American Nuclear Society
Fusion Energy Division
June 2004 Newsletter

Letter from the Chair, René Raffray, University of California-San Diego, San Diego, CA.

In my final message as Chair of the ANS Fusion Energy Division (FED), I would like to address the following topics: the Department of Energy (DOE) FY05 Fusion Budget, the ITER status, FESAC panels, and the 16th TOFE meeting.

Fusion Budget

The FED Executive Committee is very concerned about recent changes in the direction of US fusion research. We have already communicated this to all FED members as part of an ANS broadcast but I would like to summarize the situation here. As part of a change in policy regarding fusion energy related R&D, the so-called "long-range" fusion technology program has been terminated as reflected in DOE's Office of Fusion Energy Science FY 2005 budget request. DOE has also been reducing its efforts on advanced design of fusion energy systems. Such a development will directly affect the R&D activities of many members of the ANS Fusion Energy Division.

It is difficult to understand this decision to terminate the fusion nuclear technology programs given the support for fusion energy research at the highest administration levels, along with the plan for the US to join construction of the ITER device and the continuing construction of the National Ignition Facility. It would seem prudent to maintain some balance in the program between science and technology and between magnetic fusion energy (MFE) and inertial fusion energy (IFE). This is reflected in several statements from the Fusion Energy Science Advisory Committee (that provides advice and recommendations to the Director of the DOE Office of Science). Other participants in ITER, in particular the EU and Japan, have strong programs in fusion technology R&D in preparation for testing in ITER and leading to a power plant in the future. It would be regretful at this stage for the US to pull out of this R&D area and to be left in the precarious position of having to catch up with our ITER partners in the future once we decide to seriously develop the advanced technology required for an attractive fusion power plant.

As this change in policy will seriously impact the ANS Fusion Energy Division, we have requested the official support of ANS on this matter. Dr. Larry Foulke, the ANS President and the ANS Officers have been very responsive on this and we are grateful to them. They have approved the submission of written testimonies from Dr. Foulke as ANS President to the Subcommittee on Energy and Water, House Committee on Appropriations and to the Senate Energy and Water Appropriations Subcommittee for their hearings on the FY 2005 budget (a copy of the written testimony can be found at http://fed.ans.org/index.shtml).

In sharing this concern with you and in line with the "grassroots activity" advocated by Dr. Foulke, I would like to encourage you to contact your local congressional representatives about this imbalance in the fusion budget.

ITER

There are now two candidate sites to host ITER: Cadarache in France proposed by the EU and Rokkasho-Mura proposed by Japan. As of the time of this writing, no final choice has yet been made after several meetings among the six ITER participants. There seems to be a split among the participants with China, the EU and Russia favoring Cadarache and Japan, South Korea and the US favoring Rokkasho-Mura. Let us hope that a decision will soon be reached, which I believe will provide a fresh impetus to the project. For more information on US ITER activities, please refer to Dr. Ned Sauthoff's article in this newsletter.

FESAC

Panels appointed by the Fusion Energy Science Advisory Committee (FESAC) to address charges on the IFE Program and on Workforce Development in the US Fusion Program reported their findings at the last FESAC meeting in March 2004. The Committee of Visitors (COV) established by FESAC to review program management by the Office of Fusion Energy Sciences (OFES) also reported its findings in the area of fusion theory and computation. The groundwork of the new Panel appointed to address the recent FESAC charge on establishment of priorities for the fusion program was also summarized at that meeting.

A. Inertial Fusion Energy Program

A FESAC Panel chaired by Dr. Rulon Linford has been charged with reviewing the Inertial Fusion Energy (IFE) program. The Panel was impressed by the progress across the program, noting that the three main approaches (Heavy Ion Accelerators, High Average Power Laser, and Z-pinch) are at different levels of maturity but are all currently on track for developing the science and technology to properly evaluate their potential for IFE. However, the planned termination of technology programs in support of the Heavy Ion (HI) approach is not consistent with their importance to HI-IFE, and the Panel is concerned about the impact of this action. The Panel agreed with the IFE community that the most efficient way to achieve the ultimate goal of fusion energy is to carry out a coordinated program with some level of research on all of the key components (targets, drivers, and chambers), always keeping the end product and its explicit requirements in mind. In sum, the IFE Panel was of the unanimous opinion that the IFE program is technically excellent and that it contributes in ways that are noteworthy to the ongoing missions of the DOE. FESAC agreed with this conclusion, adding that methods, concepts and results from IFE science have enriched many areas of fusion research, including magnetic fusion energy science.

B. Workforce Development in the US Fusion Program

A FESAC Panel chaired by Prof. Edward Thomas reported its findings in addressing the issue of workforce development in the US fusion program. The Panel gathered extensive data, through community surveys and other means, before composing its report. A prominent finding of the report is that, while the population of fusion scientists is likely to remain close to its present size for the next 2-4 years, without prompt action the following 6-10 years may result in a significant shortage of fusion research personnel.

This prediction, based on the present demographics of fusion scientists, takes into account the increased demands of the burning plasma research program as well as an expanded base program. The Panel report includes detailed recommendations for workforce development in both the short and long terms. FESAC specifically supported the recommendation for continuation of support of fusion research programs at universities with a particular emphasis on experimental programs that will train individuals with hands-on experience. FESAC also supported the Panel conclusion that it is critical that the process of new job creation begin now, both to encourage students to enter and remain in the field and to facilitate the intellectual continuity of the field.

C. Committee of Visitors

FESAC has established a Committee of Visitors (COV) to review program management by the Office of Fusion Energy Sciences. As recommended in the charge, OFES will be reviewed by three COV's, corresponding to three major components of the program: theory and computation; confinement innovation and basic plasma science; and tokamak research and enabling technologies. Each Committee will conduct periodic reviews at intervals of three or four years. In reporting its findings, the Theory and Computation COV, chaired by Dr. William Nevins, noted the success of OFES in its implementation of comparative peer review and the quality of the reviewers chosen by the OFES Theory Team. It concluded that the competitive peer review process has improved both the fairness and accountability of the proposal review process. The COV then provided six recommendations intended to improve the comparative peer review process. FESAC agreed with the COV's conclusions and recommendations.

D. Priorities Panel

FESAC is currently working on the charge to assist the establishment of priorities for the fusion program by identifying the major science and technology issues that need to be addressed, recommending how to organize campaigns to address those issues, and recommending the priority order for these campaigns. A Panel has been appointed chaired by Dr. Charles Baker and is organizing the work through a number of working groups. The initial findings from this Panel will be reported at the next FESAC meeting in July 2004. A specific webpage has been set up for this FESAC Priorities Panel at: http://www.mfescience.org/fesac/index.html

Please refer also to the FESAC website for more information about the different FESAC activities:
http://www.ofes.fusion.doe.gov/More_HTML/FESAC_Charges_Reports.html

TOFE & Other FED News

The 16th Topical Meeting on the Technology of Fusion Energy (TOFE) will be held as a stand-alone meeting in Madison, Wisconsin on September 14-16, 2004. Prof. Gerald Kulcinski is the General Chair and Dr. Laila El-Guebaly is the Technical Program Chair. They have put together an impressive organization structure and we are looking forward to a very successful TOFE meeting. Although the deadline for abstract submission has passed, I would like to encourage all members of the fusion technology community to attend what promises to be a very informative and interesting meeting. For more information about TOFE, please refer to the article in this newsletter on 16th TOFE Updates by Prof. Gerald Kulcinski and Dr. Laila El-Guebaly.

It is the time of the year to convey our thanks to a member whose term is expiring and who will be leaving the Executive Committee (EC) as of June 2004, namely Dr. Neil Taylor. It is also the time of the year to congratulate the new officers and members, namely Prof. Jake Blanchard who will become the FED EC Chair, Prof. Said Abdel-Khalik who will become the Vice-Chair and Dr. Gianfranco Federici, Prof. Farrokh Najmabadi, Prof. Akio Sagara and Dr. Roger Stoller who will start their new terms as EC members this June.

In closing, I would like to say that it has been a pleasure over the past year to work with the members of the Executive Committee as well as with many regular FED members. I have particularly appreciated the help of Jake as current Vice-Chair and Dr. Jeff Latkowski as Secretary/Treasurer. I would encourage all FED members to look for ways to become involved in helping FED and not to hesitate in contacting any EC members for questions, comments and/or suggestions.

Officers and Executive Committee List, Wayne Meier, Lawrence Livermore National Laboratory, Livermore, CA.

We are pleased to announce and welcome the new Officers and Executive Committee members of the Fusion Energy Division. Vice-chair Jake Blanchard (University of Wisconsin) becomes our new Chair. Said Abdel-Khalik (Georgia Institute of Technology), who was an Executive Committee member, has been elected as the new Vice-Chair/Chair-Elect. Jeff Latkowski (LLNL) will continue as Secretary/Treasurer as this is now a two-year position. The newly elected Executive Committee members are Roger Stoller (ORNL), Gianfranco Federici (Max Planck Institute for Plasma Physics), and Farrokh Najmabadi (UCSD). The Division has also appointed Akio Sagara for an additional two years to fill the slot vacated by Said's election to Vice-Chair. These new members join an excellent group of individuals who have already been serving the FED as Executive Committee members. Congratulations to all. Thanks go to René Raffray (UCSD) for his service this past year as FED Chair. He will now become the Nominating Committee chair. We also express appreciation to the FED members who are serving on the many standing committees that keep the Division vital and well functioning (see list below).

