DMMSC ≠ MaRIE

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Jan. 28, 2021

Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

Welcome to the DMMSC Seminar Series

The new monthly Dynamic Mesoscale Material Science Capability Seminar Series features Lab highlights from materials science areas, including cutting-edge research at national and international light sources, in-depth investigations of technical gaps, and advanced studies of accelerator technologies that might provide probes in this region.

- Upcoming (better) talks
  - Feb. 1: Overview of DMMSC workshops: *Richard Sheffield*; Data Science and Computation for Rapid and Dynamic Compression Experiment Workflows: *Christine Sweeney*
  - March 1: Emerging Materials and Process Development for Polymer/non-metal Additive Manufacturing: *John Carpenter*; Workshop on in-situ sensing and process monitoring for NNSA relevant materials and processes: *Don Brown*
  - April 5: Methods for Characterizing Defects in Advanced Manufacturing Processes: *John Carpenter*; Carbon in Extreme Conditions: *Dana Dattelbaum*

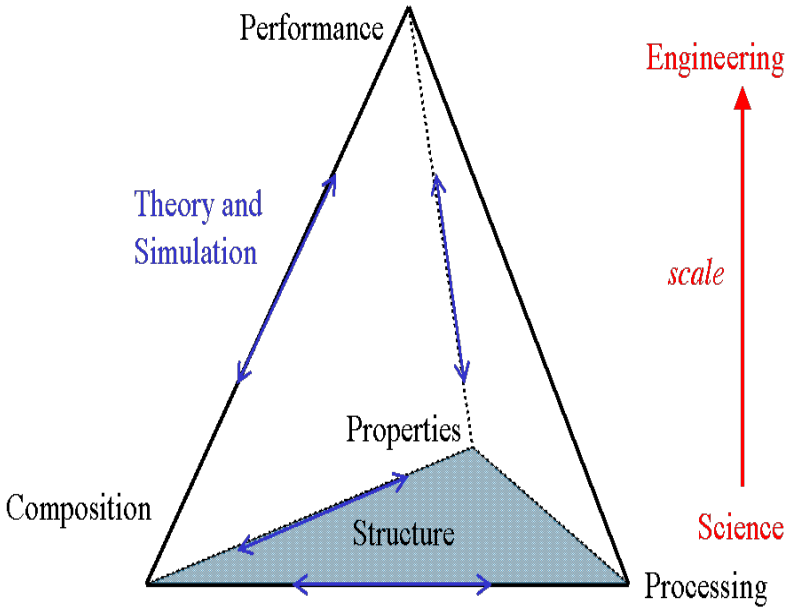
Thanks to the organizers, Rich Sheffield, John Tapia, and Mike Furlanetto

- send them ideas for future talks…

Filling the DMMSC gap today and with MaRIE in the future are institutional priorities

2019 & 2021

- The Dynamic Mesoscale Materials Science Capability (DMMSC) addresses a national unmet scientific need for understanding material performance and production at the mesoscale.
- The ultimate goal is the integration of material structure and processing to achieve desired material properties and ultimately desired performance – supporting production science.
- The MaRIE (Matter-Radiation Interactions in Extremes) Facility is one plausible solution that meets all the validated requirements for DMMSC.
- The mission need for the capability and the facility project are important priorities for DOE/NNSA and Los Alamos National Laboratory.



Understanding process-structure-property-performance relationships requires a research capability to explore mesoscale dynamics

Project Management 101: DMMSC ≠ MaRIE

- **DMMSC is NOT a new name for MaRIE**

- **DOE Order 413.3b specifies several Critical Decisions**
  - CD-0: Approve Mission Need
  - CD-1: Approve Alternative Selection and Cost Range

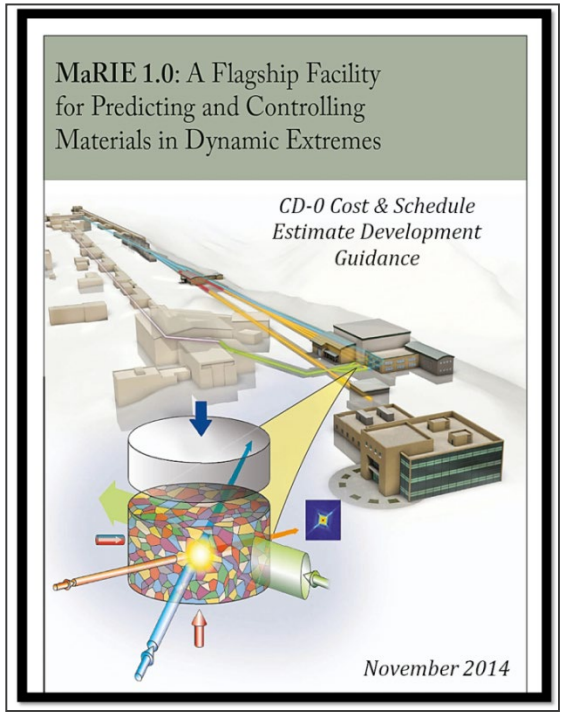
- **To be overly simplistic, CD-0 defines a ‘nail,’ CD-1 picks a ‘hammer’**
  - DMMSC is a nail
  - Many hammers can hit a nail in full or in part
  - MaRIE is one particular very-tailored and well-defined hammer

