Department of Energy
National Nuclear Security Administration
Washington, DC 20585

September 27, 2023

Dr. Colleen Hartman
Director, Board on Physics and Astronomy
The National Academies of Sciences, Engineering, and Medicine
500 5th Street, NW
Washington, DC 20001

Dear Dr. Hartman:

I would like to express my sincere appreciation for the efforts of the National Academies in completing the report *Fundamental Research in High Energy Density Science* which addressed the FY22 congressional reporting requirement "to conduct an assessment of recent advances and the current status of research in the field of high energy density physics" (P.L. 116-92, SEC. 3137, FY20 NDAA).

The findings and recommendations were insightful and carefully considered by the staff within the National Nuclear Security Administration's (NNSA) Office of Experimental Sciences (OES). We support the report's recommendations and look forward to pursuing implementation, subject to mission need, priority, and appropriated budgets.

NNSA's specific responses to the report's recommendations in *Appendix D* follow below in the order in which they were presented in the Appendix.

Leading Recommendation: To strengthen its global leadership in high energy density (HED) science and address future national needs, the NNSA should exploit and enhance the capabilities of its flagship HED facilities (e.g., the National Ignition Facility, Z Pulsed Power Facility, and Omega Laser Facility) by establishing plans over the next 5 years for (1) extending, upgrading, or replacing those facilities; (2) increasing the promotion of forefront technology development, including in high-intensity lasers; (3) enhancing academic capabilities and mid-scale facilities; and (4) broadening remote access to its major experimental and computing facilities.

Concur. NNSA has developed an ICF 10-year facility and infrastructure plan pursuant to language set forth in Senate Report 117-39 which accompanied the *National Defense Authorization Act for Fiscal Year 2022* (P.L. 117-81) as well as in House Report 117-98 which accompanied the *Energy and Water Development and Related Agencies Appropriations Bill, 2022* (P.L. 117-103). This report describes our plans for facility sustainment, upgrades to existing facilities, and potential future facilities. Sustainment activities are in progress for the National Ignition Facility at Lawrence Livermore National Laboratory, the Z Facility at Sandia National Laboratories, and the Omega Facility within the Laboratory for Laser Energetics at the University of Rochester. NNSA is in the planning stages for existing facility upgrades and replacements across its experimental science portfolio.

As a part of our 5-year high level goals for ICF, we plan to mature technology options for next generation laser architectures, which will certainly involve contributions from both the NNSA laboratories and the academic community. We are also exploring opportunities to collaborate within the Department of Energy and interagency partners on advanced laser technology.

OES works closely with Defense Programs' Academic Programs office to support the high energy density science communities through centers of excellence within the Stewardship Science Academic Alliances (SSAA) and grants through the HED Laboratory Plasmas Joint Program within the Office of Science. Academic Programs provides user travel support via the facility access program. Academic Programs is currently considering additional support to ZNetUS to best support the network of pulsed power facilities for academic users.

We will continue to assess facility availability and shot allocation policies to maximize and streamline access to our entire facility portfolio for all users.

Leading Recommendation: To enhance career pathways for high energy density science research at NNSA facilities, the NNSA should (1) broaden its current programs for achieving excellence through diversity, equity, and inclusion while improving workplace climate and (2) develop a strategic plan for balancing security and proliferation concerns with openness and accessibility, such as for collaborators internationally, and with academia and the private sector.

Concur. The recruitment, retention, and just treatment of a workforce representative of our great nation is a high priority for NNSA. NNSA headquarters and laboratory policies consider several procedures and goals to ensure this state; we will look for opportunities to broaden these programs and improve workplace climate. DOE has a strategic plan to strengthen our workforce by implementing steps across the Department that ensure respect for each individual's fundamental rights and needs throughout their careers. Additionally, DOE and NNSA are actively complying with White House guidance for implementing NSPM-33 to provide clear and effective rules for ensuring research security and researcher responsibilities. As part of our implementation of these plans, the most recent Academic Programs' Funding Opportunity Announcements required potential grantees to outline how they plan to address and improve the representation of their communities in their workforce and the fair treatment of those working within their program, using that data to inform the selection process. We look forward to working with the Academies to find further opportunities to lead in this area.