FED Officers:

Chair:	Jake Blanchard (UW)	(04-05)	blanchard@engr.wisc.edu
VC/Chair-Elect:	Said Abdel-Khalik (GT)	(04-05)	said.abdelkhalik@me.gatech.edu
Secy./Treas.:	Jeff Latkowski (LLNL)	(03-05)	latkowski@llnl.gov

Executive Committee Members:

Gianfranco Federici (IPP)	(04-07)	federig@ipp.mpg.de
Farrokh Najmabadi (UCSD)	(04-07)	najmabadi@fusion.ucsd.edu
Susana Reyes (LLNL)	(02-05)	reyessuarez1@llnl.gov
Akio Sagara (Japan)	(04-06)	sagara@LHD.nifs.ac.jp
Ken Schultz (GA)	(03-06)	ken.schultz@gat.com
Phil Sharpe (INEEL)	(03-06)	SHARJP@inel.gov
Lance Snead (ORNL)	(02-05)	sneadll@ornl.gov
Roger Stoller (ORNL)	(04-07)	stollerre@ornl.gov
Paul Wilson (UW)	(02-05)	wilsonp@engr.wisc.edu

Past Chair:	René Raffray (UCSD)	raffray@fusion.ucsd.edu
FED Standing Committee Chairs:		
	Nominating	René Raffray (UCSD) - Chair
	Honors and Awards	Farrokh Najmabadi (UCSD) - Chair
FED Special Committee Chairs:		
	Membership	Ken Schultz (GA)
FED Representatives on National Committees:		
	ANS Publications	Ken Schultz (GA)
	ANS Public Policy	Bill Hogan (LLNL)
Editors:	Newsletter	Laila El-Guebaly (UW) Dennis Bruggink (UW)
	Fusion Science & Technology Journal	Nermin Uckan (ORNL)
Liaisons to other ANS divisions and organizations:		
	ANS Board	Gary Gates (Omaha Public Power District)
	MS&T	Ken Schultz (GA)
	IEEE	George Miley (UIUC)
FED webmasters:		Mark Tillack (UCSD) Dennis Bruggink (UW)

Treasurer's Report, Jeff Latkowski, Lawrence Livermore National Laboratory, Livermore, CA.

As of December 2003, our division had a balance of $15,092. Income in 2003 included $691 from membership dues. Expenses in 2003 included $284 for conducting business meetings during the ANS National Meetings, $200 for student support, and a $300 contribution to the NEED Scholarship.

Our income for 2004 is projected to be $650 with projected expenses of $5900.

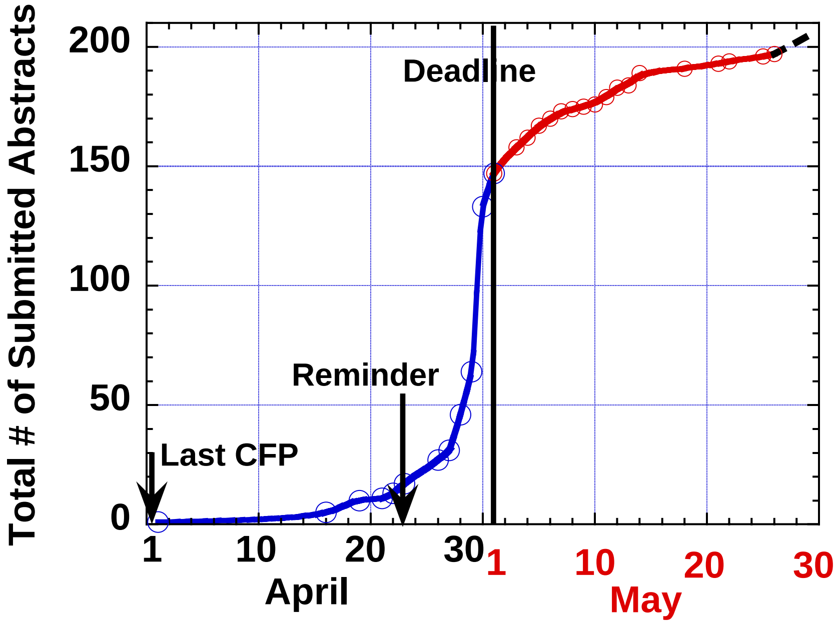
Typically, the Division receives additional income from the TOFE meeting. To be conservative, we are not assuming any income for the Division from the 16th TOFE.

Expenses for 2004 include $500 for conducting business meetings during the ANS National Meetings, $1500 to support student travel to the TOFE meeting, $3000 for awards, a $300 contribution to the NEED Scholarship, and $600 for other expenses. The awards include three cash awards of $500 to be given at the TOFE meeting and a $1500 one-time contribution to the Edward Teller Endowment Fund.

We project a balance of $9842 at the end of 2004. If the 16th TOFE is profitable, the Division will receive 25% of the profits as additional income.

16th TOFE Updates, Gerald Kulcinski and Laila El-Guebaly, University of Wisconsin-Madison, Madison, WI.

The 16th ANS Topical Meeting on the Technology of Fusion Energy (TOFE) will be held in Madison, WI on September 14-16, 2004. Over the past two months, preparations for the meeting have gained significant momentum. After issuing the last Call-for-Papers (CFP) at the end of March, we started receiving abstracts at a slow rate, then submissions picked up significantly close to the May 1 deadline (see the figure below). About 50 abstracts, mostly invited, were submitted after the deadline. The TOFE website (http://fti.neep.wisc.edu/tofe) is now closed for abstract submission, except for the plenary presentations.



We received a total of 209 abstracts (30% non-US) from 11 countries: US, Japan, Germany, England, Italy, Kazakhstan, Greece, Belgium, Bulgaria, Canada, and Russia. This represents a 20-50% increase relative to the most recent 14th and 15th Topicals and positions the 16th TOFE well for attendance. Members of the organizing committee have already reviewed the abstracts and notifications of acceptance/rejection have been E-mailed to the authors before the beginning of June.

Approximately 11 plenary, 84 oral, and 110 poster presentations will be given at the 16th TOFE, covering all areas of MFE and IFE nuclear technologies. Most of the plenary and oral presentations are invited, high-level talks. We're currently developing the technical program and will post it before the end of June on the TOFE website. Please check the site frequently for updates and for the exact date/time/duration of your presentation. Peer-reviewed full papers that are due at the meeting will be published by the ANS Fusion Science & Technology Journal. Full meeting registrants will receive the proceedings and CD-ROM after the meeting.

There are several key dates and deadlines that need your attention. Please visit the TOFE website (http://fti.neep.wisc.edu/tofe) for more details.

Nominations for ANS-FED awards	May 31, 2004
Notification to authors	June 1, 2004
Early registration deadline	August 10, 2004
Hotel reservation cutoff date	August 10, 2004
Full papers due at the meeting	September 14, 2004

We encourage you to make the hotel reservation ASAP. Two major events are taking place in Madison before and after the TOFE meeting and most hotels could be fully booked during the week of Sept. 13, 2004. Credit cards used to guarantee the first night will not be charged in advance and the first night deposit will not be charged for reservations cancelled 48 hours prior to arrival.

It will be our great pleasure to see the TOFE participants in Madison this summer.

Award for Best Student Work Presented at the 16th TOFE, Paul Wilson, U. Wisconsin-Madison, Madison, Wisconsin.

Selected members of the 16th TOFE Technical Program Committee will review all submissions with students as first authors and select the best student work presented at the meeting. Formal evaluation criteria will be used to assess the quality of the student's work based on three categories:

1. The technical merit of the work (50%), for example:
   - * Value to field
   - * Completeness/correctness
   - * Originality
2. The quality of the presentation/poster materials (25%), for example:

    - Logical layout/flow
    - Appropriate use of charts/tables/text
3. Formal interactions with the student (25%), for example:
    - Oral communication skills
    - Ability to address questions.

The student author of this work will receive a $500 cash award and a plaque recognizing their accomplishment. In addition, the Journal of Fusion Science & Technology will offer a page charge waiver to the winning author for a related full paper submitted within one year.

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

Manuscript submissions are up, with over 90% of new manuscripts being submitted electronically. For the past four years, the FS&T has been handling almost all of its manuscript reviews electronically. Recently, ANS has been looking into several Web-based electronic manuscript systems for electronic submission of manuscripts and peer review. ANS is planning to implement such a plan for all of its scientific journals, possibly in early 2005.

Two years of back issues are uploaded to the journal's online subscription database. Electronic access to FS&T is now available from 1997-to-current. Additional journal back issues will continue to be added. Recent camera-ready special issues are also available online. Tables of contents and abstracts of papers can be accessed at http://www.ans.org/pubs/journals/fst/. Individual and library subscribers can access the full text of articles at http://epubs.ans.org/.

