Inertial Confinement Fusion Ignition and High Yield

Overview

The Inertial Confinement Fusion Ignition and High Yield (ICF) program supports the U.S. Department of Energy's (DOE) national security goals by providing scientific understanding and experimental capabilities in high-energy-density (HED) physics for the validation of codes and models necessary to maintain a safe, secure, and effective nuclear weapons stockpile without underground testing. It supports stockpile assessment and certification and the Department's national security mission. Experimental validation of the models used in simulations is essential to having confidence in them. More than 99 percent of the energy from a nuclear weapon is generated in the HED state (pressures greater than 1 Megabar) that occurs once primary criticality is attained. The ICF program operates and conducts experiments in facilities that create these HED conditions. The investments in Inertial Confinement Fusion provide insights and information from experimental conditions that attempt to mimic aspects of nuclear explosions. They provide the experimental basis, in addition to archived data from the underground test program, that gives confidence in the codes and models used to support annual assessments and certifications, plan life extension programs, and resolve Significant Findings Investigations (SFIs). ICF facilities are the principle platforms on which the codes that couple transport processes with hydrodynamics models can be experimentally validated.

These insights and information are directly applicable to assessing the health of our nuclear weapons and making decisions on life extension options for future stockpile weapons. For example, the Stockpile Stewardship Program (SSP) has been developing advanced simulation capabilities to model nuclear weapons with sufficient fidelity to support certification, life-extension programs, and resolve SFIs. Science-based weapons assessments and certification require advanced experimental capabilities to validate simulations of nuclear weapon performance, understand properties of materials that will be used in the future stockpile, and strengthen the complex three-dimensional models developed to understand the boost process occurring in stockpile primaries. The ICF program contributes to these capabilities through the development and use of advanced experimental and theoretical tools and techniques, including state-of-the-art laser and pulsed power facilities for both ignition and weapon relevant non-ignition HED research and advanced simulation codes.

The ICF program supports stockpile stewardship through two principal experimental directions. First, through non-ignition HED physics research, development of diagnostics, and experimental expertise that directly supports the stockpile. Ongoing experiments explore issues in materials science, radiation transport, and hydrodynamics providing fundamental scientific knowledge relevant to nuclear weapons and are testing codes and models that underpin stockpile confidence. Second, the ICF program's goal is to achieve substantial thermonuclear burn and, ultimately, ignition in the laboratory. The demonstration and application of ignition and thermonuclear burn is important to validate models in the most extreme conditions generated in a nuclear explosion that cannot be accessed in the laboratory in any other way, and remains a major goal for the National Nuclear Security Administration (NNSA) and the DOE.

Since the early 1990s, demonstrating ignition in the laboratory has been an essential element of the U.S. Stockpile Stewardship program. From the late 1970s and through the 1980s, a basic question existed as to the possibility of designing and constructing a facility that could create implosion conditions consistent with then code predictions for laboratory ignition. Initial ignition experiments conducted after more than 10 years of National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory construction showed fundamental gaps in our understanding and incompleteness of those code predictions, revealing physics unknowns and technical complexities that require time to study and resolve. The scientific hypotheses that guide today's program of work are aimed at closing those gaps and setting a new path in ICF for demonstrating laboratory fusion ignition and eventually multi megajoule fusion yields. Implosions designed to be more stable have resulted in implosion performance closer to code simulations and close to the onset of alpha-heating. This represents a significant advance in understanding some necessary, but not sufficient, conditions to achieve ignition, with record neutron yields measured during implosions. Further progress will require a better understanding and control of hydrodynamic instabilities and implosion symmetry. It is important to continue to pursue this grand challenge to maintain scientific leadership and credibility while recruiting scientists and engineers who will participate in stockpile stewardship. As much of this research is open and shared, ICF program research provides an avenue for maintaining the quality of relevant science through the broader scientific community.

The Department requests $502,450,000 in FY 2016 for the ICF program, a $10,445,000 (-2 percent) decrease from the FY 2015 Congressional Budget Request.

NNSA continually reviews the planning basis for programs to ensure that budget and resources are aligned with requirements. Prioritizing research capabilities across multiple program elements is done in the context of requirements from the Nuclear Weapons Council (NWC) and the Requirements and Planning Document (RPD), and the25-year Stockpile Stewardship Management Plan (SSMP). Consistent with DOE's Strategic Plan 2014 – 2018, NNSA initiated a workshop, held in June 2014, to develop a 10-year scientific strategic vision for the high energy density sciences in support of the nuclear weapons program. The workshop had more than 150 attendees and addressed both ignition and non-ignition experiments across all national ICF facilities. The strategic vision formed from the workshop is the foundation for the 10-year HED Strategic Plan under development in FY 2015, a resource-informed plan for priority research directions for ignition and non-ignition HED science. The Plan will guide decisions on the program of work and on development of new capabilities in a resource constrained environment. The results of this effort are reflected in this narrative.

