



**American Nuclear Society
Fusion Energy Division
June 2007 Newsletter**

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Letter from the Chair, Jeff Latkowski, Lawrence Livermore National Laboratory, Livermore, CA.

Greetings fusioners! I would like to start this letter with a heartfelt thanks to our Secretary/Treasurer, Lee Cadwallader from the Idaho National Laboratory. It has become clear to me during this past year that a great deal of the work of the Fusion Energy Division (FED) is completed by the Secretary/Treasurer. Not only has Lee done a great job in this position for the past two years, but he has agreed to take on a second two-year term. Thanks to Lee – I know that the next two Chairs will be in great hands.

FESAC

In March, I had the pleasure of representing the Division at the Fusion Energy Sciences Advisory Committee (FESAC) meeting. A series of interesting talks were given by Dr. Raymond Orbach, Dr. Thomas Vanek, and the new Associate Director for the Office of Fusion Energy Sciences, Dr. Raymond Fonck (on his first day on the job). These covered the Office of Science budget for 2008, the OFES budget for 2008, and a new charge to FESAC, respectively. The new charge, which is to focus only upon MFE, asks FESAC to identify opportunities for U.S. leadership in fusion energy science and technology in the ITER era. Dr. Fonck indicated that he expected to issue a second charge that would address inertial fusion energy as well as the innovative confinement concepts.

Dr. James Van Dam gave an overview of the U.S. Burning Plasma Organization, and Dr. Ned Sauthoff updated the committee on the status of the ITER Project. In the fusion technology arena, I believe that Professor Mohamed Abdou was particularly effective in communicating the urgency of the United States completing a Test Blanket Module in ITER. Dr. Francis Thio described the work of an interagency task force that has studied collaboration between OFES and the National Nuclear Security Administration (NNSA) in the area of high energy density laboratory plasmas (HEDLP). The existing elements within the various agencies are to be gathered in a new joint program. Finally, Dr. John Mandrekas and Professor Arnold Kritz provided an overview of the Fusion Simulation Project, which seeks to develop a “whole device” predictive simulation capability for ITER.

17th TOFE Student Award

After a considerable delay, we are now able to announce the winner of the Best Student Paper Award from the 17th Topical Meeting on the Technology of Fusion Energy (TOFE), which was embedded within the ANS national meeting in Albuquerque, NM last November. The ANS FED Executive Committee, with assistance from Fusion Science and Technology journal editor, Nermin Uckan, reviewed promising student papers from the conference. The full collection of student papers was reduced to a short list of ten and these were reviewed in detail. Several of these student papers were very good, which made the selection process difficult. Papers were judged according to six equally-weighted attributes: organization/clarity, originality, demonstration of knowledge, validity of data, validity of conclusions, and utilization of illustrations and graphics. The reviewers have selected the paper titled “Longitudinal Tracking of Direct Drive Inertial

Fusion Targets” by J. D. Spalding, L. C. Carlson, M. S. Tillack, N. B. Alexander, D. T. Goodin, and R. W. Petzoldt as the Best Student Paper of the meeting.

18th TOFE Update

Plans for the 18th TOFE are moving along nicely. The meeting will be held at the Stanford Court Hotel in San Francisco, CA from September 28-October 2, 2008. An opening mixer will be held at the hotel on the 28th. The meeting will include 3-1/2 days of technical program, along with a half day field trip to tour the National Ignition Facility (NIF). The conference banquet will follow the NIF tour, and it will be held at the Wente Sparkling Cellars in Livermore. As usual, the conference proceedings will be peer-reviewed and published in the Fusion Science and Technology journal.

List of Officers and Executive Committee Members, Said Abdel-Khalik, Georgia Institute of Technology, Atlanta, GA.

We are pleased to welcome the new Officers and Executive Committee members of the Fusion Energy Division (FED). Vice-Chair Roger Stoller (ORNL) becomes our new Chair and Farrokh Najmabadi (UCSD) has been elected as the new Vice-Chair/Chair-Elect. Lee Cadwallader (INL) has been elected to serve a two-year term as Secretary/Treasurer. The newly elected Executive Committee members are Patrick Calderoni (INL), Mohamed Sawan (University of Wisconsin-Madison), and John Sethian (NRL). These new members join a strong group of individuals who will continue to serve the FED as Executive Committee members.

We would like to thank Gianfranco Federici (IPP) whose term as an Executive Committee member has just ended. Above all, we would like to express our appreciation to Jeff Latkowski (LLNL) for his service this past year as FED Chair. He will now become the Nominating Committee Chair. The Executive Committee members for 2007/2008 are:

FED Officers:

Roger Stoller (ORNL)	(07-08)	stollere@ornl.gov	Chair
Farrokh Najmabadi (UCSD)	(07-09)	najmabadi@fusion.ucsd.edu	Vice Chair
Lee Cadwallader (INL)	(07-09)	lee.cadwallader@inl.gov	Sec./Treas.

Executive Committee Members:

Mark Anderson (UW)	(06-09)	manderson@engr.wisc.edu
Patrick Calderoni (INL)	(07-10)	Patrick.Calderoni@inl.gov
Neil Morley (UCLA)	(05-08)	morley@fusion.ucla.edu
Brad Nelson (ORNL)	(06-09)	nelsonbe@ornl.gov
Mohamed Sawan (UW)	(07-10)	sawan@engr.wisc.edu
John Sethian (NRL)	(07-10)	sethian@this.nrl.navy.mil
Paul Wilson (UW)	(05-08)	wilsonp@engr.wisc.edu
Brian Wirth (UC-Berkeley)	(06-09)	bdwirth@nuc.berkeley.edu

Minami Yoda (GIT) (05-08) minami.yoda@me.gatech.edu

Past Chair:

Jeff Latkowski (07-08) latkowski@llnl.gov

FED Standing Committee Chairs:

Nominating: Jeff Latkowski (LLNL) - Chair

Honors and Awards: Farrokh Najmabadi (UCSD) - Chair

Program Committee: Jake Blanchard (UW) - Chair

FED Representatives on National Committees:

ANS Publications: Ken Schultz (GA)

ANS Public Policy: Said Abdel-Khalik (Georgia Tech)

Editors:

Newsletter: Laila El-Guebaly (UW), Dennis Bruggink (UW)

Fusion Science and Technology Journal: Nermin Uckan (ORNL)

Liaisons to other organizations and ANS divisions:

ANS Board: Kathryn McCarthy (INL)

MS&T: Ken Schultz (GA)

IEEE: George Miley (UIUC)

RPS: Ham Hunter (ORNL)

Webmasters:

Mark Tillack (UCSD) – FED website

Dennis Bruggink (UW) – UW website

Treasurer's Report, Lee Cadwallader, Idaho National Laboratory, Idaho Falls, ID.

As of December 31, 2006, our division had a balance of \$19,947.00. Expenses in 2006 included \$3,000 in student travel support for six students to attend the 17th TOFE, \$500 in support of Oregon State University to host the annual ANS Student Conference in the spring of 2007, a \$566 fee to set up division meetings, a \$500 cash prize to Dr. Said Abdel-Khalik for an Outstanding Achievement Award in November 2006, and \$398.15 for award plaques. Income in December 2006 included \$4,710 from the 17th TOFE meeting.

As of March 31, 2007, our division had a balance of \$20,673.00, which includes our 2007 income of \$726 from member dues. Projected 2007 expenses include \$600 for two division meetings held during national ANS meetings, \$500 in support of the spring 2008 annual ANS Student Conference, and a \$500 cash prize for the best student paper from the 17th TOFE.

Fusion Award Recipients, Laila El-Guebaly, University of Wisconsin-Madison, Madison, WI.

Fusion awards have been established to formally recognize outstanding contributions to fusion developments made by members of the fusion community. The following awards (listed in alphabetical order) were available to the newsletter editor at the time of publishing this newsletter. We encourage all members of the fusion community to submit information on future honorees to the editor (elguebaly@engr.wisc.edu) to be included in future issues. The ANS-FED officers and executive committee members congratulate the honored recipients of the 2006/2007 fusion awards on this well-deserved recognition and our kudos to all of them.