During the past six months, since the last newsletter in December 2003, FS&T has been busy with publication and scheduling of several special issues and an excellent selection of contributed papers. The 2003 (second half)/2004 (first half) issues included the following special issues:

July 2003 & September 2003	Peer-reviewed papers from the 15th Topical Meeting on the Technology of Fusion Energy (15th TOFE, Parts I & II)
November 2003	ASDEX-Upgrade Tokamak (Garching, Germany)
March 2004	Peer-reviewed papers from the 15th Target Fabrication Specialists' Meeting & Transaction/Proceedings of the Carolus Magnus Summer School
May 2004	FTU Tokamak (Frascati, Italy)

The 2004 (second half)-2006 special issues will include: papers from the 14th Int. Stellarator Workshop (Germany), ARIES-IFE Study (US), NCSX (PPPL), DIII-D Tokamak (GA), TEXTOR Tokamak (Juelich, Germany), Tritium-2004, 16th TOFE, Fast Ignition (US, JA, EU), Alcator C-Mod Tokamak (MIT), JET Tokamak (EU), magnetic fusion power plant studies (EU, JA, US), NIF program and beyond (LLNL), and much more.

Don’t miss any of these issues by signing-up for an individual ANS member subscription or through your libraries.

Looking forward to receiving your comments on FS&T content and coverage, and potential future topical areas that are timely and of interest. Contact e-mail: fst@ans.org.

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

Fusion Awards have been established by several national and worldwide organizations to formally recognize the outstanding contributions to fusion developments made by members of the fusion community. Congratulations to the 10 honored recipients of the 2003 fusion awards (listed in alphabetical order):

Dr. Robert Aymar received the 2003 Fusion Power Associates (FPA) Distinguished Career Award. Aymar, director emeritus of the international ITER project, was recognized for his many years of outstanding scientific and managerial contributions to fusion development.

Dr. John DeLooper received an FPA Special Award. DeLooper, of the Princeton Plasma Physics Laboratory, was recognized for his educational outreach efforts and logistical support for the fusion Snowmass meetings.

Dr. Stephan A. Letts received the 2003 Larry Foreman Award for Innovation and Excellence in Target Fabrication. Letts, LLNL, was recognized for his quarter century of contributions in the area of capsule fabrication, especially polymer capsules.

Professor George Miley received the 2003 Fusion Technology Award from the Institute of Electronics and Electrical Engineering’s Nuclear and Plasma Sciences Society. Miley, a professor at the University of Illinois at Urbana-Champaign, was recognized for innovative contributions to the advancement of alternate confinement fusion concepts and technology and for pioneering the development of fusion neutron sources for industrial applications.

Dr. Abbas Nikroo received the 2003 FPA Excellence in Fusion Engineering Award. Nikroo, of General Atomics, was recognized for outstanding technical contributions to the technology of inertial fusion energy.

Professor Stewart Prager received the 2003 FPA Leadership Award. Prager, physics professor at the University of Wisconsin-Madison, was recognized for outstanding contributions to fusion development.

Dr. John Sheffield received the 2003 FPA Distinguished Career Award. Sheffield, of Oak Ridge National Laboratory and the University of Tennessee, was recognized for his leadership and contributions to many fusion advisory committees.

Ian Smith received the 2003 Global Energy International Prize from the Russian Federation. Smith, deputy manager of the Pulsed Sciences Division for Titan Corporation, was honored for his research in pulsed power, a key element of inertial confinement fusion energy.

Dr. Laurence Suter received the 2003 ANS/FED Edward Teller Medal. Suter, of Lawrence Livermore National Laboratory, was recognized for his seminal work on almost all aspects of laser hohlraum physics. Over the past twenty years, he has become widely known as one of the world's leading experts on laser hohlraum physics.

Professor Hideaki Takabe received the 2003 ANS/FED Edward Teller Medal. Takabe, of ILE, Osaka University, was recognized for his pioneering work on laser-plasma interactions, atomic physics, and hydrodynamic instabilities of laser implosions.

These 10 fusion awards 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.

ONGOING FUSION RESEARCH:

The National Spherical Torus Experiment – Progress toward the Next-Level

Martin Peng, UT-Battelle ORNL, Oak Ridge, Tennessee; on assignment at PPPL, Princeton, New Jersey

The National Spherical Torus Experiment (NSTX) (see Figure 1) being operated at the Princeton Plasma Physics Laboratory (PPPL) is producing data that may revolutionize the development of fusion energy as an inexhaustible, safe, and environmentally attractive means of generating electricity for the long term. These experiments are being performed by a national team comprised of researchers from twenty-four fusion research institutions throughout the US. Scientists from U.K., Japan, Russia, Korea, France, Germany, and Canada also participate in the NSTX research.

The spherical torus (ST) [1] is an innovative confinement configuration that may lead to practical fusion energy at a reduced cost. The ST plasma is shaped like a cored apple (see Figure 2) and is theorized to permit high plasma pressure using a lower magnetic field strength. The spherical shape is further expected to help overcome plasma turbulence and instabilities, which can lead to a rapid energy leak from the plasma and premature loss of the fusion reaction. Successful experiments on NSTX could lead to the development of smaller, more economical fusion reactors, and the development steps toward the fusion reactor.

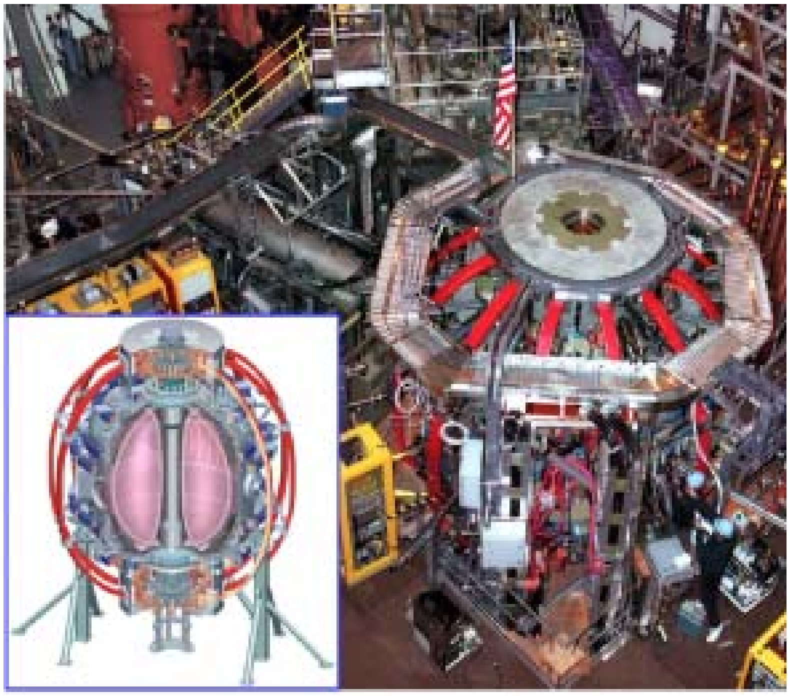


Figure 1. NSTX in the test cell and in 3D cut-out model.

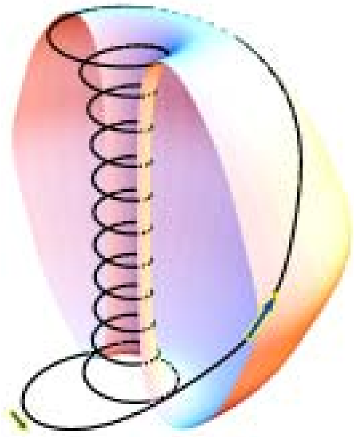


Figure 2. Typical magnetic surface and field line of a spherical torus.

NSTX Mission

The recent DOE Office of Science 20-year Strategic Plan [2] includes two fusion energy sciences facilities that are potentially based on the ST configuration (see Figure 3). The plan envisions, for the mid-term of this period, a Next Step Spherical Torus (NSST) to test the ST for confining fusion-producing plasmas. It also envisions, for the far-term, the Fusion Energy Contingency facilities, which can include a ST-based Component Test Facility (CTF) to develop and test power plant components.

The mission of the NSTX program is therefore to establish an adequate understanding of the physics properties and the scientific potentials of the ST plasma in a timely manner to support this strategic plan. Another key mission of the NSTX program is to broaden the scientific basis required to achieve practical fusion energy, taking advantage of the extended and attractive physics parameters of the ST.

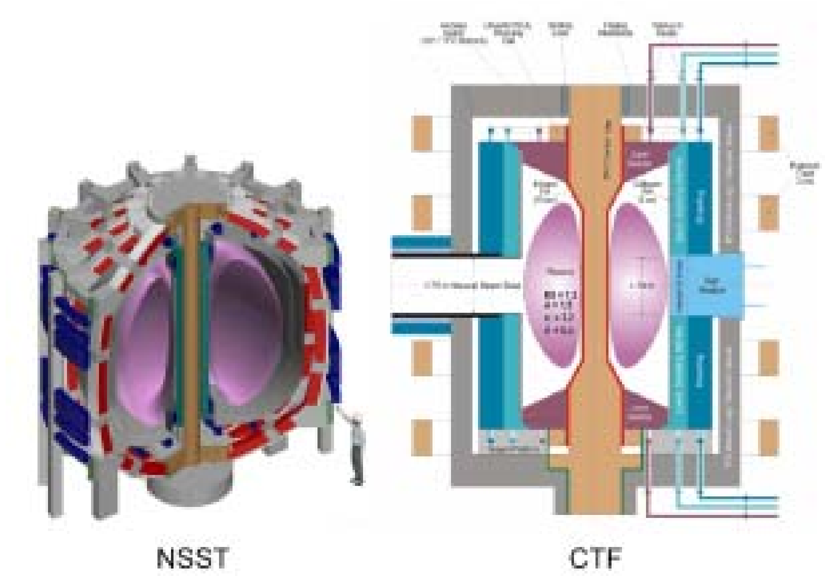


Figure 3. Design concepts of NSST with R=1.5 m and CTF with R=1.2 m

NSTX Research Plan

NSTX began research operation in September 1999. Through 2003, the NSTX National Research and Facility Operation Teams implemented numerous improvements in measurement and operation capabilities, carried out active experimental research, and made exciting progress in major plasma scientific topical areas of interest to practical fusion energy. This progress contributed to the development by the NSTX National Team of the NSTX research plan for 2004-2008, [3] which was reviewed and endorsed in June 2003 by a DOE-organized international panel. This ambitious plan (see Figure 4) aims first to explore the passive physics limits; secondly to develop advanced tools and explore high pressure plasma physics; and then thirdly to optimize and integrate the attractive elements of physics into sustained and well-confined high pressure plasmas. This plan poses scientific and technical challenges and, if fully implemented, will achieve the essential elements of the NSTX mission.

