American Nuclear Society
Fusion Energy Division
December 2008 Newsletter

Chair's Message, Farrokh Najmabadi, Center for Energy Research, University of California-San Diego, La Jolla, CA.

Firstly, the officers of the Fusion Energy Division (FED) and I would like to extend our warm wishes for a happy 2008 holiday season to all.

Professional societies exist to serve their members and I have dedicated my tenure as the Chair of the FED to strongly champion our cause within the American Nuclear Society (ANS). I would like to discuss some of our initiatives below.

ANS Fellows

A longstanding tradition in any professional society is to recognize the hard work and effort of its members by electing them as a Fellow. Unfortunately, the number of "Fusion" Fellows in the ANS has been dwindling in recent years. In addition, there had been some instances that nominations of deserving individuals were rejected by the ANS Honors and Awards Committee (some other ANS divisions have had similar experience). Several ANS Division Chairs and I raised this issue in the ANS Profession Division meeting as well as in a meeting with the ANS President. Subsequently, we had several interactions with members of the ANS Honors and Awards (H&A) Committee.

I am happy to report that the ANS H&A Committee has taken several steps to streamline the process of including new nomination forms, posting the details of the criteria they use, developing separate criteria for academic versus industry members, etc. These new steps will be implemented by June 2009 and can be found at the ANS H&A committee website.

I would like to encourage our members to nominate deserving members to become a Fellow of ANS. It is essential to prepare the files according to the ANS guidelines and make a strong case for the nomination. To help our members, Dr. Nermin Uckan has agreed to review the fellow nomination packages before submission to the ANS H&A Committee. Dr. Uckan can be reached at uckanna@ornl.gov.

Work-Force Development – Supporting Students and Young Members

We are facing an aging work force and we are in danger of losing all of our expertise as our members retire. The FED executive committee is considering various ideas to support and encourage students as well as young members. This issue resonates well with the ANS as a whole as nuclear fission faces a similar problem. I will discuss some of our initiatives in the next FED newsletter. A major difficulty is the limited funding available to FED. At present we are working with the ANS to find ways to raise our level of funding. Let me know if you would like to volunteer your time to participate in this activity and/or have any ideas on work-force development.

Journal of Fusion Science and Technology

Under the leadership of Dr. Uckan, Fusion Science and Technology is becoming the premier journal in fusion engineering. I would like to invite all members to consider submitting manuscripts to this Journal as well as encouraging your institution to take an electronic subscription.

The strength of our Division is due to the dedicated members who volunteer their time to serve the Division. I would like to thank our previous Chair, Dr. Roger Stoller, for his effort last year as well as the FED Officers for their service and dedication.

Slate of Candidates for 2009/2010 FED Executive Committee, Roger E. Stoller, Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN.

All FED members will receive a ballot early in 2009 for the election of FED officers and Executive Committee members. Please take the time to fill out and return your ballot per the instructions supplied with the ballot. The outcome of the election will be announced before the June 2009 ANS annual meeting in Atlanta. The slate of candidates is listed below. The current Vice Chairman/Chairman-Elect, Lance Snead (Oak Ridge National Laboratory) will automatically become the Chairman for 2009-2010. After doing yeoman service in a few terms as Secretary/Treasurer, Lee Cadwallader will be a candidate for Vice Chairman/Chairman Elect. Mark Anderson has agreed to be a candidate for Secretary/Treasurer.

2009/2010 Candidate Slate:

Officers:

Vice Chairman: Lee Cadwallader, INL, Lee.Cadwallader@inl.gov
Secretary: Mark Anderson, UW-Madison, manderson@engr.wisc.edu

Executive Committee:

Lucile Dauffy, LLNL, dauffy1@LLNL.gov
Zoran Dragojlovic, UCSD, zoran@fusion.ucsd.edu
Yutai Katoh, ORNL, katohy@ornl.gov
Rick Kurtz, PNNL, rj.kurtz@pnl.gov
Shahram Sharafat, UCLA, shahrams@ucla.edu

The FED is always looking for members who would like to become active in the operation of the division. If you are interested, please contact the current Chairman, Farrokh Najmabadi (UCSD), who will be chairing the nominating committee for next year's candidates, or any other member of the Executive Committee. A complete list of Executive Committee members and officers can be found at the Division website: http://fed.ans.org/members.shtml.

Highlights of 18th ANS Topical Meeting on the Technology of Fusion Energy, Jeff Latkowski and Wayne Meier, Lawrence Livermore National Laboratory, Livermore, CA.

The ANS topical meeting on the Technology of Fusion Energy (TOFE) was held September 28-October 2 in San Francisco, California. The meeting was attended by approximately 250 fusion scientists and engineers from around the world; more than half were from outside the US, with EU and Japan accounting for ~25% each. The technical program included 272 presentations, with 136 oral presentations and 146 posters during the two poster sessions.

ITER was strongly represented at the meeting. The lead-off plenary talk by Dr. Stefano Chiocchio (on behalf of Dr. Norbert Holtkamp) gave an overview of the ITER project. Dr. Michael Loughlin and Dr. Neill Taylor from the ITER Organization were also selected for plenary talks covering the ITER nuclear analysis strategy and the preliminary safety analysis, respectively. There were also two oral sessions devoted to ITER and many posters. The meeting concluded with a special plenary session that featured talks by representatives of ITER Domestic Agencies from the US (Dr. Ned Sauthoff), EU (Dr. Gianfranco Federici), Japan (Dr. Ryuji Yoshino), and the Republic of Korea (Dr. Jung-Hoon Han).

In addition to ITER, the meeting covered a wide range of fusion science and technology topics including: structural and breeding materials, test blanket modules, nuclear analysis, environment and safety studies, next steps, demo and power plants. The meeting also had excellent participation from the inertial fusion energy (IFE) community with talks on target design, fabrication and injection; lasers and heavy ion drivers; chambers and power plants. Work on the US High Average Power Laser (HAPL) Program and Lawrence Livermore National Laboratory's Laser Inertial Fusion-Fission Energy (LIFE) project were featured.

Participants were also given the opportunity to tour the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory. NIF construction is nearly complete and experiments to demonstrate inertial confinement fusion ignition and burn will begin in 2010. The NIF tour was followed by the conference banquet at Wente Winery, a historic winery in Livermore.

Nearly 200 papers have been submitted and are currently being peer reviewed. Those accepted for publication will appear in a special issue of Fusion Science and Technology next summer (July/August 2009).

In addition to the excellent technical program and local accommodations at the Stanford Court Hotel, participants enjoyed the pleasant weather, beautiful sights and fine dining offered by San Francisco.

We would like to express our thanks to the Local Organizing Committee members (especially Mila Shapovalov who handled most of the logistic details), Technical

Program Committee members, and meeting sponsors. Their hard work and support were key to the success of this meeting.

General Chair: Dr. Jeff Latkowski, LLNL
Technical Program Chair: Dr. Wayne Meier, LLNL.

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

Fusion awards have been established to formally recognize outstanding contributions to fusion development 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 2008 fusion awards on this well-deserved recognition and our kudos to all of them.