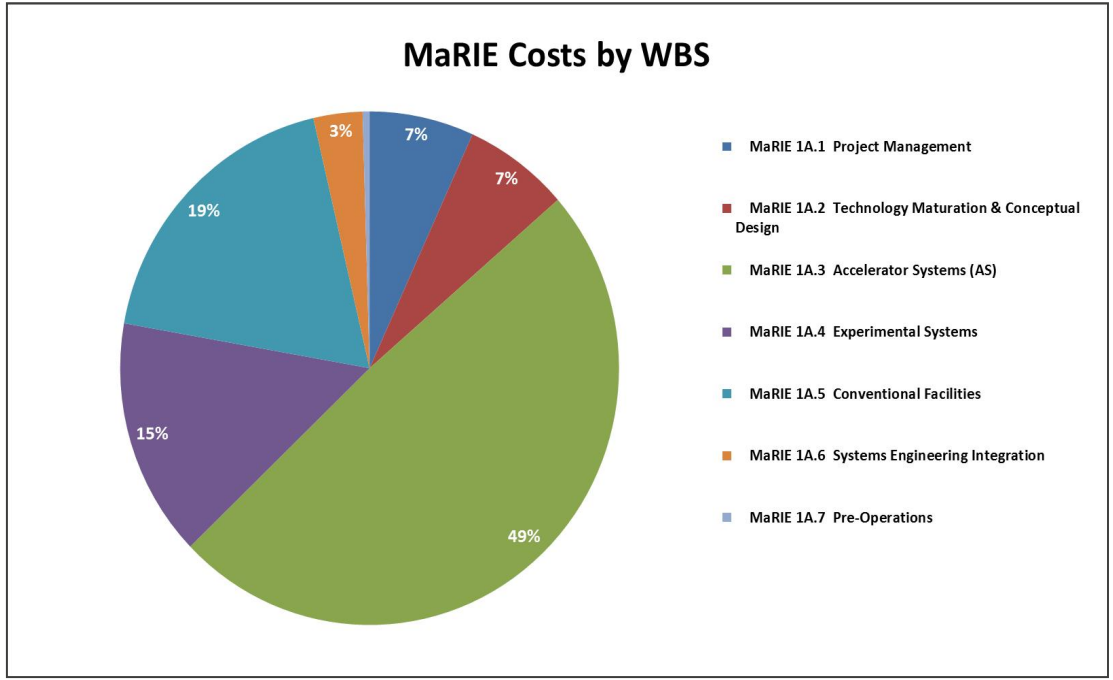
The MaRIE XFEL located adjacent to LANSCE on the TA-53 mesa

MaRIE will provide complementary capabilities to ESCE, advancing material qualification through an understanding of the microstructure-performance link

We developed a reasonably detailed design and cost estimate for the CD-0 Package

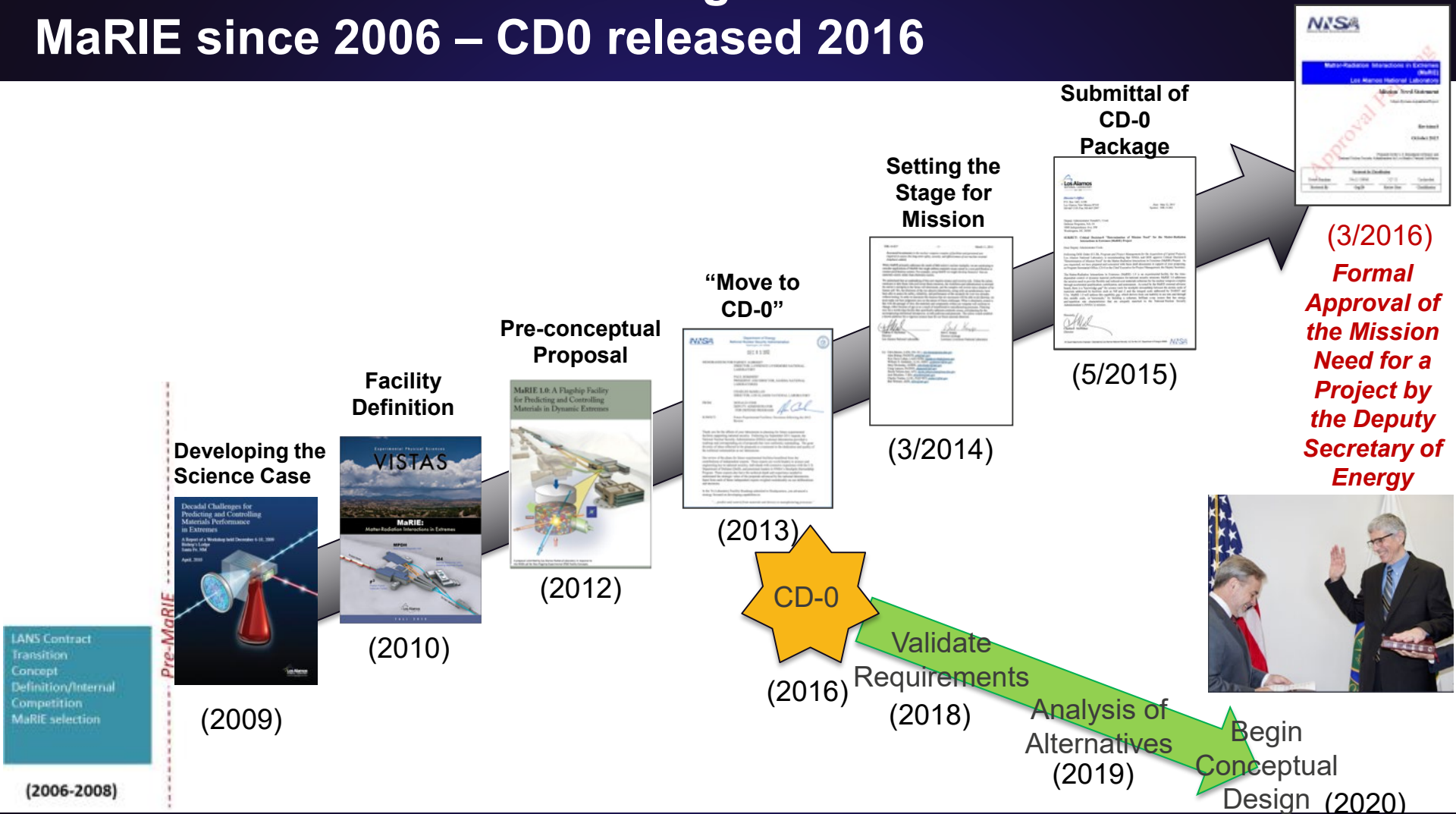
The TPC for MaRIE was independently reviewed. Key lesson is we must avoid setting cost/schedule performance expectations too early! *Cost Range in MNS is $1.9B-$3.7B*.