Recent Progress toward ST Database

Major NSTX research results through May 2004 cover all scientific topical areas of importance to the next step ST devices. This rapid progress also helped identify key near-term research targets of investigation to establish the validity of the physics basis for these devices. Key examples are highlighted below:

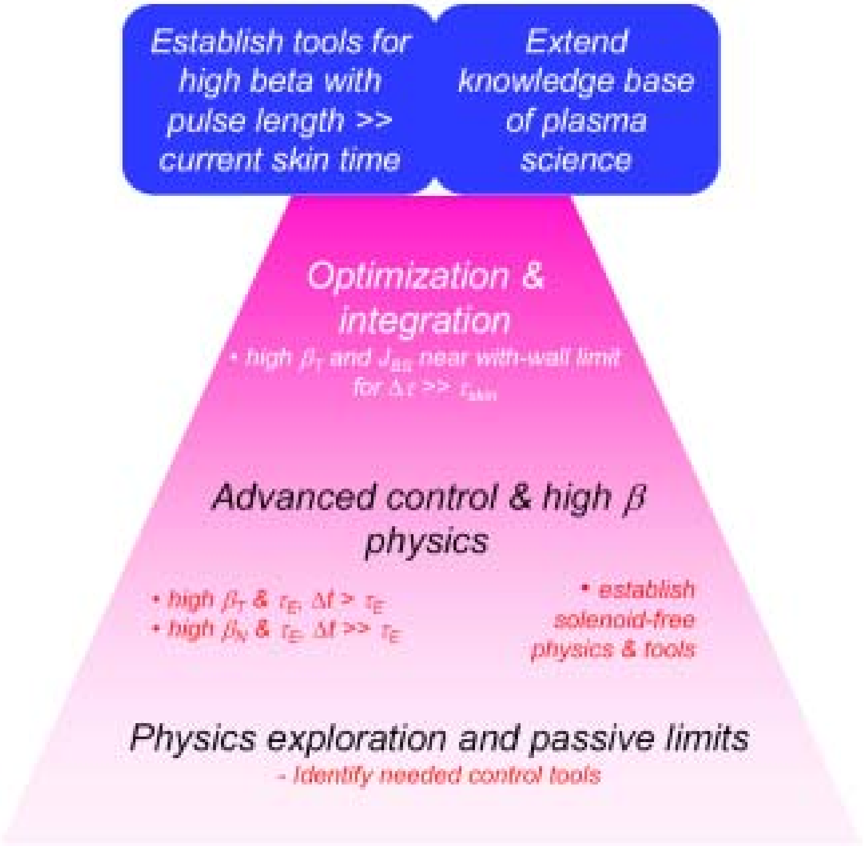


Figure 4. The goals and three phases of the NSTX Five-Year Research Plan.

A. High Plasma Pressure in Moderate Magnetic Field

As shown in Figure 5, the achieved β_T, the ratio of plasma pressure to a main component of the applied magnetic field pressure, has nearly approached the theoretical target value of 40% used in guiding the NSTX design and research program. Improvements in plasma shaping control and operating conditions during intense plasma heating by neutral beam injection (NBI) at powers up to 7 MW have been instrumental to this success. However, the study also identified two important stability regimes: a regime of highest plasma current and the highest β_T (30-40%) appropriate for high performance plasmas of limited durations in NSST, and another regime at reduced current and β_T (~20%) adequate for sustained fusion producing plasmas in CTF. New magnetic sensors, control coils, and feedback power supplies are being implemented to sort out the details of these ST stability properties.

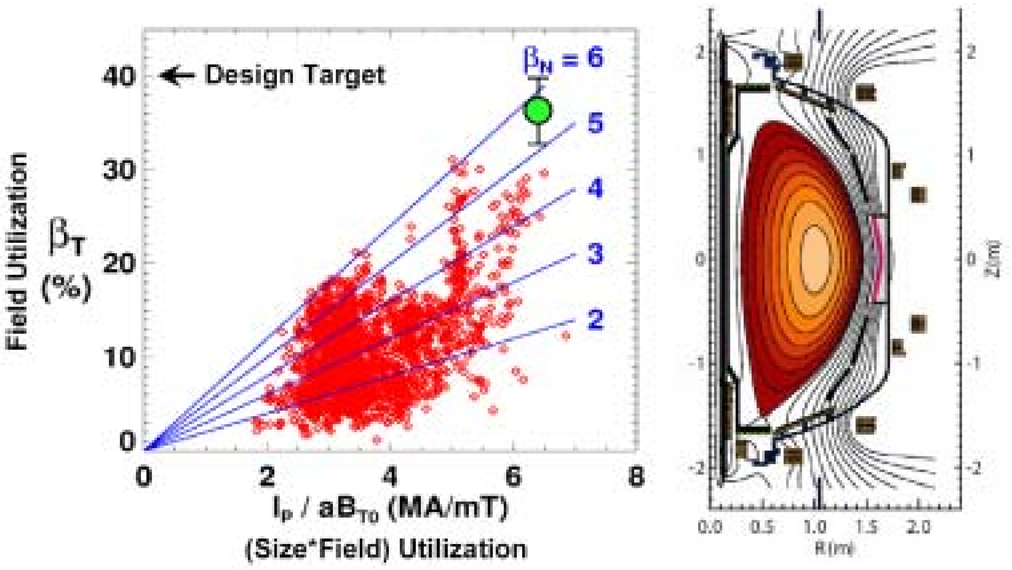


Figure 5. Rapid progress toward the $\square_T$ design target were effected by enhanced plasma shape control.

B. Efficient Confinement of Plasma Energy

As shown in Figure 6, the plasma energy confinement times of NBI-heated plasmas in NSTX have been consistently 1.5-2.5 times the normal low-confinement (L-Mode) values established from the broad tokamak database. The ST confinement times are presently at par with the best results for toroidal fusion configurations, and are quite encouraging for future ST devices. However, the results also indicated that the ions in NSTX contain their energy very efficiently, associated with a rather unique near sonic-speed rotation of the plasma core. The root turbulence and transport mechanisms for this good result are therefore likely to be rather different from the tokamaks, and hence potentially render the tokamak confinement scaling inappropriate as a guide for projections to larger ST devices. More refined measurements of the plasma profiles and fluctuations are planned or under preparation to investigate and understand these mechanisms to establish reliable projections to future experiments.

C. Approaching Sustained Operation

Nearly sustained plasmas (see Figure 7) are routinely obtained in NSTX using the NBI heating alone. For a duration longer than the plasma current redistribution time, the induction loop voltage was reduced to about 1/10 of the normal value. Analysis indicated that a large fraction (~60%) of the plasma current could already be driven by a combination of NBI and the plasma pressure gradient (the so-called “bootstrap current”). The analysis also indicated that, to remove the induction requirement in NSTX completely, radiofrequency power is needed to heat and drive current in a region toward the periphery of the plasma. The efficacy of adding high-harmonic fast wave (HHFW) power at 30 MHz in frequency is being vigorously investigated. Further, research is underway to determine the potential effectiveness of the electron Bernstein wave (EBW) for this purpose. Initial indications from theory and measurements on EBW have been very encouraging for application to sustained operations in future ST devices.

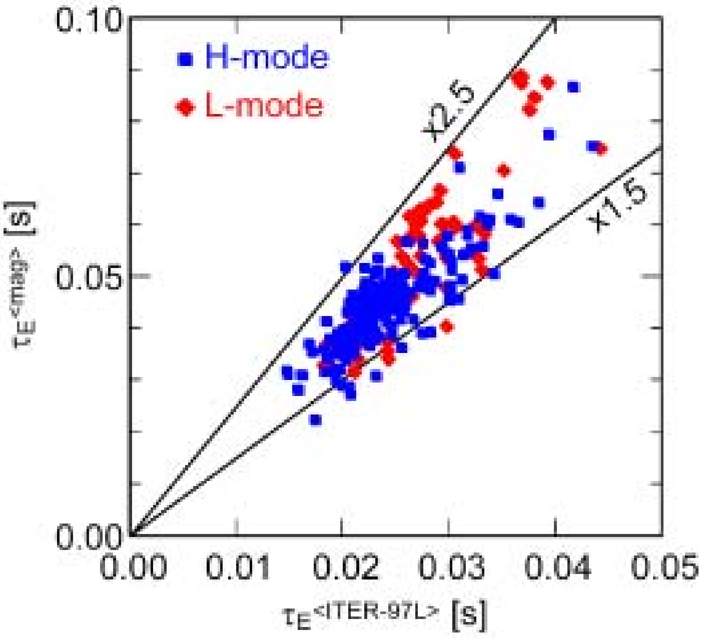


Figure 6. The energy confinement times on NSTX have been consistently much larger than the nominal values in the tokamak database.