The FY 2016 ICF Program continues the strong emphasis on HED weapons experimental support and development of advanced capabilities while continuing a balanced effort in ignition and alternate ignition concepts. Funding for research in support of stockpile science and near-term stockpile needs will continue in the Support of Other Stockpile Programs, leveraging ICF's expertise and capabilities and guided by the 2015 10-year HED Strategic Plan. This leverages ICF's expertise, providing additional support for the HED weapons efforts and NNSA's broader Stockpile Stewardship Program (SSP) needs as outlined in the Predictive Capability Framework (PCF).[a] In FY 2015, there is a plan to review progress toward laboratory ignition and the contributions of non-ignition HED experiments to weapons science and stockpile stewardship. The review will inform decisions on the ICF/HED path to ignition and program balance. Both integrated experiments and focused experiments in indirect drive, direct drive, and magnetically-driven implosion experiments will continue to look at the behavior and physics of ignition targets to improve the confidence in the simulations and to provide feedback to resolve the outstanding physics questions. This is a discovery-driven, rather than schedule-driven, program that will provide more opportunities for comparison with simulations and feedback to resolve the outstanding physics questions.

The increasing demand for shot time on the NIF at Lawrence Livermore National Laboratory (LLNL) for both ignition and non-ignition experiments to support the weapons program requires that its shot rate be increased. In FY 2014, a plan was developed to increase the shot rate and implementation began. By the end of December 2014, 11 of the 20 recommendations were implemented. The NIF demonstrated a significantly improved shot rate in FY 2014, with increasing shot rates each quarter. In FY 2014, 191 shots were executed, with 69 completed in the last quarter. The goal for FY 2015 is to complete 300 shots. Most of the improvement has come from actions taken to increase the time the facility spends taking shots and reducing time for maintenance or installation and commissioning of new capabilities. Completion of the remaining recommendations in FY 2015 and FY 2016 will further improve the shot rate. In FY 2015, NNSA will develop and begin implementation of a 5-year National ICF/HED Diagnostics Plan to optimize development of diagnostics for NNSA's HED facilities. Implementation of the plan will necessitate movement of funds between sites to improve the cost-effectiveness and maximize return on the nation's investment.

The FY 2016 Request supports operations at NNSA's three major HED facilities; the NIF, the Z Facility at Sandia National Laboratories (SNL), and the Omega Laser Facility at University of Rochester's Laboratory for Laser Energetics (LLE), including funding for support of experiments by external users. The three major HED facilities will be operated under their respective governance plans. Emphasis on improving operational efficiencies at all facilities will continue, with prioritization and execution of the most urgent experiments in support of the stockpile.

The FY 2016 budget provides around $79,540,000 for operation and utilization of the Z facility at Sandia National Laboratories (SNL). This includes $44,540,000 within the ICF program and approximately $35,000,000 within the Science program.[b] The ICF budget provides $322,500,000 for the operations of the NIF for all users and the ICF program at LLNL, and $60,500,000 for the operations of the Omega Laser Facility for all users and the ICF program at the University of

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[a] The Predictive Capability Framework (PCF) is described in the *FY 2015 Stockpile Stewardship and Management Plan.*

[b] Does not include Science funding for Capabilities for Nuclear Intelligence at SNL.

Rochester. In FY2016, roughly 8% of NIF use time will be reserved for partnering with academic institutions for science of mutual benefit to NNSA. Given this benefit, operational costs for these experiments are covered by NNSA while much of the experiment's design and analysis are provided by the academic institution in kind.

Highlights of the FY 2016 Budget Request

The FY 2016 ICF program will build upon the accomplishments of the previous years, including: 1) providing key data that reduces uncertainty in our predictions of nuclear weapons performance; 2) safely obtaining data on the properties of high-Z (high atomic weight) materials, including plutonium, under conditions that have not been previously reached in the laboratory on Z Facility at SNL and the NIF at LLNL; 3) fielding platforms at Omega and NIF to measure the complex hydrodynamic behavior of materials that is a potential concern for SFIs; 4) ongoing progress in understanding the issues that are limiting the demonstration of ignition at the NIF, informed by the FY 2015 Review, including energy coupling to the capsule, symmetry, and mix; 5) building upon the indirect drive “high foot” platform that has produced record performance, continuing experiments with alternate ablator materials, and using the record neutron yields for nuclear weapons-related experiments; 6) continuing progress in the development of the direct-drive ignition alternative on Omega and NIF, informed by the FY 2015 Review; 7) building on progress demonstrated in magnetically-driven implosions by performing magnetized liner inertial fusion (MagLIF) experiments, informed by the FY 2015 Review; 8) ongoing implementation of the National Diagnostic Strategy to optimize the cost-effective development of diagnostics for the NNSA’s HED facilities; 9) continued safe operation of NNSA’s major HED facilities, NIF, Omega, and Z, in accordance with their Governance Plans, and 10) continuing improvements in operational efficiency at the NIF through implementing the plan developed in FY 2014. In FY2015, NIF introduced a new materials science platform to study plutonium. These experiments use quantities of plutonium that are within the bounds that define a Radiological Facility.

