Fusion Energy Division
American Nuclear Society
June 2001 Newsletter

The June 2001 newsletter of the American Nuclear Society (ANS) Fusion Energy Division (FED) has been archived on the ANS-FED Web site: http://fed.ans.org/. Please share this newsletter with your colleagues. If you haven't received this newsletter directly from the editor and would like to subscribe to the biannual newsletter, forward your E-mail address to the editor (elguebaly@engr.wisc.edu). If you believe you are outside the fusion community or received this newsletter in error, please accept our apology for the inconvenience and inform the editor to unsubscribe. The topics for this issue include:

Message from the Chair, Kathryn McCarthy, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho

In my final message to you as Chair, there are three major areas I'll cover: FY-02 budget outlook, the National Energy Policy Report, and FESAC activities.

Budgets

If budgets hold, FY-02 funding will be approximately flat. The Office of Science fared well overall, given budget cuts in other parts of DOE. There are, however, ongoing efforts to increase the fusion budget. Congresswoman Zoe Lofgren (D-CA) and Congressman George Nethercutt (R-WA) have introduced H.R. 1781, The Fusion Energy Sciences Act of 2001. This bill provides $320,000,000 for fiscal year 2002 and $335,000,000 for fiscal year 2003. Please make sure your representatives are aware of the bill, and encourage their support. A Senate sponsor for the fusion bill has not yet been announced.

National Energy Policy Report

President Bush's highly anticipated National Energy Policy report was issued in May. The report was prepared by the National Energy Policy Development (NEPD) Group, chaired by Vice President Dick Cheney. The report focuses primarily on near- and mid-term energy sources, conservation and efficiency. However, due to the hard work of some members of the fusion community, fusion energy caught the attention of key people in the NEPD Group, and was included in the report. Fusion is listed with "Future Energy Sources--As we look to the long-term future of alternative energy technologies, there is significant promise in these technologies to meet an ever-growing portion of our nation's energy needs."

The summary recommendations for future energy sources are:

- *The NEPD Group recommends that the President direct the Secretary of Energy to develop next-generation technology—including hydrogen and fusion.*
- *Develop an education campaign that communicates the benefits of alternative forms of energy, including hydrogen and fusion.*
- *Focus research and development efforts on integrating current programs regarding hydrogen, fuel cells, and distributed energy.*

The section on fusion from the National Energy Policy report is reproduced below (the full report can be found at http://www.whitehouse.gov/energy):

> *Fusion—the energy source of the sun—has the long-range potential to serve as an abundant and clean source of energy. The basic fuels, deuterium (a heavy form of hydrogen) and lithium, are abundantly available to all nations for thousands of years. There are no emissions from fusion, and the radioactive wastes from fusion are short-lived, only*

requiring burial and oversight for about 100 years. In addition, there is no risk of a melt-down accident because only a small amount of fuel is present in the system at any time. Finally, there is little risk of nuclear proliferation because special nuclear materials, such as uranium and plutonium, are not required for fusion energy. Fusion systems could power an energy supply chain based on hydrogen and fuel cells, as well as provide electricity directly.

Although still in its early stages of development, fusion research has made some advances. In the early 1970s, fusion research achieved the milestone of producing 1/10 of one watt of fusion power, for 1/100 of a second. Today the energy produced from fusion is 10 billion times greater, and has been demonstrated in the laboratory at powers over 10 million watts in the range of a second.

Internationally, an effort is underway in Europe, Japan, and Russia to develop plans for constructing a large-scale fusion science and engineering test facility. This test facility may someday be capable of steady operation with fusion power in the range of hundreds of megawatts.

Both hydrogen and fusion must make significant progress before they can become viable sources of energy. However, the technological advances experienced over the last decade and the advances yet to come will hopefully transform the energy sources of the distant future.

Now that the NEPD has given fusion some airtime, it's up to all of us to contact our congresspeople and participate in public outreach activities to help promote fusion, and increase budgets to a level that will adequately support the fusion program.

FESAC Update

FESAC is currently working on the following charges:

- The readiness of the NCSX (National Compact Stellarator Experiment) for Proof Of Principle designation
- Review of the Theory and Computing Program
- Response to the National Research Council's review of the Fusion Energy Sciences Program

FESAC's response to these charges will be completed in the next month. The next FESAC meeting will be held August 1-2, 2001, at PPPL. When FESAC's responses to the various charges are complete, they will be posted on the FESAC web site (http://wwwofe.er.doe.gov/More_HTML/FESAC_Charges_Reports.html).

Wrap-up

This is an exciting time for energy research, and we need to take advantage of the current energy situation to promote fusion. Continue (or for some of us, start) those public outreach activities. Invite yourself to your children's and grandchildren's schools and teach them about fusion. Teach a summer school mini-session on fusion as part of a summer science program. There are lots of things that we all can, and should, do. (And by the way, it's fun too!)

