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International Fusion Project Finally Getting Under Way

At a ceremony on Nov. 21, nations representing more than half the world's population signed an agreement to build the first large-scale fusion energy experiment. Marsha Freeman reports.

If humanity is to have a future, it will have to put its collective scientific mind and resources to the task of creating new sources of energy, new resources, and new scientific breakthroughs. It was with this understanding that representatives of more than 20 nations met in Paris on Nov. 21, to sign an agreement creating the organization that will build the International Thermonuclear Experimental Reactor (ITER), the world's largest experimental facility to demonstrate the scientific and technical feasibility of fusion power.

As an increasing number of nations finally move into the nuclear age, making plans to build their first nuclear fission reactors, the most forward-looking have long recognized that fission, while critical to the survival of the world's population over the next decades, is a bridge to the qualitively superior and universally available power that fusion will provide.

At the signing ceremony, the chairman of India's Atomic Energy Commission, Dr. Anil Kakodkar, explained that the "momentous step" being taken was based on the "realization of our common goal, to seek a clean source of energy of a magnitude capable of supporting a decent quality of life for the entire[ty] of humanity."

Speaking about India, Dr. Kakodkar said that "in spite of being one of the top five electricity-producing countries, we still have very low per-capita electricity consumption. The objective of electrification of all villages is yet to be realized. . . . We have an ambitious program to tap fission energy, based on the closed fuel cycle approach," he reported. "However, considering the size of our country and the rapid growth in the economy, even that is not likely to be sufficient in the long term." For this reason, he stated, India has been pursuing fusion research on its own, and has built two experimental tokamak devices.

Similar sentiment was expressed by Prof. Xu Guanhua, Minister of Science and Technology of the People's Republic of China, which joined ITER in 2003. Professor Xu reported that China expects to make significant contributions to the ITER project, based on on-going research with its Experimental Advanced Superconducting Tokamak.

South Korean Deputy Prime Minister and Minister of Science and Technology Woo Sik Kim said that his government "considers fusion energy . . . to be the most viable alternative energy solution," and is seeking the passage of the "Fusion Energy Development Promotion Act" by the end of this year. He said that the delegates gathered at the ceremony have "the conviction," with a "sense of duty, to ensure the future of humanity."

ITER: The Long Road

Over the past 50 years, experiments to try to tame and control the fusion of light nuclei, in a process that powers the Sun and all of the stars, have been carried out internationally. While progress has been made in various aspects of this difficult endeavor, the time has come to build an experimental device that combines techniques to create and sustain a hot plasma, a method to prevent instabilities in the electrically charged gas, and a way to extract energy from the nuclear