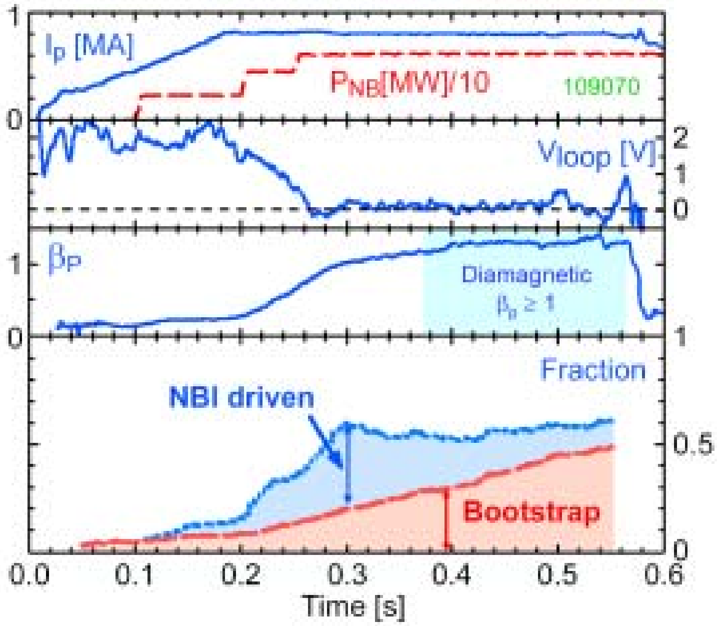


Figure 7. Using NBI heating alone, the NSTX plasmas have approached nearly sustained conditions.

D. Initiating Plasma Current without Inductive Solenoid

ST-based compact CTF and power plants cannot tolerate any central solenoid. It is therefore critically important to develop and test solenoid-free techniques that initiate and ramp up the plasma current to substantial levels (~10% of the full current). A successful transient demonstration of such a current (≤ 400 KA) was obtained (see Figure 8) using the technique of coaxial helicity injection (CHI). Tests to capture this initial current for subsequent current ramp up by other current drive methods are underway. Additional innovative methods that combine radiofrequency power (e.g., HHFW, EBW) with outer magnetic field coil currents are under planned or preparation. Recent success on a major tokamak to initiate about 100 kA in current this way has encouraged vigorous research on this topic on NSTX in the next few years.

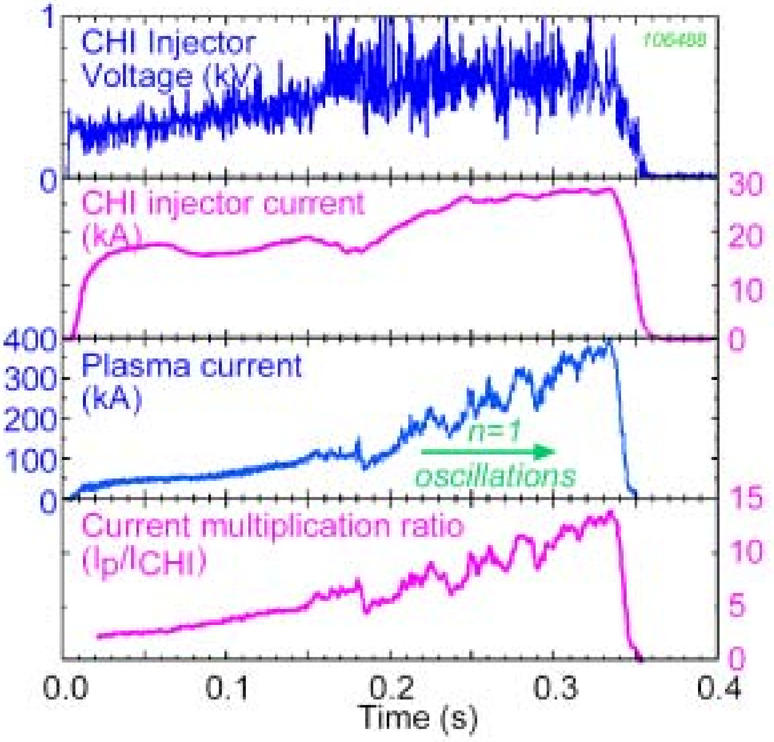


Figure 8. Coaxial helicity injection (CHI) has produced nearly 400 kA toroidal current without solenoid induction.

E. Dispersing Plasma Heat Flux

The high power densities anticipated of compact ST fusion energy devices will lead to large heat fluxes on the plasma facing components (PFC's). It is therefore equally important to develop and test ST edge plasma properties aiming to enhance dispersal of the heat flux over wider areas of the PFC. The heat flux footprint was shown (see Figure 9) to increase substantially beyond the changes of geometric ratio. A suite of measurements of plasma fluxes, spectral radiation, and fluctuations are underway or being planned to investigate the detail of this complex scientific topic. Innovative techniques of particle control, such as lithium coating, are being tested to establish a basis for deploying a liquid lithium surface module on NSTX in the future. A choice will be made in about two years' time between the lithium approach and the more conventional cryogenic pumps, based on these results.

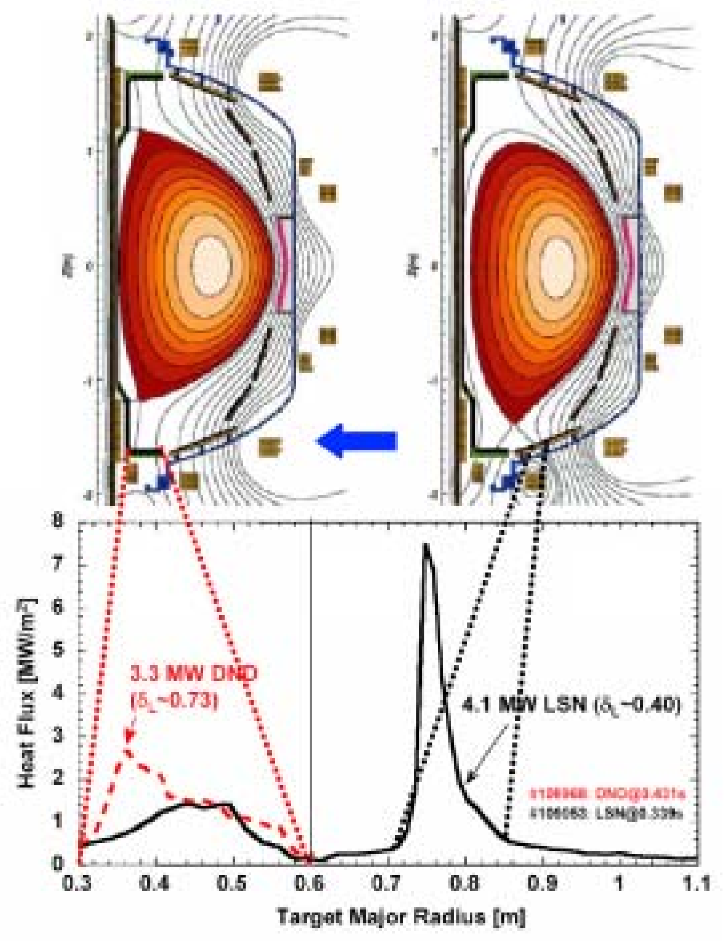


Figure 9. The divertor heat flux footprint expands dramatically as it moves toward smaller major radius.

F. Integrating the Good Results

A comparison of the present NSTX data with the broader Advanced Tokamak (AT) data was made (see Figure 10). In terms of normalized values of energy confinement time multiplied by plasma beta as a function of the plasma pulse length, the NSTX and AT plasmas have already reached comparable performance relative to the estimated future reactor requirements. The NSTX plasmas have further achieved adequate values of this product for the projected CTF operation, while still needing to verify the performance over time scales much larger than the current redistribution times. The testing and development of favorable plasmas that integrate the good plasma properties in NSTX in the upcoming years, sustained near steady state conditions, will encounter many scientific challenges and will likely reap great benefits in accelerating the development of plasma sciences and fusion energy.

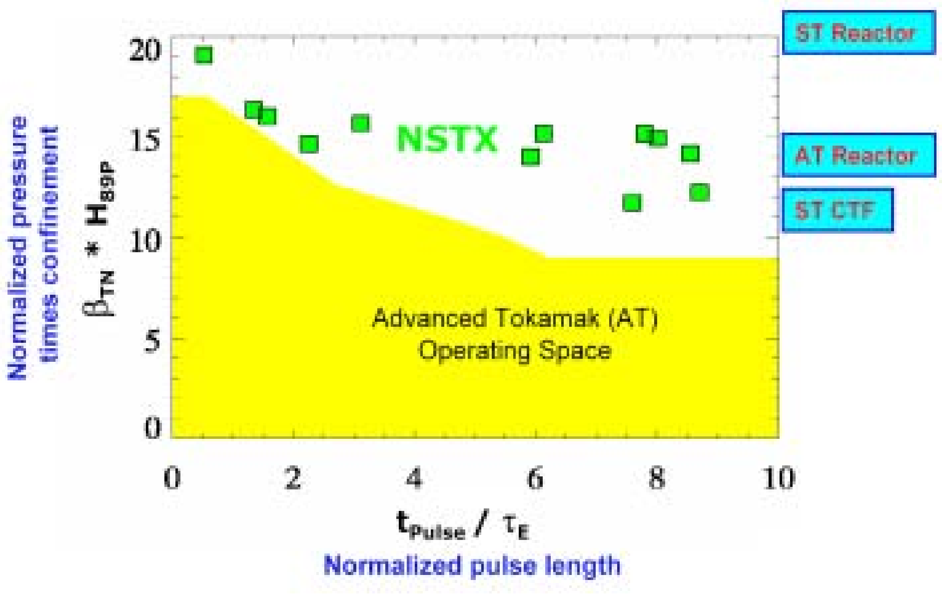


Figure 10. For moderate pulse lengths, the NSTX plasmas already reached high performance conditions needed by CTF and within 75% needed by ST reactor.