Major Outyear Priorities and Assumptions

Outyear funding levels for the ICF program total $2,198,371,000 for FY 2017 through FY 2020. The ICF program provides the scientific understanding and experimental capabilities in high-energy density physics that are needed to study matter under extreme conditions and support science-based weapons assessments and certifications to fulfill our national security mission. The ICF Program will balance efforts in HED weapons research with the ongoing investigation of ignition, including alternate ignition concepts. The FY 2015 review of progress toward ignition by the DPAC subcommittee and the program requirements of the evolving stockpile will inform research directions and investment decisions in HED capabilities. Specific investments in new capabilities for alternative ignition platforms will be made in a staged manner based upon requirements-informed prioritization and resource constraints. The development and use of a robust ignition platform remains a high priority, as is performing HED experiments for which ignition is not required. The record neutron yields obtained with the “high foot” platform will be exploited to support program requirements. The 10-year HED Strategic Plan, completed in FY 2015, requires new experimental platform development on NIF, Omega, and Z, in areas such as advanced hydrodynamics and mixing, and radiation flow in complex geometries, extension of materials equation-of-state (EOS) and strength to higher pressures (including high-Z materials such as plutonium). It includes developing new platforms for Outputs and Environments testing. These will require more sophisticated techniques, diagnostics, and simulation capabilities, as well as increasing the number of shots. The improved operational efficiency at the NIF will help meet this increased demand. The outyears budget assumes the funding level for the ICF program will be sufficient to provide the advanced experimental capabilities, including experimental platforms, diagnostics, theoretical tools and techniques that are needed to conduct the experiments and the verify codes needed for stockpile assessment and certification.

Inertial Confinement Fusion Ignition and High Yield
Funding

(Dollars in Thousands)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Inertial Confinement Fusion Ignition and High Yield					
Ignition	80,245	80,005	77,994	73,334	-4,660
Support of Other Stockpile Programs	15,001	14,935	23,598	22,843	-755
Diagnostics, Cryogenics and Experimental Support	59,897	59,483	61,297	58,587	-2,710
Pulsed Power Inertial Confinement Fusion	5,024	5,022	5,024	4,963	-61
Joint Program in High Energy Density Laboratory Plasmas	8,198	8,198	9,100	8,900	-200
Facility Operations and Target Production	345,592	344,751	335,882	333,823	-2,059
Total, Inertial Confinement Fusion Ignition and High Yield	**513,957**	**512,394**	**512,895**	**502,450**	**-10,445**

Outyears for Inertial Confinement Fusion Ignition and High Yield
Funding

(Dollars in Thousands)

	FY 2017 Request	FY 2018 Request	FY 2019 Request	FY 2020 Request
Inertial Confinement Fusion Ignition and High Yield				
Ignition	75,432	77,112	79,032	80,952
Support of Other Stockpile Programs	23,363	23,864	24,414	24,964
Diagnostics, Cryogenics and Experimental Support	68,125	76,800	80,760	84,790
Pulsed Power Inertial Confinement Fusion	4,945	4,945	4,945	4,945
Joint Program in High Energy Density Laboratory Plasmas	9,492	9,865	10,000	10,000
Facility Operations and Target Production	344,053	353,465	358,422	363,686
Total, Inertial Confinement Fusion Ignition and High Yield	**525,410**	**546,051**	**557,573**	**569,337**

Inertial Confinement Fusion Ignition and High Yield
Explanation of Major Changes
(Dollars in Thousands)

	FY 2016 vs FY 2015
Ignition: Decrease in ignition effort consistent with emphasis on priority HED weapons physics experiments and with the 10-year HED strategic plan.	**-4,660**
Support of Other Stockpile Programs: Decrease maintains strong ICF support of weapons physics HED research, consistent with the 10-year HED strategic plan.	**-755**
Diagnostics, Cryogenics, and Experimental Support: Decrease in funding slows pace of advanced diagnostics for both ignition and non-ignition experiments, partially mitigated through implementation of the National Diagnostic Plan.	**-2,710**
Pulsed Power Inertial Confinement Fusion: Slight reduction maintains the effort to advance the science of magnetically-driven implosions.	**-61**
Joint Program in High Energy Density Laboratory Plasmas: Slight reduction maintains basic science research grants that support academic participation in HED physics.	**-200**
Facility Operations and Target Production: Decrease reduces operations at HED facilities and target fabrication for experiments, partially mitigated by improvements in operational efficiencies.	**-2,059**
Total, Inertial Confinement Fusion Ignition and High Yield	**-10,445**