ANS Awards

University of Wisconsin student **Ross Radel** received two best-talk awards at the ANS Student Conference, held March 29-31, 2007, in Corvallis, Oregon at Oregon State University. **Radel** earned the two awards for his talk, "Detection of HEU Using a Pulsed Inertial Electrostatic Confinement D-D Fusion Device," in the nuclear fusion and in the non-proliferation and international safeguards categories.

A paper titled "Longitudinal Tracking of Direct Drive Inertial Fusion Targets" by **J. D. Spalding, L. C. Carlson, M. S. Tillack, N. B. Alexander, D. T. Goodin, and R. W. Petzoldt** was selected as the Best Student Paper of the 17th Topical Meeting on the Technology of Fusion Energy, held November 13-15, 2006 in Albuquerque, NM. In this paper, **Spalding** and his co-authors described a fringe counting method, including the modifications needed for a spherical reflector, techniques for improving signal-to-noise ratios, laser stability considerations, and the results obtained using a scaled tabletop experimental apparatus. **Spalding**, who is currently an MS student at the University of California-San Diego, will receive a certificate and a cash prize from the ANS FED.

DOE Awards

Dr. **Steven J. Zinkle** (Oak Ridge National Laboratory) has been named a winner of the Department of Energy's Ernest Orlando Lawrence Award, which honors midcareer scientists and engineers for exceptional contributions in research and development. **Zinkle**, a UT-Battelle Corporate Fellow and director of ORNL's Materials Science and Technology Division, is a materials scientist whose work has focused on physical metallurgy of structural materials and the investigation of radiation's effects on ceramic materials and metallic alloys for fusion and fission reactors and space reactor systems. **Zinkle's** award for nuclear technology cites his work in broadening the understanding of performance limits on materials subjected to extreme, highly radioactive environments such as those found in nuclear reactors and reactor-powered spacecraft.

FPA Awards

Academician **Vladimir T. Tolok** is a recipient of Fusion Power Associates Distinguished Career Award. In 1960, Acad. **Tolok** developed a stellarator fusion research program at the Kharkov (Ukraine) Institute of Physics and Technology (KIPT). From 1966 - 1987 he oversaw all fusion research at KIPT. After leaving KIPT in 1988, he organized and

headed the laboratory on vacuum-plasma technology in the physico-technical faculty of the Kharkov National University. He has published over 200 scientific papers in various journals. In 2001, he published “A History of Stellarators in the Ukraine” in the Journal of Fusion Energy.

Larry Foreman Award

Dr. **Masaru Takagi** (Lawrence Livermore National Laboratory) received the Larry Foreman Award for Excellence and Innovative in Inertial Confinement Fusion (ICF) Target Fabrication. Dr. **Takagi** is the inventor of the chemical processes used to make extremely round and smooth plastic shells that are the starting point for ICF capsules fabrication. His work has enabled the production of both plastic and beryllium shells that meet the stringent specification required for ignition experiments on the NIF laser. The award was presented at the 17th Target Fabrication Specialists Meeting, held in San Diego, California, October 1-5, 2006.

News from Fusion Science and Technology (FS&T) Journal, Nermin A. Uckan, FS&T Editor, Oak Ridge National Laboratory, Oak Ridge, TN.

During the past twelve months (May 1, 2006 – April 30, 2007), FS&T received 454 manuscripts for FS&T regular issues and 118 camera-ready papers for FS&T Transactions. [Transactions are FS&T supplements and not fully refereed in the same sense as journal issues.]

The following special/dedicated issues have been published during the reporting period:

- Selected papers from 16th IFE Target Fab. – FS&T May06 (49 papers)
- Papers from 15th IEA Stellarator (Parts 1,2,3):
 - FS&T Aug06 (26 papers)
 - Oct06 (17 papers)
 - Jan07 (15 papers)
- NCSX Stellarator – FS&T Feb07 (7 papers)
- Open Systems 2006 – FS&T Transactions, Mar07 (118 camera-ready papers)
- Alcator C-Mod Tokamak (MIT) – FS&T Apr07 (14 papers).

The following special issues are scheduled for the remainder of 2007:

- Selected papers from 17th IFE Target Fab. – FS&T May07 (49 papers)
- EC Wave Physics, Technology and Applications (Part 1) – FS&T Aug07 (23 papers)
- TOFE06 Proceedings – FS&T camera-ready, Oct/Nov 2007 (~140 papers, scheduled).

The following issues are planned for 2008 and beyond:

- EC Wave Physics, Technology and Applications (Part 2) – FS&T Jan08 (25 papers)
- MFE Diagnostics (EU, JA, RF, US) – FS&T regular issue (13 papers, to be scheduled)
- JET Tokamak (Culham, England) – FS&T regular issue (11 chapters, under review)
- ARIES Compact Stellarator Study – FS&T regular issue (11 papers, under review)
- 8th Tritium Science & Technology 2007 – FS&T Proceedings (papers due late 2007)

- 8th Carolus Magnus Summer School – FS&T Transactions (papers due late 2007)
- 16th IEA Stellarator (2007) – FS&T regular issues (under discussion for 2008)
- DEMO Studies (EU, JA) – FS&T regular issue (in planning/preparation)
- IFMIF (EU, JA, US) – FS&T regular issue (in planning/preparation)
- Test Blankets (EU, JA, RF, US) – FS&T regular issue (in planning/preparation)
- KSTAR (Korea) – FS&T regular issue (under discussion for 2008/09)
- W7-X (Germany) – FS&T regular issue (under discussion for late 2008/09).

FS&T has been offering color printing for special issues, and recently start offering online color figures for regular and special issues. The April 2007 C-Mod special issue served as a test case for online color figures (all future b&w print copies will now have color online option).

Please check your library subscription. Electronic access to FS&T is available from 1997-to-current. Tables of contents and abstract of papers can be accessed at <http://www.ans.org/pubs/journals/fst/>. Individual and library subscribers can access the full text articles at <http://epubs.ans.org/>.

Please send your comments and suggestions on FS&T content and coverage and potential future topical areas that are timely and of interest to fst@ans.org.

ONGOING FUSION RESEARCH:

Status of the NIF Project, Edward I. Moses, Lawrence Livermore National Laboratory, Livermore, CA.

Ground was broken for the National Ignition Facility, a stadium-sized complex, in 1997. When complete, the project will contain a 192-beam, 1.8 megajoule, 500-terawatt laser system adjoining a 10-meter-diameter target chamber with room for nearly 100 experimental diagnostics. NIF's beams will compress and heat small capsules containing a mixture of hydrogen isotopes of deuterium and tritium. These targets will undergo nuclear fusion, producing more energy than the energy in the laser pulse and achieving scientific breakeven. NIF experiments will allow scientists to study physical processes at temperatures approaching 100 million kelvins and 100 billion times atmospheric pressure—conditions that exist naturally only in the interior of stars and in nuclear weapon detonations.

On Schedule for Success

A cornerstone of the National Nuclear Security Administration's Stockpile Stewardship Program, NIF will help ensure the reliability of the U.S. nuclear weapons stockpile by allowing scientists to validate computer models that predict age-related effects on the stockpile. Access to these regimes will also make possible new areas of basic science and applied physics research. This article summarizes the current status of the NIF project and discusses plans for the first science experiments on NIF.

NIF's 192 beams are organized in quads, bundles and clusters. Quads are four beams with the same pulse shape. Each NIF bundle—an upper and lower quad—is controlled

independently from the others. In July 2001, the NIF project began working on an accelerated set of milestones leading to NIF Early Light (NEL), a campaign to demonstrate NIF's capability to deliver high-quality laser beams to the target chamber in support of early experiments. The first quad was activated in December 2002. On May 30, 2003, NIF produced 10.4 kilojoules of ultraviolet laser light in a single laser beamline, setting a world record for laser performance. By the end of the NEL campaign in October 2004, more than 400 shots had been performed. After NEL, NIF began installation of production laser hardware in the rest of the lasers. The first cluster of 48 beams became operational on Dec. 7, 2006, with the demonstrated capability of producing more than a megajoule of infrared laser energy—establishing NIF's ability to achieve 4.2 megajoules in the infrared when all beams are activated.

