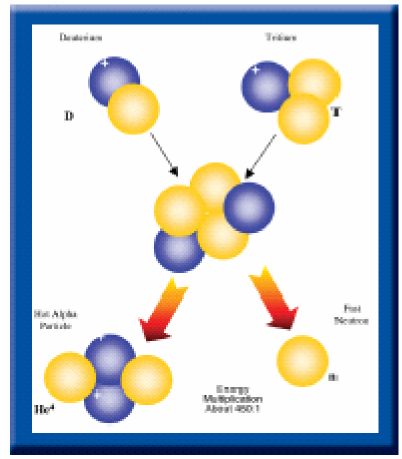
Office of Science
U.S. Department of Energy

Fusion Energy Sciences

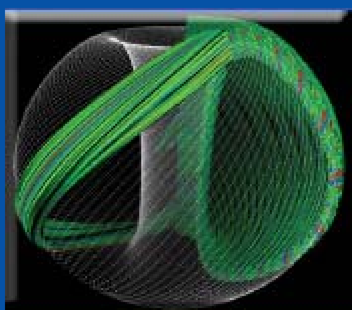
The Office of Science's Fusion Energy Sciences (FES) program supports advances in plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source. FES is pursuing this goal through an integrated program of research based in U.S. universities, industry, and national laboratories, augmented by a broad program of international collaboration.

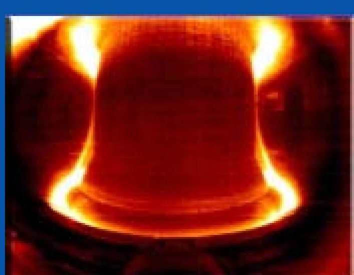
The Opportunity

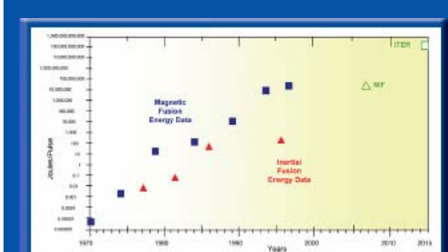
Fusion is the power source of the Sun and the stars. It occurs when forms of the lightest atom, hydrogen, combine to make helium in a very hot (100 million degree centigrade) ionized gas, or plasma. A small amount of matter involved in the reaction is converted to a large amount of energy. When developed, fusion will provide a virtually inexhaustible, safe, environmentally benign, and affordable energy source. Fusion's fundamental fuel, deuterium and tritium, are readily available from sources as common as seawater, and thus would be accessible to all nations.



Fusion reaction


Advanced scientific computing in Fusion Energy Sciences


C-Mod plasma



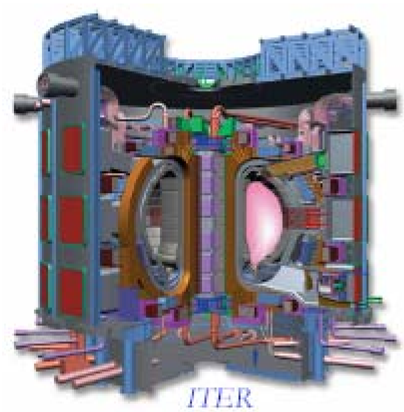
Progress in fusion energy production

The Challenge

Researchers supported by the FES program now have high confidence that it will be possible to design and build a fusion power plant. The major scientific challenge today is to make fusion energy practical by advancing our predictive capability based on detailed experimental campaigns, sophisticated modeling, and terascale computing. Dramatic advances in the scientific understanding of fusion plasmas have been achieved using the Department of Energy's (DOE) advanced computing capability. New instrumentation allows a much more refined measurement of the interior of these complex hot plasmas. The net result is an improvement in our ability to design and build the machines of the future. Enhanced scientific diagnostic and computational capabilities will be key to further advances.

There are two distinct approaches to producing fusion energy. Magnetic fusion energy (MFE) uses a magnetic field to confine a plasma and hold it at the required density and temperature. The fusion energy produced in individual magnetic confinement fusion experiments has risen by a factor of more than one trillion since 1970 while computer speed has risen by a factor of 100,000 (see graph). Progress in fusion energy has produced much deeper understanding of the underlying plasma science.

To date, MFE has been the primary subject of research worldwide for fusion energy applications. Consequently, the U.S. fusion program is highly leveraged against more than $1 billion in magnetic fusion research performed by other nations. Magnetic fusion research performed by other nations. Magnetic fusion research is an international effort in which experimental results are openly shared and in which collaboration on experiments is extensive.



The next major frontier for this program is understanding the physics of a "burning" plasma —a plasma in hich the burnup of the fusion fuel contributes the heat necessary to sustain the fusion reaction—of the type necessary for a fusion power plant. The ability to extend fusion to practical energy applications is critically dependent upon this understanding, which requires construction of a new experimental facility such as ITER (which in Latin means "the way"). The U.S., the European Union, Canada, Japan, the Russian Federation, China, and South Korea are now I negotiations about the construction and operation of ITER, and candidate sites have been identified in Europe, Japan, and Canada. Decisions on where, when, and how to proceed are expected later in 2003.

To achieve inertial fusion energy (IFE), powerful lasers or particle beams are focused on a small pellet of fuel for a few billionths of a second. IFE research has been pursued primarily as a key component of DOE's Stockpile Stewardship Program. Leveraging this large investment is an excellent opportunity because IFE may also present a promising path to practical fusion power.

Investment Plan

The FES research plan focuses on the following areas:

- Basic plasma science and computational programs
- Innovative experiments to broaden the science base and perhaps make fusion more practical
- Advanced understanding and innovation in high performance plasmas on major facilities and participation in a burning plasma physics experiment
- Research on inertial fusion energy and high energy density physics
- A fusion technology program in support of fusion science experiments and the longer term needs of fusion energy.

Construction of an innovative new experimental facility, the National Compact Stellarator Experiment (NCSX) at Princeton Plasma Physics Laboratory is the product of several years of advanced 3-D computer modeling and offers potential improvements over the more extensively researched tokamak concept.

The Benefits

A science-based approach to fusion offers the fastestpath to commercial fusion energy and is advancing our knowledge of plasma physics and associated technologies, yielding near-term benefits in a broad range of scientific disciplines. Examples include plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative materials coatings, the efficient destruction of chemical and radioactive wastes, and more efficient space propulsion.

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