After the June ANS meeting, Jim Stubbins will be taking over as Chair of the Fusion Energy Division. Thank you for all the support that you have given me, and I know that you will give him the same support. I'm sure Jim will do a great job!

Thanks for the great year! Kathy

Officers and Executive Committee List, Clement Wong, General Atomics, San Diego, California

The following is a listing of our 2001-2002 FED officers.

Chair:	James Stubbins (UIUC)	(01-02)	jstubbin@staff.uiuc.edu
VC/Chair-Elect:	Wayne Meier (LLNL)	(01-02)	meier5@llnl.gov
Secy/Treas:	René Raffray (UCSD)	(01-02)	raffray@fusion.ucsd.edu
Exec Committee:			
	James Blanchard (UW)	(99-02)	blanchard@engr.wisc.edu
	Lee Cadwallader (INEEL)	(99-02)	lcc@inel.gov
	Chris Hamilton (GA)	(00-03)	hamiltonc@gat.com
	Jeffery Latkowski (LLNL)	(00-03)	latkowski@llnl.gov
	Akio Sagara (Japan)	(01-04)	sagara@LHD.nifs.ac.jp
	Roger Stoller (ORNL)	(01-04)	stollerre@ornl.gov
	Neill Taylor (England)	(01-04)	neill.taylor@ukaea.org.uk
	Scott Willms (LANL)	(99-02)	willms@lanl.gov
	Dennis Youchison (SNL)	(00-03)	dlyouch@sandia.gov

FED Standing Committee Chairs:		
	Nominating	Kathryn McCarthy (INEEL) - Chair
	Program	Steve Herring (INEEL) - Chair
	Honors and Awards	Gerald Kulcinski (UW) - 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)
ANS Public Information	Julie Van Fleet (Van Fleet & Associates)

Editors:

Newsletter	Laila El-Guebaly (UW)
Fusion Science and Technology Journal	Nermin Uckan (ORNL)

Liaisons to other ANS divisions and organizations:

ANS Board	Gary Gates (Omaha Public Power District)
AAD	Jim Anderson (DOE)
MS&T	Ken Schultz (GA)
IEEE	George Miley (UIUC)

Web site maintenance: Mark Tillack (UCSD)

Treasurer's Report, Rene Raffray, University of California, San Diego

As of December 2000, our division has a balance of $2,342. Income in 2000 included:
- $555 from membership
- $5,103 carry forward from 1999

As of that date, no profit from the October 2000 Topical Meeting in Park City has been reported. Expenses in 2000 included:
- $1,500 for awards
- $1,200 for student support
- $616 for national meeting expenses (conference calls).

For 2001, our income will include approximately:
- $500 from membership
- $2,342 carry forward from 2000
- $3,000 (current estimate) from profit from the October 2000 Topical Meeting in Park City

Anticipated expenses in 2001 include:
- $300 for NEED scholarship
- $600 for national meeting expenses (conference calls).

The projected balance at the end of 2001 is approximately $4,942.

Fusion Science and Technology Journal, Nermin A. Uckan, Editor, Oak Ridge National Laboratory, Oak Ridge, Tennessee

I am honored and humbled to become the new editor of the *Fusion Science and Technology* (*FS&T*). With the July 2001 issue, the journal has a new name and new Editorial Team.

Most of us came into the fusion program with a dream of fusion energy. These are both difficult and exciting times and the dream persists. Our new name, *Fusion Science and Technology*, highlight the importance and the need for the partnership and unification of the fusion science and technology communities behind a common goal of the development of fusion energy. The *FS&T* will publish original research and review papers on fusion plasma physics and plasma engineering, fusion nuclear technology and materials sciences, fusion plasma enabling science and technology, fusion applications, and fusion design and systems studies.

I am grateful to Drs. Yasuo Shimomura, Roberto Andreani, and Englen Azizov for agreeing to serve as the Associate Editors for Asia, Europe, and Russia, respectively. Drs. Charles C. Baker, David Campbell, Gianfranco Federici, Jeffrey P Freidberg, William J. Hogan, Kathryn A. McCarthy, Farrokh Najmabadi, Yuichi Ogawa, Jérôme Pamela, Per F. Peterson, L. John Perkins, John A. Schmidt, Kenneth R. Schultz, Masahiro Seki, Weston Stacey, Michael A. Ulrickson, R. Scott Willms, and Steven J. Zinkle will be helping and guiding the direction of the journal on the Editorial Advisory Board.