Inertial Confinement Fusion Ignition and High Yield
Ignition

Description

The development of thermonuclear ignition in the laboratory and its use as a platform provides the scientific and technical understanding to address key weapons issues and to validate the codes needed to assess and certify the stockpile in a regime not accessible in any other way. Demonstrating ignition is a major goal for the NNSA and DOE. The Ignition subprogram supports research activities that optimize prospects for achieving ICF ignition on the NIF, the development and applications of robust, burning-plasma platforms, and advanced ignition. Detailed theoretical designs and simulations (in 2- and 3-dimensions) support experiments on NNSA's HED facilities, closely coupled with the Advanced Simulation and Computing (ASC) and the Science programs. The near-term emphasis is on those activities required to develop a detailed physics understanding to improve ignition designs and to demonstrate ignition on the NIF. In the longer-term, this program will develop advanced ignition concepts that may provide advantages over the current indirect-drive ignition platform, such as higher yield and/or gain. Achieving ignition and understanding any limitations to the simulation tools are key parts of meeting DOE's national security goals. The Science programs, Directed Stockpile Work (DSW), and other stockpile program elements rely on the capabilities developed in this subprogram to successfully execute their programs.

FY 2017-FY 2020 Key Milestones

- Development of the first ignition platform to support SSP needs. The ignition platform must be repeatable and sufficiently robust such that the effects of minor changes in design can be clearly identified.
- Use the first ignition platform to support SSP needs, in particular critical experiments requiring burning plasmas and igniting plasmas, in support of the PCF. Demonstrate one or more Advanced Ignition concepts on the NIF to meet requirements of SSP physics applications of ignition.
- Use the high neutron yields of sub-ignition and igniting targets for experiments in support of the PCF.
- Develop an understanding of the interrelated roles of time-dependent symmetry, hydrodynamic instabilities and mix, and laser plasma instabilities and hot electron generation on the performance of ignition target designs.

Ignition

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Ignition $77,794,000	**Ignition $73,334,000**	**Ignition -$4,660,000**
• Conduct Progress Review of all fusion approaches with respect to the program plan defined in FY 2013 and out-year plans for ICF and high yield platforms needs defined in the PCF. • Conduct physics and integrated indirect-drive experiments on NIF to: assess agreement between models and simulation of implosion compression and pressure, to test predictions of hydrodynamic instability and mix, and to quantify the effect of alpha heating in layered capsule implosions. • Conduct physics and integrated experiments with an alternate ablator to compare with plastic capsule ablators. • Continue integrated cryogenic Deuterium-Tritium (DT) implosions on Omega to establish the predictive basis for NIF-equivalent hydro performance. • Conduct polar direct drive experiments to test alternate ablators designed to mitigate hot electron production and to increase hydrodynamic efficiency, and to assess the impact of laser imprinting on shell stability and to study target options for imprint mitigation. • Continue NIF Polar Drive experiments to study crossed beam energy transfer mitigation.	• Conduct experiments to test modeling of hohlraum energy transport and dynamics. • Develop techniques to measure time dependent symmetry and its effect on performance in indirect-drive targets. • Continue integrated cryogenic DT implosions on Omega to establish the predictive basis for NIF-equivalent hydro performance. • Develop an implementation plan for crossed beam energy transfer mitigation. • Develop a working concept to field a layered target for polar direct drive experiments.	• The ignition subprogram budget is decreased $4,660,000 (-6.0%). This is consistent with NNSA's increased emphasis on priority weapons physics research and the 10-year HED Strategic Plan.

Inertial Confinement Fusion Ignition and High Yield
Support of Other Stockpile Programs

Description

High-energy-density (HED) physics/weapon relevant experiments using the ICF program's suite of HED facilities are key contributors to assessing and certifying the stockpile and to meeting DOE's security goals. This subprogram leverages the experience of the ICF-funded researchers to support NNSA's SSP nuclear weapons-relevant HED physics needs, developing and integrating the experimental infrastructure and capabilities required to execute experiments on ICF facilities. This includes the development of laser, target, and diagnostic capabilities. The ICF's HED facilities are used to perform experiments where ignition and burn are not the focus – for example, material properties, hydrodynamics, and radiation transport. It includes platform and diagnostic development on NIF, Omega, Z and supporting facilities. The understanding gained and capabilities developed validate the codes used to certify the stockpile. The Science program, DSW, and other stockpile program elements rely on the capabilities developed in this subprogram to successfully execute their programs. Ongoing experiments test codes and models that underpin stockpile confidence and provide fundamental scientific knowledge relevant to nuclear weapons, supporting stockpile assessments and certifications. The subprogram develops and uses HED/ICF experimental capabilities and personnel to resolve important stockpile questions in cooperation with other components of the Office of Research, Development, Test, and Evaluation. NNSA is completing a 10-year HED Strategic Plan in FY 2015, focused on four topical areas: Nuclear (includes materials properties, hydrodynamics, and nuclear physics), Thermonuclear (includes mix, burn, plasma properties, and application of capsule output), Radiation (includes radiation transport and opacities), and Output & Effects (includes weapon output, weapon effects, and forensics). The strategic plan is reflected in this narrative. Work within this subprogram is performed in collaboration with the Science program.

