



# National Ignition Facility

**ML Morrison**



## **National Ignition Facility:**

**The National Ignition Facility** Jim Wells, Gary Boss, 2000-12 The Univ of CA under contract to the DoE to operate Lawrence Livermore Nat Lab is building the Nat Ignition Facility DoE considers the Nat Ignition Facility an essential component of its Stockpile Stewardship Program which is responsible for ensuring the safety documents the reasons for them assesses the effects of the Nat Ignition Facility's cost schedule on other weapons programs Tables *The National Ignition Facility (NIF) and the National Ignition Campaign (NIC)*. ,2009 The National Ignition Facility NIF the world's largest and most powerful laser system for inertial confinement fusion ICF and experiments studying high energy density HED science is now operational at Lawrence Livermore National Laboratory LLNL NIF construction was certified by the Department of Energy as complete on March 27 2009 NIF a 192 beam Nd glass laser facility will ultimately produce 1.8 MJ 500 TW of 351 nm third harmonic ultraviolet light On March 10 2009 total 192 beam energy of 1.1 MJ was demonstrated this is approximately 30 times more energy than ever produced in an ICF laser system The principal goal of NIF is to achieve ignition of a deuterium tritium DT fuel capsule and provide access to HED physics regimes needed for experiments related to national security fusion energy and broader frontier scientific exploration NIF experiments in support of indirect drive ignition began in August 2009 These first experiments represent the next phase of the National Ignition Campaign NIC The NIC is a national effort to achieve fusion ignition and is coordinated through a detailed execution plan that includes the science technology and equipment Equipment required for ignition experiments includes diagnostics a cryogenic target manipulator and user optics Participants in this effort include LLNL General Atomics GA Los Alamos National Laboratory LANL Sandia National Laboratory SNL and the University of Rochester Laboratory for Energetics LLE The primary goal for NIC is to have all of the equipment operational integrated into the facility and ready to begin a credible ignition campaign in 2010 With NIF now operational the long sought goal of achieving self sustained nuclear fusion and energy gain in the laboratory is much closer to realization Successful demonstration of ignition and net energy gain on NIF will be a major step towards demonstrating the feasibility of Inertial Fusion Energy IFE and will likely focus the world's attention on the possibility of an ICF energy option NIF experiments to demonstrate ignition and gain will use central hot spot CHS ignition where a spherical fuel capsule is simultaneously compressed and ignited The scientific basis for CHS has been intensively developed Achieving ignition with CHS will open the door for other advanced concepts such as the use of high yield pulses of visible wavelength rather than ultraviolet and Fast Ignition concepts Moreover NIF will have important scientific applications in such diverse fields as astrophysics nuclear physics and materials science The NIC will develop the full set of capabilities required to operate NIF as a major national and international user facility A solicitation for NIF frontier science experiments is planned for summer 2009 This paper summarizes the design performance and status of NIF and plans for the NIF ignition experimental program A brief summary of the overall NIF experimental program is also presented **The National**

**Ignition Facility and the Golden Age of High Energy Density Science** ,2007 The National Ignition Facility NIF is a 192 beam Nd glass laser facility being constructed at the Lawrence Livermore National Laboratory LLNL to conduct research in inertial confinement fusion ICF and high energy density HED science When completed NIF will produce 1.8 MJ 500 TW of ultraviolet light making it the world's largest and highest energy laser system The NIF is poised to become the world's preeminent facility for conducting ICF and fusion energy research and for studying matter at extreme densities and temperatures