Professor George Miley has served as the Editor of the *Fusion Technology* (and its predecessor *Nuclear Technology/Fusion*) since its inception in January 1981. During this time *Fusion Technology* (*FT*) has become the premier journal for the publication of research papers on fusion engineering and fusion technology. Our deep thanks are due to Dr. Miley for his two decades of dedicated service and contributions to the journal.

With the editorial change, the location of the *FS&T* Editorial Office has moved to the ANS headquarters in LaGrange Park, Illinois. Deborah Nall, ANS Scientific Publications Department, will serve as the Editorial Assistant for the journal. All new manuscripts submitted for consideration by *Fusion Science and Technology* should be directed to the FS&T office at ANS Headquarters: 555 N. Kensington Avenue, LaGrange Park, IL 60526 USA. I would like to assure all the authors that their papers will be handled as expeditiously as possible and we have a very efficient and effective communication channels in-place between the ANS headquarters in Illinois and Oak Ridge, Tennessee, where I have been working for the past 25 plus years.

In the July 2001 *FS&T* issue, we have a diverse group of papers ranging from options for deployment of large fusion power plants, ITER performance predictions, neutral transport at the plasma edge, and electrostatic confinement, to summary of 18th IAEA fusion energy conference papers on technology and power plants. I am pleased to note that we (ANS, *FS&T*) have made an agreement with the IAEA to publish the 18th IAEA Fusion

Energy Conference [FEC2000, Sorrento, Italy] summaries in *FS&T*. The summary on 'technology and power plants' is included in the July issue. The summaries on 'stability, current drive and heating, and energetic particles' and 'inertial fusion energy' will be included in the upcoming, September 2001 issue. We hope to continue this collaboration and tradition with the IAEA in future years. We hope to initiate similar working relationship and exchange agreement with other national and international societies to share publishing of information that are of vital interest to fusion science and technology readership.

During the coming months, we will be working with the ANS to implement electronic publishing and subscription and we will be working with the Universities, with the faculty and students alike, to bring the journal (*FS&T*) to the classrooms.

We are also working with experimental groups (magnetic and inertial fusion) around the world to contribute to series of special issues to recognize and highlight the "science and technology contributions of the present experimental programs to next step 'burning plasma' devices on the path to fusion development." I am delighted that all groups have accepted the invitation to participate and these special issues will appear within the next 15 to 30 months. When completed, these series will have a long lasting value to the fusion community, from desktops to the classrooms.

In future issues, each Editorial Advisory Board Member will organize and serve as 'Guest Editor' for at least one special issue during their tenure. We will announce these 'topical' issues and solicit your inputs as the plans develop. We are looking forward to receiving your suggestions and proposals as to how to improve the journal and which topical areas you would like to see be highlighted by the Journal and in which areas you would be able to coordinate and/or contribute manuscripts.

While these plans are in place to improve the future quality and health of the journal, at the present time, the paper submissions are at an alarmingly sub-critical level in conventional fusion science and technology areas. Most papers in the hopper [and most new submissions] are cold fusion papers! We need a quick short-term relief. It is imperative that all of us, as members of the ANS-FED, take immediate active role in soliciting papers, contributing papers, and organizing special topical issues. For *FS&T* to become and remain the leading journal, we must keep a steady flow of high-quality papers. I know we can do it. Let's roll up our sleeves and start working.

Working together we can strengthen the reputation of the journal. The strength of any journal is as good as the papers it publishes and reviewers that serve beyond their parochial boundary. I am looking forward to working with all of you to make the journal as the world's premier journal in fusion science and technology. We ultimately judge ourselves and are judged by others in terms of progress towards our goal in attracting and publishing high quality papers and in satisfying and maintaining broad readership of our journal. I would like to see each of you to take ownership of the journal and be a participant, not a spectator. *The Fusion Science and Technology* belongs to all of us and I am counting on your continued help to keep the journal strong by submitting and publishing your papers and by providing timely, critical reviews of papers when asked. Together, we can keep *FS&T* strong and vibrant in the 21st Century.

Ongoing Fusion Research:

Inertial Fusion Target Fabrication Activities at General Atomics, Ken Schultz, General Atomics

General Atomics has long been one of the major contributors in the magnetic fusion area. We have built and operated a number of magnetic confinement devices, including the DIII-D tokamak, now the largest operating tokamak in the USA. We have long had a comprehensive program of magnetic fusion theory, experiment and technology development.