ANS Awards

The 2008 *Outstanding Achievement Award* is the most prestigious award of the FED and is presented to an ANS member in recognition of exemplary individual achievement requiring professional excellence and leadership of high caliber in Fusion Science and Engineering. This year the award is given to Dr. **John D. Sethian** in recognition of his research in laser and target systems for inertial fusion energy and for his superlative technical leadership of the High Average Power Laser program.

The 2008 *Technical Accomplishment Award* is presented in recognition of an exemplary technical accomplishment requiring professional excellence of a high caliber in the Fusion Science and Engineering. Two individual awards are given this year to Drs. **Joseph Minervini** and **Mark S. Tillack**. The award to Dr. **Minervini** is made in recognition of his outstanding work and leadership on the US ITER Central Solenoid Model Coil. The award to Dr. **Tillack** is made for his scientific research on laser-matter interactions and final optics for inertial fusion energy systems.

A special *Distinguished Service Award* is given to Dr. **Kenneth R. Schultz** for his many years of service and leadership in the ANS Fusion Energy Division. Throughout his career, in addition to his research and technical leadership, Dr. **Schultz** has consistently supported the Fusion Energy Division by holding many division offices, several times serving on the executive committee, serving on national committees and the board of directors, serving on technical and editorial boards, and mentoring students and younger FED members. The Fusion Energy Division of the ANS gratefully acknowledges this significant and exemplary service.

The 2008 *Outstanding Student Paper Award* at the 18th TOFE is given to **Samuel Zenobia** of the University of Wisconsin-Madison for his paper "Retention and Surface Pore Formation in Helium Implanted Tungsten as a Fusion First Wall Material."

APS Awards

Ronald C. Davidson (Princeton Plasma Physics Laboratory) is the 2008 recipient of the American Physical Society's prestigious *James Clerk Maxwell Prize for Plasma Physics*. Dr. **Davidson** is cited for pioneering contributions to the physics of one-component non-neutral plasmas, intense charged particle beams, and collective nonlinear interaction processes in high-temperature plasmas.

Stewart Prager (University of Wisconsin-Madison) and **Michael Zarnstorff** (Princeton Plasma Physics Laboratory) are the recipients of the APS 2008 *John Dawson Award for Excellence in Plasma Physics research*. The award cites Drs. **Prager** and **Zarnstorff** for demonstrating that the parallel Ohm's law in axisymmetric toroidal plasmas with impurities is governed by Coulomb collision processes, including neoclassical resistivity and the bootstrap current.

The *Marshall N. Rosenbluth Outstanding Doctoral Thesis Award* provides recognition to exceptional young scientists who have performed original thesis work of outstanding scientific quality and achievement in the area of plasma physics. The recipient of the 2008 award is **Yang Ren** (University of Wisconsin-Madison) for experimental characterization of collisionless magnetic reconnection in a laboratory plasma, including the out-of-plane Hall effect magnetic field and the diffusive electron out-of-flow channel.

FPA Awards

Osamu Motojima, Director of the National Institute for Fusion Science (NIFS) in Japan, has been selected by Fusion Power Associates (FPA) Board of Directors to receive the 2008 *Distinguished Career Award*. In selecting Prof. **Motojima**, the FPA Board recognizes his key roles in the design and construction of a series of large stellarator facilities and subsequent experimentation on them, in fostering international cooperation in fusion research, and his leadership of the NIFS.

Ed Moses (Lawrence Livermore National Laboratory) and **Tony Taylor** (General Atomics) have been selected by the FPA Board to receive the 2008 *Leadership Awards*.
In selecting Dr. **Moses**, the FPA Board recognizes his more than 20 years of leadership in the development of laser technologies at LLNL and his current leadership of the construction of the National Ignition Facility (NIF). In selecting Dr. **Taylor**, the FPA Board recognizes his leadership of the DIII-D National Fusion Program, the influential role he is playing in guiding the U.S. burning plasma program and ITER research planning effort, and his role in several FESAC and Academies policy panels.

Phillip Sharpe (Idaho National Laboratory) is the recipient of the FPA 2008 *Excellence in Fusion Engineering Award*. The award recognized individuals in the relatively early part of their careers who have shown both technical accomplishment and potential to become exceptionally influential leaders in the fusion field. In selecting Dr. **Sharpe**, the FPA Board notes his many technical accomplishments, including key research on plasma-materials interactions, tritium behavior in materials and inertial fusion blanket design, and his leadership in the important area of fusion reactor safety.

Nuclear Fusion Award

The winner of the 2008 *Nuclear Fusion Award* is **T. E. Evans** (General Atomics) et al. for their paper "Suppression of large edge localized modes with edge resonant magnetic fields in high confinement DIII-D plasmas." This experimental paper demonstrates the efficacy of using resonant magnetic field perturbations (RMPs) for the suppression of large amplitude edge localized modes (Type I ELMs) – a critical issue for ITER and other reactor grade machines. This paper will be available to read until the end of March 2009: http://www.iop.org/EJ/news/-topic=1355.

Special Award

Luigi Serio, Section Leader of the ITER Cryogenic System, has been awarded the *100 years of Liquid Helium Special Award* for the best paper concerning a 21st century major cryogenic project at the International Cryogenic Engineering Conference in Seoul, Korea, (July 21-25, 2008). The Paper's title is "Conceptual design of the cryogenic system for ITER." Authors: L. Serio, D. Henry, V. Kalinin, M. Sanmarti, and B. Sarkar.

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 12 months (from October 1, 2007 to September 30, 2008), FS&T received a total of 360 papers: 170 from North America, 85 from Asia, 101 from Europe and Russia, and 4 from other countries. During this period, we have also received 47 lectures from Carolus Magnus Summer School (CMSS07), published in FS&T Transactions (Feb 2008). CMSS07 papers are not included in paper counts.

In CY2008 (Volumes 53 & 54), FS&T published 269 articles, appearing in 2720 journal pages with the following breakdown: 1590 pages in typeset regular issues; 650 pages in camera-ready Proceedings (Tritium07); and 480 pages in camera-ready Transactions (CMSS07).

The following special (dedicated) issues have been published in 2008:

- EC Wave Physics & Technology (Part 2) – FS&T Jan 2008
- MFE Diagnostics (EU, JA, RF, US) – FS&T Feb 2008
- 8th Carolus Magnus Summer School – FS&T Transactions Feb 2008
- JET Tokamak (Culham, England) – FS&T May 2008
- 8th Tritium2007 Proceedings (Parts 1 & 2) – FS&T Jul/Aug 2008
- ARIES Compact Stellarator Study – FS&T Oct 2008.

The following issues are planned for 2009:

- Selected full papers from EC-15 (Part 1) – FS&T Jan 2009
- Regular papers and EC-15 (Part 2) – FS&T Feb 2009
- Selected papers from 8th Target Fab Meeting (Parts 1 & 2) – FS&T Apr/May 2009
- 18th TOFE2008 Proceedings (Parts 1 & 2) – FS&T Jul/Aug 2009

- Tore-Supra (France) Tokamak Special – FS&T regular issue (under peer review)
- LHD Stellarator (Japan) 10^{th} Anniversary – FS&T regular issue (due early 2009).