*IGNITION AND FRONTIER SCIENCE ON THE NATIONAL IGNITION FACILITY.* ,2009 The National Ignition Facility NIF the world's largest and most powerful laser system for inertial confinement fusion ICF and experiments studying high energy density HED science is now operational at Lawrence Livermore National Laboratory LLNL The NIF construction Project was certified by the Department of Energy as complete on March 30 2009 NIF a 192 beam Nd glass laser facility will produce 1.8 MJ 500 TW of light at the third harmonic ultraviolet light of 351 nm On March 10 2009 a total 192 beam energy of 1.1 MJ was demonstrated this is approximately 30 times more energy than ever produced in an ICF laser system The principal goal of NIF is to achieve ignition of a deuterium tritium DT fuel capsule and provide access to HED physics regimes needed for experiments related to national security fusion energy and for broader frontier scientific exploration NIF experiments in support of indirect drive ignition will begin in FY2009 These first experiments represent the next phase of the National Ignition Campaign NIC The NIC is a 1.7 billion dollar national effort to achieve fusion ignition and is coordinated through a detailed execution plan that includes the science technology and equipment Equipment required for ignition experiments include diagnostics cryogenic target manipulator and user optics Participants in this effort include LLNL General Atomics GA Los Alamos National Laboratory LANL Sandia National Laboratory SNL and the University of Rochester Laboratory for Energetics LLE The primary goal for NIC is to have all of the equipment operational and integrated into the facility and be ready to begin a credible ignition campaign in 2010 With NIF now operational the long sought goal of achieving self sustained nuclear fusion and energy gain in the laboratory is much closer to realization Successful demonstration of ignition and net energy gain on NIF will be a major step towards demonstrating the feasibility of Inertial Fusion Energy IFE and will likely focus the world's attention on the possibility of an ICF energy option NIF experiments to demonstrate ignition and gain will use central hot spot CHS ignition where a spherical fuel capsule is simultaneously compressed and ignited The scientific basis for CHS has been intensively developed and has high probability of success Achieving ignition with CHS will open the door for other advanced concepts such as the use of high yield pulses of visible wavelength rather than ultraviolet and Fast Ignition concepts Moreover NIF will have important scientific applications in such diverse fields as astrophysics nuclear physics and materials science The NIC will develop the full set of capabilities required to operate NIF as a major national and international user facility A solicitation for NIF frontier science experiments to be conducted by the academic community is planned for summer 2009 This paper summarizes the design performance and

status of NIF experimental plans for NIC and will present a brief discussion of the unparalleled opportunities to explore frontier basic science that will be available on the NIF

*The National Ignition Facility*, 2004 The National Ignition Facility NIF at Lawrence Livermore National Laboratory is a stadium sized facility that when completed in 2008 will contain a 192 beam 1.8 Megajoule 500 Terawatt ultraviolet laser system together with a 10 meter diameter target chamber and room for 100 diagnostics NIF is the world's largest and most energetic laser experimental system and will provide a scientific center to study inertial confinement fusion and matter at extreme energy densities and pressures NIF's energetic laser beams will compress fusion targets to conditions required for thermonuclear burn liberating more energy than required to initiate the fusion reactions Other NIF experiments will study physical processes at temperatures approaching 10<sup>8</sup> K and 10<sup>11</sup> bar conditions that exist naturally only in the interior of stars and planets NIF has completed the first phases of its laser commissioning program The first four beams of NIF have generated 106 kilojoules in 23 ns pulses of infrared light and over 16 kJ in 3.5 ns pulses at the third harmonic 351 nm NIF's target experimental systems are being commissioned and experiments have begun This paper provides a detailed look the NIF laser systems laser and optical performance and results from recent laser commissioning shots We follow this with a discussion of NIF's high energy density and inertial fusion experimental capabilities the first experiments on NIF and plans for future capabilities of this unique facility

**Take a Tour of the Target Bay at the National Ignition Facility (360).**, 2017 The National Ignition Facility of Lawrence Livermore National Laboratory is the world's largest and most energetic laser system The Target Bay contains NIF's 192 laser beams