Cost estimate is fully burdened with 38% average contingency

Los Alamos has been working toward our vision of MaRIE since 2006 – CD0 released 2016



Getting DMMSC (formerly MaRIE) to line-item funding by FY 2022 was a Defense Programs (and LANL) priority

May 9, 2018

LANL Top-3 NA11-Related Major Construction List

Tasking

In order to inform ongoing FY20 FYNSP programming discussions, NA-11 requests that each Lab provide a list of your top three major (>$20 M) construction projects by lab/site requiring NA-11 funding no later than 9 May 2018. These projects should include only those that require funding starts within the FYNSP (FY 20-24) and NOT include any projects already funded under an existing 413.3b project.

LANL Response

Weapon Science and Engineering

Project Name	Description	Brief Needs Statement	Proposed start date (CD-0)	Mission need date (CD-4)	Co ($!
MaRIE	FEL, multi-probe diagnostic hall for materials characterization	Mission requires ability to probe the impact of meso-scale material features on down-stream weapon performance; particularly important for understanding impact of aging of materials and impact of newly-manufactured AM- materials	FY16	FY30	3,0
Future HPC Infrastructure	Electrical infrastructure upgrade inside SCC; enables all 40MW of power available at the wall of the building, to be usable inside the building	Mission work increasingly requires more detailed, 3D simulations, particularly as weapons age; need will be met, in part, on ATS-5 and CTS-4 machines to be deployed at LANL in FY25	FY19	FY24	13
Energetic Materials Characterization (EMC) Facility	Consolidates and replaces 18 aging HE facilities whose buildings are falling out of safety compliance	Assessing and evolving the stockpile requires developing and synthesizing HEs to address technical requirements, resolve significant SFIs, and evaluate material responses to all phases of the stockpile-to-target sequence defined in mission requirements for each weapon	FY19	FY22	10

"September 2020 conceptual design" for FY 2022 line-item authorization and appropriations

July 12, 2018 Defense Program Tasking Memo:

"FY 19 AoA

- NA-11 ADA
  - Matter Radiation Interactions in Extremes (MaRIE)" [now DMMSC]

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

July 12, 2018

MEMORANDUM FOR DISTRIBUTION

FROM: PHILIP T. CALBOS
ACTING DEPUTY ADMINISTRATOR
FOR DEFENSE PROGRAMS

SUBJECT: Defense Programs Capital Acquisition (CapAx) Requirement Development and Analysis of Alternatives Authorization

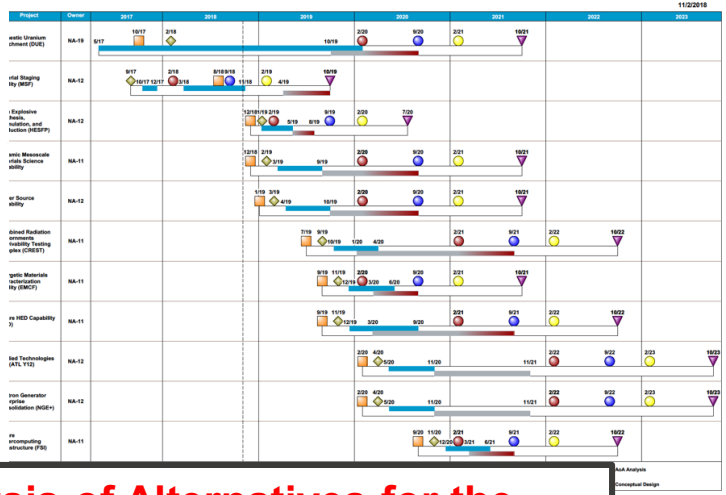
In FY17, the Defense Programs (DP) Office of Decision Support (NA-14) initiated an integrated DP capital acquisition Planning, Programming, Budgeting, and Evaluation process known as CapAx. The first year of this annual process generated a 25-year schedule of line-item project proposals for the FY19 Stockpile Stewardship and Management Plan with discrete CD-0 target dates, CD-4 target dates, and cost estimates. The first five years of this planning schedule was input into FY20 programming discussions based on Assistant Deputy Administrator (ADA) prioritization. While FY20 budget discussions are ongoing, the DP ADAs shall begin CD-0 activities and Analysis of Alternatives (AoA) on the projects identified in the first two years of the schedule; these actions are described in more detail below.

Actions for ADA Sponsors

- Complete a CD-0 Approval of Mission Need
  - Develop a Mission Need Statement and Program Requirements Document
  - Follow the DP Requirements Management Advisory Board (RMAB) Process to validate requirements
  - Apply for CD-0 Approval
- Complete an Analysis of Alternatives
  - Reference the DP AoA Guidance, NNSA BOP-03.07, and DOE G 413.3-22 for more information on AoA process requirements

Some projects may not complete CD-0 or AoAs by the dates listed due to project requirement complexity or DOE review schedules. The Program Offices that manage

A-10 AoA Schedules



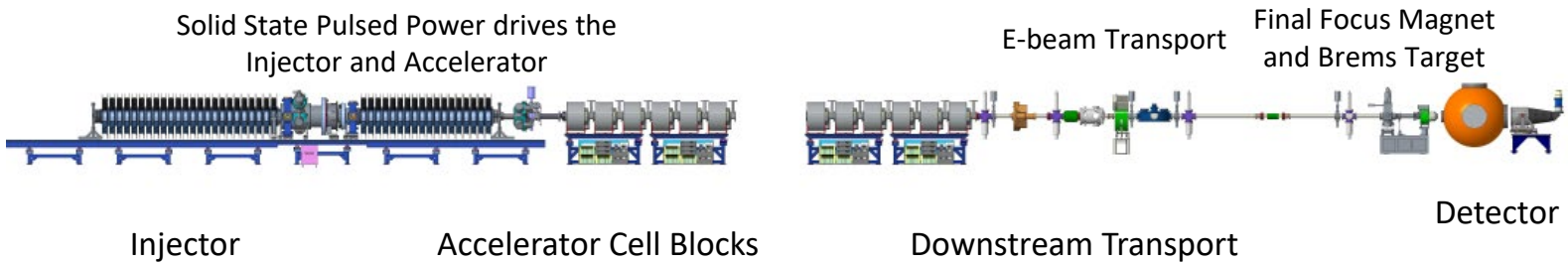
On March 20, 2019 NA-11 approved Delay of the Analysis of Alternatives for the DMMSC Project, and cancelled all activities relating to pursuit of CD-1 for FY 2020.