The following issues are in the discussion/planning stages for 2010 and beyond:

- 9^{th} Carolus Magnus Summer School – FS&T Transactions (in preparation)
- JT-60U (update of JT-60 Tokamak Special published in 2002) – in preparation
- JT-60SA (part of ITER Broader Approach) – FS&T regular issue (in planning)
- DEMO Studies (EU, JA) – FS&T regular issue (in planning)
- IFMIF (EU, JA) – FS&T regular issue (in planning)
- KSTAR (Korea) – FS&T regular issue (in planning)
- Fusion Neutronics (ITER Partners) – FS&T regular issue (under discussion)
- W7-X (Germany) – FS&T regular issue (under discussion)
- Test Blankets (ITER Partners) – FS&T regular issue (under discussion).

FS&T has been offering color printing for the past several years and in 2007 started offering color online figures for black and white print issues. All (regular/special) FS&T issues are now color online.

Please check for your library subscription. Electronic access to FS&T is available from 1997-to-current. 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 articles at http://epubs.ans.org/. Please send your comments on FS&T content and coverage as well as suggestions for potential future topical areas that are timely and of interest to mailto:fst@ans.org.

50 Years of Magnetic Fusion Research (1958-2008): Brief Historical Overview and Future Trends,

Laila El-Guebaly, Fusion Technology Institute, University of Wisconsin-Madison, Madison, WI.

Since the 1958 Second Conference on the "Peaceful Uses of Atomic Energy" held by the United Nations in Geneva, Switzerland, the secrecy surrounding controlled thermonuclear fusion by magnetic confinement had been lifted allowing researchers in the US, Russia, UK, and other countries to freely share the technical results and discuss the challenges of harnessing fusion power. In the 1960s, hundreds of fusion scientists were engaged in a variety of theoretical analyses and experiments to more fully understand and advance fusion physics and technology. The energy crisis of the early 1970s encouraged all nations to seriously investigate other nuclear energy sources (like fusion and renewable) to supplement fission. Building on the early progress made in the 1950s and 1960s, the world's fusion researchers realized the need for better understanding of the physics and technology of fusion energy. Numerous fusion studies, extensive research and development (R&D) programs, more than 100 operating experiments worldwide, impressive international collaboration in all areas of research, and a large body of accumulated knowledge have led to the current wealth of fusion information and understanding. For decades, the International Atomic Energy Agency (IAEA) and International Energy Agency (IEA) have organized fusion conferences and workshops and provided a framework for collaborative programs that covers a broad range of fusion topics (such as plasma physics, materials, power plant studies, safety, environmental, and economic aspects, and social acceptance). Just recently in October

2008, the IAEA held its 22nd Fusion Energy Conference in Geneva to celebrate the golden anniversary of magnetic fusion research. As part of the conference, the IAEA produced a CD containing the proceedings of the 1958 Geneva Summit and a 28-page brochure titled: "Fifty Years of Magnetic Confinement Fusion Research – A Retrospective." The brochure is available at:
http://www-naweb.iaea.org/napc/physics/2ndgenconf/sets/Home.html.

In the early 1950s, there were only four magnetic confinement fusion concepts pursued internationally: tokamak (a donut configuration with toroidal plasma current), stellarator (steady-state toroid without plasma current), mirror (steady-state linear system with magnetic wells), and pinch (simple toroidal device). The tokamak, stellarator, and pinch concepts have experienced substantial modifications over the past 60 years. The mirror concept was actively pursued in the US, but suspended in 1986 due to budgetary constraints, while continuing at a very low level in Japan and Russia. After the first 1969 "International Fusion Reactor Conference" in Culham, England, more than 50 conceptual power plant design studies have been conducted in the US, EU, Japan, Russia, and China. During the 1970-2008 period, numerous D-T fueled fusion power plant designs were developed for both magnetic fusion energy (MFE) and inertial fusion energy (IFE) concepts, covering a wide range of new and old design approaches: tokamaks, stellarators, spherical tori (ST), field-reversed configurations (FRC), reversed-field pinches (RFP), spheromaks, tandem mirrors (TM), and laser/heavy-ion/Z-pinch driven inertial fusion. Most of the studies and experiments are currently devoted to the D-T fuel cycle, since it is the least demanding to reach ignition. The stress on fusion safety has stimulated worldwide research on fuel cycles other than D-T, based on 'advanced' reactions, such as D-D, D-^{3}He, p-^{11}B, and ^{3}He-^{3}He. In addition, a few smaller-scale projects investigated non-electric applications of fusion along with the technological means to lessen the likelihood of proliferation.

Internationally, the tokamak concept is regarded as the most viable candidate to demonstrate fusion energy generation. The tokamak (acronym from the Russian phrase "Toroidal Chamber with Magnetic Coil") was invented in 1951 by Russian physicists Sakharov and Tamm while named a few years later by Golovin. In 1956, the first tokamak experiment started in Kurchatov Institute, Moscow. Ever since, the confinement concept has been successfully demonstrated with more than 100 worldwide experimental facilities, of which ~35 experiments are currently operational in Russia, US, EU, Japan, South Korea, China, India, and other countries [1]. Over the years, strong domestic and international experimental programs addressed the tokamak physics and technology issues. The collaborative worldwide effort materialized in the design and construction of the International Thermonuclear Experimental Reactor (ITER) [2] – a large burning plasma experiment with ~500 MW of fusion power. ITER is being designed, constructed, and operated by a consortium of seven parties: EU, Japan, US, Russia, China, South Korea, and India. France has been chosen as the site for ITER with construction starting around 2011 and first plasma in 2018 (refer to Taylor's article in this issue).

Figure 1 displays the timeline of large-scale MFE power plants developed since the early 1970s by US research teams. Numerous conceptual commercial plant designs were developed for all seven magnetic approaches, especially for the tokamak. The decade of the 1980s witnessed a transition period aimed at temporarily impeding the US large-scale tokamak studies in order to investigate alternate concepts: stellarator, ST, FRC, RFP, spheromaks, and TM. In the late 1980s, the US decided to pursue all concepts, except the tandem mirror.

