Appendix A: Acronyms and Glossary of Terms

A

ACRONYMS

AEC	Atomic Energy Commission
ATF	Advanced Toroidal Facility, Oak Ridge, Tennessee
BPX	Burning Plasma Experiment
CDA	conceptual design activity
CIT	Compact Ignition Tokamak, proposed for Princeton Plasma Physics Laboratory, Princeton, NJ
CPMP	Comprehensive Program Management Plan
DIII-D	Double III upgrade, General Atomics, San Diego
D-D Reaction	deuterium-deuterium fusion reaction
DEMO	Demonstration Fusion Powerplant
DOE	U.S. Department of Energy
D-T Reaction	deuterium-tritium fusion reaction
EDA	engineering design activity
EPACT	Energy Policy Act of 1992
ERAB	Energy Research Advisory Board
ETR	engineering test reactor
FEAC	Fusion Energy Advisory Committee
FMIT	Fusion Materials Irradiation Test Facility
FPAC	Fusion Policy Advisory Committee
FRC	field reversed configuration
ICF	inertial confinement fusion
IFE	inertial fusion energy
ILSE	Induction Linac System Experiments
ITER	International Thermonuclear Experimental Reactor
JET	Joint European Torus
JT-60 super upgrade	Japan Tokamak 60 super upgrade
JT-60U	Japan Tokamak 60 upgrade
LBL	Lawrence Berkeley National Laboratory, Berkeley, CA
LHD	Large Helical Device
LLNL	Lawrence Livermore National Laboratory, Livermore, CA
LSX	Large S Experiment
MeV	million electron volts
MFAC	Magnetic Fusion Advisory Committee
MFE	magnetic fusion energy

MFEEA	Magnetic Fusion Energy Engineering Act of 1980
MFPP	Magnetic Fusion Program Plan
MFTF-B	Mirror Fusion Test Facility B
MW	megawatts
NAS	National Academy of Sciences
NES	National Energy Strategy
NIF	National Ignition Facility
OFE	Office of Fusion Energy
ORNL	Oak Ridge National Laboratory, Oak Ridge, TN
PBX-M	Princeton Beta Experiment-Modification
PCAST	President's Council of Advisors on Science and Technology
PPPL	Princeton Plasma Physics Laboratory, Princeton, NJ
Q	Energy gain
RFP	reversed field pinch
R&D	research and development
SSAT	steady-state advanced tokamak
SEAB	Secretary of Energy Advisory Board
T-15	large superconducting tokamak, Kurchatov Institute, Russia
TFTR	Tokamak Fusion Test Reactor
TPX	Tokamak Physics Experiment

GLOSSARY

Advanced fuel cycles: The use of fuels other than D-T to sustain fusion reactions. Alternate fuel cycles include enhanced D-D reactions, reactions of deuterium with helium-3 (D-^{3}He), or lithium-6 (D-^{6}Li), and proton-Boron-11 (p-^{11}B) reactions. Achieving fusion with these fuels would typically require higher temperatures and Lawson confinement parameters than required for D-T fuels as well as substantial improvements in available plasma technologies. The attraction of these fuel cycles is that they require little or no tritium, and produce fewer and lower energy neutrons thus reducing radiation damage, allowing the use of existing materials and minimizing radioactive wastes.

Advanced tokamak: A tokamak incorporating features such as steady-state current drive or shaping of the plasma in order to attain higher performance or more efficient operation than the conventional tokamak. See "Tokamak" or "Conventional tokamak."

Alpha particle: A positively charged particle, identical to a helium-4 nucleus, composed of two protons and two neutrons. An alpha particle is emitted in the radioactive decay of many naturally occurring radioisotopes such as uranium and thorium; it is also one of the products of the D-T fusion reaction.

Alpha particle heating: Heating of a fusion plasma by alpha particles generated during the fusion reaction colliding with deuterium and tritium in the plasma. Alpha particle heating is expected to be the principal source of heating in a D-T fusion plasma once ignition is achieved.

Alternate concept or alternate confinement concept: As used in this report, a nontokamak confinement concept.

Ash: An end product of a fusion reaction. For the D-T fusion reaction, the "ash" is helium gas.

Auxiliary heating: External systems that heat plasmas to higher temperatures than can be reached from the heat generated by electric currents within the plasma. Neutral beam heating and radiofrequency heating are both examples of auxiliary heating systems.

Beta: The ratio of the outward pressure exerted by the plasma to the inward pressure that the magnetic confining field is capable of exerting. Beta is equivalent to the ratio of the energy density of particles in the plasma to the energy density of the confining magnetic fields.

Blanket: Structure surrounding the plasma in a fusion reactor within which the fusion-produced neutrons are slowed down, heat is transferred to a primary coolant, and tritium is bred from lithium.

