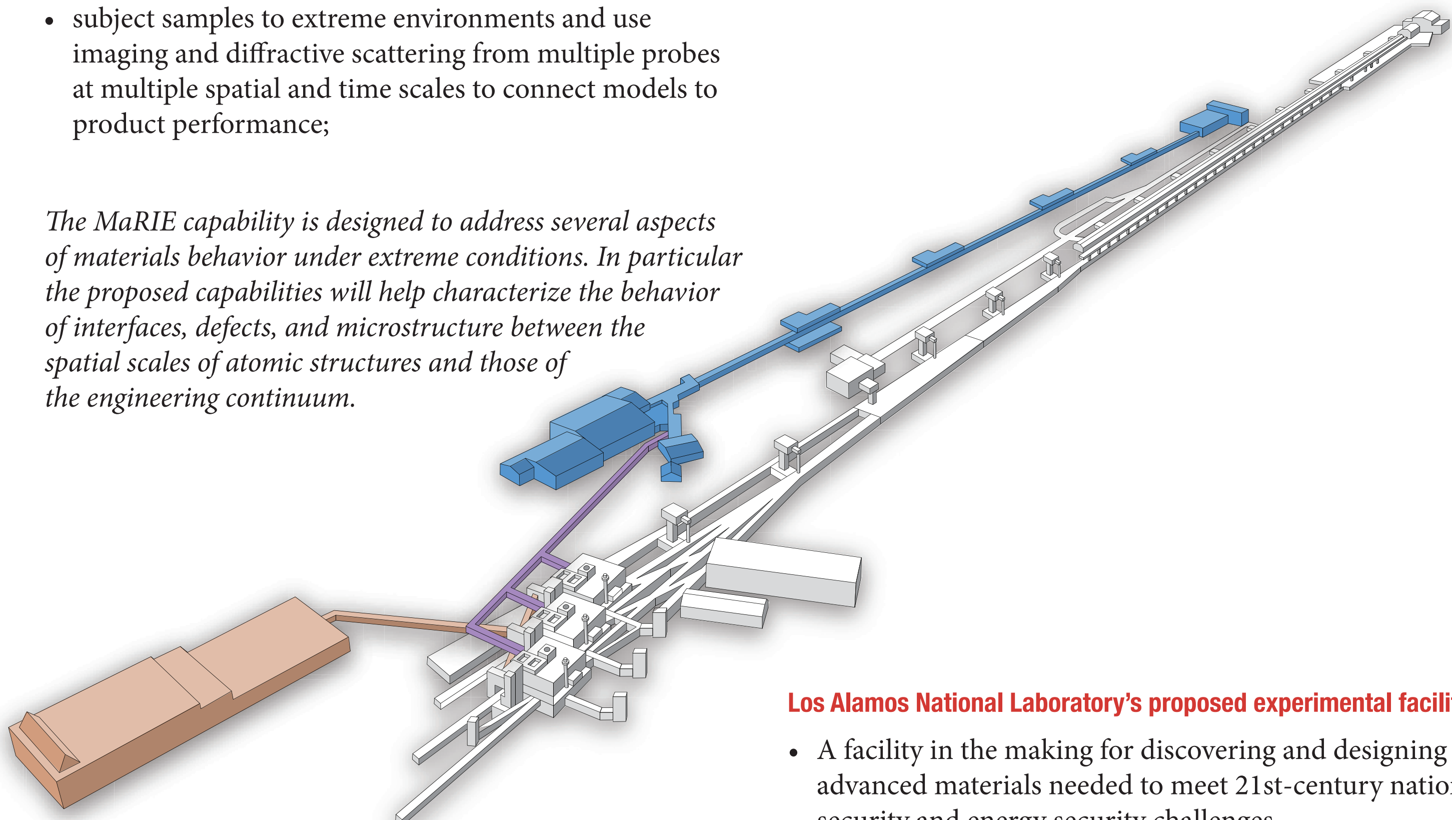

Artist’s rendering of a MaRIE preconceptual design.

Los Alamos National Laboratory’s proposed experimental facility

- A facility in the making for discovering and designing the advanced materials needed to meet 21st-century national security and energy security challenges.
- Will provide the tools scientists need to develop and manufacture next-generation materials that will perform predictably and with controlled functionality in extreme environments.
- As a national user facility, MaRIE will enable Los Alamos National Laboratory to attract the best and the brightest scientists across a broad range of disciplines.