Current path forward for DMMSC and MaRIE

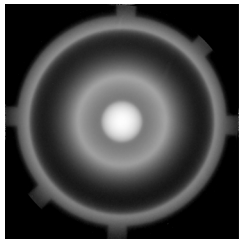
- **The Laboratory needs to deliver on LAP4 (Los Alamos Plutonium Pit Production Project) and especially ASD (Advanced Sources & Detectors)**
  - Both projects provide key needed capabilities for materials research and accelerator stewardship AND demonstrate project execution competence
- **Focus on developing capabilities and science for DMMSC**
  - Increased focus on mesoscale science in Lab Agenda and capability pillars
    - Materials for the Future Pillar
    - Lab Agenda element 2.2 (accelerator stewardship); ALDPS Accelerator Strategy Office
  - 'Momentum Initiative' Workshops engaging the external science community
    - … as well as this series of seminars
  - Support for Mesoscale Science through Experimental Sciences (Campaign 2)
- **Engagement with NNSA (NA-113) on DMMSC-informed projects**
  - NNSA Investment at SC Light Sources
  - LANSCE Modernization Project (LAMP)

Advanced Sources and Detectors (ASD) Project: *"A 21st century version of one arm of DARHT," Thom Mason*

- Multi-pulse high current (~ 2 kA) electron beam creating x-rays at energies that balance metal transparency with particle production (~20 MeV) have been demonstrated as useful tools for characterizing implosion hydrodynamics (DARHT@LANL and CFF/FXR@LLNL)



Scorpius is the radiographic diagnostic



French Test Object Radiograph

- Scorpius will take time dependent x-ray images of implosions to provide data for code validation, enabling the certification of stockpile changes in the absence of testing

ASD Scorpius

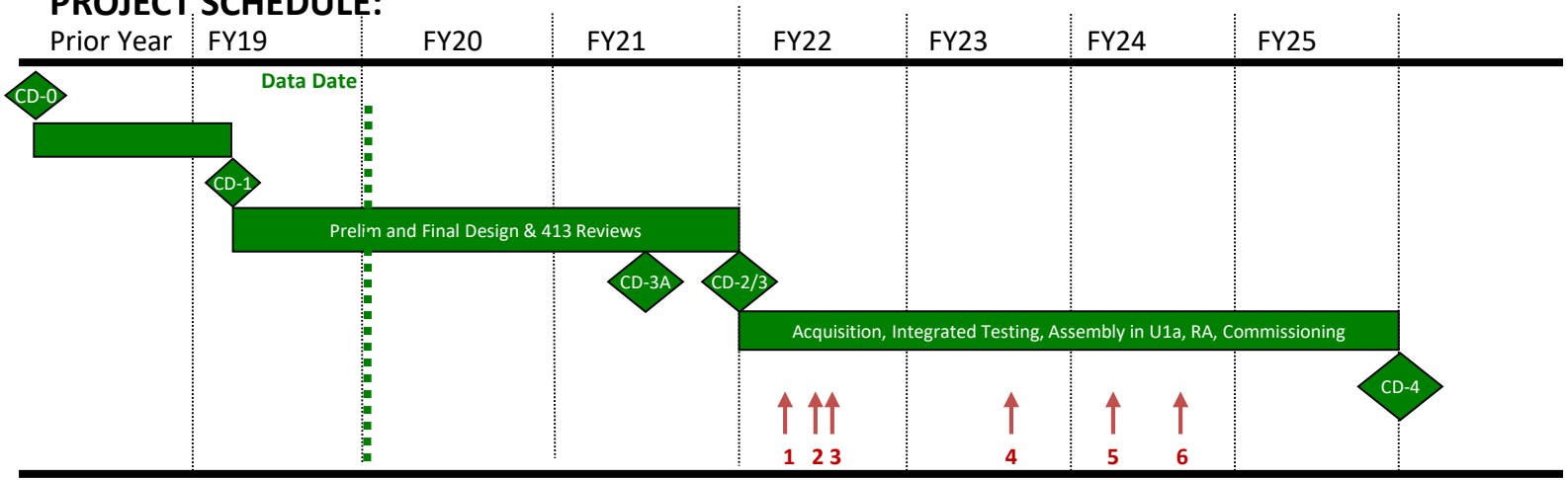
Courtesy: Dave Funk

The plan is to 'under-promise' and 'over-deliver' the capability in early FY25 – 4th QTR FY25 is the published commitment

TPC: $500M-$1100M | **FPD EAC to CD-4:** $885M | **FPD Forecasted CD-4:** Sept 2025

Project CD-4: Sept 2025 | **CPD EAC to CD-4:** $691 M | **CPD Forecasted CD-4:** Sept 2025

PROJECT SCHEDULE:



UCEP/ASD Interproject Links

1. Ready to Install Equipment U1a.103, and Global Systems U1a.104 (December 2021)
2. Ready to Install Equipment U1a.102 (March 2022)
3. Ready to Install Accelerator U1a.104 (April 2022)
4. ZR Ready for Detector, Global Systems, other Diagnostics (May 2023)
5. ECSE Complex Ready for Testing (January 2024)
6. ECSE Complex Ready for Operation (July 2024)

ASD Scorpius

Courtesy: Dave Funk, ~2019

NNSA

Filling the DMMSC gap today and with MaRIE in the future are institutional priorities