GA has also become a major contributor to inertial fusion. About 20% of GA's fusion research and development activities are devoted to inertial fusion. These inertial fusion activities began in the late 1970s with design studies of inertial fusion energy power plants, such as the Cascade study done in support of the Lawrence Livermore National Laboratory (LLNL). These activities built strongly upon GA's magnetic fusion technology programs. In 1990, GA was selected by the US DOE to be the Inertial Confinement Fusion (ICF) Target Support Contractor. We have just received our third 5 year contract to carry out this work. We provide research, development and production of the targets and target handling systems used in the ICF experiments conducted by the five US ICF Labs as part of the DOE's Science-Based Stockpile Stewardship program. These Labs are: LLNL, Los Alamos National Laboratory (LANL), Naval Research Laboratory (NRL), Sandia National Laboratories (SNL) and the University of Rochester Laboratory for Laser Energetics (UR/LLE). Since the beginning of this activity, GA has been teamed with Schafer Corporation as our partner and major subcontractor to carry out this important task.

The GA/Schafer team develops and produces the spherical capsules that are the heart of an ICF target. These capsules range from as small as 250 μm in diameter for certain experiments on the Omega laser at UR/LLE to as large as 5 mm diameter for some experiments on the z-pinch facility called Z! at SNL. Most indirect drive experiments on Omega, where the capsule in enclosed in a radiation case or hohlraum, use 0.5 mm diameter capsules, while most direct drive experiments need 1 mm diameter capsules. The experiments on the National Ignition Facility now under construction at LLNL will generally use capsules 2 to 3 mm in diameter. The capsules are generally made of polymer, frequently with a variety of dopants at different locations in the capsule wall. The wall thicknesses vary from 1.0 μm to over 100 μm, depending on the experiment for which it is intended. We fabricate these capsules using the "PAMS/GDP decomposable mandrel process." A spherical hollow shell or "mandrel" is made by density-matched microencapsulation of poly-alpha-methyl styrene or PAMS. Droplets of pure water, surrounded by PAMS dissolved in solvent, surrounded by a water stream are formed with a triple-orifice droplet generator. By adjusting the concentrations and temperatures to maintain proper density matching and stirring gently, beautifully spherical PAMS shells can be formed as the solvent escapes into the surrounding water. The shells are dried and are then used as the inner mandrels upon which a very uniform layer of amorphous glow discharge polymer (GDP) (about $CH_{1.8}$) can be deposited using a plasma polymer coater with the mandrels placed in a gently agitated pan placed in the C-H plasma stream. Finally, the coated mandrels are heated to 300°C to decompose the PAMS polymer back to the monomer, which diffuses out of the shell, leaving the completed GDP capsule which is both very spherical and highly uniform. The GDP process can incorporate various dopants at different locations and concentrations in the capsule wall to tailor the opacity of the wall or to serve as diagnostic markers. A thin layer of poly-vinyl alcohol or an even thinner layer of aluminum must be added to retain the fill gas. The capsules are filled with deuterium or DT and various diagnostic gases by permeation at elevated temperature and pressure. We produce several thousand targets per year for the ICF experiments.

For indirect drive experiments, the capsules are placed within a radiation case or hohlraum that converts the incident laser light into x-rays that ablate and compress the capsule. The GA/Schafer team fabricates the hohlraums by turning an inner mandrel on a high precision lathe called a "diamond turning machine" which uses a single crystal, gem quality diamond as the cutting tool. This mandrel, generally made of copper, is electroplated or sputter coated with the hohlraum material, generally gold, and the inner mandrel is dissolved, leaving the empty hohlraum into which the capsule can be mounted.

In addition to capsules and hohlraums, the GA/Schafer team fabricates a variety of planar targets for Raleigh-Taylor instability studies and other laser-plasma interaction experiments, and numerous foam target components, some with densities as low as 5 mg/cc. The planar targets may have complex patterns on one or both surfaces, and may be composed of multiple layers of different materials.

A principal challenge of inertial fusion target fabrication is precision. The dimensional tolerances for ICF targets are very tight. The maximum out-of-round for a 1 mm diameter capsule is typically less than 0.5 μm. The wall thickness uniformity specification is usually also about 0.5 μm. The surface finish must be better than about 100 Å. Hohlraums and other components have similarly strict specifications.

To fabricate targets with extreme accuracy requires characterization of those targets with even more extreme accuracy. We use high quality optical and white light interferometric microscopes to measure the diameter, out-of-round and wall thickness of the capsules. Micromachined components such as hohlraums and witness plates are measured with laser micrometers and high precision microscopes. We use an x-ray fluorescence spectrometer to determine chemical composition and interference profilometers to measure surface finish. We create a "pedigree" of measurements for each target delivered. Many of the capsules are "spheremapped" and "wallmapped" to document their quality. We rotate the capsule against the tip of an atomic force microscope, making multiple traces of the surface profile in several orthogonal directions. A laser interferometer measures the thickness of the shell at a small spot on the surface as the capsule is rotated. This information is then Fourier transform processed to obtain the spherical harmonic modal representations of the shell surface and wall thickness and their modal power spectra from modes 2 through as high as 2000.