The International Thermonuclear Experimental Reactor

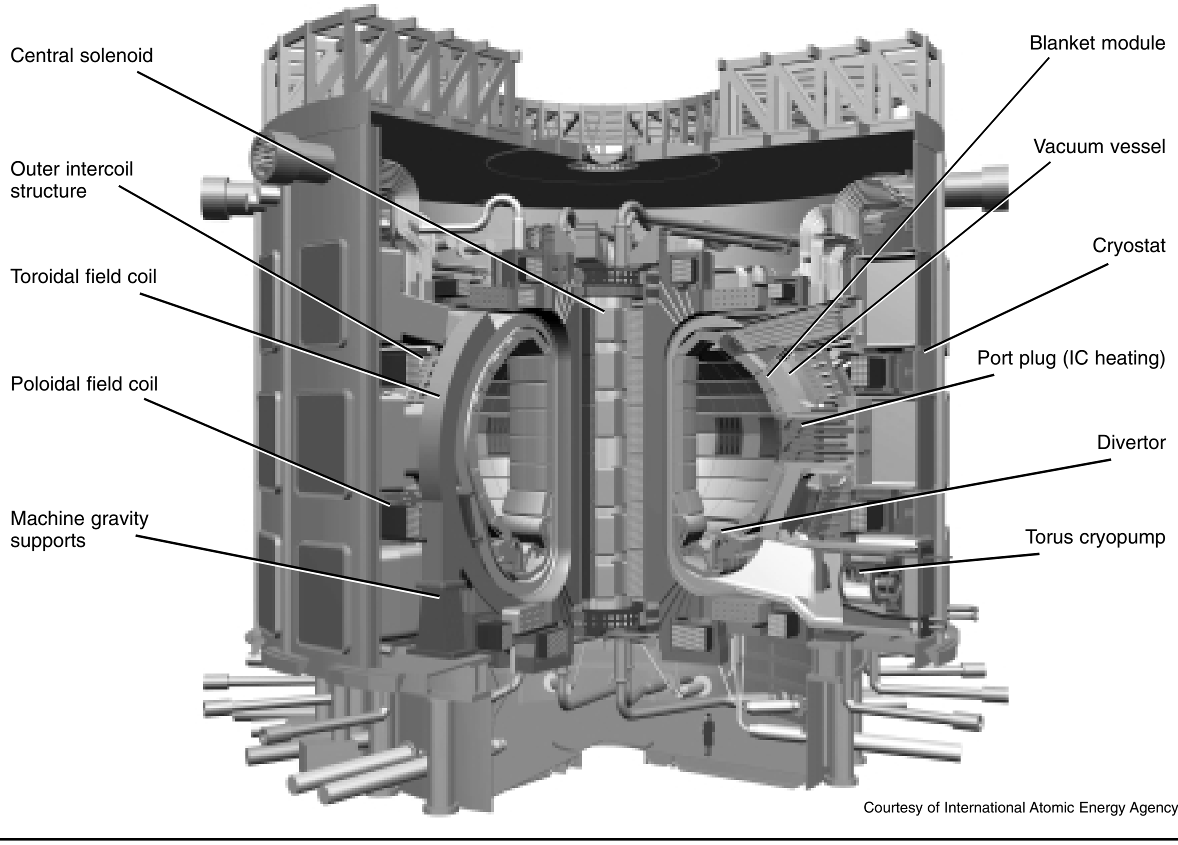
The international effort to construct the world's first continuous-burn fusion reactor is moving ahead. Construction on ITER should begin in 2007 at the Caderache site in France. ITER will be capable of generating 500 megawatts of fusion power for hundreds of seconds, and is intended as a step toward the development of a demonstration fusion power plant that could generate large amounts of electricity continuously. ITER will cost approximately $6 billion to build and is planned to operate for more than two decades.

Fusion is the energy process that powers the Sun. Nuclei of light elements, such as hydrogen, are fused, or joined together, under conditions of very high temperature and pressure, producing a new element, and in the process releasing more energy than was required to cause the reaction. The problem of harnessing fusion power is how to contain the super-hot gas of hydrogen isotopes, known as a plasma, which contains the nuclei that must be fused. The plasma is so hot that it would melt a crucible made of any known material, so some other means must be found to contain it. The two principal methods of plasma containment are known as magnetic confinement (sometimes called a "magnetic bottle") and inertial confinement (which includes laser fusion).

ITER is a magnetic confinement device. The key to magnetic confinement is that the plasma is an ionized gas, meaning that it consists of positively charged electrical particles and negatively charged electrons. Charged particles can be controlled by the fields of powerful magnets, just as the electrons in a television picture tube are guided by magnetic coils surrounding the tube. Much of the research in fusion power has been devoted to finding the best ways to configure the magnets so as to best contain the plasma and cause fusion to occur.

The ITER is the type of magnetic confinement design known as a tokamak. It is a toroidal (donut) shape, as can be seen here in this artist's concept of the cross section, with a major radius of 6 meters (about 19 feet). Two sets of wire coils (field coils) carry high-energy electric currents which produce the magnetic fields that contain the plasma. These are the **toroidal field coils** which curl around the small radius of the torus, and the **poloidal field coils,** which go the long way around the torus. The field coils are superconducting and must be kept at very low temperature within a **vacuum vessel** by the **cryostat** and **torus cryopump.** The **central solenoid** induces a current within the plasma particles.