NIF is now more than 90% complete, and several significant milestones were recently reached. Seventy-two main laser beamlines are now operating in Laser Bay 2. Each beam has been qualified at 19,000 joules, for an equivalent energy for these 72 beams of 1.4 megajoules (Figure 1). This is more than 20 times the 1 W energy that any other laser facility has routinely delivered. In addition, 3,731 line replaceable units (LRUs) have been installed. This includes 98% of all LRUs in Laser Bay 2 and 60% in Laser Bay 1. Delivery of laser light into the target bay will begin this summer.

The very complex small optical systems in the laser bays are now nearly 70% complete and progressing quickly. The controls hardware installation is more than 85% complete. Alignment laser light has been brought back to the target chamber center for the first time since the NEL campaign ended in October 2004—an exciting achievement that foreshadows the return to experiments this coming winter. The facility utility work is moving along rapidly with completion expected by the July 4th holiday. Each of these accomplishments is impressive in its own right. Together, they are truly remarkable. The official project end date is March 31, 2009, a little more than 100 weeks from now, and NIF is on schedule for success.

Big Lasers, Small Targets

As NIF heads toward completion, the enormity of the project has become apparent. Its twin laser bays are each 400 feet long, amplifying beams that are about 16 inches square. The 33-foot-diameter target chamber consists of a million pounds of concrete and aluminum. But NIF's business end—the ignition capsule target—is tiny: just two millimeters in diameter. These capsules are positioned inside a small (one centimeter long) canister known as a hohlraum inside the cavernous NIF target chamber (Figure 2). The 192 laser beams enter the hohlraum from top and bottom, creating X-rays that heat the capsule to temperatures as high as those within the sun. This creates pressures that compress and heat the deuterium-tritium fuel contained inside the capsule, forcing the nuclei inside to undergo fusion while releasing a tremendous burst of energy.

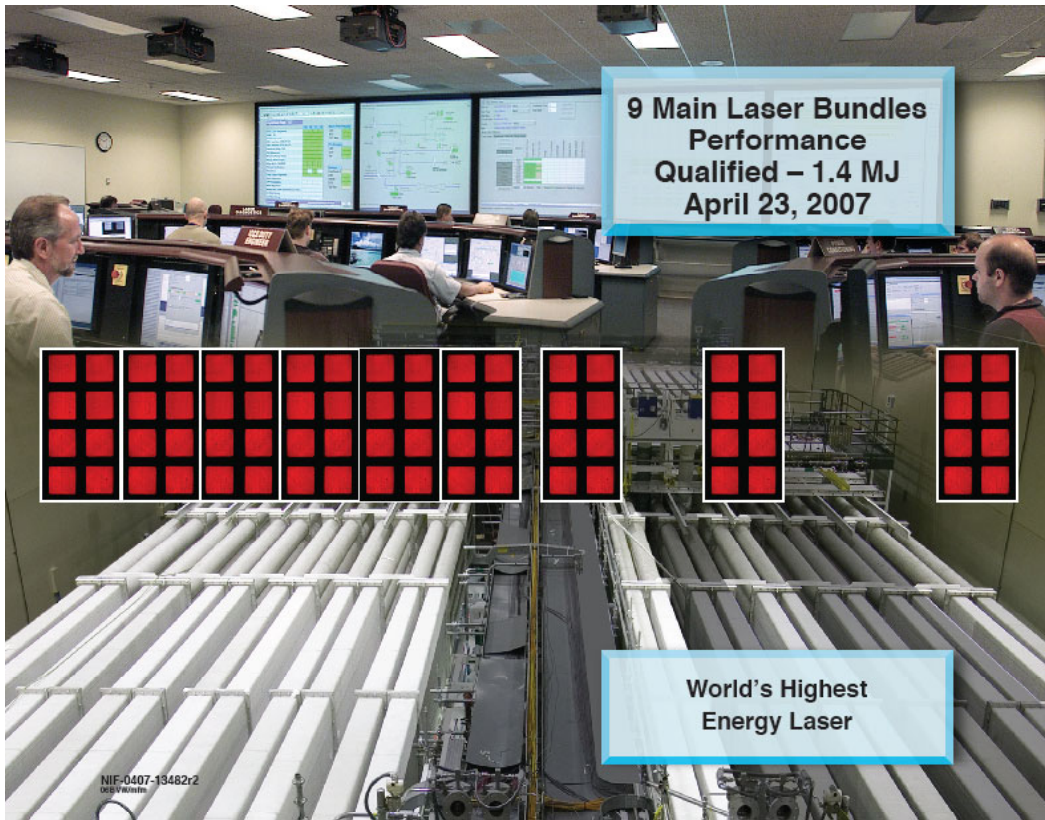


Figure 1. Seventy-two main laser beamlines are now operating in Laser Bay 2 of the National Ignition Facility. Each beam has been qualified at 19,000 joules, for an equivalent energy for these 72 beams of 1.4 megajoules.

The National Ignition Campaign (NIC) integrates the activities required to perform a credible ignition experimental campaign on NIF. NIC is a collaborative effort involving Lawrence Livermore National Laboratory, the University of Rochester Laboratory for Laser Energetics, General Atomics, Los Alamos National Laboratory and Sandia National Laboratories. The NIF and NIC activities are merging at a rapid rate. It is only a little more than a year until 96-beam commissioning activities in the target chamber. This Early Opportunity Shots (EOS) series will establish NIF as a preeminent international high energy density (HED) physics facility and set the facility directly on the path to the first ignition experiments in 2010.

NIF produces pulses lasting from 0.2 to 10's of nanoseconds. During recent tests in the Precision Diagnostic Station (PDS) all of NIF performance requirements have been demonstrated on a single-beam basis. These tests demonstrated NIF's capabilities for HED experiments in support of the Department of Energy's Stockpile Stewardship Program and for basic science experiments to explore such topics as the origin and makeup of the planets and the hydrodynamics of supernovae—explosions of massive stars.

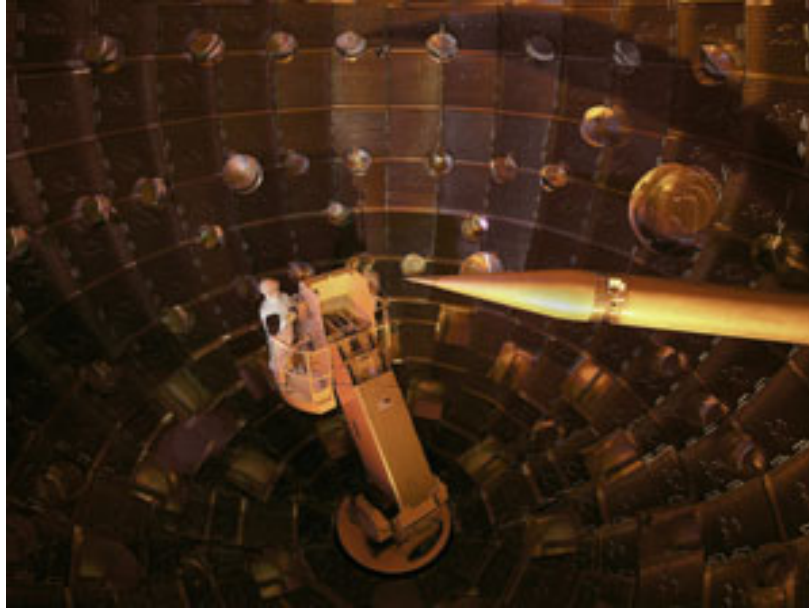


Figure 2. The NIF target chamber is constructed from 4-inch-thick aluminum and coated with a 16-inch-thick neutron shielding concrete shell. The entire assembly weighs about one million pounds. The target positioner, which holds the target at its tip, is on the right.