Current ICF experiments mostly use DD or DT gas inside the capsules. This gas is compressed and heated to fusion conditions by ablation and compression of the capsule. To obtain the high densities needed for ignition (about 1000 times normal solid density), ignition targets will start with DT ice rather than gas. The DT ice must be formed into a very smooth and very uniform layer inside the capsule. The GA/Schafer team is working with LANL and LLNL to perfect the techniques needed to form this DT ice layer. The energy from beta decay of the tritium provides a natural energy source to achieve a uniform layer. If the outer surface of the capsule is held at a precisely uniform temperature, thicker areas of DT ice will produce more heat and thus reach higher temperature than thinner areas. The DT will sublime from thick areas and deposit on thin ones, resulting in a uniform layer. The difficulty is in achieving sufficiently precise temperature control (to about 25 μK) and obtaining adequately smooth ice surface finish (better than about 1 μm). Auxiliary infrared or microwave heating may be needed. We are carrying out experiments to develop these technologies.

To field cryogenic targets on ICF experiments will require specialized and precision target handling equipment. The ICF capsules must be filled with DT gas to pressures as high as 1500 atm and then cooled to cryogenic conditions of < 20 K to condense and freeze the fuel. The DT must be layered inside the capsule, the layer and its surface must be characterized, and the target must be transported to the target chamber, all under precisely controlled cryogenic conditions. In the target chamber, the target must be protected from the thermal radiation from the chamber by protective shrouds until just milliseconds before shot time. The shroud must then be removed and moved far enough away from the target to not block the incident laser beams, and to avoid being damaged by the shot. We worked with LANL and UR/LLE to design, develop and fabricate the cryogenic target system for the Omega laser at UR/LLE, which was delivered in 1999. We have now begun work on the cryogenic target system for the National Ignition Facility.

GA has used the skills and technologies developed on the ICF Target Support activities described above to also contribute to the inertial fusion energy (IFE) program. We are a part of the ARIES team investigating IFE power plants. We are working closely with LANL to develop target fabrication and injection technologies for IFE as part of the Office of Fusion Energy Science's Virtual Laboratory for Technology. GA is also a part of the project team, led by NRL, that is pursuing laser IFE as part of the DOE Defense Programs High Average Power Laser initiative. GA is working on target fabrication, injection and tracking as part of this team. The challenge for IFE target fabrication is to achieve the same precision of manufacture as is needed for ICF targets, but to produce them at the rate of about 500,000 per day and at a cost of only about 25 cents apiece. We are investigating industrial mass production processes such as fluidized bed coating deposition for this fabrication. Initial results have been quite positive. We are also developing the technologies to inject the mechanically and thermally fragile targets into an IFE target chamber at the rate of about 1 to 10 Hz, to accurately place the targets at the chamber center, and to even more accurately track the targets so the driver beams can be focused to hit them. The required accuracy for direct drive targets is expected to be about $\pm$ 20 μm and for indirect drive about $\pm$ 200 μm. We are building an experimental target injection system that will be capable of injecting cryogenic direct and indirect drive targets at speeds up to 400 m/s into a simulated high temperature target chamber and precisely measuring the accuracy of injection and tracking, and the survival of the targets.

General Atomics has been working for several years on the physics aspects of inertial fusion energy and has recently begun work with UC Davis, PPPL and LLNL under an OFES grant to carry out experiments on several overseas petawatt-scale laser facilities on the physics of "fast ignition". The fast ignition inertial fusion concept involves using "conventional" target compression without the central DT gas pocket which normally provides the hot spot to start ignition. Theory predicts that if this very dense lump of compressed fusion fuel is hit with a brief flash of energy at extreme power density -- about 10^{19} W/cc for about 10^{-11} seconds -- a propagating fusion burn will occur that will ignite the entire lump. This concept is highly exploratory but promises higher gains than hot spot ignition with lower capsule compression and lower required input energies. That is, it promises improved performance with relaxed compression requirements and a cheaper development pathway. Because of this promise, there is a lot of excitement about fast ignition. GA is now deeply involved in experiments and analysis to understand the physics of fast ignition under the extreme conditions it requires.

For further information, please check the following web sites:
General Atomics Fusion Program: http://fusion.gat.com/
GA's Inertial Fusion Program: http://fusion.gat.com/icf/
DOE Defense Programs Inertial Confinement Fusion: http://www.dp.doe.gov/ifnif/
DOE OFES Virtual Laboratory for Technology Inertial Fusion: http://vlt.ucsd.edu/inertial.pdf

Socio-economic Perspectives on Fusion Energy, Ronald Miller, University of California, San Diego

Using the term 'socio-economics' to collect and organize a broad set of concerns and issues beyond the usual engineering considerations of technical feasibility, efficiency, safety, reliability, etc., it is possible to anticipate the metrics (decision criteria) that will affect the adoption of fusion energy as a future energy technology.