**The National Ignition Facility**, 2004 The National Ignition Facility NIF at Lawrence Livermore National Laboratory when completed in 2008 will contain a 192 beam 1.8 Megajoule 500 Terawatt ultraviolet laser system together with a 10 meter diameter target chamber and room for 100 diagnostics NIF is housed in a 26 000 square meter environmentally controlled building and is the world's largest and most energetic laser experimental system NIF provides a scientific center for the study of inertial confinement fusion and the physics of matter at extreme energy densities and pressures NIF's energetic laser beams will compress fusion targets to conditions required for thermonuclear burn liberating more energy than required to initiate the fusion reactions Other NIF experiments will study physical processes at temperatures approaching 10<sup>8</sup> K and 10<sup>11</sup> bar conditions that exist naturally only in the interior of stars and planets NIF is currently configured with four laser beams activated in late 2002 These beams are being regularly used for laser performance and physics experiments and to date nearly 250 system shots have been conducted NIF's laser beams have generated 106 kilojoules in 23 ns pulses of infrared light and over 16 kJ in 3.5 ns pulses at the third harmonic 351 nm A number of target experimental systems are being commissioned in support of experimental campaigns This paper provides a detailed look the NIF laser systems laser and optical performance and results from laser commissioning shots We also discuss NIF's high energy density and inertial fusion experimental capabilities the first experiments on NIF and plans for

future capabilities of this unique facility      *Advances in Inertial Confinement Fusion at the National Ignition Facility (NIF)*. ,2009 The 192 beam National Ignition Facility NIF at the Lawrence Livermore National Laboratory LLNL in Livermore CA is now operational and conducting experiments NIF the flagship facility of the U S Inertial Confinement Fusion ICF Program will achieve high energy density conditions never previously obtained in the laboratory temperatures over 100 million K densities of 1 000 g cm<sup>3</sup> and pressures exceeding 100 billion atmospheres Such conditions exist naturally only in the interiors of the stars and during thermonuclear burn Demonstration of ignition and thermonuclear burn in the laboratory is a major NIF goal To date the NIF laser has demonstrated all pulse shape beam quality energy and other specifications required to meet the ignition challenge On March 10 2009 the NIF laser delivered 1.1 MJ of ultraviolet laser energy to target chamber center approximately 30 times more energy than any previous facility The ignition program at NIF is the National Ignition Campaign NIC a national collaboration for ignition experimentation with participation from General Atomics LLNL Los Alamos National Laboratory LANL Sandia National Laboratories SNL and the University of Rochester Laboratory for Laser Energetics LLE The achievement of ignition at NIF will demonstrate the scientific feasibility of ICF and focus worldwide attention on fusion as a viable energy option A particular energy concept under investigation is the LIFE Laser Inertial Fusion Energy scheme The LIFE engine is inherently safe minimizes proliferation concerns associated with the nuclear fuel cycle and can provide a sustainable carbon free energy generation solution in the 21st century This talk will describe NIF and its potential as a user facility and an experimental platform for high energy density science NIC and the LIFE approach for clean sustainable energy      **The National Ignition Facility and the Path to Fusion Energy** ,2011 The National Ignition Facility NIF is operational and conducting experiments at the Lawrence Livermore National Laboratory LLNL The NIF is the world's largest and most energetic laser experimental facility with 192 beams capable of delivering 1.8 megajoules of 500 terawatt ultraviolet laser energy over 60 times more energy than any previous laser system The NIF can create temperatures of more than 100 million degrees and pressures more than 100 billion times Earth's atmospheric pressure These conditions similar to those at the center of the sun have never been created in the laboratory and will allow scientists to probe the physics of planetary interiors supernovae black holes and other phenomena The NIF's laser beams are designed to compress fusion targets to the conditions required for thermonuclear burn liberating more energy than is required to initiate the fusion reactions Experiments on the NIF are focusing on demonstrating fusion ignition and burn via inertial confinement fusion ICF The ignition program is conducted via the National Ignition Campaign NIC a partnership among LLNL Los Alamos National Laboratory Sandia National Laboratories University of Rochester Laboratory for Laser Energetics and General Atomics The NIC program has also established collaborations with the Atomic Weapons Establishment in the United Kingdom Commissariat à l'Energie Atomique in France Massachusetts Institute of Technology Lawrence Berkeley National Laboratory and many others Ignition experiments have begun that form the basis of the overall NIF strategy for

achieving ignition Accomplishing this goal will demonstrate the feasibility of fusion as a source of limitless clean energy for the future This paper discusses the current status of the NIC the experimental steps needed toward achieving ignition and the steps required to demonstrate and enable the delivery of fusion energy as a viable carbon free energy source *M - Pk* ,