For more information please contact mpeng@pppl.gov or visit http://nstx.pppl.gov/.

References:
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[2] "Office of Science Strategic Plan, Feb. 2004," http://www.science.doe.gov/Sub/Mission/Mission_Strategic.htm.
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Georgia Tech Research on the Thermal-Hydraulics of Fusion Reactor Chambers

, Minami Yoda and Said Abdel-Khalik, Georgia Institute of Technology, Atlanta, GA.

Over the last six years, the thermal-hydraulics group in the G. W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology (GT) has performed a wide range of experimental and numerical studies of the fluid dynamics and heat transfer aspects of liquid-protected fusion energy chamber and divertor technologies. Previous studies focused on thick and thin liquid protection schemes for inertial fusion energy reactor chamber first walls proposed in the HYLIFE-II and Prometheus designs. Recent research has emphasized liquid-protected divertors and first walls for magnetic fusion energy systems, and liquid droplet dynamics in expanding plasmas for chamber clearing applications. This article introduces the research capabilities of the GT group, and presents a brief review of their previous contributions and ongoing studies.

Thick Liquid Protection: Turbulent Liquid Sheets

The HYLIFE-II design uses arrays of high-speed oscillating and stationary slab jets, or turbulent liquid sheets, of molten Flibe (Li_2BeF_4) to protect the reactor chamber first walls from damage due to the fusion blast (Figure 1) [1]. The GT group has carried out extensive experimental studies of various fluid dynamics aspects of oscillating and stationary turbulent vertical sheets of water issuing into ambient air. A simple model based upon particle trajectories was found to predict the maximum extent of oscillating liquid sheets with good accuracy [2].

Reducing surface ripple due to free-surface fluctuations in liquid sheets is important in order to minimize driver beam clipping while maximizing protection. The free-surface geometry of stationary turbulent liquid sheets has therefore been extensively characterized using planar laser-induced fluorescence for various operating conditions and jet nozzle designs. We have found simple nozzle and settling chamber designs that produce nearly prototypical liquid sheets with surface smoothness that meets the current HYLIFE requirements [3]. These designs were manufactured using stereolithography rapid prototyping.

Mass collection experiments have been conducted to quantify the "hydrodynamic source term", or the rate at which droplets are continuously ejected from the jet free-surface into the chamber due to primary turbulent breakup. Initial results showed that this term could have a major effect on driver beam propagation and target delivery. We have therefore implemented boundary-layer cutting for the first time in turbulent liquid sheets and recently demonstrated that removing as little as 0.25 mm from the mean free-surface essentially eliminates the hydrodynamic source term [4].

Current efforts involve correlating how initial conditions, namely turbulence intensities in the nozzle, affect both surface ripple and the hydrodynamic source term. In addition to greatly expanding the design database available to fusion energy power plant designers for such flows, these studies have demonstrated that high-speed "liquid curtains" have sufficient smoothness and stability to be viable "building block" flows for thick liquid protection schemes.

Thin Liquid Protection: Liquid Films on Downward-Facing Surfaces

The Prometheus design uses a combination of two types of thin liquid-lead films to protect the chamber first wall: 1) a "wetted wall", where liquid is supplied through a porous SiC structure; and 2) a "forced film," where liquid is injected at high speed through slots to create a few millimeter-thick attached film (Figure 2) [5]. The GT group has numerically and experimentally studied the thermal-hydraulic aspects of both types of film flows. The research has focused on the "worst case" scenario for droplet formation and film detachment—namely, films on the underside of horizontal and inclined surfaces [6].

A. Wetted Walls

A "state of the art" numerical method was used to simulate the evolution of a film on the underside of a horizontal surface over a wide range of liquid properties with evaporation and condensation at the free surface. The results show that the liquid must be injected above a minimum velocity to prevent dry spot formation and that the repetition rate must exceed a given value to keep liquid from dripping into the reactor cavity between explosions. The numerical simulations have been validated by experimental studies using water and a water-glycerin mixture as simulant fluids. The minimum injection velocity and minimum repetition rate criteria are given in terms of nondimensional groups that enable designers to identify appropriate “design windows” for successful wetted wall protection schemes for a wide variety of candidate liquids.

B. Forced Films

Experiments were performed for water films injected onto downward-facing flat and curved surfaces at orientations up to 45° below the horizontal for a wide range of liquid-solid contact angles and initial conditions. Since film detachment was found to occur earlier or farther upstream for nonwetting surfaces and for flat (*vs*. curved) surfaces, the nonwetting flat surface results were used to establish a conservative “design window” for forced film detachment. The results show that multiple injection slots will be required for adequate coverage of a 4 m radius hemispherical upper chamber endcap. Experiments on forced-film flow around beam ports and cavity penetrations suggest that such penetrations will significantly disrupt the film, and may present a major design challenge for thin liquid protection schemes.

The “hydrodynamic source term” was measured using mass collection. Initial results at Weber numbers much lower than prototypical values suggest that this term is significant, though most of these droplets will likely remain near the first wall and are unlikely to interfere with target injection or driver ignition [7]. Overall, wetted walls appear to have significant advantages over forced films for thin liquid protection.

Liquid-Protected Divertors: Thermocapillary-Induced Film Dryout

Both the ALPS and APEX programs have extensively studied plasma surface interactions for liquid-surface protected plasma facing components. Operating temperature windows were established based upon the fluid properties and power conversion efficiency requirements. Constraints were imposed on the maximum fluid surface temperature to limit evaporation and the resulting plasma impurities.

The GT group has focused instead on determining the maximum allowable temperature gradient to prevent film “dryout”. Spatial variations in the wall and liquid surface temperatures are expected due to variations in the wall loading and film convection; thermocapillary forces created by such temperature gradients can lead to film rupture and dryout. A level contour reconstruction method is used to simulate films subject to various temperature gradients; studies were conducted for a variety of liquids over a wide range of operating conditions. Experimental studies are underway to validate the numerical results. The temperature gradient limits are presented in general nondimensional form to allow system designers to identify design windows for successful operation of liquid-protected plasma-facing components for different liquids.

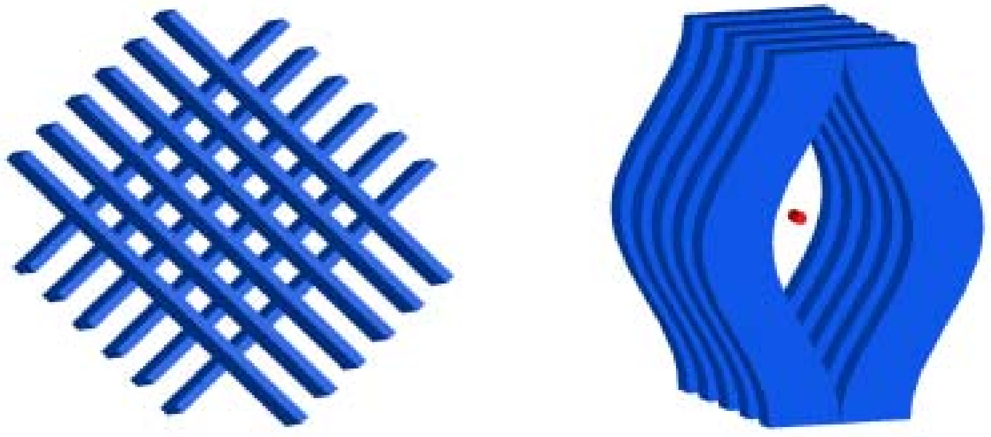

Figure 1. The lattice of stationary jets [left] and the protective pocket formed by arrays of oscillating jets [right] proposed to protect the HYLIFE-II reactor chamber first walls.