From the formal Systems Engineering (SE) viewpoint, this activity implies a broadened set of systems requirements consistent with a larger envelope (the national or global energy system) in contrast to ordering the next plant. Another perspective is the multi-disciplinary Industrial Ecology (IE) approach [1]. Although the outcomes may differ, the methodologies apply to studies of fission and non-nuclear energy sources. Socio-economic studies have been used in a narrow sense to assess the impacts of large facilities; a recent fusion example is work related to the possible siting of the

International Thermonuclear Experimental Reactor (ITER) in Canada [2]. The broadened sense allows consideration of public acceptance issues (e.g., life-cycle cost and safety), environmental concerns (e.g., waste streams and climate change), and intergenerational issues (e.g., sustainability). Often this consideration takes the form of cost-benefit analyses, including so-called 'externalities' (i.e., costs or benefits of an activity that accrue beyond the organization carrying on the activity).

Several components of the U.S. fusion R&D program of the Department of Energy, Office of Fusion Energy Sciences (OFES) are explicitly identified as socio-economic studies. Socio-economic activities related to magnetic fusion have been initiated as a Task 7 under the International Energy Agency (IEA) Cooperative Program on the Environmental, Safety and Economic (ESE) Aspects of Fusion Power; consistent with the generalized IEA collaboration described in a recent ANS FED Newsletter [3]. The reader may wish to contact the appropriate contact person: EU, Ian Cook (UKAEA Culham) [Task Leader]; Japan, Yuichi Ogawa (U. Tokyo); RF, Boris Kolbasov (KIAE); and US, Ronald Miller (UCSD). One goal of this work is to improve the visibility of fusion options in the coupled deployment and climate modeling being used to characterize scenarios spanning the next century [4,5]. Finally, since the results of socio-economic studies can be expected to be used in public-policy discussion, explicit distinctions should be made between 'analysis' and 'advocacy' in order to preserve the objectivity of the former.

References:

[1] B. R. Allenby, Industrial Ecology: Policy Framework and Implementation (Prentice Hall, 1999)
[2] See the web site: http://www.itercanada.com
[3] Michael Roberts, "International Activities," ANS FED Newsletter (December 2000)
[4] IEA "Mapping the Energy Future- Energy Modeling and Climate Change Policy," (1998)
[5] See the web site: http://www.ipcc.ch

International Activities:

The UK's Fusion Industry Initiative, Cleve Forty, EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon, UK.

A few miles to the south of the famous university city of Oxford lies the Culham Science Centre, home to the UK's main magnetic confinement fusion laboratory, and also to the European flagship experiment, JET. Fusion research began at Culham in the early 60s on a number of promising concepts before eventually settling on the tokamak line. This theme has continued to the present day with two conventional aspect ratio tokamaks, COMPASS and JET, and one spherical tokamak, MAST, currently in operation on site. Throughout its forty-year history, Culham has relied on outside industry to design and build key components for various fusion devices often to demanding levels of tolerance and quality. The construction of JET, the largest machine of its type, generated a need for considerable industrial input and expert planning. A few years ago it was realized that the even bigger challenge of building ITER would require further increases in industrial involvement if the project were to succeed. Clearly, industry is key to the success of future fusion science.

We also live in a rapidly evolving economic climate. With big science budgets under continual scrutiny, the need to demonstrate that taxpayers' money is being well spent and has some greater societal value is ever present. With this background very much in mind, the UKAEA stepped up its industrial liaison activities in 1997 with the launch of its 'Fusion & Industry' initiative. The objectives behind the new initiative were focused in two main areas, i.e.: 1) an increase in involvement of UK industry in the world fusion scene and 2) greater encouragement for UK industry to exploit technology developed from fusion research and development.

The first of these objectives involves UKAEA assisting companies in procuring fusion contract work. In practice this means mainly targeting the UK's domestic fusion experiments and JET, but also covers the supply of services and equipment to other European fusion laboratories and support for ITER technology tasks. Many of the large value contracts come from the construction of new machines, such as MAST and the W7-X stellarator at Greifswald, Germany: with our assistance, British companies have successfully bid for and won two recent contracts to supply superconducting planar coil sets and diamond microwave transmission windows for W7-X. Other important contracts arise from major machine upgrades such as those occurring on the Tore Supra superconducting tokamak at Cadarache, France and the TJ-II heliac at Madrid, Spain. At any given time, there is also a steady stream of requests from other laboratories to supply smaller items such as new plasma diagnostic instruments, auxiliary heating components, control systems and the like.