**The National Ignition Facility** ,2011 The National Ignition Facility NIF at the Lawrence Livermore National Laboratory LLNL in Livermore CA is a Nd Glass laser facility capable of producing 1.8 MJ and 500 TW of ultraviolet light This world's most energetic laser system is now operational with the goals of achieving thermonuclear burn in the laboratory and exploring the behavior of matter at extreme temperatures and energy densities By concentrating the energy from its 192 extremely energetic laser beams into a mm<sup>3</sup> sized target NIF can produce temperatures above 100 million K densities of 1000 g cm<sup>3</sup> and pressures 100 billion times atmospheric pressure conditions that have never been created in a laboratory and emulate those in the interiors of planetary and stellar environments On September 29 2010 NIF performed the first integrated ignition experiment which demonstrated the successful coordination of the laser the cryogenic target system the array of diagnostics and the infrastructure required for ignition Many more experiments have been completed since In light of this strong progress the U S and the international communities are examining the implication of achieving ignition on NIF for inertial fusion energy IFE A laser based IFE power plant will require a repetition rate of 10-20 Hz and a 10% electrical optical efficiency laser as well as further advances in large scale target fabrication target injection and tracking and other supporting technologies These capabilities could lead to a prototype IFE demonstration plant in 10 to 15 years LLNL in partnership with other institutions is developing a Laser Inertial Fusion Energy LIFE baseline design and examining various technology choices for LIFE power plant This paper will describe the unprecedented experimental capabilities of the NIF the results achieved so far on the path toward ignition the start of fundamental science experiments and plans to transition NIF to an international user facility providing access to researchers around the world The paper will conclude with a discussion of LIFE its development path and potential to enable a carbon free clean energy future Preparing for Ignition

Experiments on the National Ignition Facility ,2007 The National Ignition Facility NIF is a 192 beam Nd glass laser facility presently under construction at Lawrence Livermore National Laboratory LLNL for performing ignition experiments for inertial confinement fusion ICF and experiments studying high energy density HED science NIF will produce 1.8 MJ 500 TW of ultraviolet light  $\lambda = 351$  nm making it the world's largest and most powerful laser system NIF will be the world's preeminent facility for the study of matter at extreme temperatures and densities for producing and developing ICF The ignition studies will be an essential step in developing inertial fusion energy IFE the NIF Project is over 93% complete and scheduled for completion in 2009 Experiments using one beam have demonstrated that NIF can meet all of its performance goals A detailed plan called the National Ignition Campaign NIC has been developed to begin ignition experiments in 2010 The plan includes the target physics and the equipment such as diagnostics cryogenic target manipulator and user optics

required for the ignition experiment Target designs have been developed that calculate to ignite at energy as low as 1 MJ Plans are under way to make NIF a national user facility for experiments on HED physics and nuclear science including experiments relevant to the development of IFE

Assuring Safety in the National Ignition Facility, 1998 The National Ignition Facility NIF is a US Department of Energy inertial confinement laser fusion facility currently under construction at the Lawrence Livermore National Laboratory LLNL The NIF mission is to achieve inertial confinement fusion ICF ignition access physical conditions in matter of interest to nuclear weapons effects testing contribute to the development of inertial fusion for electrical power production and to support basic science and technology

*The Ignition Target for the National Ignition Facility*, 2007 The National Ignition Facility NIF is a 192 beam Nd glass laser facility presently under construction at Lawrence Livermore National Laboratory LLNL for performing inertial confinement fusion ICF and experiments studying high energy density HED science When completed in 2009 NIF will be able to produce 1.8 MJ 500 TW of ultraviolet light for target experiments that will create conditions of extreme temperatures 10<sup>8</sup> K pressures 10 GBar and matter densities 100 g cm<sup>3</sup> A detailed program called the National Ignition Campaign NIC has been developed to enable ignition experiments in 2010 with the goal of producing fusion ignition and burn of a deuterium tritium DT fuel mixture in millimeter scale target capsules The first of the target experiments leading up to these ignition shots will begin in 2008 Targets for the National Ignition Campaign are both complex and precise and are extraordinarily demanding in materials fabrication machining assembly cryogenics and characterization An overview of the campaign for ignition will be presented along with technologies for target fabrication assembly and metrology and advances in growth and x ray imaging of DT ice layers The sum of these efforts represents a quantum leap in target precision characterization manufacturing rate and flexibility over current state of the art