Blanket test facility: A plasma-based large volume neutron source device to be used for the testing of blanket components and materials needed to recover the heat of fusion reactions and to produce new tritium fuel. The need for construction of a separate blanket test facility is dependent on the timing and scope of the ITER blanket test program.

Bootstrap current: A plasma current driven by the plasma itself.

Breakeven: The point at which the fusion power generated in a plasma equals the amount of heating power that must be added to the plasma to sustain its temperature.

Breakeven-equivalent: Attainment in a non-tritium-containing plasma of conditions (temperature, density, and confinement time) that would result in breakeven if the plasma contained tritium. Because plasmas not containing tritium are far less reactive than those containing tritium, the actual amount of fusion power generated by a breakeven-equivalent plasma will be far less than would be produced under actual breakeven conditions.

Burning plasma: A plasma in which the fusion reactions supply a significant fraction of the energy needed to sustain the plasma.

Celsius: Centigrade.

Centigrade: A thermometric scale on which the interval between the freezing point of water and the boiling point of water is divided into 100 degrees with 0° representing the freezing point and 100° representing the boiling point.

Conceptual design: The basic or fundamental design of a fusion reactor or experiment that sketches out device characteristics, geometry, and operating features but is not at the level of detail that would permit construction.

Confinement: Restraint of plasma within a designated volume. In magnetic confinement, this restraint is accomplished with magnetic fields.

Confinement concept: An approach to controlling the range of motion of a plasma. Due to the extremely high temperatures needed to allow fusion to occur, no solid container can confine a fusion energy plasma. Instead, a variety of approaches, such as using magnetic fields or inertia to confine the plasma can be used.

Confinement parameter: The product of plasma density and confinement time that, along with temperature, determines the ratio between power produced by the plasma and power input to the plasma. Also called "Lawson parameter."

Confinement time: A measure of how well the heat in a plasma is retained. The confinement time of a plasma is the length of time it would take the plasma to cool down to a certain fraction of its initial temperature if no heat were added.

Conventional tokamak: A tokamak device not incorporating advanced steady-state current drive or plasma shaping technology. See "Tokamak," "Advanced tokamak."

Current drive: A technique for making the toroidal plasma current using RF or neutral beam power, i.e., without the use of an inductive transformer.

D-D reaction: A fusion reaction in which one nucleus of deuterium fuses with another. Two different outcomes are possible: a proton plus a tritium nucleus, or a neutron plus a helium-3 nucleus.

D-T reaction: A fusion reaction in which a nucleus of deuterium fuses with a nucleus of tritium, forming an alpha particle and a neutron and releasing 17.6 million electron volts of energy. The D-T reaction is the most reactive fusion reaction.

Decommissioning: The steps taken to render a plant, particularly a nuclear reactor, safe to the environment at the end of its operating lifetime.

Density: Amount per unit volume. By itself, the term "density" often refers to particle density, or the number of particles per unit volume. However, other quantities such as energy density or power density (energy or power per unit volume, respectively) can also be defined.

Deuterium (D or ^{2}H): A naturally occurring isotope of hydrogen containing one proton and one neutron in its nucleus. Approximately one out of 6,700 atoms of hydrogen in nature is deuterium. Deuterium is one of the fuels (along with tritium) needed for the D-T fusion reaction, the most reactive fusion reaction.

Diagnostics: The procedure of determining (diagnosing) exactly what is happening inside an experimental device during an experiment. Also, the instruments used for diagnosing.

Divertor: A component of a toroidal fusion device used to shape the magnetic field near the plasma edge so that particles at the edge are diverted away from the rest of the plasma. These particles are swept into a separate chamber where they strike a barrier, become neutralized, and are pumped away. In this way, energetic particles near the plasma edge are captured before they can strike the walls of the main discharge chamber and generate secondary particles that would contaminate and cool the plasma.

Driver: A machine that provides the energy to heat and compress an inertially confined fusion target in the form of intense, high-power beams of laser light or particles.

Electron: An elementary particle with a unit negative electrical charge and a mass 1/1837 that of a proton. In an atom, electrons surround the positively charged nucleus and determine the atom's chemical properties.

Electron volt (eV): A unit of energy equal to the energy that can be acquired by a singly charged particle (e.g., an electron) from a one-volt battery. Since the temperature of a system is proportional to the average energy of each particle in the system, temperature is also measured in electron volts.

Energy gain (Q): The ratio of the fusion power produced by a plasma to the amount of power that must be added to the plasma to sustain its temperature.

Engineering feasibility: The ability to design and construct all the components, systems, and subsystems required for a fusion reactor.

Engineering test reactor: A next-generation fusion experiment to study the physics of long-pulse ignited plasmas, provide opportunities to develop and test reactor blanket components under actual fusion conditions, and integrate the various systems of a fusion reactor.