FY 2017-FY 2020 Key Milestones

- In FY 2017, demonstrate a deuterium-tritium burn platform that meets the needs of the SSP.
- Continue support for experiments and platforms identified in the 10-year HED Strategic Plan.
- Continue to develop platforms for initial experiments to support validation of opacity models
- Demonstrate platform that can acquire high pressure materials data.
- By FY 2018, complete initial set of experiments identified in the 10-year HED Strategic Plan.

Support of Other Stockpile Programs

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Support of Other Stockpile Programs $23,598,000	**Support of Other Stockpile Programs $22,843,000**	**Support of Other Stockpile Programs -$755,000**
• Provide support for experiments and non-ignition HED data using NIF, Omega, Z, and other facilities to support NNSA's SSP needs. • Provide support for experiments, acquire high-pressure material data and develop platforms to validate models of secondary performance and to validate opacity models. • Develop a predictive capability for complex hydrodynamics and to determine aspects of a predictive mix model. • Continue to develop and use platforms that can acquire high-pressure materials data. Conduct experiments on high-Z (high atomic weight) materials, including plutonium, on Z and NIF. Conduct the SSP-relevant high-Z material dynamic diffractions experiments at high strain rate and high pressure on NIF. • Obtain first high-energy backlit images of the evolution of complex hydrodynamics experiments. • Complete first series of turbulence experiments for model validation. • Start first radiation transport experiment in complex SSP-relevant geometry. • Provide platform and diagnostic capabilities for validating the impact of surety technologies in the future stockpile. • Complete the 10-year HED Strategic Plan that supports the requirements of the SSMP.	• Measure the effect of shell mixing on deuterium tritium burn. • Provide support for experiments and non-ignition HED data using NIF, Omega, Z, and other facilities to support NNSA's SSP needs. Continue to develop and use platforms that can acquire high-pressure materials data that supports the PCF. Provide data in support of PCF pegposts, including a materials data set on plutonium with the diffraction platform on NIF. • With the Science program, continue implementation of 10-year HED Strategic Plan to support the requirements of the SSMP, including demonstrating an HED-coupled hydro-burn platform. • Validate models relevant to thermonuclear burn. • Provide platform and diagnostic capabilities for validating the impact of surety technologies in the future stockpile.	• The Support of Other Stockpile subprogram's FY 2016 budget request is $22,843,000, a decrease of $755,000 (-3.2%). The decrease slows experimental efforts while maintaining strong ICF support for HED weapons research, consistent with the 10-year HED Strategic Plan.

Inertial Confinement Fusion Ignition and High Yield
Diagnostics, Cryogenics, and Experimental Support

Description

Science-based weapons assessments and certification require advanced experimental capabilities that can create and study matter under extreme conditions that approach the HED environments found in a nuclear explosion. This subprogram develops the specialized technologies needed for ignition and HED experiments on ICF facilities, diagnostics, cryogenic systems, and user optics. It includes the design and engineering of a complex array of diagnostic and measurement systems, including advanced diagnostics that operate in the harsh ignition environment, and the associated information technology subsystems needed for data acquisition, storage, retrieval, visualization, and analysis. The data generated by these diagnostics provides key information required for HED physics experiments. This subprogram develops and deploys user optics to meet the needs of a broad range of experiments for national security applications and for ICF, HED, and fundamental science applications. It provides key capabilities required for experiments to study matter under extreme conditions at the HED facilities. The development of advanced diagnostics that operate in the harsh weapon-related physics environment is required to use ignition as a tool to support stockpile certification through verification of codes. Major activities in this subprogram in FY 2016 include the implementation of a National ICF/HED Diagnostics Plan to cost-effectively develop the highest priority diagnostics to meet the program's needs.

FY 2017-FY 2020 Key Milestones

- Continue efforts from FY 2015 to develop and support diagnostic capabilities, cryogenic systems, and user optics at NIF and Omega, at a pace commensurate with facility operations.
- Engineer a polar-drive target insertion cryostat for the NIF.
- Continue efforts on the NIF advanced diagnostic suite as defined in the FY 2016 Diagnostics Plan, including installing some diagnostics that can operate in the harsh ignition environment. Examples include a mirrored gated x-ray detector and a high resolution gamma ray diagnostic.
- Continue development, testing, and deployment of advanced diagnostics on NIF, Omega, and Z.
- In FY 2017, complete NIF advanced diagnostics suite defined in FY 2014.