Major Recommendation: The NNSA should work with the academic and national laboratory user community, relevant government agencies, and industry to develop a high-performance computing (HPC) strategy for high energy density science over the next 2 years. This strategy should include benchmarking and the verification and validation of codes, code comparisons, the close integration of simulations using HPC with experiments, co-development of hardware and software for the research community, open-source documentation of codes and experimental results in a standardized open format (e.g., to enhance use and effectiveness of machine learning and artificial intelligence tools), and an industry-relevant implementation plan.

Concur, within security constraints. NNSA HPC strategies consider the needs of their broad user base, which includes the HEDS community. NNSA's Advanced Simulation and Computing (ASC) program published the ASC Computing Strategy[1] in July 2022, which provides an updated approach to the development and procurement of high-performance computing platforms. OES continues to collaborate with ASC on sustained code development and modernization for Hydra, the main code capability supporting HED modeling for the ICF program. ASC provides HPC systems and coordinates with the computing industry, so Hydra optimally uses advanced architectures on experimental design and diagnostic analyses. The ICF program is planning to align the HED scope to the goals outlined in the ASC

[1] *2022 ASC Computing Strategy*, https://asc.llnl.gov/file-download/download/public/3706

strategy, and over the next two years it will prioritize ASC/HED strategic planning and integration to maximize the value of computational and experimental tools for NNSA and academic users.

Major Recommendation: The NNSA and the national laboratories should, in coordination with partner science agencies (e.g., including the Department of Energy's Office of Science and the National Science Foundation), academia, and industry, set expectations for rigorous benchmark experiments that can provide solid foundations for multi-scale high energy density simulations. Particular emphasis should be given to characterizing material properties under extreme and non-equilibrium conditions, including conditions accessible at university- and mid-scale facilities, and develop a new generation of diagnostics that can take advantage of modern technology such as higher repetition rate (e.g., compact light sources) that access a range of time and length scales.

Concur. NNSA agrees with the need for rigorous benchmarking of multi-scale simulations and the pursuit of high-fidelity experiments at higher repetition rate and looks forward to working with our partners to advance these efforts.

Major Recommendation: The inertial confinement fusion community should redouble efforts to focus on the underlying basic science to (1) achieve robust ignition and the maximum yield with optimal efficiency, (2) establish the best uses of laboratory burning plasmas, and (3) help identify the best path for future experimental and computational facilities. In particular, the sustainment of innovation and breakthrough research will require a careful balance between yield-producing and non-ignition experiments. Additionally, the NNSA should work with the relevant agencies (e.g., the Department of Energy's Fusion Energy Sciences and Advanced Research Projects Agency–Energy and the National Science Foundation) and private industry to leverage research in inertial fusion energy and—where possible—partner in research areas of mutual interest.

Concur. Addressing recommendations (1)-(3) are among the NNSA's ICF Program's highest priorities. It achieved ignition on December 5, 2022 at the National Ignition Facility (NIF) and subsequently set a new yield record with a second ignition shot on July 30, 2023. It has achieved one of its key strategic goals for 2023 – a robust and repeatable megajoule (MJ) fusion platform – and will aggressively pursue both higher yields and fusion applications over the coming year. NNSA and Department of Defense partners are actively working to establish the best uses of that and future fusion platforms. Ongoing NNSA strategic planning efforts will identify the best paths for both experimental and computational facilities, building on a recent FY 2022 10-year Facility and Infrastructure plan and FY 2023 delivery of exascale computing capability to Lawrence Livermore National Laboratory. OES is also exploring collaboration opportunities across government, academia, and the private sector to leverage research investments in inertial fusion energy and partner where appropriate.

Recommendation: The NNSA should take steps to enable institutions working on high energy density research to (1) assess the climate; (2) get help from subject-matter experts to make explicit and quantifiable diversity, equity, inclusion, and accessibility (DEIA) goals; and (3) implement and ensure achievement of these DEIA goals.

Concur, maintaining a representative and effective workforce that values each employee by recognizing and addressing their individual needs is a high priority for NNSA. We will continue our efforts to enable all of our partner institutions to set and meet such goals.

Recommendation: The NNSA should support more internships, postdoctoral opportunities, faculty visitorships, and early career programs in high energy density science, coordinating across the NNSA in a manner similar to that supported by the Department of Energy's Office of Science.

Concur. We broadly support continuing to grow the community of early career HED science experts within budget constraints. Currently, NNSA Defense Programs sponsors a broad range of graduate-level fellowships and academic centers, including the DOE NNSA Stewardship Science Graduate Fellowship (SSGF) and the DOE NNSA Laboratory Residency Graduate Fellowship (LRGF). We will evaluate opportunities to further build on our support for postdoctoral and early career programs.