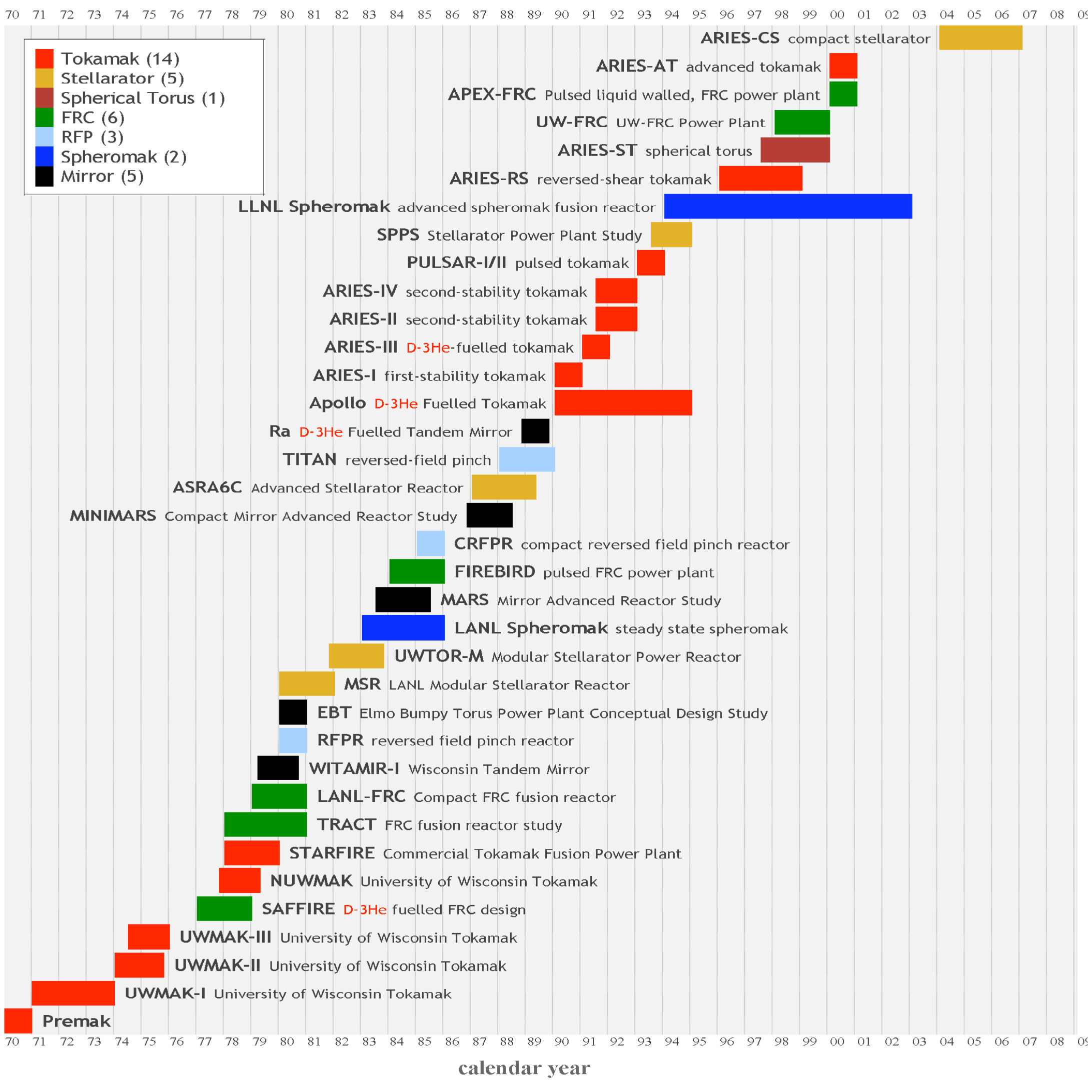

Figure 1. Timeline of large-scale MFE conceptual power plant designs developed in the US.

Tokamak Power Plant Studies

Power plant studies help the fusion community and the funding agencies understand the major technical issues involved in fusion and provide guidance for the R&D program to deliver an attractive and viable end product. Any fusion power plant must be safe, reliable, economically competitive, maintainable, environmentally attractive, and meet public acceptance. The philosophy adopted in international fusion power plant designs varies widely in the degree of physics extrapolation, technology readiness, and economic competitiveness. Some designs are viewed as a roll-forward step with a modest extrapolation beyond ITER. Other designs suggest using the cost of electricity with its underlying factors as a figure of merit measured against competing energy sources, mandating advanced physics, high performance hardware with related future technologies to be competitive.

As Fig. 1 indicates, numerous tokamak conceptual design power plant studies were developed over the last four decades to assess the viability of different approaches and recommend productive R&D directions. In the US, the conceptual studies progressed steadily from the early 1970s pulsed UWMAK series [3], to the 1980 STARFIRE [4] that first promoted steady-state current drive, to the more advanced 1990s steady-state ARIES series [5]: ARIES-I, II, IV, RS, and AT. Improvements were apparent, progressing from ARIES-I to ARIES-AT and all studies stressed the practicality, safety, and economic competitiveness of fusion power, taking into consideration the fabricability, constructability, operability, and maintainability of fusion devices. The latest tokamak design (ARIES-AT) demonstrated superior performance and benefited greatly from several developments: high toroidal beta of 9%, SiC/LiPb blanket operating at high temperature (~1000ºC) with high thermal conversion efficiency (59%), and high system availability (85%) with an efficient maintenance scheme.

Fusion Roadmaps and Timeline of Fusion Power

Power plant studies normally identify the ultimate characteristics of fusion power plants in a fully mature, commercial fusion market (tenth of a kind plant). Since the early 1970s, researchers have been developing roadmaps with the end goal of operating the first fusion power plant in 50 years (i.e., by 2020), believing strongly that fusion should be an option in the 21st century energy mix. But this has been a sliding scale vision with the current expectation still remaining at 50 years in many countries. Recently, optimism about fusion has resurfaced with the construction of ITER in France. Nevertheless, developing fusion energy will cost billions of dollars and would span decades. The key strategic questions are: what technologies remain to be developed and matured for a viable fusion power plant (refer to Tillack's article in this issue), what other facilities will be needed between ITER and the first power plant, what will it cost, and how long will it take, assuming the existing social and political climate continues? On the other hand, if the social and political climate creates a demand-pull situation, how long will it take to construct the first fusion power plant if the fusion program is treated as a "Manhattan" project with unlimited funds and a limited timetable?

In the early 2000s, the US Fusion Energy Sciences Advisory Committee (FESAC) developed a plan with the end goal of the start of operation of a demonstration (Demo) fusion power plant in approximately 35 years [6]. The Demo is viewed as the last step before the first commercial power plant. The FESAC plan recognized the capabilities of all fusion facilities around the world and identified critical milestones, key decision points, needed major facilities, and required budgets for both MFE and IFE. Assuming ITER operates successfully, the FESAC report recommends three MFE facilities before the construction of a tokamak Demo in 2029: Performance Extension Facility, International Fusion Materials Irradiation Facility (IFMIF) operating in parallel with ITER, and Component Test Facility (CTF) operating in 2023. A more recent FESAC study highlighted the specifics of the US Demo [7]. It is a net electrical power producing tokamak plant, demonstrating fusion is practical, reliable, economically competitive, and meeting public acceptance, operating reliably and safely for long periods of time, and employing the same physics and engineering technologies that will be incorporated in commercial power plants. This last requirement is fundamental in determining the unique features of the US Demo that demonstrates and matures the commercial power plant systems. Generally, the US plan has an aggressive vision for Demo (based on advanced modes of performance and operation) with the CTF as an essential element of the US fusion development program.

Since electricity from fusion is a few decades away, numerous researches suggested a departure from the traditional approach of making electricity and proposed a number of non-electric applications, such as hydrogen production, transmutation of fission waste, breeding of fissile fuels, production of medical radioisotopes, desalination, space propulsion, explosives detection, and altering materials properties. These applications take advantage of the neutron-rich fusion system and offer near-term opportunities to advance fusion development with modest physics and technology requirements. If successful, the public will retain interest in fusion and recognize its potential contributions to society before fusion penetrates the commercial market in 2030 or beyond.

Summary

Fusion promises to be a major part of the energy mix in the 21st century. Internationally, the D-T fuelled tokamak is regarded as the most promising candidate for magnetic fusion energy generation. Its program accounts for over 90% of the worldwide magnetic fusion effort. The roadmap to fusion energy is influenced by the timeline anticipated for the development of the essential physics and technologies for Demo and power plants as well as the demand for safe, environmentally attractive, economical, and sustainable energy sources. The worldwide roadmaps take different approaches, depending on the anticipated power plant concept and degree of extrapolation beyond ITER. Several Demos with differing approaches should be built in the US, EU, Japan, China, and other countries to cover a wide range of near-term and advanced fusion systems. Recognizing the capabilities of national and international fusion facilities, it appears that, with unlimited funding and a limited timetable, the first fusion power plant could add electricity to the grid by 2030-2035.