Diagnostics, Cryogenics, and Experimental Support

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Diagnostics, Cryogenics and Experimental Support $61,297,000	**Diagnostics, Cryogenics and Experimental Support $58,587,000**	**Diagnostics, Cryogenics and Experimental Support -$2,710,000**
• Continue efforts from FY 2014 to develop and support diagnostic capabilities, cryogenic systems, and user optics at NIF and Omega, at a pace commensurate with facility operations. • Continue development and testing of advanced diagnostics on NIF, Omega, and Z, including: development of a fifth-harmonic probe beam and the Compton gamma spectrometer on NIF, completion of a high resolution soft x-ray spectrometer for NIF, deploying a gated Kirkpatrick-Baez x-ray imager on OMEGA and an ultrahigh resolution x-ray spectrometer on the OMEGA EP Laser, and the magnetic recoil spectrometer, gamma reaction and neutron burn history diagnostics for Z. • Develop and implement a 5-year National ICF/HED Diagnostics Plan that identifies gaps in capabilities, prioritizes diagnostics for development and implements the most cost-effective approach for research, development, testing of new diagnostics.	• Continue efforts from FY 2015 to develop and support diagnostic capabilities, cryogenic systems, and user optics at NIF, at a pace commensurate with facility operations. • Continue development and testing of advanced diagnostics on NIF, Omega, and Z, including: extending x-ray spectrometer capability to 10-20 kiloelectronVolts (keV) on NIF, developing time-resolved x-ray diffraction diagnostics and higher photon energy x-ray imaging for NIF, Omega, and Z, design of a fifth harmonic probe beam for OMEGA, develop higher time-resolution gamma spectrometer and a time-dependent neutron spectrometer for NIF, ongoing improvements to the beamlet laser on Z. • Continue implementation of the National ICF/HED Diagnostics Plan.	• The Diagnostics, Cryogenics, and Experimental Support subprogram's FY 2016 budget request is $58,587,000, a decrease of $2,710,000 (-4.4%). The decrease in funding slows development of advanced diagnostics for both ignition and non-ignition experiments, with balancing to reflect investments identified in the National Diagnostics Plan.

Inertial Confinement Fusion Ignition and High Yield
Pulsed Power Inertial Confinement Fusion

Description

The Pulsed Power Inertial Confinement Fusion subprogram funds computational target design, experiments, and experimental infrastructure to assess pulsed power to achieve thermonuclear fusion in the laboratory. This subprogram's technical effort advances the science of magnetically-driven implosions as a means to achieving higher energy densities for SSP applications and as a promising path to achieving nuclear weapons relevant physics environments and high fusion yield. A mixture of focused and integrated experiments will be conducted to address key physics uncertainties and to improve the design of the target for the Magnetized Liner Inertial Fusion (MagLIF) approach to fusion ignition. Specific activities include performing Z experiments and relevant focused experiments on Omega and NIF, designing and building targets, improving simulation tools, and developing the experimental infrastructure (diagnostics and capabilities) needed to study advanced approaches to ICF. An objective is to determine the requirements for an advanced pulsed power driver that would achieve robust ignition and single-shot high fusion yield. The subprogram provides an ignition alternative that has potential to provide significantly higher yields than will be possible on the NIF and supports the assessment of pulsed power as a means to achieve thermonuclear fusion in the laboratory, including computational target design, experiments, and experimental infrastructure. It maintains the level of excellence in the technical staff at Z through challenging work that builds competencies critical to the SSP and helps avoid technological surprise.

FY 2017-FY 2020 Key Milestones

- Complete scaling study of MagLIF concept exploring sensitivity to laser energy and magnetic field strength.
- Perform optimized magnetized liner inertial fusion experiment at Z Facility.
- Assess the stagnation dynamics of MagLIF target experiments and compare with simulations.
- Evaluate fusion performance and stagnation plasma parameters at enhanced drive conditions using cryogenic fuel and compare results with simulations.
- Define requirements for and perform scoping studies of a pulsed power facility that can demonstrate robust ignition and high fusion yield.