The fusion fuel, a mixture of the hydrogen isotopes deuterium and tritium, is heated to millions of degrees Celsius, while the magnetic fields trap the resulting plasma, causing repeated collisions, and producing more energy than that consumed by operating the reactor. The heat produced by the reaction can be absorbed by the **blanket module.** A **divertor** skims impurities from the plasma. In an actual commercial reactor, the heat from the fusion process would be used to produce steam to drive electrical generators, or power industrial processes.



Courtesy of International Atomic Energy Agency fusion reaction. ITER is designed to demonstrate that such a machine—using the Russian tokamak design—can be engineered.

ITER was first proposed by Russia's Academician E.P. Velikhov in 1985, as a worldwide effort to create this new source of energy. It was discussed at the first Reagan-Gorbachov summit in 1985, and agreement was reached to construct the world's first operating experimental fusion reactor. The European Union and Japan were invited to join, and subsequently, Canada also decided to participate.

After initial design work was done by teams of scientists from more than a dozen nations, by 1997, U.S. budget balancers decided that the $12 million being requested by the Department of Energy was too much money for the United States to spend on the international effort. Then-chairman of the House Science Committee James Sensenbrenner (R-Wisc.) told the Department that the ITER project "has failed. . . . It defies common sense that the United States should agree to continue to participate in a dead-end project that continues to waste the American taxpayer's dollars."

Scientists fought a losing battle, and two years later, the United States formally withdrew from ITER.

Other nations were not so short-sighted. Design work on ITER continued. In July 2001, the International Atomic Energy Agency (IAEA) marked the official completion of the engineering design for ITER, describing it as a "landmark achievement in fusion energy research." The IAEA noted that ITER "will be capable of generating 500 megawatts of fusion power for hundreds of seconds," and could "lead to the construction of a demonstration fusion power plant that generates large amounts of electricity." The United States continued to sit on the sidelines.

An international lobbying campaign began, to try to coax the U.S.A. back into the ITER program, with visits to Washington by Japanese government officials, letter-writing campaigns by scientists, and even some "qualified" support from Capitol Hill. As has been the case on many other technology frontiers, it was begining to dawn on some policymakers that the world would move ahead in fusion, with or without the United States.

Then, in 2003, President Bush announced that the United States would be rejoining the negotiations to choose a site and establish the framework for ITER. The fact that India, China, and South Korea, with more half of the world's population, were joining the previously "Western" effort, undoubtedly caused Washington to rethink the consequences of its lack of participation.

With the design for the ITER reactor in hand, the next important decision on the table was where the experiment would be built. The U.S.A. rejoined the project just in time to try to exert political pressure on the other parties, and to stall making the decision of where to site ITER.

The proposals under consideration were from Japan and from France. While Japan made a serious offer to host the

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One of the technological challenges of building the ITER tokamak is a series of superconducting magnetic coils, that must be kept at temperatures near absolute zero. To develop new manufaturing techniques to accomplish this, test components have been created, such as this section of a central solenoid, which was made in the United States by Lockheed Martin, and then shipped to Japan for testing.

project, France's proposed site at Caderache already contains much of the infrastructure a project the size of ITER requires. It is home to a nuclear research center with 4,000 people and 18 nuclear installations, in a nation where nearly 80% of the electricity is provided by nuclear fission.

For more than a year, the six parties to ITER wrangled over where to build it. The European Union, Russia, and China preferred the site in France. Japan and South Korea were in favor of the site in Japan, as was the United States. It was widely believed that the Bush Administration made this decision based not on the technical merits of the Japanese site, but in spiteful resentment of France for its refusal to support the war against Iraq.

The six-to-six deadlock was finally broken at a meeting of the ITER parties in Moscow in June 2005, when Japan acceeded to have France host ITER. The stalemate would have ended, in any case, two months later, when India became the seventh partner in the ITER consortium.

With a design and site chosen, the last remaining step is the creation of an international institution to carry out the project. The Nov. 21 agreement creates the ITER Organization, which will operate the project with participation from, and on behalf of, all of the partners. The agreement will be ratified by each government, and construction of ITER is expected to begin next year.

Within a decade, ITER should be completed and producing results. Europe will contribute approximately half of the 5 billion euro cost of construction, with each of the other six partners contributing equally to the rest of the cost. Each partner will provide hardware for the experiment, and reserve funds for staff salaries and other expenses.