**The National Ignition Facility** G. H. Miller, 2003 The National Ignition Facility NIF at Lawrence Livermore National Laboratory is a stadium sized facility containing a 192 beam 1.8 Megajoule 500 Terawatt ultraviolet laser system together with a 10 meter diameter target chamber and room for 100 diagnostics NIF is the world's largest and most energetic laser experimental system providing a scientific center to study inertial confinement fusion and matter at extreme energy densities and pressures NIF's energetic laser beams will compress fusion targets to conditions required for thermonuclear burn liberating more energy than required to initiate the fusion reactions Other NIF experiments will study physical processes at temperatures approaching 10<sup>8</sup> K and 10 bar conditions that exist naturally only in the interior of stars and planets NIF has completed the first phases of its laser commissioning program The first four beams of NIF have generated 106 kilojoules in 23 ns pulses of infrared light and over 16 kJ in 3.5 ns pulses at the third harmonic 351 nm NIF's target experimental systems are being commissioned and experiments have begun This paper discusses NIF's current and future experimental capability plans for diagnostics cryogenic target systems specialized optics for experiments and potential enhancements to NIF such as multi color laser operation and high energy short pulse operation

**Overview of the**



**National Ignition Facility** ,2007 The National Ignition Facility NIF at Lawrence Livermore National Laboratory will be the world s largest and most powerful laser system for inertial confinement fusion ICF and experiments studying high energy density HED science NIF is a 192 beam Nd glass laser facility that will produce 1 8 MJ 500 TW of ultraviolet light making it over fifty times more energetic than present ICF facilities The NIF Project began in 1995 and is scheduled for completion in 2009 Ignition experiments on NIF which will use tritium are scheduled to begin in 2010 Tritium will arrive at the facility in individual target assemblies The assemblies will be mounted to the Cryogenic TARget POSitioner TARPOS which provides the cryogenic cooling systems necessary to complete the formation of the ignition target s fuel ice layer It also provides the positioning system that transports and holds the target at the center of the NIF chamber during a shot After a shot unburned tritium will be captured by the cryopumps Upon regeneration the cryopump effluent will be directed to the Tritium Processing System part of NIF s Personnel and Environmental Protection Systems These systems also include local contamination control systems area and stack tritium monitoring systems a decontamination area and waste packaging and characterization capability This equipment will be used along with standard contamination control practices to manage the tritium hazard to workers and to limit releases to the environment to negligibly small amounts Beretning om det forenede Velgjørenheds-Selskabs Virken og Status i Aaret 1844 ,1845 National Ignition Facility United States. General Accounting Office,2000 **The National Ignition Facility** ,2002 The National Ignition Facility NIF currently under construction at the University of California s Lawrence Livermore National Laboratory is a stadium sized facility containing a 192 beam 1 8 Megajoule 500 Terawatt 351 nm laser system and a 10 meter diameter target chamber with room for nearly 100 experimental diagnostics NIF is being built by the National Nuclear Security Administration and when completed will be the world s largest laser experimental system providing a national center to study inertial confinement fusion and the physics of matter at extreme energy densities and pressures NIF s 192 energetic laser beams will compress fusion targets to conditions where they will ignite and burn liberating more energy than required to initiate the fusion reactions NIF experiments will allow the study of physical processes at temperatures approaching 100 million K and 100 billion times atmospheric pressure These conditions exist naturally only in the interior of stars and in nuclear weapons explosions In the course of designing the world s most energetic laser system a number of significant technology breakthroughs have been achieved NIF is now entering the first phases of its laser commissioning program Low energy preamplifier rod laser shots have been successfully propagated through the entire laser chain Higher energy shots are planned through the end of 2002 NIF s target experimental systems are also being installed in preparation for laser performance and experimental capability commissioning starting in 2003 **Operations on the National Ignition Facility** ,2014

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