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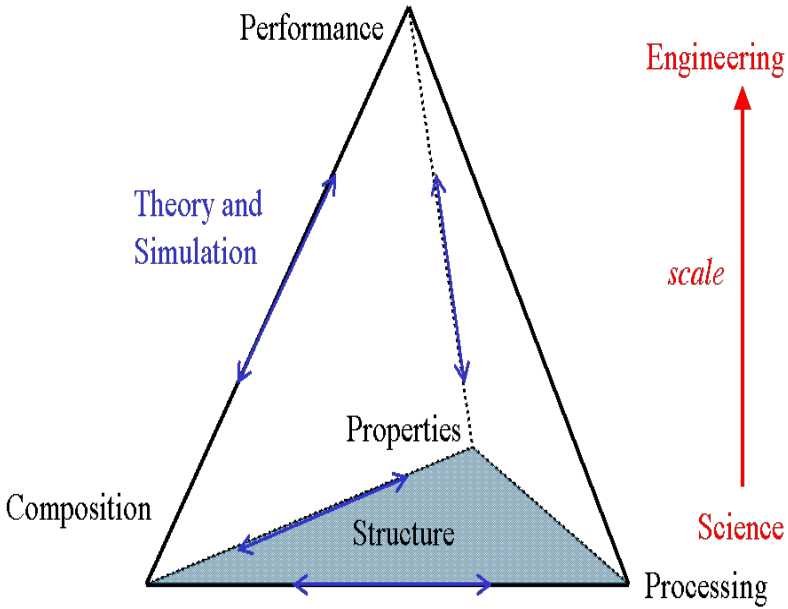
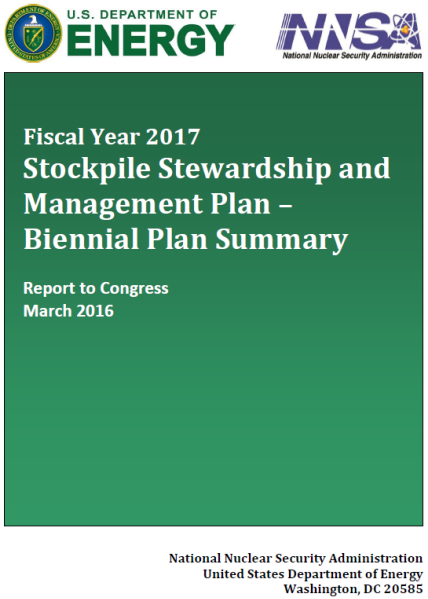


Understanding process-structure-property-performance relationships requires a research capability to explore mesoscale dynamics

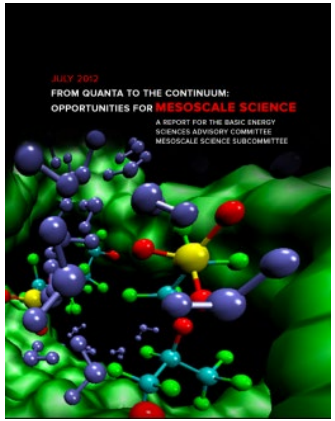
NNSA's need to predict and control the microstructure of materials is also a science frontier…

~2017

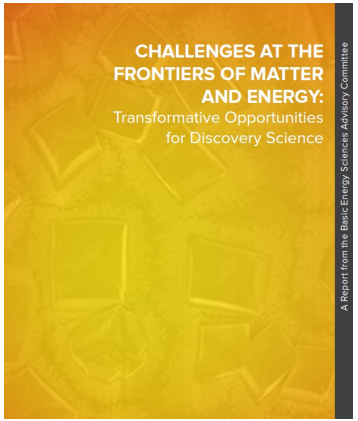


"In particular, we believe that filling the gap in our ability to 'predict and control from materials and devices to manufacturing processes' is especially urgent."

From Quanta to the Continuum: Opportunities for Mesoscale Science



Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science

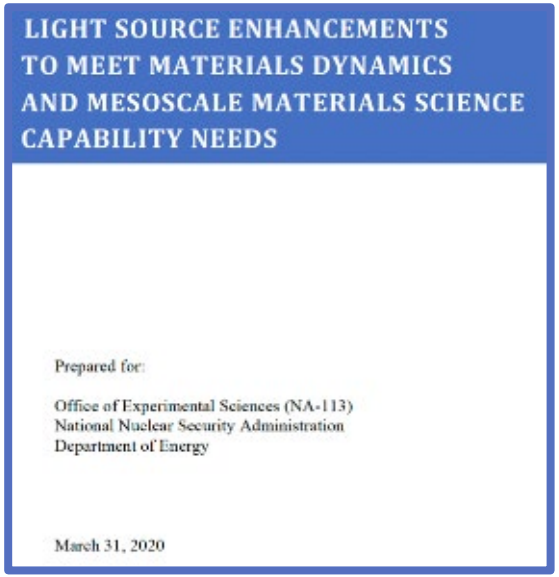


science.energy.gov/bes/news-and-resources/reports/basic-research-needs/

…that motivates new capabilities and will demand co-design for success

NNSA's need to predict and control the microstructure of materials is also a science frontier…

2021

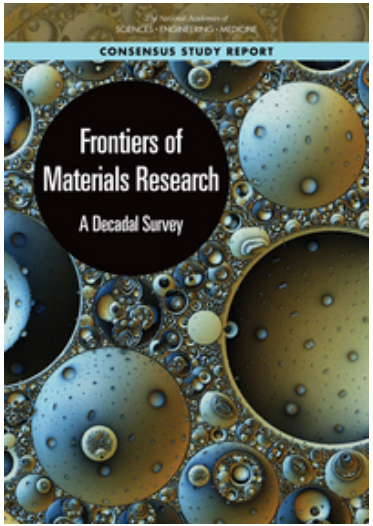

LIGHT SOURCE ENHANCEMENTS TO MEET MATERIALS DYNAMICS AND MESOSCALE MATERIALS SCIENCE CAPABILITY NEEDS

Prepared for:

Office of Experimental Sciences (NA-113)
National Nuclear Security Administration
Department of Energy

March 31, 2020

"Collectively, these new ultrabright sources will drive further advances in the techniques, enabling The **transformative studies of materials with nanoscale resolution while under operating conditions and on ultrafast time scales.** United States had a significant fraction of all the world-leading capabilities 20 years ago, but that lead has eroded and today's landscape is one of intense competition from both Europe and Asia."



"The National Nuclear Security Administration (NNSA) has an unmet capability need to improve our ability to predict how changes in a material's microstructure impact its performance in weapons environments. Certification of the future stockpile; maintenance of the current, aging stockpile; and qualification challenges associated with materials and manufacturing changes will rely heavily on an understanding of materials in extreme environments."