The NIF Control System

Another important achievement involved NIF's automated shot controls. The Integrated Computerized Control System (ICCS) was able to fire the entire shot cycle for Cluster 3's 48 beams, including shot setup, data archiving, shot data analysis and post-shot amplifier cooling, in just over three hours. This is the same time previously completed for a single bundle shot cycle and demonstrates scaling of the controls to full NIF capability. The facility has begun around-the-clock operations, Sunday through Friday, in preparation for eventually becoming a 24/7 operating user facility.

Every NIF experimental shot requires the coordination of complex laser equipment. In the process, 60,000 control points of electronic, optical and mechanical devices—such as motorized mirrors and lenses, energy and power sensors, video cameras, laser amplifiers, pulse power and diagnostic instruments—must be monitored and controlled. The precise orchestration of these parts will result in the propagation of 192 separate nanosecond-long bursts of light over a one-kilometer path length. These 192 beams must arrive within 30 picoseconds of each other at the center of a target chamber 10 meters in diameter, and pointed to within 50 micrometers of their assigned spot on a target measuring less than one centimeter long.

Fulfilling NIF's promise requires a large-scale computer control system as sophisticated as any in government service or private industry. Conceived and built by a team of 100 software developers, engineers and quality control experts, the ICCS software, now nearly 85 percent complete, will soon have about 1.6 million lines of code running on more than 850 computers. ICCS, which is operated from a main control room (Figure 3),

fires the laser and conducts these experiments automatically. The alignment control system software determines the position of NIF's laser beams on the optics by analyzing sensor video images with a variety of computer-vision algorithms.

Motor control robotics software uses the sensor information to remotely position more than 9,000 stepping motors and other actuators. These devices point the beams through pinholes, center them on mirrors and lenses and focus them onto the target—achieving greater precision and effectively eliminating the need for personnel to adjust the beamlines manually.

Over the next two years, the rest of the laser bundles will be completed and computers and software that were fielded for the initial bundles will be replicated. NIF's independent bundle architecture simplifies the task of controlling the laser because each bundle is prepared for the upcoming shot independently. The bundles are synchronized just before shot time so that even the most complex experiments can be carried out efficiently with a short turnaround time.



Figure 3. Operators in the NIF Control Room can continuously track data generated by the integrated computer control system on their monitors. The Shot Director's station is on the left.

Lessons from NASA

The design of the NIF central control room is modeled after the National Aeronautics and Space Administration's (NASA) mission control room in Houston, Texas. Both control rooms have operator stations corresponding to different hardware systems. In NIF's case, each console corresponds to a functional system on the laser. Similar to NASA operators in the Launch Center control room, operators located in the NIF control room continuously track data on their monitors. There are other similarities between executing

a NIF shot and launching a Space Shuttle. Launch of a Space Shuttle is controlled by software centered in the Launch Center control room until T minus 31 seconds—or 31 seconds before liftoff; then computers on board the shuttle take over. Similarly, countdown for a NIF shot includes computer checks of every subsystem, and the control system will automatically stop events from proceeding unless all conditions are satisfactory. At T minus 2 seconds, the ICCS software turns over control to a high-precision integrated timing system designed to trigger thousands of laser modules and diagnostics at exactly the right instant.

The modular control system concept dovetails well with plans for NIF experiments. For example, although achieving ignition will require all 192 beams, many experiments will require fewer laser beams. Each NIF experimental series will require different laser parameters such as wavelength, energy, and pulse duration; different configurations of the laser beam; different laser targets; and different diagnostic instruments. By taking advantage of the facility's experimental flexibility, teams will be able to create an extraordinary range of physical environments, including densities ranging from one-millionth the density of air to 10 times the density of the core of the sun, temperatures ranging from a terrestrial lightning bolt (about 10^4 K) to the core of a carbon-burning star (10^9 K) and pressures from 1 to 100 terapascals (1 gigabar). Researchers will study phenomena at timescales ranging from fractions of a microsecond (10^{-6} seconds) to picoseconds (10^{-12} seconds).

Exploring Frontier Science

In addition to supporting the Department of Energy's Stockpile Stewardship Program, NIF will provide researchers from universities and DOE national laboratories unparalleled opportunities to explore "frontier" basic science in astrophysics, planetary physics, hydrodynamics, nonlinear optical physics and materials science. About 15 percent of NIF shots will be devoted to science experiments in these fields. The first science studies will focus on re-creating in the laboratory the properties of celestial objects under scaled conditions. With its 192 beams together generating up to 1.8 megajoules of energy, the giant laser will allow scientists to explore some of the most extreme conditions in the universe such as the hot, dense plasmas found in stars.

NIF experiments will help scientists understand the mechanisms driving new stars, supernovae, black holes, and the interiors of giant planets. The physical processes of stars have long been of interest to Livermore researchers because the prime stellar energy mechanism, thermonuclear fusion, is central to the Laboratory's national security mission. For decades, Livermore researchers have advanced astrophysics by applying their expertise in HED physics and computer modeling of the nuclear processes that take place in these regimes.

Once NIF attains ignition (a burst of fusion reactions in which more energy is liberated than is input), a flux of 10^{32} to 10^{33} neutrons per square centimeter per second will be generated, a rate that may allow excited-state nuclear reactions to occur. This neutron flux will also enable scientists to study aspects of heavy element nucleosynthesis, that is, of those nuclei more massive than iron. Scaled NIF experiments will permit researchers

to study many features of the lifecycle of a massive star, from its birth in a cold, dense molecular cloud through its subsequent stages of evolution to an explosive death such as a supernova.

Once formed, stars are heated by nuclear fusion in the interior and cooled by radiation emissions at their surface, called the photosphere. Opacities of each layer control the rate at which heat moves from the core to the surface. In this way, opacity plays a major role in determining the evolution, luminosity and instabilities of stars. Experiments will mimic stellar plasma to obtain information on the opacities of key elements such as iron and determine how opacity changes with plasma density and temperature throughout a star's lifetime. Experimenters plan to simultaneously measure the radiation transmission, temperature and density of a material sample.

NIF managers are devising a detailed plan for engaging external participation and collaboration. The goal is to turn NIF into a premier international center for experimental science, much like the Advanced Photon Source at Argonne National Laboratory or the Stanford Linear Accelerator Center. The plan is for NIF to be a user facility by 2012 in areas of HED and basic science and uses of ignition.



Figure 4. The National Ignition Facility, the world's largest laser, has 192 laser beams, covers the area of three football fields, and stands 85 feet tall. Currently under construction at Lawrence Livermore National Laboratory in California, it will be completed in 2009.

This work was performed under the auspices of the U.S. Department of Energy National Nuclear Security Administration by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

State-of-the-Art Modeling of Fusion Facilities for 3-D Nuclear Assessment, Paul Wilson, University of Wisconsin-Madison, Madison, WI.

Recent advances in radiation transport simulation tools enable an increased fidelity and accuracy in modeling complex geometries. Future neutronics calculations for design and analysis will increasingly be based directly on 3-D CAD geometries, allowing enhanced model complexity, reduced human effort and improved quality assurance.

The Direct Accelerated Geometry MCNPX (DAG-MCNPX) software permits the direct use of CAD-based solid models in MCNPX. In addition to improving the workflow for simulating complex 3-D geometries, it allows a richer representation of the geometry compared to the standard 2nd-order polynomial representation. In addition to an international benchmark for CAD-based neutronics tools for ITER, DAG-MCNPX is being used for 3-D modeling of the ARIES Compact Stellarator and ITER First Wall & Shield modules.

DAGMC Approach

The Direct Accelerated Geometry Monte Carlo (DAGMC) library is a software library for integration in Monte Carlo codes to replace the traditional geometry tracking routines with CAD-based geometry tracking routines. While these routines have a history of being substantially slower than the optimized routines that are implemented in most Monte Carlo codes, the DAGMC library uses techniques borrowed from computer graphics to accelerate the process and bring the total computational performance to within a factor of 3-4 of the native performance. Most notable among these accelerations is the use of an oriented bounding box tree that reduces the number of ray-surface intersections that are necessary. This slight performance penalty for some problems provides some benefits, particularly the ability to represent higher-order surfaces that are not supported in native Monte Carlo representations.