British companies nominated by UKAEA have been particularly successful in procuring ITER related contracts. These tasks usually require a high degree of expertise and a proven track record from the companies selected. They often involve detailed design activities, and the manufacture of machine mock-up components to test fabrication methods and materials performance.

The second main objective of the initiative is to demonstrate that fusion funding has immediate short-term benefits, in addition to the long-term strategic goals of energy production. Such benefits arise from technology transfer, the most apparent being so-called 'hardware' spin-off. Some notable fusion success stories in recent years have been spin-offs in the areas of a micro-calorimeter for use in national standards measurements; plasma diagnostic electronics for space applications; computer modeling for financial markets; and novel engineering bearing design used in large flywheel generator/pumped hydro storage systems.

Interestingly, we have also identified many other subtle industrial benefits that extend the definition of technology (or perhaps more appropriately named 'knowledge') transfer, some examples being:

- The contribution that fusion training makes to the sum of highly skilled people in fields outside fusion.
- The increased capability that companies develop by close contact with fusion research giving rise to the potential to expand their business portfolios outside the fusion sector.
- Improvements in management, procedural and quality systems.
- Access by industry to fusion expertise, facilities and equipment.

The last of these has proved particularly fruitful in recent years with UKAEA working hand-in-hand with industry on a variety of joint projects. These projects have included engineering design help with electromagnetic yarn actuators in large weaving machines; surface physics analyses and circuit design for plasma-glass interactions in inductively driven plasma lamps for car tail lights; and sophisticated fabrication and bonding techniques used in a miniature gas chromatograph instrument designed for use on a cometary space probe.

The success of this 'fusion' consultancy type of collaboration with industry has prompted us to expand and formalize these activities through the launch of a dedicated innovation centre at Culham. The centre with office and laboratory space for 25-30 companies, is managed by a private organization who are expert at running high technology incubators – places where start-up businesses are nurtured through the difficult early years of trading. Technical assistance to the start-ups is provided by UKAEA and takes the form of consultancy advice, use of fusion facilities and equipment and access to services such as libraries, engineering design offices and mechanical and electronics workshops. For start-ups with a strong technological overlap with fusion science, the centre represents a real opportunity to promote a two-way technology transfer flow. We launched the centre in the spring of 2001 and already have six start-up companies occupying space and accessing fusion expertise. Sector activities for these companies include medical applications for semiconductor technology; the manufacture of industrial plasma processing equipment; and research and development into ultra-high efficiency heat exchangers for aerospace applications.

Building on the core elements established since 1997, we see the various 'industrial liaison' activities plus the launch of the innovation centre as an excellent opportunity to get British industry in shape for the future challenges of fusion in the years ahead

International Cooperation in Fusion Research, Tom Dolan, Head Physics Section, IAEA, Vienna, Austria

The following Table lists IAEA Technical Committee Meetings (TCM) planned for 2001.

TCM Title	**Dates**	**Place**	**Contact persons**	**Website**
Research Using Small Fusion Devices	25-27 June	Sao Paulo, Brazil	Ivan Cunha Nascimento Laboratory of Plasma Physics University of Sao Paulo Sao Paulo - Brazil Tel: +55-11-3818-7001; Secretariat 3818-7067 Fax: +55-11-3818-7014 inascime@if.usp.br & Thomas J. Dolan, IAEA t.dolan@iaea.org	http://www.14TCM2001.if.usp.br/rusfd
Control, Data Acquisition and Remote Participation for Fusion Research	16-19 July	Padova, Italy	Volker Schmidt, Adriano Luchetta Consorzio RFX Padova, Italy Tel: +39-049-829-5219 Fax: +39-049-870-0718 tcm2001@igi.pd.cnr.it & Ursula Schneider, IAEA, u.schneider@iaea.org	http://tcm2001.igi.pd.cnr.it/
Spherical Tori	1-3 Aug.	Sao Jose dos Campos, Brazil	Gerson Otto Ludwig Laboratory of Plasma Physics National Institute for Space Research (INPE) Sao Jose dos Campos, Brazil Tel: +55-12-345-6698 Fax: +55-12-345-6710 ludwig@plasma.inpe.br & Ursula Schneider, IAEA, u.schneider@iaea.org	
H-Mode Physics and Transport Barriers	5-7 Sept.	Toki, Japan	Katsumi Ida National Institute for Fusion Science 322-6 Oroshi-cho Toki, 509-5292, Japan Tel: +81-572-58-2182 Fax: +81-572-58-2619 ida@nifs.ac.jp	