References:

[1] Worldwide Tokamak Experiments: http://www.toodlepip.com/tokamak/conventional-large-tokamaks.htm.

[2] The ITER Project: http://www.iter.org/.

[3] B. Badger, K. Audenaerde, H. Avci, J. Beyer, D. Blackfield, R.W. Boom et al., "NUWMAK - A Tokamak Reactor Design Study," University of Wisconsin Fusion Technology Institute Report, UWFDM-330 (1979). Available at: http://fti.neep.wisc.edu/pdf/fdm330.pdf.

[4] C.C. Baker, M.A. Abdou et al., "STARFIRE – A Commercial Tokamak Fusion Power Plant Study," Argonne National Laboratory report ANT/FPP-80-1 (1980).

[5] The ARIES project: http://aries.ucsd.edu/ARIES/.

[6] "A Plan for the Development of Fusion Energy," Final Report to FESAC (2003). Available at: http://fire.pppl.gov/fesac_dev_path_wksp.htm

[7] "Priorities, Gaps and Opportunities: Towards A Long-Range Strategic Plan for Magnetic Fusion Energy," Final Report to FESAC (2007). Available at: http://www.science.doe.gov/ofes/fesac.shtml.

ONGOING FUSION RESEARCH:

Evaluating Gaps in Fusion Energy Research Using Technology Readiness Levels, Mark Tillack, University of California, San Diego, Center for Energy Research, La Jolla, CA.

As the ITER burning plasma experiment proceeds into its construction and operation phases, magnetic fusion energy research is entering a new era. The physics feasibility of magnetic fusion is likely to be demonstrated in ITER. In that case, many countries involved in fusion research around the world are asking the question: "what else is needed to demonstrate the credibility of fusion as an energy source?"

The ARIES Team is currently engaged in an effort called the "ARIES Pathways Study". One of the goals of this study is to evaluate remaining R&D needs toward practical fusion energy. In order to evaluate our current state of readiness and remaining R&D needs, we adopted a methodology called "Technology Readiness Levels", or "TRLs". Technology Readiness Levels are commonly used in industry, especially those receiving federal support. They provide a systematic and objective measure of the maturity of a particular technology. The National Aeronautics and Space Administration (NASA) originally developed TRLs in the 1980s [1]; with minor modification, they can be used to express the readiness level of almost any technology project.

In a 1999 report [2], the General Accounting Office (GAO) encouraged the use of TRLs and concluded that failure to properly mature new technologies in the "laboratory" environment almost invariably leads to cost and schedule overruns. The report puts it this way: "Maturing new technology before it is included on a product is perhaps the most important determinant of the success of the eventual product." The Department of Defense adopted this methodology as a best practice to evaluate the readiness levels of new technologies and to guide their development toward the state where they can be considered “operationally ready”, thus helping to ensure that new technologies can be included in new programs with a lower degree of risk.

TRLs encompass 9 levels of achievement, or hurdles, that must be passed in order to progress toward a final product. These levels include:

1. Basic principles observed and reported. This is the lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated. Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept. Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment. Basic technological components are integrated to establish that they will work together. This is relatively “low fidelity” compared to the eventual system. Examples include integration of “ad hoc” hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment. Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include “high fidelity” laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment. Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment. Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment. Examples include exposing a prototype to the true operational environment on a surrogate platform, demonstrator, or test bed.
8. Actual system completed and qualified through test and demonstration. Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended final form to determine if it meets design specifications.
9. Actual system proven through successful mission operations. Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Compelling reasons for adopting this methodology were highlighted by the GAO [3]. TRLs:

- *"Provide a common language among the technology developers, engineers who will adopt/use the technology, and other stakeholders;*
- *Improve stakeholder communication regarding technology development – a by-product of the discussion among stakeholders that is needed to negotiate a TRL value;*
- *Reveal the gap between a technology's current readiness level and the readiness level needed for successful inclusion in the intended product;*
- *Identify at-risk technologies that need increased management attention or additional resources for technology development to initiate risk-reduction measures; and*
- *Increase transparency of critical decisions by identifying key technologies that have been demonstrated to work or by highlighting still immature or unproven technologies that might result in high project risk."*

These features clearly express the current needs of the fusion research program. In order to help guide the US fusion program toward the adoption of TRLs and to further demonstrate their utility, we undertook to further define and apply TRLs to a fusion-specific example.

We chose to consider a commercial fusion power plant as the ultimate goal to be reached at level 9. In order to quantify readiness, first we must describe technology challenges in the form of issues, components or systems that comprehensively describe the requirements for a practical and attractive energy source. In our first application of TRLs, we derived issues from the criteria for practical fusion energy developed by the ARIES Utility Advisory Committee and EPRI Fusion Working Group in 1994 [4]. In order to succeed, fusion must be economically competitive, gain public acceptance, and operate in a reliable and stable manner comparable to existing nuclear and non-nuclear sources of electricity. By using these criteria as a starting point, we believe we will maximize the probability that the technologies developed will lead to commercialization of a competitive energy source.

Using this list of criteria, we were able to derive a set of 12 technical issues related to the three themes of economic power production, safety and environmental attractiveness, and reliable and stable plant operations. Next, for each of these 12 issues, we refined the generic descriptions of readiness levels to R&D needs specific to fusion energy. For example, readiness levels for the first issue – Plasma power distribution – are summarized in Table I. We attempted to make these descriptions, to the extent possible, independent of specific design concepts.

Table I. TRLs for plasma power distribution

TRL	**Issue-Specific Definition**
1	Development of basic concepts for extracting and handling outward power flows from a hot plasma (radiation, heat, and particle fluxes).
2	Design of systems to handle radiation, energy and particle outflux from a moderate-beta core plasma.
3	Demonstration of a controlled plasma core at moderate beta, with outward radiation, heat, and particle power fluxes to walls and material surfaces, and technologies capable of handling those fluxes.
4	Self-consistent integration of techniques to control outward power fluxes and technologies for handling those fluxes in a high temperature plasma confinement experiment.
5	Scale-up of techniques and technologies to realistic fusion conditions and improvements in modeling to enable a more realistic estimate of the uncertainties.
6	Integration of systems for control and handling of base level outward power flows in a high performance reactor-grade plasma with schemes to moderate or ameliorate fluctuations and focused, highly energetic particle fluxes. Demonstration that fluctuations can be kept to a tolerable level and that energetic particle fluxes, if not avoided, at least do not cause damage to external structures.
7	Demonstration of the integrated power handling techniques in a high performance reactor grade plasma in long pulse, essentially steady state operation with simultaneous control of the power fluctuations from transient phenomena.
8	Demonstration of integrated power handling system with simultaneous control of transient phenomena and power fluctuations in a steady state burning plasma configuration.
9	Demonstration of the integrated power handling system in a steady state burning plasma configuration for lifetime conditions.