ITER CAD-based Neutronics Benchmark

In order to support the 3-D neutronics needs for the ITER project, a number of CAD-based approaches to neutronics calculations are being compared. The test problem is a detailed 3-D model of a 40° sector of the ITER machine (Fig. 1), from the central solenoid to back of the equatorial ports. This model uses over 900 cells and nearly 10000 surfaces. In addition to the DAGMC approach, three CAD-translation to MCNP approaches are being compared. Since the CAD-translation approaches have inherited the limitations of MCNP's surface representation, the benchmark model has been simplified to include only low-order surfaces. The benchmark participants (U.S., Germany, China and Japan) are to calculate the poloidal distribution of the neutron wall loading, a number of flux and heating responses in the divertor, the nuclear heating in the inboard toroidal field (TF) coils, and the neutron flux at various points along the equatorial ports behind the shield plugs. Initial results from all parties are consistent with each other and with previous analyses. A final benchmark comparison assessment will be available in fall 2007.

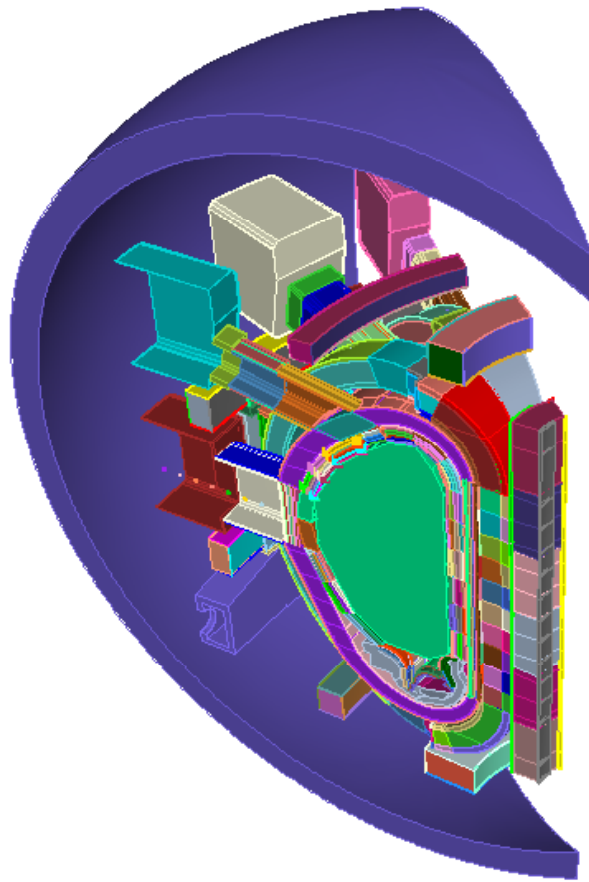


Figure 1. CAD model used for ITER benchmark showing 40° sector of device with substantial detail. Large spherical sector is added to geometry to provide location to truncate neutron histories.

ARIES Compact Stellarator

A fundamental characteristic of stellarators is the complex nature of the surfaces that represent the magnetic flux surfaces and, in most designs, also the first wall. The Compact Stellarator system studied by the ARIES team was no different and all boundaries between major components in the blanket and shield were modeled as offsets from the last closed magnetic surface (see Figure 2). Modeling such a system with the native geometry of MCNP would not be possible without significant human effort and substantial approximation of the surfaces. It was also necessary to generate a detailed 3-D model of the neutron source for this system. A detailed analysis of the neutron wall loading distribution was performed (Figure 3-a) to determine where the maximum and minimum wall loadings occurred. For a device with a major radius of 7.75 m and a scrape-off layer thickness of 5 cm, the maximum wall loading (5.26 MW/m^2) is two times larger than the average wall loading and occurs near the mid-plane on the outboard side and near a toroidal angle of 0° . The neutron source distribution was found to be important. If a volumetrically uniform source were used (Figure 3-b), the peak wall loading would be 3.56 MW/m^2 , only 39% larger than the average, and at a different toroidal angle (near -50°).

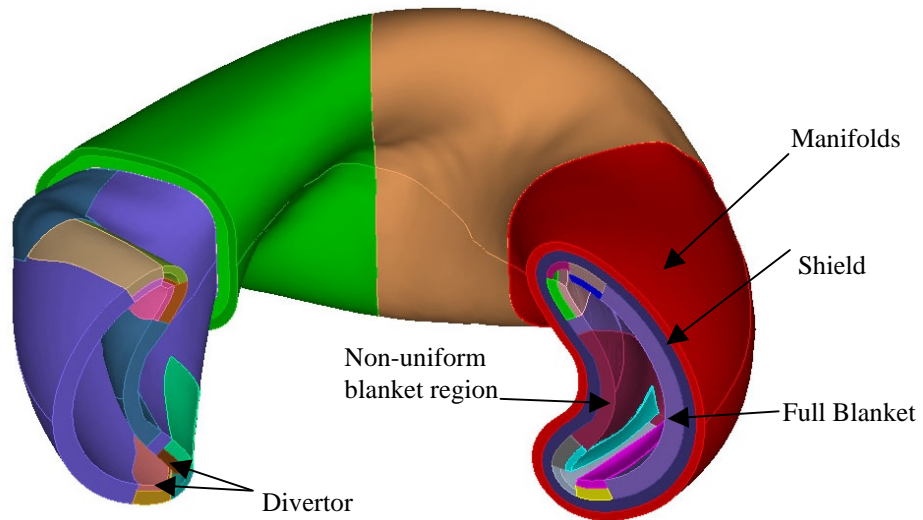


Figure 2. A cut-away view of the ARIES-CS machine showing the different major components.

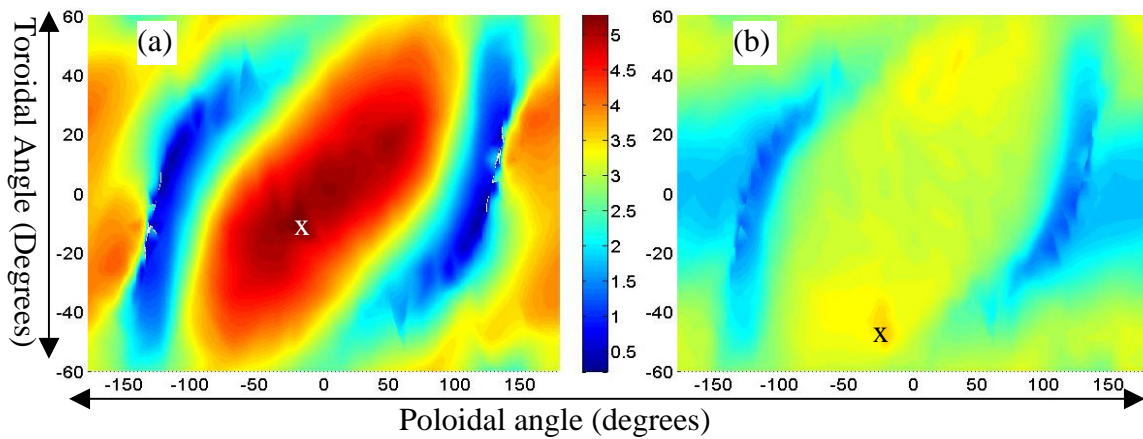


Figure 3. Neutron wall loading maps for the ARIES CS power plant with a 5 cm scrape-off layer, comparing the detailed 3-D source distribution (a) with a volumetrically uniform source distribution (b). The locations of the peak neutron wall loading are indicated by an 'x'.