High Average Power Drivers (together with IFSA 2001)	9-14 Sept/	Kyoto, Japan	Masakatsu Murakami Institute of Laser Engineering (ILE) Osaka University Osaka, Japan Tel: +81 6-6879-8743 Fax: +81 6-6877-4799 mym@ile.osaka-u.ac.jp & Ingo Hofmann High-Current Beam Physics Group Gesellschaft f. Schwerionenforschung Darmstadt, Germany Tel: +49-6159-71-2409 Fax: +49-6159-71-2985 i.hofmann@gsi.de	http://www-aix.gsi.de/~hidif/tcm.html
Divertor Concepts	11-14 Sept.	Aix-en-Provence France	Philippe Ghendrih Association Euratom-CEA, DRFC, CEA Cadarache, St Paul lez Durance, France Tel: +33-4-42-25-2993; Secretariat 25-6340 Fax: +33-4-42-25-4990 Ghendrih@drfc.cad.cea.fr and Ghendrih@cea.fr & Ursula Schneider, IAEA, u.schneider@iaea.org	http://wshop.free.fr/divconcepts/index.html
Energetic Particles in Magnetic Confinement Systems	8-11 Oct.	Gothen-burg, Sweden	Mietek Lisak Association EURATOM-NFR Department for Electromagnetics Chalmers University of Technology Göteborg, Sweden Tel.: +46-31-772-1565 Fax: +46-31-772-1573 elfml@elmagn.chalmers.se & Ursula Schneider, IAEA, u.schneider@iaea.org	http://www.elmagn.chalmers.se/tcm/

The next IAEA Fusion Energy Conference will be held in Lyon, France, in the fall of 2002.

An IAEA Coordinated Research Project typically involves 5-15 countries, has a Research Coordination Meeting every 18 months, lasts 3-5 years, and results in a Technical Document. The current projects dealing with fusion research are:

Comparison of compact toroid configurations	(1998-2002)
Atomic & molecular data for plasma diagnostics	(2000-2003)
Elements of power plant design for inertial fusion energy	(2000-2004)
Applications of dense magnetized plasmas	(2001-2004)
Tritium inventory in fusion reactors	(2002-2004)
Data for molecular processes in edge plasma	(2001-2005)

Calendar of Upcoming Conferences on Fusion Technology

ANS Annual Meeting
June 17-21, 2001, Milwaukee, WI, USA
http://www.ans.org/

Second International Workshop on Magnetized Target Fusion
August 7-9, 2001, Reno, Nevada, USA
http://www.mtf.unr.edu/
lmaestas@lanl.gov

2nd International Conference on Inertial Fusion Science and Application - IFSA-2001
September 9-14 , 2001, Kyoto, Japan
http://www.ile.osaka-u.ac.jp/ifsa2001/
ifsa01@ile.osaka-u.ac.jp

13th International Stellarator Workshop
September 24-28, 2001, Canberra, Australia
http://wwwrsphysse.anu.edu.au/admin/stellarator/
helen.hawes@anu.edu.au

FPA Annual Meeting and Symposium: Frontiers in Fusion Research
Sept 25-26, 2001, Washington, D.C., USA
http://fusionpower.org
fpa@compuserve.com

19th IEEE/NPSS Symposium on Fusion Energy - SOFE-01
October 2-5, 2001, Atlantic City, NJ, USA
http://www.pppl.gov/sofe01/
mabrown@pppl.gov

10th International Conference on Fusion Reactor Materials - ICFRM-10
October 14-19, 2001, Baden-Baden, Germany
http://www.icfrm.fzk.de/

ANS Winter Meeting
November 11-15, 2001, Reno, Nevada, USA
http://www.ans.org/

6th International Conference on Tritium Science and Technology
November 11-16, 2001, Tsukuba, Ibaraki, Japan
http://tritium2001.jaeri.go.jp
nishi@tritium2001.jaeri.go.jp

4th US/Japan Workshop on Laser-IFE
March 13-15, 2002, Osaka, Japan

6th International Symposium on Fusion Nuclear Technology - ISFNT-6
April 7-12, 2002, San Diego, CA, USA
http://cer.ucsd.edu/isfnt.html
chennessy@vlt.ucsd.edu

ANS Annual Meeting
June 9-13, 2002, Hollywood, Florida, USA
http://www.ans.org/

14th International Conference on High-Power Particle Beams and 5th International Conference on Dense Z-Pinches
June 23-28, 2002, Albuquerque, New Mexico, USA
http://www.sandia.gov/BeamsDZP

15th ANS Topical Meeting on Technology of Fusion Energy
November 17-21, 2002, Washington, D.C., USA
http://fed.ans.org/

ANS Winter Meeting
November 17-21, 2002, Washington, D.C., USA
http://www.ans.org/

22nd Symposium on Fusion Technology - SOFT
September 8-13, 2002, Helsinki, Finland
http://www.vtt.fi/val/soft2002/

IAEA Fusion Energy Conference
October 2002, Lyon, France
u.schneider@iaea.org