…that motivates new capabilities and will demand co-design for success

Congress is listening…

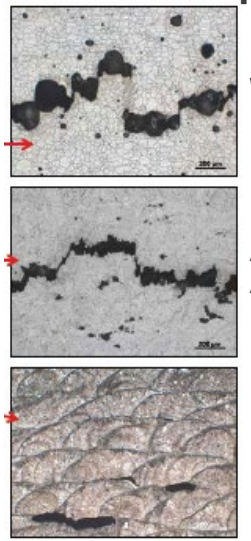
"The Committee strongly encourages the NNSA to develop additional partnerships with the Office of Science to utilize the Advanced Photon Source [APS] and Linac Coherent Light Source [LCLS] …. The NNSA is directed to brief the Committee within 90 days of enactment of this act on its plans to work with the Office of Science to incorporate additional capabilities in the planned upgrades at LCLS and APS that will address NNSA mission needs to interrogate the behavior of materials at length and timescales necessary to study materials aging and modern manufacturing methods."

-FY21 Omnibus Appropriations Act

DMMSC will address the control of performance and production of materials for national security science at the mesoscale

~2015

Performance of additively-manufactured (AM) structural components



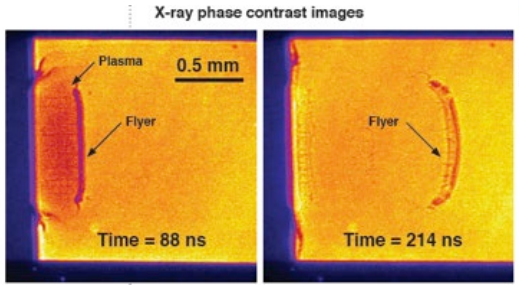
Wrought

AM Annealed

AM

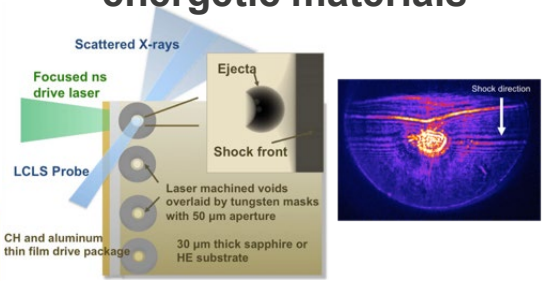
Damage in wrought vs additively-manufactured steel

High Explosive performance and safety



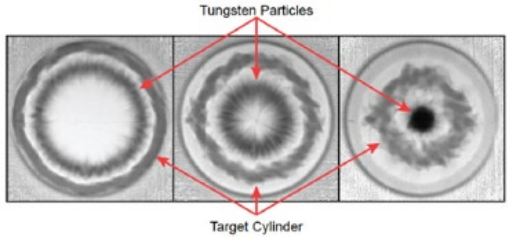
Movies of functioning slapper detonators

Void Collapse in energetic materials



Identify mechanisms of initiation

Ejecta and Mix



Movies of ejecta in convergent geometry

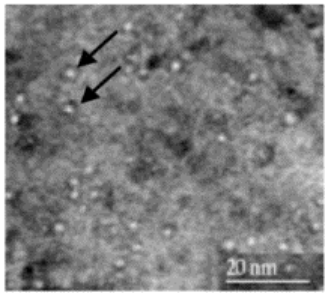
Requirements for MaRIE are set from analysis of such experiments. -- *"(U) MaRIE First Campaigns," LA-CP-15-00501, June, 2015*

DMMSC fills a critical gap in length scale between the integral scale addressed by DARHT and U1a and facilities such as NIF and Z.

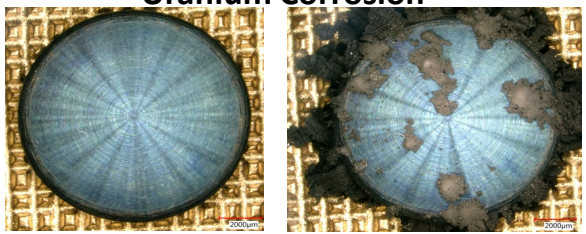
Materials structure *at the mesoscale* affects weapons performance and behaviors across the stockpile lifecycle

- We need a predictive understanding of how mesoscale structure impacts performance
  - Aging modifies all the materials inside our existing nuclear weapons
  - Modern approaches to manufacturing are different than in the legacy stockpile (pits, cases, HE…)

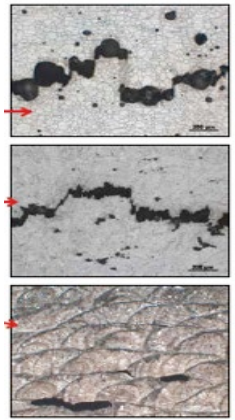
Helium Bubbles in Aged Plutonium



Uranium Corrosion



Damage in wrought vs additively-manufactured steel

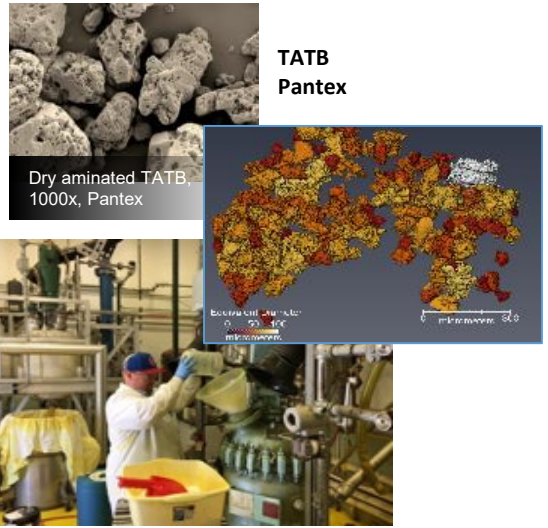


Wrought

AM Annealed

AM

High explosives



TATB Pantex

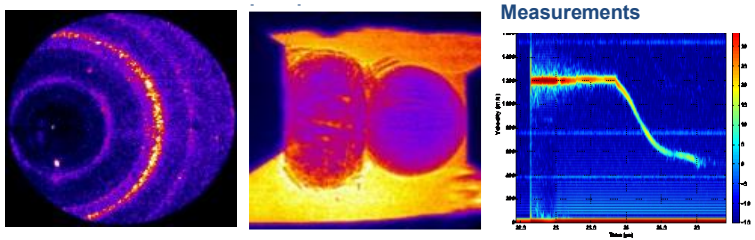
NNSA must certify that these changes do not impact weapons performance, safety or reliability