In order to evaluate readiness toward a fusion power plant, it is necessary to specify features of a power plant. In our case, we chose to evaluate a "moderately aggressive reference concept" that is sufficiently attractive to become a power plant without excessive extrapolation and R&D uncertainty. The reference concept for energy capture and conversion components uses:

- Helium cooled first wall and blanket structure,
- Dual coolant (lead lithium and helium) blanket,
- First wall and blanket structure fabricated with reduced activation ferritic steel,
- SiC flow channel inserts,
- Permeator tritium extraction system from PbLi,
- Helium cooled divertors based on W-alloys,
- Brayton cycle power conversion system with helium temperatures up to 800˚C.

Additional details can be found in Ref. 5.

With this definition of the ultimate goal and a complete set of TRL definitions, we evaluated our current state of readiness using the in-house expertise of the ARIES Team. Similar exercises could be performed through broader-based community workshops.

The result of this evaluation is presented in Table II. In some cases, we provided a further breakdown on the TRL level that has been already completed and the TRL level that is underway. In general, most of the issues for commercial fusion energy applications remain in the "concept development" phase in levels 1–3. Perhaps surprisingly, even the issues of plasma power management and plasma control have achieved only a TRL level of 3-4. Highly automated and very short maintenance time capability (with high availability), which is a critical requirement for a power plant, is the least advanced.

Table II. Summary of evaluation of current readiness for the reference power plant concept

Technical Issue									
	1	2	3	4	5	6	7	8	9
Power management									
Plasma power distribution	completed	completed	completed	in progress	with ITER	with ITER	with ITER		
Heat and particle flux handling	completed	completed	in progress						
High temperature & power conversion	completed	completed	in progress	with ITER					
Power core fabrication	completed	completed	in progress						
Power core lifetime	completed	completed	in progress						
Safety and environment									
Tritium control and containment	completed	completed	completed	in progress	with ITER	with ITER			
Activation product control	completed	completed	completed	completed	with ITER	with ITER			
Radioactive waste management	completed	completed	in progress						
Reliable/stable plant operations									
Plasma control	completed	completed	completed	completed	with ITER	with ITER	with ITER		
Plant integrated control	completed	completed	in progress						
Fuel cycle control	completed	completed	in progress	with ITER	with ITER				
Maintenance	completed								

Legend: completed: [dark teal] in progress: [light cyan] with ITER: [hatched]

In addition to our evaluation of the present-day status, we examined the expected contribution of ITER to advance each issue. We assumed that ITER would be successful at meeting all of its goals, and that a test module program would be carried out including all of the essential ancillary systems, albeit at rather low neutron flux and substantially reduced operating time and neutron fluence. The results of our evaluation showed that the primary beneficiary of ITER would be plasma control and plasma power management. Many of the technologies used in ITER are not power plant relevant, and therefore cannot be expected to advance technology readiness for a power plant. An exception is the fuel cycle, which shares many common elements with a power plant, and power conversion, which is expected to benefit somewhat from R&D related to blanket test modules (although ITER has no power conversion system, and the coolant exit temperatures from the test blankets may be considerably lower than needed in a power plant).

One of the topics of current interest in the US fusion energy sciences program is the determination of R&D needed to fulfill the science mission of the program. In other words, what is the minimum amount of R&D needed to establish the credibility of fusion as an energy source, and to transition from a science program into an energy development program? Which new facilities will be needed for this goal? The TRL methodology provides a possible framework for quantifying this question. In a general sense, TRL6 represents a transition point from a science-based "proof of principle" program to a technology-driven development program.

Under this assumption, what would it take, in addition to an assumed successful ITER, in order to achieve TRL6 for each issue? Since we expect the key feasibility questions for plasma-related issues to be largely answered by ITER, the remaining credibility questions for fusion are found primarily in the power core and plant systems.

Beyond TRL6, it is clear that additional major facilities will be needed to bridge the gap to a demonstration power plant. These facilities must advance the level of integration and prototypicality of materials and environmental conditions. The TRL methodology provides a framework for evaluating the utility of proposed facilities.

Acknowledgements

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INTERNATIONAL ACTIVITIES:

US ITER Report, Ned Sauthoff, US ITER Project Office, Oak Ridge National Laboratory, Oak Ridge, TN.

Over the past months, the integrated ITER team, consisting of the ITER Organization and the seven domestic agencies, has focused on completing the design, estimating the cost, and developing an integrated project schedule. Increased emphasis is being placed on "integration": integration of the technical design and integration of the ITER team. Technical integration refers to the top-down flow of requirements from the Project Specification and the compilation of system requirements and interface definitions. This is a major activity, since it enables distributed design and assures overall system performance and compatibility. Team integration emphasizes the role of the ITER Organization (IO) as the system integrator and the Domestic Agencies (DA) as the completers of the design and the performers of the fabrication, utilizing industry for final design and manufacturing. The Council approved three prototype "integrated product teams (IPTs)" which are aimed at establishing a more productive working arrangement for the staff of the ITER Organization and the Domestic Agencies: one in blankets, one in the vacuum vessel, and one in power supplies. These IPT's will report to the relevant Deputy Director Generals (DDG), who report to the Principal Deputy who chairs both the IO-DA Coordination Meeting and the Configuration Control Board, positioning them to advance the overall design in the IPT and to refer areas of challenge to the DDG and the Principal Deputy for resolution. Such IPT's have been tried in other major projects and have demonstrated their ability to improve productivity.

On 19-20 November 2008, the ITER Council met, with a focus on scope, cost and schedule. The Council heard the report of an independent assessment of the team's status and plans and decided on the next steps for simultaneously advancing the design and refining the cost estimate and the schedule. The Council members saw first-hand the progress on civil construction, particularly the platform leveling of the 180 hectare construction site. The new ITER headquarters building was dedicated and opened for use.

The US ITER team is operating with a minimal budget, due to the 2008 Omnibus Bill and the 2009 Continuing Resolution. Focus is on mitigating the highest technical and cost/schedule risks and positioning for a rapid engagement of industry when the 2009 appropriation is available.

Licensing ITER at Cadarache - the Story So Far, Neill Taylor, ITER Organization, Cadarache, France.

It sometimes seems like a long story, having begun six years ago, and with a long way still to go - the process of licensing ITER, the first ever fusion device that is truly a *nuclear* facility, is bringing new experiences to everyone involved.

In the Beginning: the DOS

It was 2002, early in the lengthy period of selecting a site for ITER, that the French nuclear safety authorities (then called DGSNR, but now known as Autorité de Sûreté Nucléaire (ASN)) received a formal submission about the project. As part of preparing Cadarache as a candidate site, the French atomic energy commission (Commissariat à l'Énergie Atomique (CEA)) submitted a safety options report (Dossier d'Options de Sûreté (DOS)). This first stage in the nuclear licensing process in France presents to the authorities the main features of the proposed facility and an overview of the potential hazards and the provisions taken to protect against them.

This DOS was based largely on the information in the Generic Site Safety Report (GSSR), which had been prepared by the ITER team in 2001, supplemented by more site-specific information coming from work performed by several of the European Fusion Associations. The DOS was examined by the French regulators and by a panel of independent experts, leading to a set of recommendations which listed topics that the authorities need to see covered in later submissions.