Recommendation: The NNSA should provide explicit support and recognition for national laboratory scientists to increase collaborations, mentorship, and outreach with the fundamental research community, in order to build public excitement and the future workforce. Examples include joint appointments or sabbatical opportunities and travel/lectureship programs that partner with minority-serving institutions and the public at large.

Concur. NNSA's Academic Programs is considering how to support opportunities for laboratory scientists to foster deeper collaborations with academia and will explore the possibility of providing recognition, perhaps through an award, to laboratory scientists that engage with the research community.

Recommendation: The NNSA should periodically assess and, where possible, reduce barriers to university collaborations—for example, by formally recognizing the importance of, and therefore supporting and rewarding, laboratory staff engaged in effective collaborations.

Concur. Promoting university and laboratory collaborations is a priority for NNSA and we will continue to explore ways to deepen our support for effective collaborations.

Recommendation: NNSA laboratories should enforce concrete policies for accountability around intolerable, unacceptable behaviors.

Concur. NNSA agrees that the community cannot tolerate unacceptable behaviors and will consider options for prioritizing accountability within its laboratory and academic management models.

Recommendation: In addition to training Ph.D. scientists, NNSA laboratories should invest in educational (apprenticeship) programs at institutions for training of technicians and technical staff at the bachelor's or master's level, doing so in line with the laboratories' diversity, equity, inclusion, and accessibility goals.

Concur. A new undergraduate training program led by NNSA's largest academic partner will be an important pilot for such efforts; we plan to learn from and build on its success.

Recommendation: NNSA national laboratories should promote collaborations with academia by sharing data related to unclassified research (in consistent data format) and providing open/educational versions of their computational codes.

Concur, within security constraints. In particular, NNSA will consider opportunities for improved data sharing to strengthen its academic collaborations. We are also currently focused on identifying opportunities for providing access to computational codes or simulation results to partners in the inertial fusion energy community. However, given the nature of the NNSA mission and its supporting tools, we will continue to prioritize managing the associated security risks prudently.

Recommendation: The NNSA should collaboratively develop industry-relevant technical roadmaps for critical capabilities in computation, diagnostics, and targets and provide more—and more frequent—funding opportunities for industry to provide these capabilities.

Concur. NNSA will continue to pursue opportunities to deepen industry collaborations and planning. With respect to target development, NNSA primarily partners with General Atomics (GA); we are developing a set of technical priorities to inform research and development efforts. With respect to diagnostic capabilities, NNSA currently collaborates across the National Laboratories, international partners, industry, and academia through the National Diagnostics Working Group to foster technical development[2]. With respect to computation capabilities, NNSA ASC works with all the major leading US HPC vendors (HPE, Dell, IBM and Penguin) as well as component suppliers such as Intel, AMD, NVIDIA and Micron, to develop new generations of technologies for supercomputing platforms. Recently, ASC announced partnerships with Cerebras and Samba Nova. These new projects are focused on understanding computational systems which can support fast modeling and simulation activities blended with the inline use of, or training of, complex machine learning models.

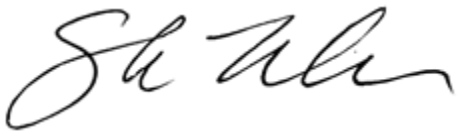
Recommendation: To strengthen its global leadership in high energy density science and address future national needs, the NNSA should increase the promotion of forefront technology development, and in particular take the necessary steps to achieve ultra-high power laser capabilities on par with what is being developed around the world.

Concur, within the constraints of NNSA mission priorities. Ultra-high-power lasers are not among NNSA's highest mission-driven capability gaps. However, we share the Academies' concern in this area and will explore partnerships across the interagency to advance national competitiveness where possible.

Recommendation: To enhance career pathways for high energy density science research at NNSA facilities, the NNSA should promote international collaborations and increase remote access to those facilities.

Concur, within the security constraints of NNSA facilities.

Sincerely,



Dr. Sarah Nelson
Director (Acting), Office of Experimental Sciences
Defense Programs
National Nuclear Security Administration

[2] The National Diagnostic Plan (NDP) for HED Science, S. Ross et al., September 2021(LLNL-TR-827518) - https://www.osti.gov/servlets/purl/1823688