Pulsed Power Inertial Confinement Fusion

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Pulsed Power Inertial Confinement Fusion $5,024,000	**Pulsed Power Inertial Confinement Fusion $4,963,000**	**Pulsed Power Inertial Confinement Fusion -$61,000**
• Review progress of all fusion approaches with respect to the program plan defined at end of FY 2013 and out-year plans for ICF and high yield platforms. • Conduct integrated fusion (MagLIF) target experiments with increased laser energy and increased magnetic fields and begin scaling study. • Perform optimized classified fusion experiments on the Z Facility. • Compare accumulated data from magnetically-driven fusion experiments on Z with 3-D radiation magnetohydrodynamic simulations. • Evaluate fusion performance and stagnation plasma parameters at enhanced drive conditions and compare results with simulations.	• Review initial MagLIF performance over a range of optimized parameters, compare against goals, and identify most promising avenues of future research. • Evaluate, through small scale and Z facility experiments, the mechanism by which Magneto Rayleigh Taylor instabilities are seeded in magnetically driven liner implosions. • Document results of programs of laser heating experiments relevant to MagLIF (e.g., on Omega-EP, Z-Beamlet). Programs will include focused experiments on understanding the relevant physics (e.g., laser propagation in magnetized gasses) and optimization experiments aimed at increasing coupling of laser energy to deuterium fuel. • Assess, based on validated 2- and 3-dimensional simulations, magnetically driven target designs that could obtain fusion ignition on plausible next step pulsed power facilities.	• The Pulsed Power ICF subprogram's FY 2016 budget request is $4,963,000, a decrease of $61,000 (-1.2%). The slight decrease in funding slows the effort, but maintains support to advance the science of magnetically-driven implosions.

Inertial Confinement Fusion Ignition and High Yield
Joint Program in High Energy Density Laboratory Plasmas

Description

The Joint Program in High-Energy Density Laboratory Plasmas (HEDLP) supports DOE's mission by developing and maintaining a cadre of qualified researchers to support the SSP. It is a joint program with the DOE's Office of Science to support basic HEDP research that strengthens the Science, Technology, and Engineering base. This subprogram provides support for external users at the Omega Laser Facility through the National Laser Users' Facility (NLUF) Program and a joint solicitation with the Office of Science for HEDLP research to be performed at universities and DOE laboratories. It includes some of the HED-related Stockpile Stewardship Academic Alliances funding and other ICF-funded university programs. It funds academic programs to steward the study of laboratory HED plasma physics, maintain a cadre of qualified HED researchers and ongoing development of the next generation of scientists to provide expertise in HED today and qualified stockpile stewards for the future.

FY 2017-FY 2020 Key Milestones

- Continue activities from FY 2015 supporting research grants and cooperative agreements to fund individual investigator and research center activities.

Joint Program in High Energy Density Laboratory Plasmas

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Joint Program in High Energy Density Laboratory Plasmas $9,100,000	**Joint Program in High Energy Density Laboratory Plasmas $8,900,000**	**Joint Program in High Energy Density Laboratory Plasmas -$200,000**
• Continued support of High Energy Density Laboratory Plasma research through solicitations and awards to fund individual investigator and research centers activities. • Award grants from the FY 2014 Financial Opportunity Announcement for the National Laser Users' Facility (NLUF) Program.	• Continue research activities from FY 2015 in HED plasma physics.	• The Joint Program in High Energy Density Laboratory Plasmas subprogram's FY 2016 budget request is $8,900,000, a decrease of $200,000 (-2.2%), modestly reducing support for grants.

Inertial Confinement Fusion Ignition and High Yield
Facility Operations and Target Production

Description

This subprogram provides infrastructure and operations support for the ICF HED facilities that allow the ICF and Science programs to conduct the experiments needed to meet stockpile assessment and certification needs and broader goals of the SSP. It funds the experimental operations of NIF, Omega, and Z, to support ICF and Science subprogram's research to meet the stockpile assessment and certification needs. This subprogram supports fabrication of the very sophisticated targets required for related weapons physics experiments, as well as operation of the Trident facility at LANL, the ICF program including external reviews, and users' meetings such as the Omega Laser Facility Users Group and the NIF Users Group. Over half of the ICF budget supports experiments and operations at the ICF facilities, all of which will continue to be operated safely and securely. Efforts began in FY 2014 to identify and implement actions to increase the shot rate at the NIF. By the end of FY 2014, 11 of 20 recommendations described in the 120 day study of NIF operations were implemented; and changes to date have resulted in significantly improved shot rates.

FY 2017-FY 2020 Key Milestones

- Safely and efficiently operate HED facilities to support the needs of the SSP.
- Continued improvements in operational efficiency at all facilities and in target fabrication.
- Demonstrate Linear Transform Driver (LTD) module prototypes.
- Conduct annual assessment of infrastructure and mission needs and recommend following fiscal year investments across all HED facilities.