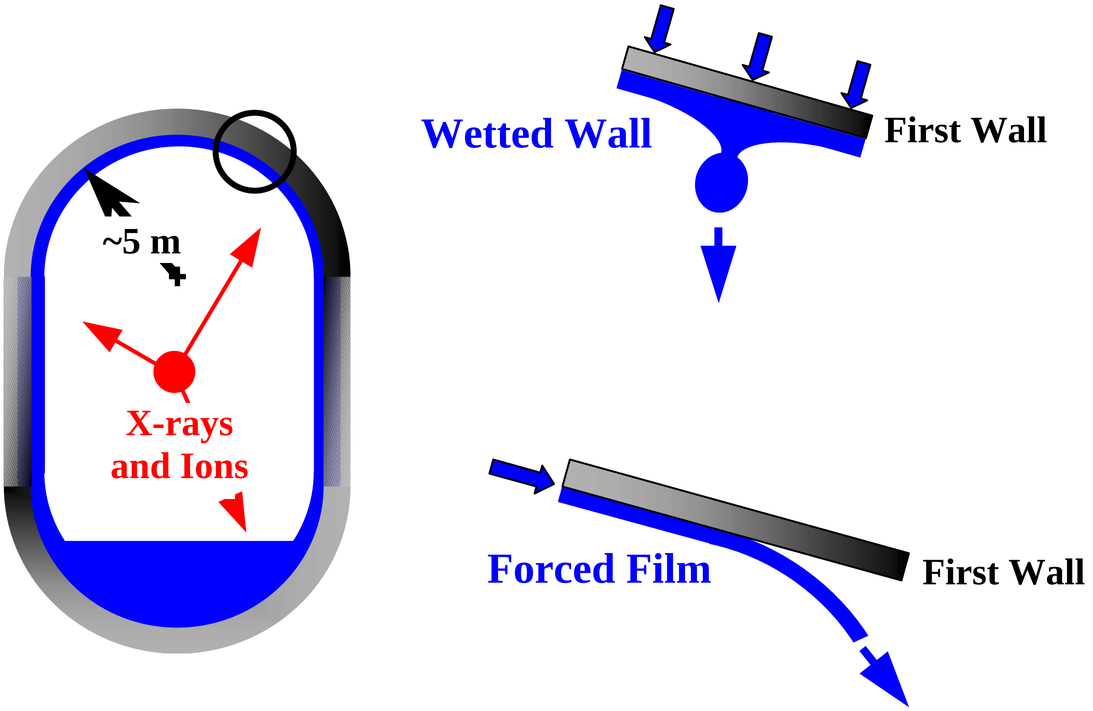

Figure 2. Schematic of the Prometheus chamber and the wetted wall and forced film concepts proposed to protect the chamber upper endcap.

Chamber Clearing: Droplet Lifetimes in Expanding Plasmas

In liquid protected IFE systems, significant amounts of liquid are evaporated and introduced into the chamber following each explosion. Liquid is also continuously added to the chamber by the "hydrodynamic source term". The chamber must therefore be cleared before the next explosion to ensure successful beam propagation and target delivery. Our work in this area has focused on quantifying how rapidly the vapor and liquid contaminants can be removed. Initial experiments are underway on the interactions between liquid droplets and expanding plasmas at prototypical pressures and temperatures corresponding to chamber conditions following target explosions. The evolution of a liquid droplet traveling through the plasma is studied using high-speed photography. These data will be used to validate predictions of computer models such as the HEIGHTS package.

For further information, please contact the authors: minami.yoda@me.gatech.edu or said.abdelkhalik@me.gatech.edu.

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[2] L.C. Elwell et al.,"Dynamics of Oscillating Turbulent Liquid Sheets," Fusion Technology, **39** (2,II), 716–720 (2001).

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[7] B.T. Shellabarger et al., "Turbulent Primary Breakup in Turbulent Liquid Films on Downward-Facing Surfaces," to appear in Fusion Science and Technology (2004).

INTERNATIONAL ACTIVITIES:

US ITER Activities, Ned Sauthoff, DOE Princeton Plasma Physics Laboratory, Princeton, NJ.

In January 2003, President Bush announced that the US would join Negotiations on the siting and construction of ITER, a reactor-scale tokamak experiment aimed at demonstrating the scientific and technological feasibility of magnetic fusion energy. ITER would produce much more fusion power than the external heating power, with the plasma's self-heating from the fusion-produced alpha particles being dominant.

Since the start of US participation in ITER Negotiations, the US has participated in several formal Negotiations meetings and numerous exploratory discussions, and has undertaken technical work to commence US participation in the construction activity.

Department of Energy Office of Science Director Dr. Raymond Orbach and DOE Secretary Spencer Abraham have led the US delegations to the formal Negotiations meetings, held in Vienna and Washington. A major international accomplishment was the achievement of 100%-coverage of ITER costs for the Japanese site at Rokkasho and for the European site at Cadarache, France; in essence, both sites are technically acceptable and fully funded. The difficulty now is deciding between the two viable sites. After 6-party (China, European Union, Japan, Korea, Russian Federation, and United States) technical expert meetings on site characteristics and broader approaches, the focus is now on domestic “homework” and bilateral discussions.

Providing support to the US Negotiators have been experts from both the federal government (e.g., DOE, Department of State, and other agencies) and the US fusion community. Meetings of the Negotiators Standing Sub Group (NSSG) have addressed a wide range of arrangements: management structure, staffing regulations, procurement systems/methods, procurement allocations, resource management/regulations, risk management, intellectual property, and decommissioning. Of particular interest to ANS-FED members would be the procurement allocations: how responsibility for the fabrication of the many ITER components would be assigned to the six ITER parties.

A Burning Plasma Program Advisory Committee, chaired by Professor Stewart Prager of the University of Wisconsin, provided useful inputs on both management arrangements and procurement allocations.

After extensive discussions between the ITER International Team and the six Participant Teams, a tentative allocation of roughly 85% of the ITER systems was achieved; this arrangement was then presented to the Negotiators who declared it to be suitable for proceeding (but not final). The tentative procurement allocations include US activity in the areas of superconducting magnets, plasma-facing components, vacuum, fueling, tritium processing, ion cyclotron and electron cyclotron systems, diagnostic instrumentation, power supplies, and some conventional systems. The US mix includes an attractive selection of areas of US strength and interest, along with a requisite portion of lower-tech components, adding up to the negotiated US fraction while staying within the approved US ITER budget.

In the area of plasma diagnostics, which are of particular interest to ANS-FED members, the discussions led to the creation of a multi-party Diagnostics Working Group, that examined a variety of approaches for assigning the diagnostics and eventually developed a concept for a menu of choices based on “ports”; based on the recognition that the integration of the many complex diagnostics that share a port would be quite challenging, the party-assignments will be for “ports”, with the lead party responsible for the integration of that port with its collection of diagnostic instruments, some of which would be provided by other parties. Based on that concept, a tentative allocation of ITER diagnostic ports and associated diagnostics has been arranged.

As part of its partnership in the ITER Transitional Arrangements, the US is performing formally negotiated ITER tasks in areas such as magnet design, qualification of suppliers of superconducting strand, safety, and materials; future tasks will likely involve design of blankets, divertor, fuelling systems, vacuum system, and conventional systems. There are US members on working groups dealing with magnets, breeding blankets, codes and standards, and diagnostics. In addition, the US is arranging to provide members of the ITER Central Team in Naka, Japan and Garching, Germany; the currently planned assignments are in the areas of magnets, first wall/blankets, ion cyclotron system, and ports/diagnostics.

The Department of Energy is in the process of selecting the DOE laboratory that will serve as the host for the US ITER Project Office.

Following multi-party agreement on the ITER site and associated cost-sharing, it is expected that a Director General and senior managers will be selected and that they will start establishing the Construction Team and related structures. Each of the ITER parties will establish its Domestic Agency to perform its agreed scope.

Finally, DOE and US fusion program leaders are discussing possible organizational structures for the US Burning Plasma Program, which will complement the US ITER Project activity in facilitating burning plasma research both now on existing facilities and on the future ITER.

Recent Status of Fusion Research Network in Japan, Akio Sagara, National Institute for Fusion Science, Japan.

History

Based on the plasma and fusion research activities in universities of Japan, the National Institute for Fusion Science (NIFS) was established in 1989. In this new stage of fusion research, an activity was started in 1991 under the direction of Prof. A. Iiyoshi, the first Director General of NIFS, with the support of a Grant-in-Aid for scientific research provided by the Ministry of Education, Science and Culture, to discuss how to integrate the organization of fusion research activities in Japan. Since 1994, with combining the three research areas of Fusion Science, Fusion Engineering, and Plasma Science, this activity continued to establish a fusion research network. The main subjects in these activities were: what categories of research fields we have and need to have; what is a suitable grouping of these fields and their mutual relations to the fusion research network; what is the main role and expected output of the network; and so on. After five years of preparation, the “Fusion Research Network” was established and started its activities in 1996 [1].