Licensing ITER – the French Approach

From the information provided in DOS, it was clear how ITER would be categorized within French nuclear licensing. The facility is a basic nuclear installation (Installation Nucléaire de Base (INB)), but is classified along with hot labs, fuel plants and storage facilities – not fission reactors. There is a well-established roadmap for the licensing process, but ITER is something new and different, and in some ways does not fit easily into the expectations of those familiar with the safety cases of other INB facilities.

The approach of nuclear licensing in France is not so much proscriptive, it is more demonstrative. That is to say that, while there are indeed many laws and regulations that must be obeyed, fundamentally it is up to the operator of a proposed new facility to demonstrate that what is being proposed will be acceptable. For all the possible hazards, internal and external, for all situations that may occur in all operational phases, including postulated accidents, it has to be shown that adequate provisions have been taken to minimize the impact on the public, the environment, and personnel. There are, of course, limits that must be respected in terms of this impact, but it is most important to show that the performance against safety measures is optimized, and that the very best provisions are taken to minimize the impacts, even when they are far below the regulatory limits.

In 2006, France enacted a new law governing the licensing of nuclear facilities known as "TSN law" (loi relative à la Transparence et à la Sécurité en matière Nucléaire), which ensures public transparency in the process. ITER is the first major installation to be licensed under this law, and although it does not represent a great departure from the previous legislation, unfamiliarity with its implementation has been another factor.

Preparation for the License Application

In June 2005, the site at Cadarache was eventually selected as the site for ITER construction, and the CEA, acting on behalf of the future ITER organization, restarted the interactions with the regulators. As part of this, a series of meetings on technical topics was launched. These were attended by representatives of ASN, their technical advisors IRSN (Institut de Radioprotection et de Sûreté Nucléaire), CEA Agency ITER France (AIF), the ITER safety team, and other specialists from ITER depending on the topics being discussed. Some ten meetings were held over a period of eighteen months, in parallel with the writing of the files for the licensing submission. At these meetings, the ITER team would typically present and discuss aspects of the ITER design and its safety provisions. Topics included confinement, operating limits, tritium processing, buildings, codes and standards, neutron activation and waste, and accident analyses. These meetings were held in a very constructive and supportive atmosphere and were useful for helping all involved to gain a better understanding, particularly since for IRSN, fusion was a new area and inevitably there was a tendency to view ITER as if it were a fission reactor. After the meetings, IRSN usually sent to ITER a set of written questions to which the ITER safety team sent written replies. This process was useful in revealing some of the concerns that would have to be addressed in the safety case.

Once ITER became the legal entity ITER Organization (IO) in October 2007, it took over from CEA as the formal applicant for the licence. By that stage, the files for submission were nearing completion.

Submission of the Demands

Under the TSN law, the operator of a proposed nuclear facility must submit a request for authorization to create the facility (Demande d'Autorisation de Création (DAC)). For ITER this DAC is a set of 12 files, the most significant of which is the preliminary safety report (Rapport Préliminaire de Sûreté (RPrS)). Other DAC files include an environmental impact study, maps of the site and surrounding areas, summaries of the facility design and an overview of the risks that are presented in more detail in RPrS.

The production of the RPrS was overseen by CEA Agence ITER France, who employed contractors, AREVA TA, to do most of the actual writing. The ITER safety team and other parts of IO provided technical input, and important support came from other fusion associations in Europe. As the files all had to be submitted in French, most of the writing was done in French, with translation into an English version that could be reviewed by IO staff and a "safety commission" – a panel of independent safety experts from several of the ITER parties, who performed a thorough review of the RPrS.

Finally, following an intense period of final revisions, the DAC files including the RPrS were submitted to the authorities at the end of January 2008. The technical content of RPrS, summarized elsewhere [1], provided a broad and rather high-level view of ITER, its safety provisions, and analyses of the impacts of normal operation and the potential consequences of postulated incidents and accidents.

Acceptability of the Files

After submission of the DAC, the ASN and IRSN spent some months in a first examination of them. In June 2008, a group of specialists from IRSN came to Cadarache to meet with the ITER safety group and present their first assessment, outlining the extra information that they would like to see contained in the RPrS. At the end of July 2008, a letter was received from ASN that formalized these requests, and listed some 60 items where an improvement in the files was required before they could be considered as acceptable for the next stage in the licensing process. The requests were mainly for additional detail, more depth in the presentation of the analyses, or better justification of some of the assumptions or claims that are made.

Updating of the RPrS and other DAC files is currently in progress. It is being done mainly within the ITER Nuclear Safety and Environment Division, with some support from CEA and other external bodies. For most of the requests, the required additional information already exists in some form, but in some cases further analyses have to be undertaken. Some meetings between IO staff and IRSN are being held to clarify more precisely what is expected in response to some of the demands.

This time the modifications and additions are all being written first in English and will then be translated into French for submission. To cover all the necessary materials, a number of reference documents will be annexed and all of these are being translated into French, too.

What Next?

The target is to resubmit the licensing files in the spring of 2009, after review, translation and final checking. If the authorities consider them acceptable, they will convene a public enquiry at which the license application will be considered based on the contents of the DAC files. After this, the files will come under the scrutiny of a group of independent experts – the Groupe Permanent. It is expected that they will raise a number of technical questions and challenges, which ITER will have to respond to. Eventually, when everything is satisfied, a decree should be issued (Décret d'Autorisation de Création), allowing the IO to proceed with construction of the ITER facility. It should be noted that the permission to start civil construction works – excavation and buildings – has already been obtained by a completely separate process.

Over the years that follow, while construction proceeds, work will continue on providing more detail in the safety case. This will respond to any demands that are made when the decree is issued, and will lead to a further safety submission, the provisional safety report (Rapport Provisoire de Sûreté (RPS)), submitted towards the end of the construction phase and leading to a further decree that will authorize the start of operation.

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25th Symposium on Fusion Technology, SOFT-2008, Robert Wolf, Max-Planck-Institut für Plasmaphysik, Greifswald, Germany, and Thomas Todd, UKAEA Culham Science Centre, Oxfordshire, UK.

The 25th Symposium on Fusion Technology (SOFT 2008) was held September 15-19, 2008 at HanseMesse in Rostock, situated in the northeast of Germany on the coast of the Baltic Sea. The conference has a long term tradition of taking place every second year in a different European country. This year's organizer of the conference, the 25th event in this series, was the Max Planck Institute for Plasma Physics in Greifswald, Germany. More than 680 scientists and engineers from 28 countries attended this important symposium on fusion technology. A total of 535 contributions were presented: 18 invited and 33 oral presentations, and 484 poster presentations in four poster sessions. The Symposium topics ranged from experimental fusion devices, plasma heating and current drive, plasma engineering and control, and diagnostics, data acquisition and remote participation to magnets and power supplies, plasma facing components, vessel/in-vessel engineering and remote handling, fuel cycle and blanket breeding, materials technology, and finally power plants, safety and environment, socio-economics and transfer of technology.

The objective of the SOFT is to exchange information on design, construction and operation of fusion experiments and on the technology for present and future fusion machines and power plants. With the start of ITER construction, fusion research is now making a big step forward. Accordingly, ITER and its demanding requirements were a major topic – more than 50 percent of the oral presentations were referring to this experimental reactor. The peer-reviewed papers of the Symposium will appear in the Elsevier publication Fusion Engineering and Design.