ITER First Wall and Shield

In support of the engineering design and analysis of the first wall and shield (FWS) modules for ITER, DAG-MCNPX is being used to calculate high-fidelity neutron responses on a detailed 3-D geometry. In a hybrid 1-D/3-D analysis, a detailed geometric model of FWS module 13 is placed in the appropriate position of an otherwise 1-D cylindrical model of the ITER system. A uniform volume source is implemented in the plasma region and the neutron responses (nuclear heating, He production and radiation damage) are tallied on a fine mesh (0.5 cm x 0.5 cm x 1 cm) throughout the FWS module (Figure 4). The results are normalized to the neutron wall loading experienced in module 13 to provide an absolute magnitude for the results. One of the most important results for FWS module designers is the detailed distribution of the nuclear heating. From this kind of analysis we can determine that the variations in neutron flux spectrum due to local heterogeneities in the model lead to detectable variation in the nuclear heating near the steel/water interface. Figure 4 shows the results for nuclear heating as well as for the lifetime radiation damage (in dpa) and helium production (in appm) for a slice located 11.5 cm from the plasma-facing surface of the first wall. In this slice, the water reservoirs at the front of the shield block are surrounded by steel. Note that the nuclear heating in steel near the water/steel interface is up to 30% higher than the average value due to the photons generated in the water and the slightly softer neutron flux spectrum.

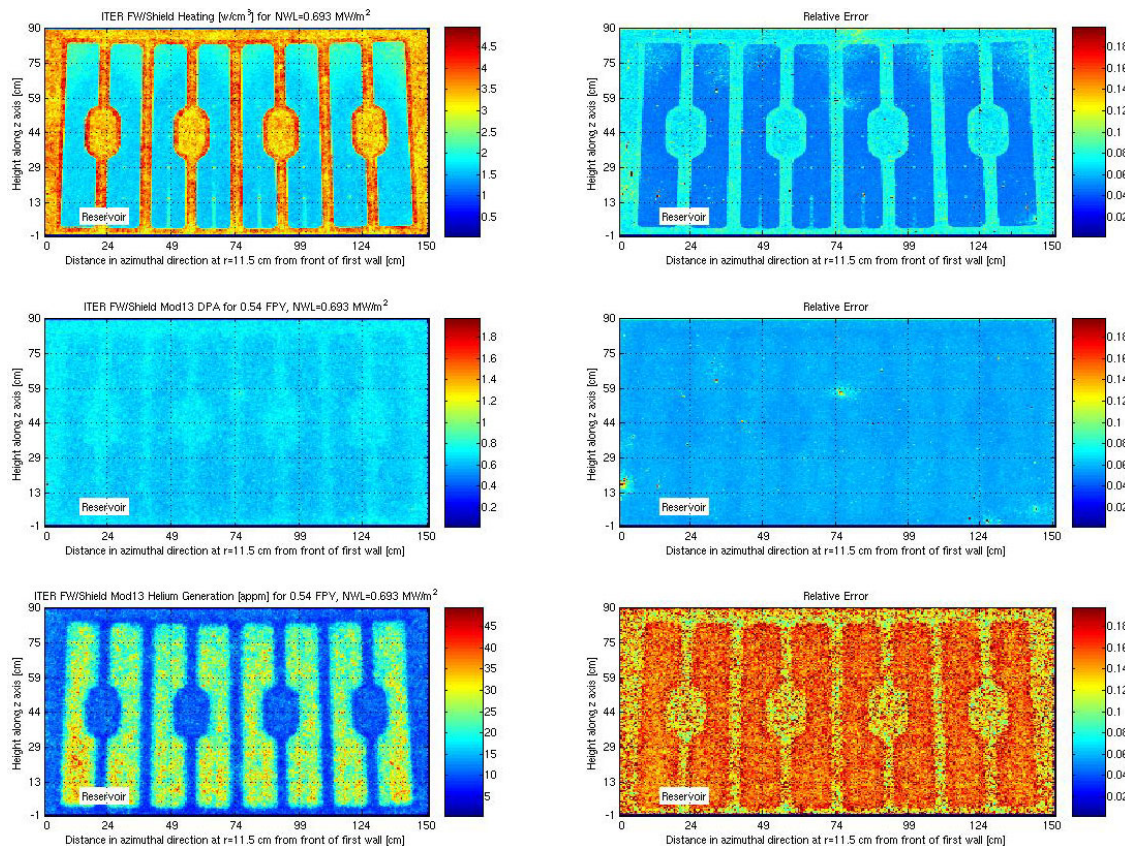


Figure 4. High fidelity nuclear heating (top), radiation damage (middle) and helium production (bottom) results for a slice of the ITER first wall and shield module 13 mockup at a distance of 11.5 cm from the front of the first wall. At right are maps of the relative statistical error.

Summary

The DAG-MCNPX software is already being used in a wide array of problems to make valuable and unique contributions to the nuclear analysis of fusion systems. The ability to generate high-fidelity neutron responses in complex 3-D geometries will open the door to more advanced understanding of the nuclear system and to the possibility of design innovations that will take advantage of this new information. The DAGMC software library is being extended in ways that will further reduce the necessary human effort and further accelerate the computational efficiency of the direct geometry approach.

Community Workshop on Inertial Fusion Energy, Wayne Meier, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory (LLNL) hosted the Inertial Fusion Energy (IFE) Science and Technology Strategic Planning Workshop, April 24-27, 2007 in San Ramon, California. The purpose of the workshop was to assess near-term and long-term research opportunities and to update plans pertaining to IFE and the associated high energy density physics (HEDP) and technologies. The workshop was well attended with 108 researchers from the IFE, ICF and HEDP communities. The first day featured overviews from the major IFE programs and also included talks on cross-cutting and emerging science. Day two was devoted to energy-related HEDP. OFES and NNSA leaders discussed the newly formed joint NNSA/OFES program on HEDLP. Overviews of ICF/HEDP facilities and R&D were given by representatives from LLNL, UR-LLE, SNL, NRL, and LANL. While the workshop focused on U.S. activities, overviews of the Japanese, European and IAEA work on IFE were given on the third day. Breakout sessions on HEDP and IFE planning were conducted and the findings were summarized on the last day. Also, on the last day, a panel of university researchers discussed issues and opportunities related to university participation in IFE. The poster session, with 26 posters covering a wide range of research areas, generated a lot of discussion and interest. The complete agenda can be found on the workshop website: <http://ifeworkshop.llnl.gov/>. Presentations and posters will be posted there as soon as possible.

INTERNATIONAL ACTIVITIES:

ITER Progress, Ned Sauthoff, U.S. ITER Project Office, Oak Ridge National Laboratory, Oak Ridge, TN.

On November 21, 2006, in the Palais de l'Elysee in Paris, the ITER parties signed the Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project. The impressive ceremony highlighted the significance of the scientific and technological progress that has been made, enabling the ITER parties to agree that the benefits exceed the costs and that the world is ready to proceed to the study of burning plasmas and fusion energy. ITER was heralded not only for its science and technology, but also for its international nature.

The signing of the agreement led to the provisional application of many of the terms of the agreement; however, final application awaits ratification by several of the parties, which is expected in the summer of 2007. The provisional establishment of the ITER Organization has enabled the team in Cadarache, France, to begin hiring direct employees and placing contracts.

The ITER Director General (DG) has sent to the seven ITER parties several sets of job position descriptions and has requested candidates for those positions. The U.S. ITER Project Office posts those positions for which the U.S. will consider offering candidates on the website <http://www.usiter.org/> for a specific period of weeks. After assembling and selecting the U.S. candidates, the U.S. sends its response to the DG's request for his integration with the other Parties' candidates and his selection. Selected candidates are contacted and informed of the terms of the ITER job offer. In April 2007, the U.S. has nine members of the ITER staff in Cadarache.

The design review activity is underway under the leadership of the Principal Deputy Director General Nominee Norbert Holtkamp, seeking to establish an updated baseline by the end of 2007. This will be the first official re-baselining since the 2001 Final Design Report. Multiple international working groups are addressing the design issues and developing recommendations to ITER management who will work with the Parties and recommend the revisions and new baseline to the ITER Council for its decision.

The next meeting of the Interim ITER Council is scheduled for July 2007 in Japan. A preparatory meeting was held in Marseille to consider the many documents to be presented to the Council and to address concerns from the Parties.