Structure

The Fusion Research Network (http://f-net.nifs.ac.jp/ in Japanese) has been established as a combination of three research areas (see the figure). Each area consists of research groups as follows:

(1) Fusion Science Network (http://f-net.nifs.ac.jp/fs_main.html)
- Main Fusion Systems
- Fusion Plasma Control
- Advanced Fusion
- Theory and Simulation
- Basic Fusion Science

(2) Fusion Engineering Network (http://fecenter.nifs.ac.jp/fe-net/index-j.html)
- Reactor Materials and Fuels
- Electromagnetics and Magnet Technology
- Reactor System and Safety
- Inertial Fusion Technology

(3) Plasma Science Network (http://rdecw.nifs.ac.jp/~plasma/)
- Fusion
- Astrophysics, High-Energy Science
- Material Science

The chair and secretaries for each network area are selected every two years from the network members. Furthermore, each research group consists of several research fields. For instance, the research fields for the Fusion Science Network group are as follows:

- Main Fusion Systems
    1. Helical
    2. Tokamak
    3. Laser
- Fusion Plasma Control
    1. Heat and Particles
    2. Diagnostics
    3. Atomic Data
    4. Heating and Current Drive
    5. Energy Transfer
    6. Pulse Power
- Advanced Fusion
    1. Spherical Tokamak
    2. Open System
    3. RFP
    4. Compact Torus
    5. New Relaxation Configuration
    6. Z-Pinch
    7. Heavy Ion Beam
    8. Electrostatic Inertial Fusion

- Theory and Simulation
    1. Theory
    2. Core Plasma Simulation
    3. Peripheral Plasma Simulation
- Basic Fusion Science

There are a few coordinators in each field and advisory members for the Fusion Engineering Network. The research fields for each research group are as follows:

- Reactor Materials and Fuels
    1. Plasma Facing Materials
    2. Structural Materials
    3. Blanket Technology
    4. Tritium Science and Technology
- Electromagnetics and Magnet Technology
    1. Superconducting Magnet
    2. Electromagnetic Engineering
    3. Fusion Electrical Power Engineering
- Reactor System and Safety
    1. Tritium Biological Effects
    2. Thermal and Mechanical Engineering
    3. Reactor Design Engineering
    4. System Safety Engineering
    5. Neutronics
- Inertial Fusion Technology
    1. Inertial Fusion Engineering

Members

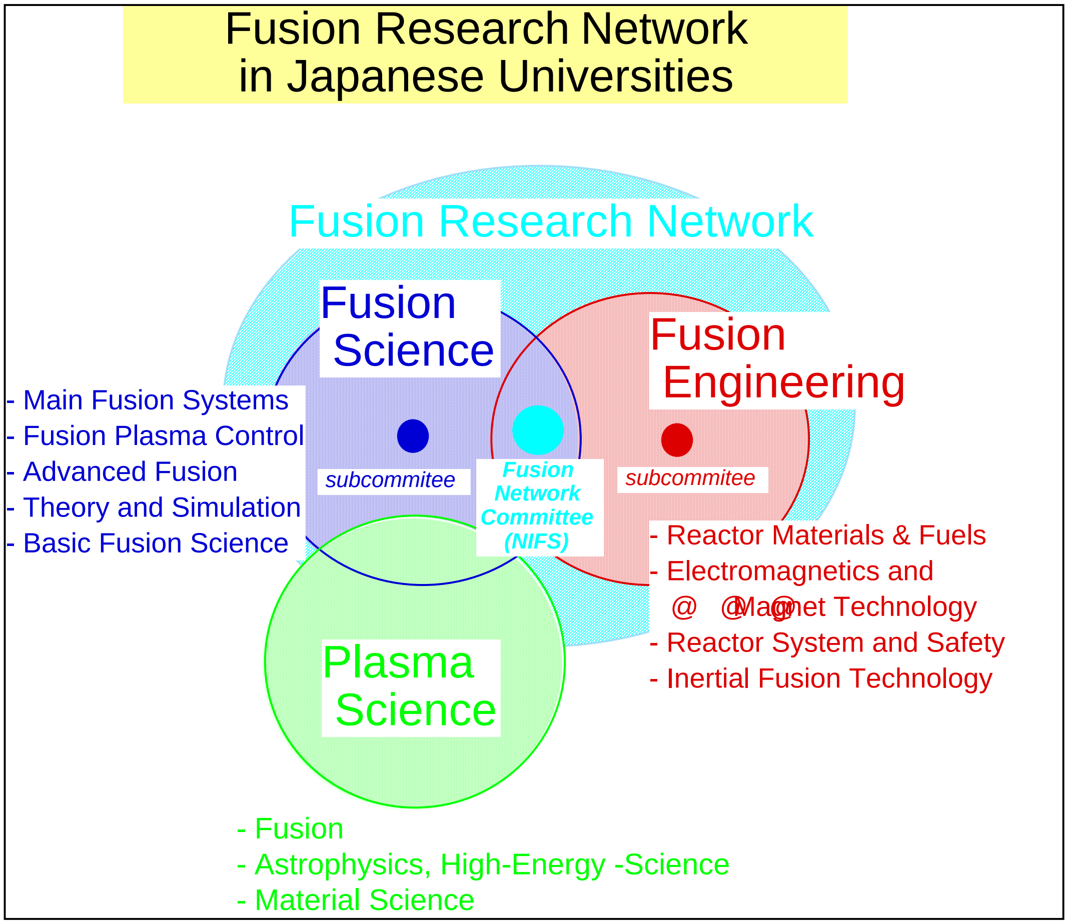
At present, the Fusion Research Network has about 550 members from ~80 universities and ~7 institutes in Japan. Joining the network is free for scientists in fusion research fields. All members are on the "FE-net" mailing list, that is managed by the chair and secretaries.

Activities

The main activities of the Fusion Research Network are information exchange and research planning for fusion-related investigations and resources. As for information exchange that includes the FE-net and discussion meetings, NIFS plays an important central role and provides some funding. As for the research planning, many activities have been arranged so far in the network to propose research collaborations under discussions on directions in each research field and relations between fields. Such planning is not easy in academically oriented scientific societies. Recently, based on these activities, the importance of the Fusion Research Network is growing significantly in Japan to discuss and make comments on future directions of key research projects such as ITER, IFMIF, domestic planning, international planning, and so on.

Reference:

[1] S. Tanaka, "Status of Fusion Technology Activities in Japan", Fusion Technology, **39**, No. 2, Part 2, 298 (2001).



Fusion Research Network
in Japanese Universities

Fusion Research Network

Fusion
Science

- Main Fusion Systems
- Fusion Plasma Control
- Advanced Fusion
- Theory and Simulation
- Basic Fusion Science

subcommitee

Fusion
Network
Committee
(NIFS)

Fusion
Engineering

subcommitee

- Reactor Materials & Fuels
- Electromagnetics and
@ @Ma@net Technology
- Reactor System and Safety
- Inertial Fusion Technology

Plasma
Science

- Fusion
- Astrophysics, High-Energy -Science
- Material Science

Calendar of Upcoming Conferences on Fusion Technology

2004:

15th International Symposium on HI Inertial Fusion
June 7-11, 2004, Princeton, NJ, USA
http://nonneutral.pppl.gov/HIF04/generalinfo.php

ANS Annual Meeting
June 14-17, 2004, Pittsburgh, Pennsylvania, USA
http://www.ans.org/

28th European Conference on Laser Interaction with Matter (ECLIM)
September 6-10, 2004, Roma, Italy
eclim@efr406.frascati.enea.it
http://www.frascati.enea.it/XXVIIIeclim/

ANS 16th Topical Meeting on the Technology of Fusion Energy – TOFE-2004
September 14-16, 2004, Madison, WI, USA
http://fti.neep.wisc.edu/tofe
elguebaly@engr.wisc.edu

7th International Tritium Conference
September 12-17, 2004, Baden-Baden, Germany
http://Tritium2004.fzk.de/

22nd Symposium on Fusion Technology - SOFT
September 20-24, 2004, Venice, Italy
gnesotto@igi.pd.cnr.it

20th IAEA Fusion Energy Conference
November 1-6, 2004, Vilamoura, Portugal
http://www.cfn.ist.utl.pt/
fserra@cfn.ist.utl.pt

ANS Winter Meeting
November 15-18, 2004, Washington, D.C., USA
http://www.ans.org/

46th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 15-19, 2004, Savannah, GA, USA
dahlburg@utopia.nrl.navy.mil
http://apsdpp.org/

2005:

7th International Symposium on Fusion Nuclear Technology - ISFNT-7
May 22-27, 2005, Tokyo, Japan
http://isfnt.naka.jaeri.go.jp/
isfnt7@fusion.naka.jaeri.go.jp

ANS Annual Meeting
June 5-9, 2005, San Diego, California, USA
http://www.ans.org/

12th International Conference on Emerging Nuclear Energy Systems (ICENES-2005)
August 21-26, Brussels, Belgium
http://www.sckcen.be/sckcen_en/activities/conf/conferences/icenes2005/index.shtml

4th International Conference on Inertial Fusion Sciences and Applications – IFSA-2005
September 4-9, 2005, Biarritz, France
ifsa05@celia.u-bordeaux1.fr

21st Symposium on Fusion Engineering – SOFE-2005

September 2005, Knoxville, Tennessee, USA
uckanna@ornl.gov

47th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
October 24-28, 2005, Denver, Colorado, USA

ANS Winter Meeting
November 13-17, 2005, Washington, D.C., USA
http://www.ans.org/

2006:

ANS Annual Meeting
June 4-8, 2006, Reno, Nevada, USA
http://www.ans.org/

48th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
October 30 - November 3, 2006, Philadelphia, PA, USA

ANS Winter Meeting
November 12-16, 2006, Albuquerque, New Mexico, USA
http://www.ans.org/

ANS 17th Topical Meeting on the Technology of Fusion Energy – TOFE-2006
November 13-16, 2006, Albuquerque, New Mexico, USA
http://www.ans.org/

2007:

ANS Annual Meeting
June 2007
http://www.ans.org/

ANS Winter Meeting
November 2007
http://www.ans.org/

49th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 12-16, 2007, Orlando, Florida, USA

22nd Symposium on Fusion Engineering – SOFE-2007

13th International Conference on Emerging Nuclear Energy Systems (ICENES-2007)

2008:

ANS Annual Meeting
    June 2008
    http://www.ans.org/

ANS Winter Meeting
    November 2008
    http://www.ans.org/

ANS 18th Topical Meeting on the Technology of Fusion Energy – TOFE-2008

50th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
    November 17-21, 2008, Dallas, Texas

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