Equivalent Q: For a plasma not containing tritium, a measure of what Q would have been in a tritium-containing plasma that attained the same temperature and confinement parameter. See "Confinement parameter."

Field-reversed configuration (FRC): A magnetic confinement concept with no toroidal field, in which the plasma is essentially cylindrical in shape. The FRC is a form of compact toroid.

Fission: The process by which a neutron strikes a nucleus and splits it into fragments. During the process of nuclear fission, several neutrons are emitted at high speed, and heat and radiation are released.

Flux: The amount of a quantity (e.g., heat, neutrons) passing through a given area per unit time.

Fusion: The process by which the nuclei of light elements combine, or fuse, to form heavier nuclei, releasing energy.

Fusion nuclear technology: The engineering systems needed to fuel, maintain, and recover energy from a fusion reactor.

Fusion self-heating: Heat produced within a plasma from fusion reactions. Since alpha particles produced in fusion reactions remain trapped within the plasma, they contribute to self-heating by transferring their energy to other plasma particles in collisions. Fusion-produced neutrons, on the other hand, escape from the plasma without reacting further and do not contribute to self-heating.

Heavy ion: An ion of high mass (e.g., an electrically charged atom of an element from the middle to the high end of the periodic table).

High-energy gain: A fusion reaction producing many (10 or so) times as much power as must be input to the reaction to maintain its temperature.

Hydrogen (H): The lightest element. All hydrogen atoms have nuclei containing a single proton and have a single electron orbiting that nucleus. Three isotopes of hydrogen exist, having 0, 1, or 2 neutrons in their nuclei in addition to the proton. The term hydrogen is also used to refer to the most common isotope, technically called "protium," that has no neutrons in its nucleus.

Ignition: The point at which a fusion reaction becomes self-sustaining. At ignition, fusion self-heating is sufficient to compensate for all energy losses; external sources of heating power are no longer necessary to sustain the reaction.

Impurities: Atoms present in a plasma that are heavier than fusion fuel atoms. Impurities are undesirable because they dilute the fuel and because they increase the rate at which the plasma's energy is radiated out of the plasma.

Inertia: Inertia is the property of an object to resist external forces that would change its motion. Unless acted on by external forces, an object at rest will remain at rest, and an object moving in a straight line at constant speed will continue to do so. Under the influence of external forces, objects with differing inertias will respond at different rates.

Inertial confinement: An approach to fusion in which intense beams of light or particles are used to compress and heat tiny pellets of fusion fuel so rapidly that fusion reactions occur before the pellet has a chance to expand. The pellet's own inertia, or its initial resistance to expansion even when it is being blown apart, holds the pellet together long enough for fusion energy to be produced.

Instabilities: Small disturbances that become amplified, or become more intense, once they begin. A cone balanced upside-down on its tip is subject to an instability, since once it begins to wobble, it will become more unbalanced until it falls over. A stable system, on the other hand, responds to disturbances by opposing them. Small disturbances in a stable system decrease in intensity until they die away. If a ball sitting in the bottom of a bowl is disturbed, for example, it will eventually come to rest again at the bottom of the bowl.

Ion: An atom (or molecularly bound group of atoms) that has become electrically charged as a result of gaining or losing one or more orbital electrons. A completely ionized atom is one stripped of all its electrons.

Isotope: Different forms of the same chemical element whose atoms differ in the number of neutrons in the nucleus. (All isotopes of an element have the same number of protons in the nucleus and the same number of electrons orbiting the nucleus.) Isotopes of the same element have very similar chemical properties and are difficult to separate by chemical means. However, they can have quite different nuclear properties.

Laser fusion: A form of inertial confinement fusion in which a small pellet of fuel material is compressed and heated by a burst of laser light. See "Inertial confinement."

Lawson parameter: See "Confinement parameter."

Light ion: An ion of low mass, typically an electrically charged atom or the bare atomic nucleus of an element near the light end of the periodic table. In inertial confinement fusion, light ions are typically accelerated across a small gap in a high voltage short-pulse diode accelerator.

Linac: Linear accelerator; a device for accelerating heavy ions to drive inertial confinement fusion targets.

Low-activation materials: Materials that, under neutron irradiation, do not generate intensely radioactive, long-lived radioactive isotopes. Examples include certain vanadium alloys and ceramics such as silicon carbide. Fusion reactors made of low-activation materials would accumulate far less radioactivity over their lifetimes than reactors made with more conventional materials such as steels. Low-activation materials also produce less afterheat following a reactor shutdown than more conventional materials.

Magnetic confinement: Any means of containing and isolating a hot plasma from its surroundings by using magnetic fields.