A Fusion Technology Forum with 38 exhibitors supplemented the scientific sessions, bringing together industry, research laboratories and institutions active in fusion technology. Promoting exchange between industry and research was also the objective of a round table discussion entitled "ITER and Industrial Development". Chaired by Harri Tuomisto from the Finnish power and heat company Fortum, Didier Gambier and Maurizio Gasparotto, resp. Director and Chief Engineer of F4E, Hans-Dieter Harig, former EoN C.E.O., Dr. Claude Jablon from the Comité Industriel ITER, Kurt Ebbinghaus from Deutsches ITER-Industrie-Forum, and Philippe Garderet, the Scientific Vice President of AREVA, discussed the industrial involvement in fusion technologies and in the implementation of ITER.

The keynote speech launching the main meeting was given by Quintana Trias, on the topic, "Achievements and challenges of the European fusion energy research programme and ITER". Among other things, he noted that while it was true that the European Union speaks with one voice on matters such as ITER, it has to achieve a consensus of 27 countries in order to do so, and that the new European Strategic Energy Technology (SET) plan now recognized fusion as an energy option of the future. Norbert Holtkamp followed this with an upbeat talk on the status of ITER, introducing the new ITER logo, apparently based upon a rising sun. Lutz Wegener then gave a very interesting talk on the progress in the assembly work for the flagship of the host nation of the conference – the massively complex W7X stellarator. The session concluded with the first of the more detailed technical talks, presented by Neil Mitchell on the design of the ITER magnets.

Delegates faced an afternoon choice between two parallel oral presentation sequences, one of which included the first in-vessel trials of the Articulated Inspection Arm in Tore Supra (by Laurent Gargiulo) and another talk (by Alessandro Tesini) stressing the need for serious attention to remote handling compatibility from the earliest stages of component design for fusion reactors like ITER and beyond. There followed the usual multi-parallel session of about 120 posters, after which the delegates made their way downtown for the conference reception, where an excellent taste of the local beers was provided.

Tuesday began with Toshihide Tsunematsu presenting the status of the Broader Approach to Fusion Energy, which includes IFMIF, JT60SA and a new supercomputer facility. Jean Jacquinot was next, informing us about heating and current drive plant for ITER, with Volker Erckmann then covering the development trends towards steady-state ECRH systems, including multi-frequency gyrotrons. The pre-lunch oral sessions divided on materials technology, with several talks on aspects of IFMIF, and on ITER NBI and ICRH developments, not least the JET ITER-like ICRH Antenna (by Frederic Durodie).

After lunch, the initial orals covered further details on ITER systems and a selection of work on other machines, e.g. ELM control coils in ASDEX-U (by Wolfgang Suttrop). Those taking up the challenge of selecting which of the ~120 posters to visit were rewarded, *inter alia,* with substantial sets on various features of W7X and on initial designs for remote handling in IFMIF and DEMO as well as JET and ITER. Subsequently, downtown in an old monastery, we were exquisitely entertained with classical music examples from the work of Mozart, Beethoven, Schubert and Brahms**,** enlightened by the Trio Quintillian participating professor describing the contemporary circumstances of the composers.

Didier Gambier launched the proceedings on Wednesday, describing the work of Fusion for Energy (aka F4E). He stressed that EU procurements for ITER would take significant account of “value for money” in tendering adjudication, not simply the tendered prices. Maurizio Gasparotto followed with a talk on the design and technical status of the EU work for ITER, emphasizing the importance of design reviews, project risk assessments and procurement strategy. In a break from the conventional plenary session format, the rest of the first session was taken up with a panel discussion, “ITER and Industrial Involvement”, which featured a range of practical views from senior industrialists (Ebbinghaus, Jablon, Garderet and Harig). These included, “Companies differ widely in their awareness of ITER”, “We welcome the opportunity to attend a technical seminar soon to be given at F4E on ITER” and “ITER must take care not to leak the Intellectual Property Rights of specific companies to their competitors”. Gambier and Gasparotto added that, “Fusion must freely give to industry its specialist knowledge on, for example, plasma diagnostics” and “We are developing the methods necessary to allow us to achieve successful procurement liaison between all seven of the ITER parties”. Only

~110 posters to decide between in the remainder of the morning, with a notable number on the newly commissioned KSTAR tokamak, then a traveling lunch on the way to Greifswald to visit the beautiful old city, very extensively and classically refurbished since reunification, and the fascinating stellarator project W7X.

Thursday commenced with an overview of JET results and forward plans by Francesco Romanelli, whose slides included the tentative continuation of operation through the end of 2014, with a significant DT experiment towards the end of that period. Bernard Saoutic was next, covering ITER-related development work on Tore Supra such as the "Passive-Active Module" lower hybrid wave launching grille and sustained long pulse tokamak discharges, currently exhibiting a curious tendency for the walls to keep absorbing fuel species gas at a near-constant rate, "even over five hours of accumulated discharge time". Last before the tea-break was Otto Gruber, summarizing ASDEX-Upgrade enhancements in support of ITER including their approach to a complete tungsten wall surface and associated operational experience, and plans to introduce dual (and perhaps multi-) frequency gyrotrons. Continuing the plenary session after the break, Mickey Wade took us through the issues of ELM control in ITER, as modeled in DIIID experiments with pellet injection pacing and n=3 resonant magnetic perturbations. Eberhard Diegele ended the session with a presentation on breeder blanket materials development in the EU, noting among other things that presently, hot isostatically pressed materials, popular with fusion reactor designers, are not within the materials permitted by the nuclear licensing regulatory bodies of any country.

The parallel oral sessions after lunch covered a range of fusion reactor issues and two machine status updates. These were on KSTAR (by Yeong-Kook Oh), which was very positive since it was reporting first plasma achieved in this important new all-superconducting tokamak, and on NCSX (by Lawrence Dudek), which was necessarily a little negative because it covered the mothballing of this advanced hybrid stellarator-tokamak before its construction was completed. Into the last poster session, again with about 120 posters to choose between, here there were many on plasma diagnostics, some as proposals and developments for ITER, others reporting results from various machines operating today, and a good number on materials research in support of the fusion fuel cycle. Maintaining a long and successful tradition, the evening of this penultimate day of the conference saw the conference banquet or "Gala Dinner", which was held in a stunning location on the edge of the sea at the Hohe Düne yacht harbor residence.

On the last day of the meeting, the sessions were entirely plenary, beginning with three talks on conventional fusion topics. These were about progress in the LHD stellarator (by Hiroshi Yamada), the EU vision for DEMO (by Minh Quang Tran) and key R&D issues for DEMO (by Jerome Pamela). These DEMO talks complemented the significant number of posters on this machine, reinforcing the seriousness with which the next step after ITER is now being considered in many circles. The last "proper" talk was by Herman Ken Take from CERN, on lessons learned in the project management and procurement of the world-class toroidal magnetic structure of the ATLAS detector for the Large Hadron Collider. It was evident that the problems encountered in that project were very similar to those arising in large-scale fusion projects equally demanding in fabrication technology and quality assurance. Finally, a talk was given by one of us (Thomas Todd), summarizing the high points of the conference as perceived by the International Organizing Committee.

More information about the conference can be found on the website:
http://www.ipp.mpg.de/eng/for/veranstaltungen/soft2008/.