evolved to sophisticated simulations that run on today's state-of-the-art supercomputers.

Some of this progress can be explained by improvements in computer hardware, but most is attributable to the development of efficient mathematical techniques and complex computer programs, or "codes," needed to solve the physics problems. Researchers use these computations to explore fusion reactor design concepts as well as to understand basic plasma phenomena on a microscopic level.

Particle Codes – Particle codes are computer programs developed almost entirely within the fusion program that describe the path followed by individual plasma particles as they move within their own and surrounding electric and magnetic fields. Particle codes combine Newton's equations of mechanical motion, and Maxwell's equations of electromagnetic field behavior and have proved valuable in understanding a number of effects observed in plasmas that are not described well by other approaches.

The physics principles described in the particle codes are also encountered in many other scientific and engineering disciplines. In solid state physics, particle codes are used to describe the behavior of electrons in semiconductor chips, such as microcircuits. In studies of single galaxies and the phenomena of galactic clustering, astrophysicists use particle codes to better understand cosmic evolution.

National Magnetic Fusion Energy Computer Center (NMFECC) – Underlying the advancements in computational physics is the emergence of the NMFECC as one of the Nation's foremost supercomputer networks and a model that is highly regarded throughout the scientific community. Established in 1975, the NMFECC is now acknowledged as a major innovator in the management and operation of the largest and most powerful supercomputers in the world. Its data communications network, providing users convenient, 24-hour access through high speed land and satellite links, is being emulated by other scientific networks under design and construction. The Center has made a particularly significant contribution to increasing the efficient use of the supercomputer itself through development of the Cray Time Sharing System.

Construction of Experimental Devices

A particular strength of the United States fusion program has been its broad base, which includes research on several confinement systems to ensure that the maximum potential of fusion is realized. A number of different types of devices have been built, each representing a concept for assembling the energy producing core of a commercial reactor.

There are only two basic magnetic structures which have been shown to confine plasmas of fusion interest: the magnetic mirror and the magnetic torus. Each of these magnetic confinement systems has several variations. These confinement systems differ in practice by emphasizing particular principles of fusion science to improve plasma confinement or to simplify the technical requirements for producing the magnetic fields used to confine the plasma.

Tokamaks – Tokamaks are toroidal (donut shaped) devices designed to produce power in pulses (see Figure 1). Both external magnet coils and a current through the plasma provide the magnetic fields that confine the fusion fuel. All current heating methods have been tested on tokamaks.

Historically, the tokamak embodied a set of principles which were comparatively easy to implement in the laboratory. As a result, most of the scientific progress in magnetic plasma confinement has been made with tokamak confinement systems. Today tokamaks are unique in the ability to produce for scientific study, fusion plasmas resembling those expected in a fusion power reactor. Systems based on the tokamak concept are being pursued by all International Energy Agency countries with MFE Programs and the Soviet Union.

Scientific progress on tokamak systems in the United States has been especially dramatic. The most recent tokamak device yet built by the United States, TFTR, began operating in December 1982.

Tandem Mirrors – The tandem mirror is a device in which plasma fuel is confined in a cylindrical shape. The ends of the plasma cylinder are confined by magnetic and electrostatic barriers, hence the term "magnetic mirrors." It operates in a steady state using external coils to produce magnetic fields, which confine the plasma. All present methods for heating the plasma have been tested on tandem mirrors.

In 1982 the Tandem Mirror Experiment confirmed the basic principles of the tandem mirror. The Mirror Fusion Test Facility, recently dedicated at the Lawrence Livermore National Laboratory, is the largest tandem mirror fusion device in the world. Both the United States and Japan continue to explore tandem mirror fusion systems.

Alternate Concepts – In addition to tokamaks and tandem mirrors, several concepts for alternative confinement systems have been devised and tested in the research program, although none have been taken to the levels of development of tokamak and mirror devices. The primary objective of pursuing research on alternate concepts is to advance the study of the scientific principles of magnetic confinement which may lead to more attractive fusion devices.

The reverse-field-pinch and the stellerator/torsatron, two particularly attractive magnetic confinement