Meanwhile, technical work continues in the ITER parties and in the ITER Organization. The participant teams are addressing their allocated scopes and are performing tasks agreed between the ITER Organization and each Party. After the baseline has been updated, procurement arrangements will be developed between the ITER Organization and each Party to specify the technical and managerial aspects of the hardware contributions of that party. These procurement arrangements are key to the establishment of the U.S. ITER Project Baseline within the context of the DOE Project Management Order.

Status of the Korean Fusion Program, Ki-Jung JUNG, ITER-Korea Project Office, National Fusion Research Center, Daejeon, Korea.

In the last week of December of 2006, The National Assembly of the Republic of Korea passed the Fusion Energy Promotion Act, which will play a supportive role in promoting fusion energy development in Korea. It has been 27 years since the first fusion experimental device began construction in a small laboratory in Seoul National University. There is no doubt that the KSTAR project, started in 1995, is a milestone heralding Korea's start in major fusion energy development activities.

The Korea Superconducting Tokamak Advanced Research (KSTAR) device is under construction at the National Fusion Research Center in Daejeon, Korea. The project mission is to develop a steady-state capable advanced superconducting tokamak to establish the scientific and technological bases for an attractive fusion reactor. The project is a collaboration with many joint research institutes and companies. In phase I, completed in 1998, preliminary conceptual design and R&D work was achieved. During phase II, completed in 2002, the meticulous engineering design work was finished. The building for the KSTAR tokamak was completed in 2002. In phase III, ending in August 2007, the KSTAR tokamak is being constructed and assembled. As of April 2007, construction of KSTAR reached 98% completion and the assembly will be completed by the end of August 2007, followed by the engineering commissioning and first plasma generation scheduled in June 2008.

Major technical challenges in KSTAR (major radius 1.8 m, minor radius 0.5 m, toroidal field 3.5 T, and plasma current 2 MA) are to develop the following components:

- (1) The Nb₃Sn superconducting magnets and structures
- (2) Changeable internal structures for handling steady-state power and particle loads
- (3) Unique equipment for heating, diagnostics, magnet power supply
- (4) New assembly tools.

To solve these crucial issues in constructing KSTAR, several domestic companies have extensively contributed their technology. The assembly of KSTAR has been progressing well reaching the point that all major subsystems such as vacuum vessel, thermal shields, 30 superconducting magnets, supporting structures, buslines, and helium-cooling piping system are assembled at the right positions as shown in Fig. 1. Before the cryostat cylinder assembly, we continued various preliminary tests for ensuring the quality of the in-cryostat components repeatedly. The remaining assembly activity is the welding of the port extensions to the vacuum vessel. Figure 2 is the current picture of the KSTAR main experimental hall. Since the assembly process is on schedule, we are preparing for the integrated commissioning of KSTAR. The commissioning is preceded by individual subsystem tests such as leak tests of vacuum structures, electrical insulation tests, superconducting magnet power supply tests with dummy loads, helium refrigeration system, heating and diagnostic system, and tests of the local and central control system. When the device begins normal operation in September 2008, Korea will join the group of advanced countries in the field of fusion technology exploring the physics of advanced steady-state plasmas, concurrently with ITER.

Korea is a country that imports about 97 percent of its energy requirements and is eager to make fusion energy a commercially viable source of energy in the future. Korea joined the ITER project in June 2003 and actively participated in the negotiations among seven Parties for drafting the ITER Joint Implementation Agreement (JIA) that was signed on November 21, 2006 in Paris. Korea is keen to become a member of the ITER fusion project and is willing to undertake a 9.09% share of in-cash and in-kind contributions for ITER construction during the next 10 years, which amounts to 600 million dollars. Ten procurement packages for in-kind contributions were allocated to Korea including TF Conductors, Vacuum Vessel Main and Ports, Blanket First Wall and Shield Block,

Thermal Shield, Assembly Tools, Tritium Storage and Delivery, Coil Power Supply, and Diagnostics. Eight staff members in the professional category including one DDG, have been seconded to the ITER Organization (IO) up to now.

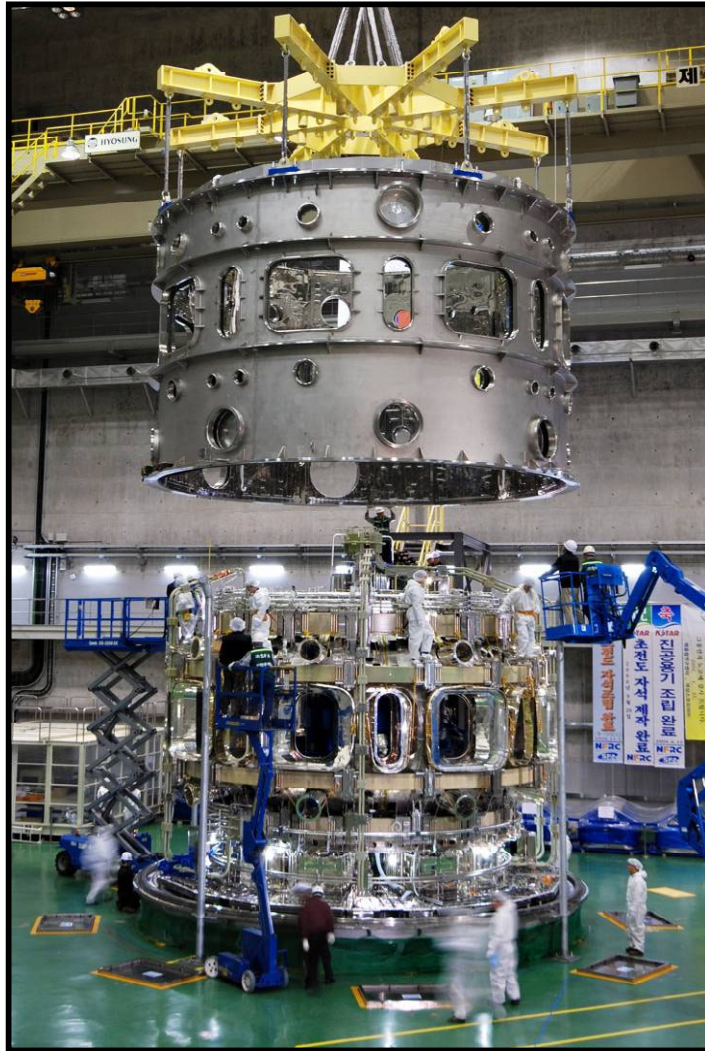


Figure 1. Assembly of the KSTAR cryostat cylinder (January 12, 2007).

To implement the ITER project in Korea, the ITER Korea Project Office was established at the National Fusion Research Center (NFRC) in October 2005 in Daejeon. To comply with IO requests, the domestic office has strongly taken actions to develop the internal tools for project and procurement management and to make preparations for procurement arrangements. R&D tasks for design and development of the 10 in-kind procurement packages were launched in 2006 and R&D activities have been coordinated to catch up with the engineering design and basic technology accumulated during the last 10 years of ITER EDA/ITA. Korea is supporting the current design review activities for the IO to be finalized by the end of this year resulting in the FDR 2007. On April 2, 2007, the Korean

National Assembly ratified the ITER agreements. This is a reflection of the commitment by the Korean people and government in support of the ITER project.