In a recent interview, following the Nov. 21 signing of the ITER agreement, Russian fusion scientist Vladimir Vlasenko recalled that the first proposal for a broad, international effort in fusion research was made in 1956 by Academician Igor Kurchatov, followed by Academician Velikhov's ITER proposal in 1985. "The signing of the ITER agreement is a turning point," Dr. Vlasenko said. "Now we go from paper to hardware. . . . This is a date . . . when dreams become reality."

Why Fusion?

In his feature article on the Isotope Economy (*EIR,* Oct. 6, 2006), Dr. Jonathan Tennenbaum explained that the existing array of today's nuclear fission technologies has created the ability to manipulate matter on the atomic level, creating new isotopes of elements that are used in medicine, basic physics research, agriculture, biology, and materials research. Nuclear fission is not simply an alternative way to produce electricity, but ultimately, more importantly, a "transmutation machine," using a flux of neutrons to transmute material into a wide spectrum of new chemical isotopes.

Fusion, which can produce not only a neutron flux but a wide range of electromagnetic radiation that can be fine-tuned to specific wave-lengths, will create more sophisticated methods of creating new isotopes. In addition to this "artifical generation of elements," with fusion it will be possible to synthesize macroscopic amounts of atoms of any desired species, increasingly at will," Dr. Tennenbaum wrote. New materials, with desired characteristics, will be able to be designed. In addition, the application to materials of the energy-dense fusion plasma, designed to separate any material into its constituent elements, can provide a first-order solution to the accelerating exhaustion of the high-quality raw materials and fossil energy resources that mankind depends upon for its standard of living today.

Many technological problems remain. The inner surface of the ITER reactor must be able to withstand temperatures for which there is no existing appropriate material. Techniques for removing cooled plasma, which interfere with the ongoing fusion reactions, are required. Energy to sustain the fusion must be supplied. And what has been a pulsed system must be transformed into a steady-state system to supply base-load electric power.

Dr. Tennenbaum pointed out that the ITER tokamak magnetic fusion design is a "brute force" approach. While it is an inelegant approach, which attempts to suppress nature's self-organizing structures in a fusion plasma, rather than taking advantage of what are described as "instabilities," through great effort and decades of dedicated research, ITER is approaching success.

The Challenges

Although there are many scientific and engineering challenges that will be faced in building and operating a tokamak fusion reactor, the greatest challenge may be the required scientific and engineering talent. Various efforts are under way to be prepared.

In his interview, Dr. Vlasenko explained that Russia had established a Fusion Center in Moscow, of which he is the deputy director, to help the Federal Agency for Atomic Energy (Rosatom) coordinate its activities related to ITER. A Russian Domestic Agency, he said, under Rosatom, will be created to be responsible for fulfilling Russian obligations to ITER.

Asked if young scientists in Russia were interested in fusion research, Dr. Vlasenko said they are having difficulty, while "trying hard," to attract young people to the field, since scientists in Russia are so poorly paid. But, he said, "I am convinced that this situation is going to change very soon."

Meanwhile, the European Commission has established a "European Fusion Training Scheme," to "ensure the provision of engineers who have been trained with the technically demanding requirements of ITER in mind." Under this program, the Jülich Research Center in Germany, along with research institutes in the Netherlands, the United Kingdom, Denmark, and the Czech Republic have created a training program called "Engineering of Optical Diagnostics for ITER." Under this program, eight young engineers will be offered the oppportunity to work on existing fusion experiments and take additional courses, to be deployed to ITER or domestic fusion programs.

China expects to send 30 scientists to France to work on ITER, and is focussing attention on attracting young scientists to fusion research, both for its participation in ITER, and its own domestic fusion experiments.

A week after the ITER agreement was signed, Academician Velikhov stated that over the next year, the project may be joined by other nations. "I know that Kazakstan is interested in the ITER project," he said, "and it may also be joined by some Latin American countries, in particular Brazil and Mexico, as well as by Canada."

The success of ITER will depend upon the realization that there is no alternative to the development of fusion power, for the future development of humanity.