Courtesy: Dana Dattelbaum

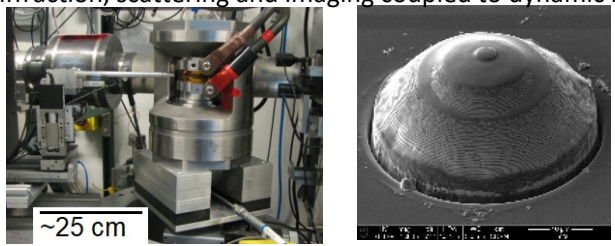
NNSA has been growing its efforts at U.S. and international light sources over the last decade to address NNSA missions

- **Advanced Photon Source**
  - Two NNSA owned sectors: Dynamic Compression Sector and HP-CAT
  - Studies of material structure and dynamics in extreme environments
  - Dedicated dynamic platforms coupled to x-rays and first detonation experiments at U.S. light source

X-ray Diffraction | Phase Contrast | Continuum Measurements

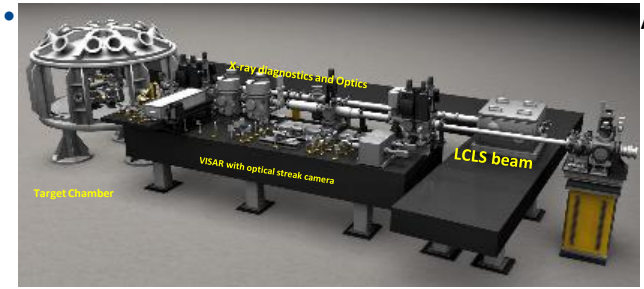


Diffraction, scattering and imaging coupled to dynamic loading



Large volume press and diamond anvil cells at HP-CAT

- **Current MEC at LCLS**
  - Dynamic compression coupled to coherent x-rays
  - A

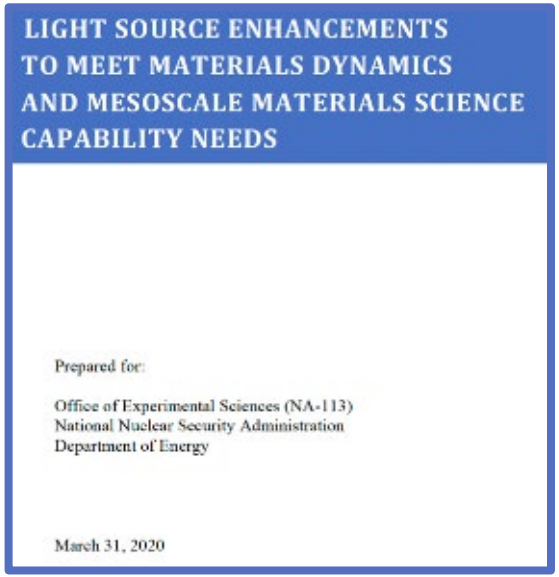


- **HED endstation at Eu-XFEL**
  - LANL and LLNL were part of first experiments in October 2019, and NNSA made in-kind contribution in 2020

Control room during 1st experiments at Eu-XFEL

Courtesy: Dana Dattelbaum

The Tri-Lab is championing a mesoscale materials dynamics capability investment at APS and LCLS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Prepared for:

Office of Experimental Sciences (NA-113)
National Nuclear Security Administration
Department of Energy

March 31, 2020

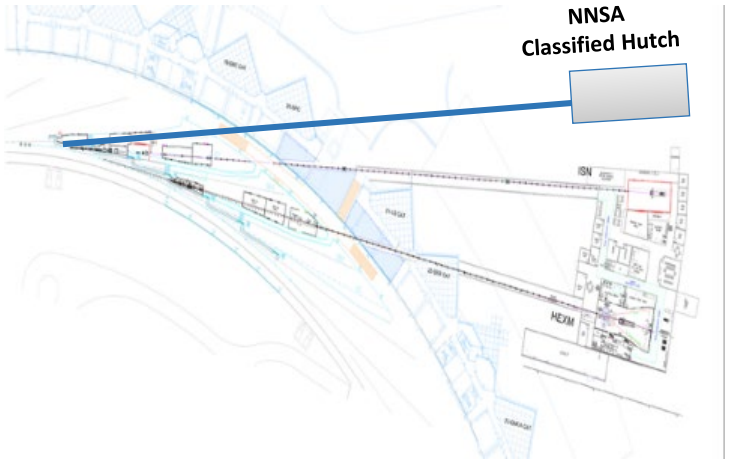
This investment would address two important aspects of the DMMSC mission need:

- Acquisition of unprecedented materials structure-property-performance data supporting current stockpile missions on real materials of interest to NNSA, with enhancement of driver platforms at APS in a dedicated-use sector.

- Dramatically improved fundamental understanding of the underlying phenomena connecting mesoscale to dynamic performance, with development of unique diagnostics and experimental platforms enabled by the coupling of high brilliance LCLS x-rays with high-fidelity drivers at the new Matter in Extreme Conditions (MEC) end-station.

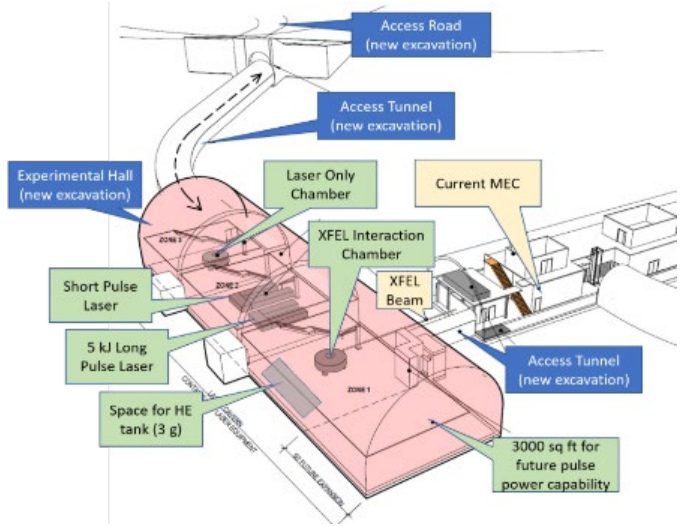
The Mesoscale Material Dynamic Capability (MMDC) leverages the significant Office of Science upgrades to address NNSA mission needs