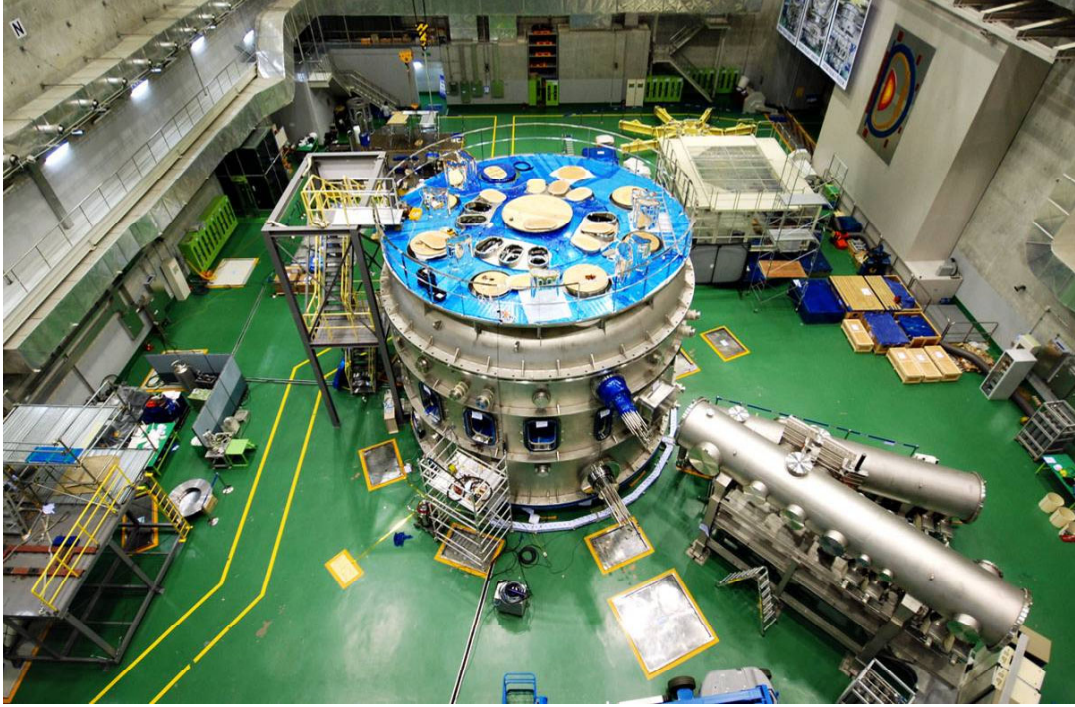


Figure 2. KSTAR main experimental hall (April 26, 2007).

Now that Korean fusion engineers have obtained much experience in fabrication technologies through the construction of KSTAR applicable to ITER procurement, Korea's participation in ITER can be expected to result in a synergistic effect setting up fusion reactor technologies for the future. In reaching Korea's ultimate goal of realizing a commercial fusion reactor, it is necessary to coordinate domestic research activities in all sectors of the fusion community including universities, institutes, and industry. On that point, the ITER project will be an ideal opportunity for Korea to carry out coordinated activities in preparation for the construction of a DEMO and commercial fusion power plant. We strongly believe that the journey to achieve the ITER goals will be hard but navigable with the collaboration of the world fusion community.

Japan and EURATOM Signup to Fusion Cooperation

An agreement creating a privileged partnership between Japan and EURATOM in fusion energy research was signed on 5 February in Tokyo. The agreement is part of the “Broader Approach” to fusion research, approved during the negotiations on the ITER project. ITER involves the EU, the US, Japan, Russia, South Korea, China and India.

Under the agreement, Japan and EURATOM will work together over 10 years on three individual projects intended to accelerate the realization of fusion energy. Fusion is a potential clean and sustainable energy source for the 21st century.

“ITER and the Broader Approach, together with the current level of fusion research being undertaken worldwide, represent a big step towards the realization of fusion power,” said the nominee Director General of the ITER Organization, Kaname Ikeda.

The three projects, to be carried out in Japan, are the following:

- Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility (IFMIF/EVEDA):
The future realization of fusion energy will require materials that have endurance and show low radioactivity against the exposure to the harsh thermal and irradiation conditions inside a fusion reactor. The IFMIF will allow testing and qualification of advanced materials in the environment conditions of a future fusion power reactor. The engineering validation and design activities aim at producing a detailed, complete and fully integrated engineering design of IFMIF.
- International Fusion Energy Research Centre (IFERC):
This will involve activities relating to the demonstration power reactor (DEMO), and in particular design research and development (R&D), computational simulation and ITER Remote Experimentation.
- Satellite Tokamak Program:
The JT-60 tokamak will be upgraded to an advanced superconducting tokamak JT-60 SA, and exploited under the framework of this Agreement as a 'satellite' facility to ITER. The Satellite Tokamak Program is expected to develop operating scenarios and address key physics issues for an efficient start-up of ITER experimentation and for research towards DEMO.

Calendar of Upcoming Conferences on Fusion Technology

2007:

13th International Conference on Emerging Nuclear Energy Systems (ICENES-2007)
June 3-8, 2007, Istanbul, Turkey
<http://www.icenes2007.org/>

22nd Symposium on Fusion Engineering – SOFE-2007
June 18-22, 2007, Albuquerque, NM, U.S.A.
<http://sofe22.sandia.gov/>

2nd IAEA TM on First Generation of Fusion Power Plant: Design and Technology
June 20-22, 2007, Vienna, Austria
Physics@iaea.org

ANS Annual Meeting
June 24-28, 2007, Boston, MA, U.S.A.
<http://www.ans.org/>

EUROMAT 2007, Materials for Fusion Applications
September 10-13, 2007, Nuremberg, Germany
<http://www.euromat2007.fems.org/>

4th IAEA TM on Physics and Technology of Inertial Fusion Energy Targets and Chambers
5th International Conference on Inertial Fusion Sciences and Applications – IFSA-07
September 10-14, 2007, Kobe, Japan
<http://www.ile.osaka-u.ac.jp/ifsa07/>

8th International Conference on Tritium Science and Technology
September 16-21, 2007, Rochester, New York, U.S.A.
<http://meetings.ile.rochester.edu/Tritium/>

8th International Symposium on Fusion Nuclear Technology - ISFNT-8
September 30 - October 5, 2007, Heidelberg, Germany
<http://www.fzk.de/isfnt-8>

16th International Stellarator/Heliotron Workshop
October 15-19, 2007, Gifu, Japan
<http://itc.nifs.ac.jp/index.html>

ANS Winter Meeting
November 11-15, 2007, Washington, DC, U.S.A.
<http://www.ans.org/>

49th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 12-16, 2007, Orlando, FL, U.S.A.

13th International Conference on Fusion Reactor Materials - ICFRM-13
December 10-14, 2007, Nice, France

2008:

ANS Annual Meeting
June 8-12, 2008, Anaheim, CA, U.S.A.
<http://www.ans.org/>

17th International Symposium on Heavy Ion Inertial Fusion

ANS Winter Meeting
November 9-13, 2008, Reno, NV, U.S.A.
<http://www.ans.org/>

ANS 18th Topical Meeting on the Technology of Fusion Energy – TOFE-2008
September 28-October 2, 2008, San Francisco, CA, U.S.A.
latkowski@llnl.gov

IAEA Fusion Energy Conference - 50th Anniversary of Controlled Nuclear
Fusion Research
October 22, 2008, Geneva, Switzerland

50th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 17-21, 2008, Dallas, TX, U.S.A.

25th Symposium on Fusion Technology - SOFT-2008
September 2008, Rostok, Germany

2009:

ANS Annual Meeting
June 14-18, 2009, Atlanta, GA, U.S.A.
<http://www.ans.org/>

23rd Symposium on Fusion Engineering – SOFE-2009

6th International Conference on Inertial Fusion Sciences and Applications – IFSA-09

ANS Winter Meeting
November 8-12, 2009, Washington, DC, U.S.A.
<http://www.ans.org/>

51st American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 2-6, 2009, Atlanta, GA, U.S.A.

2010:

ANS Annual Meeting

June 13-17, 2010, San Diego, CA, U.S.A.

<http://www.ans.org/>

18th International Symposium on Heavy Ion Inertial Fusion

26th Symposium on Fusion Engineering – SOFT-2010

ANS Winter Meeting

November 14-18, 2010, New Orleans, LA, U.S.A.

<http://www.ans.org/>

ANS 19th Topical Meeting on the Technology of Fusion Energy – TOFE-2010

November 14-18, 2010, New Orleans, LA, U.S.A.

<http://www.ans.org/>

52nd American Physical Society - Division of Plasma Physics (APS-DPP) meeting

November 8-12, 2010, Chicago, IL, U.S.A.

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