Facility Operations and Target Production

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Facility Operations and Target Production $335,882,000	**Facility Operations and Target Production $333,823,000**	**Facility Operations and Target Production -$2,059,000**
• Continue operations at NIF, Omega, Z, and Trident facilities in support of stockpile stewardship experiments, basic science users, and other national security users. Additional funds for Z requested in the Science budget. • Operate NIF, Omega, Z, and Trident in a safe, secure, and efficient manner in accordance with their governance plans. • Continue to implement the recommendations of the 120-Day Study on Improving Efficiency at NIF. • Complete installation of the high-contrast front-end for NIF-ARC. • Conduct annual assessment of infrastructure and mission needs and recommend following fiscal year investments across all HED facilities.	• Continue activities from FY 2015, with similar level of facility operations at NIF, Omega, Z, and Trident. Continued strong emphasis on highest priority experiments in support of the stockpile and on improving operational efficiencies. • Continue improvements in efficiency at NIF through implementation of final recommendations from the 120-Day Study.	• The Facility Operations and Target Production subprogram's FY 2016 budget request is $333,823,000, a decrease of $2,059,000 (-0.6%). The reduction in funding for operations is partially mitigated by recent improvements in operational efficiencies.

Inertial Confinement Fusion and High Yield Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
Key Extreme Experiments - Cumulative percentage of progress towards achievement of key extreme experimental condition of matter needed for predictive capability for nuclear weapons performance.							
Target	90% of progress (cumulative)	100% of progress (cumulative)	N/A	N/A	N/A	N/A	N/A
Result	90						
Endpoint Target	By the end of FY 2015, achieve temperature and pressure conditions in the laboratory relevant to weapons' primaries. This activity is performed in collaboration with the Science program within the Office of Research and Development.						
High Energy Density Physics Research - Cumulative percentage of progress towards completion of the high energy density physics research needed to support the nuclear weapons program as embodied in the Predictive Capability Framework (PCF).							
Target	N/A	10% of progress (cumulative)	20% of progress (cumulative)	30% of progress (cumulative)	40% of progress (cumulative)	50% of progress (cumulative)	60% of progress (cumulative)
Result	N/A						
Endpoint Target	By FY 2024, complete the ICF Program activities needed to complete the PCF pegposts, including demonstrating advanced burning plasma concepts that improve predictive capabilities and the application of physics for achieving ignition. These activities are performed in collaboration with the Science program within the Office of Research and Development.						

Note: NNSA replaced two ICF program measures, Advanced Ignition Demonstration and Application of Ignition, with a new single measure, High Energy Density Physics Research. The new measure reflects the recent rebalancing of the program to support both ignition and non-ignition SSP efforts and provides a better determination of relevant mission accomplishments for the ICF program.

Inertial Confinement Fusion Ignition and High Yield
Capital Summary

(Dollars in Thousands)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Capital Operating Expenses Summary (including (Major Items of Equipment (MIE)							
Capital Equipment >$500K (including MIE)	17,002	10,608	2,085	2,085	2,131	2,178	+47
Plant Projects (GPP) (<$10M)	0	0	0	0	0	0	0
Total, Capital Operating Expenses	**17,002**	**10,608**	**2,085**	**2,085**	**2,131**	**2,178**	**+47**
Capital Equipment > $500K (including MIE)							
Total Non-MIE Capital Equipment (>$500K)	17,002	10,608	2,085	2,085	2,131	2,178	+47
Total, Capital Equipment (including MIE)	**17,002**	**10,608**	**2,085**	**2,085**	**2,131**	**2,178**	**+47**
Plant Projects (GPP and IGPP) (Total Estimated Cost (TEC) <$10M)							
Total Plant Projects (GPP) (Total Estimated Cost (TEC) <$5M)	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total, Plant Projects (GPP) (Total Estimated Cost (TEC) <$10M)	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total, Capital Summary	**17,002**	**10,608**	**2,085**	**2,085**	**2,131**	**2,178**	**+47**

Outyears for Inertial Confinement Fusion Ignition and High Yield

	(Dollars in Thousands)			
	FY 2017 Request	FY 2018 Request	FY 2019 Request	FY 2020 Request
Capital Operating Expenses Summary (including (Major Items of Equipment (MIE)				
Capital Equipment >$500K (including MIE)	2,226	2,275	2,325	+2,376
Plant Projects (GPP) (<$10M)	0	0	0	0
Total, Capital Operating Expenses	**2,226**	**2,275**	**2,325**	**+2,376**
Capital Equipment > $500K (including MIE)				
Total Non-MIE Capital Equipment (>$500K)	2,226	2,275	2,325	+2,376
Total, Capital Equipment (including MIE)	**2,226**	**2,275**	**2,325**	**+2,376**
Plant Projects (GPP) (Total Estimated Cost (TEC) <$10M)				
Total Plant Projects (GPP) (Total Estimated Cost (TEC) <$5M)	0	0	0	0
Total, Plant Projects (GPP) (Total Estimated Cost (TEC) <$10M)	**0**	**0**	**0**	**0**
Total, Capital Summary	**2,226**	**2,275**	**2,325**	**+2,376**