Advanced Photon Source-New Sector



- New Sector to enable 250 g IHE detonations
- Manufacturing Hutch
- Immediate classified operations capability
- Future double containment capability

Linac Coherent Light Source-Partnership in MEC Upgrade



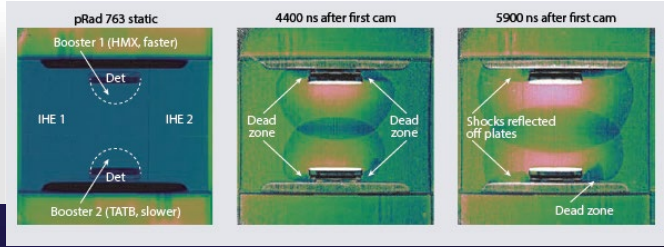
- First Major NNSA Investment at US XFEL
- 5 kJ laser to enable mesoscale material performance questions at relevant scales
- HE detonation chamber and imaging station
- Opportunity for future pulsed power capability

NNSA and Office of Science should partner to fully realize the benefits stemming from modernization of U.S. light sources

Courtesy: Dana Dattelbaum

LANSCE is pursuing experimental advances enabling mesoscale research

- **Options include:**
  - Scattering science
    - Additional/replacement beamlines to enable three-dimensional residual stress measurements
    - Addition of a compact light source to enable multiprobe studies of samples
  - Static radiography
    - Beamlines to enable routine two- or three-dimensional isotope-resolved neutron imaging
  - Dynamic radiography
    - *Higher-resolution* proton radiography to achieve ~micron resolution (through advanced lens design or enhanced energy)
    - Multiple-axis radiography for three-dimensional reconstructions
    - Pu@prad capability at Area C
- A series of workshops in the next few months will refine these proposals and determine the ones which would have the most impact
- Area A, a currently unutilized experimental area at LANSCE, is being refurbished as a future home for some of these options in the late 2020s



The LANSCE Modernization Project (LAMP) will ensure reliable delivery of assessment & certification data over the coming decades

There is an enduring need for LANSCE material science and nuclear data to support component qualification, SFI resolution, LEP certification, and studies of advanced manufacturing, material aging, and mesoscale science

LAMP will be a ~7-year project to replace the highest-risk elements of the 48-year-old LANSCE accelerator

- The LANSCE accelerator ”front end”, consisting of the Cockcroft-Walton accelerator and drift-tube linac, is seeing end-of-life failures, and many components have no viable pathway for repair or replacement
- Replacement with high-TRL modern equivalents will increase reliability, decrease maintenance costs, and improve peak beam current by ~2x - thus improving data quality and enabling future enhancements to experimental areas
- LAMP planning is consistent with parallel efforts by NA-50 to address deferred maintenance at LANSCE

A pre-conceptual design report is complete and CD-0 document preparation is underway; the cost estimate for the pre-conceptual design is $200-500M (Class V: -50% to +100%)

- Submitted as an MIE to the NA-113 Capital Acquisition Process
- Sequential nature of the accelerator means that this could be split into two independent smaller projects (Cockcroft-Walton injector region and drift-tube linac) with ~10-20% increase in total cost and ~1-2 additional years

ALDPS is the champion for the Materials Pillar: Our Vision Is to Develop Materials with Controlled Functionality and Predictable Performance

Vision

Controlled Functionality and ***Performance Prediction***

Strategy

We predict performance and control functionality through forefront science and engineering across three themes:

- Defects and Interfaces
- Extreme Environments
- Emergent Phenomena

Execution

Strong coupling between experiment and theory, computation and modeling

Our Strategy Links Leadership Areas through Science Themes to Achieve Overarching Goals

GOALS

Performance Prediction and Controlled Functionality

SCIENCE THEMES

Defects and Interfaces

Extreme Environments

Emergent Phenomena

AREAS OF LEADERSHIP

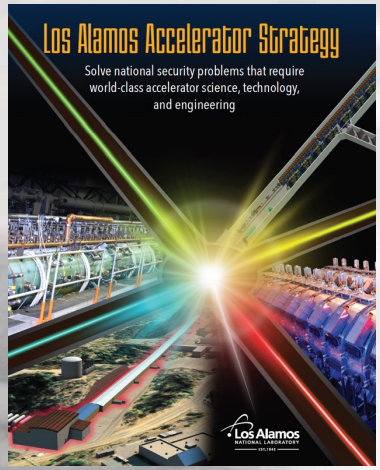
Complex Functional Materials	Material Resilience in Harsh Service Conditions	Manu-facturing Science	Actinides & Correlated Electron Materials	Integrated Nano-materials	Energetic Materials	Materials Dynamics

FY22 LDRD SIP- MAT Priority #2: Dynamic Materials Science (links to Extreme Environments) Development and advancement of the capability, at light sources and/or with laboratory systems, for dynamic, mesoscale interrogation of both structural and functional materials

The Accelerator Strategy Office (ALDPS-ASO) will enable simultaneous excellence in LANL accelerator efforts (Lab Agenda 2.2)

- **We have a clear sense of our strategic priorities for the next generation of stockpile stewardship**
  - We must also steward people, facilities, and research
- **Accelerator capability stewardship (physics, engineering, execution/ operations) is a shared priority**
  - LANSCE, DARHT, ASD, LANSCE modernization → DMMSC
    - Right-sized/sustainable workforce to address integrated total scope
- **ASO will support simultaneous excellence in all LANL accelerator efforts, facilitate project capture strategies and project management execution, and promote mesoscale science awareness**

John Tapia
Office Director



FY21 Objectives

- Enhance our ability to plan and capture major acquisition projects and prepare for project management execution
- Promote staff awareness of worldwide activities in mesoscale science and related technologies addressing mission critical gaps

Summary

Filling the DMMSC gap today and with MaRIE in the future are institutional priorities

- We are actively pursuing “DMMSC science” today with partners at existing facilities
- We are working to reduce technology risk for our preferred alternative MaRIE to meet the DMMSC mission need
- We are developing capacity, especially through ASD:Scorpius, to ensure project delivery, should we be given the opportunity
- We continue to proactively engage the community and look forward to your participation