Magnetic field: The property of the space near a magnet that results, for example, in the attraction of iron to the magnet. Magnetic fields are characterized by their direction and their strength. Electrically charged particles moving through a magnetic field at an angle with respect to the field are bent in a direction perpendicular to both their direction of motion and the direction of the field. Particles moving parallel to a magnetic field are not affected. Therefore, magnetic fields cannot prevent plasma particles from escaping along field lines.

Magnetic fusion energy: Energy released by a thermonuclear reaction in the fuel of a magnetically confined plasma.

Magnetic mirror: A generally axial magnetic field that has regions of increased intensity at each end where the magnetic field lines converge. These regions of increased intensity "reflect" charged particles traveling along the field lines back into the central region of lower magnetic field strength.

Mirror: See "Magnetic mirror."

Muon: A short-lived elementary particle that can be used to substitute an electron in a D-T molecule. It is much heavier than the electron thus reducing the size of the molecule and the distance between the nuclei. This effect makes fusion of the two nuclei much more likely to occur.

Neutral beam heating: Heating a confined plasma by injecting beams of energetic (typically greater than 100 keV) neutral atoms into it. Neutral atoms can cross magnetic lines of force to enter the plasma, where they transfer their energy to plasma particles through collisions. In these collisions, the neutral beam particles become ionized, and, like the other electrically charged plasma particles, are then confined by the magnetic fields.

Neutral beam injection: A technique of using high-energy beams of neutral atoms to penetrate the magnetic confinement fields of a fusion plasma for fueling, heating, and current drive. Once inside the plasma, the neutral atoms are ionized and are then confined.

Neutron: A basic atomic particle, found in the nucleus of every atom except the lightest isotope of hydrogen, that has no electrical charge. When bound within the nucleus of an atom, the neutron is stable. However, a free neutron is unstable and decays with a half-life of about 13 minutes into an electron, a proton, and a third particle called an antineutrino.

Neutron flux: A measure of the intensity of neutron irradiation. It is the number of neutrons passing through one square centimeter of a given target in one second.

Plasma: An ionized gaseous system composed of approximately equal numbers of positively and negatively charged particles and variable numbers of neutral atoms. The charged particles interact among themselves, with the neutral particles, and with externally applied electric and magnetic fields. The plasma state is sometimes called "the fourth state of matter" due to the fundamental differences in behavior between plasmas and solids, liquids, or neutral gases.

Plasma current: Electrical current flowing within a plasma. In many confinement schemes, plasma currents generate part of the confining magnetic fields.

Plasma physics: The study of plasmas.

Proof-of-concept experiment: An experiment done at a relatively early stage of development of a confinement concept to determine the limits of plasma stability, explore how the confinement properties appear to scale, and develop heating, impurity control, and fueling methods. Successful completion of such an experiment verifies that the confinement concept appears capable of operating successfully on a scale much closer to that needed in a reactor.

Proof-of-principle experiment: An experiment one stage beyond the "proof-of-concept" stage to determine optimal operating conditions, to establish that the concept is capable of being scaled to near-reactor level, to extend methods of heating to high power levels, and to develop efficient mechanisms for fueling and impurity control.

Proton: An elementary particle with a single positive electrical charge. Protons are constituents of all atomic nuclei. The atomic number of an atom is equal to the number of protons in its nucleus.

Pulsed operation: Noncontinuous operation of a fusion reactor. This term refers to reactors that must periodically stop and restart. In pulsed operation, individual pulses may last as long as hours.

Reactor-scale experiment: Experiment to test a confinement concept by generating a plasma equivalent to that needed in a full-scale reactor. Such an experiment must achieve reactor-level values of beta and must demonstrate temperature, density, and confinement times sufficient for the production of net fusion power. Furthermore, its heating, fueling, and other technologies must also be able to support a reactor-level plasma.

Remote maintenance: Conducting maintenance on reactor systems or components by remote control, rather than "hands-on." Remote maintenance will be required in fusion reactors and in many future fusion experiments because the radioactivity levels near and inside the plasma chamber will be too high to permit human access.

Reversed field pinch: A closed magnetic confinement concept having toroidal and poloidal magnetic fields that are approximately equal in strength, and in which the direction of the toroidal field at the outside of the plasma is opposite from the direction at the plasma center.

Scaling: Extension of results or predictions measured or calculated under one set of experimental conditions to another situation having different conditions. One of the most important functions of a confinement experiment is to determine how confinement properties scale with parameters such as device size, magnetic field, plasma current, temperature, and density. It is important to understand the scaling properties of a confinement concept—either empirically or theoretically—to assure that future experiments have a reasonable probability of succeeding.

Scientific feasibility: The successful completion of experiments that produce high-gain or ignited fusion reactions in the laboratory using a confinement configuration that lends itself to development into a net power producing system.

Spheromak: A magnetic confinement concept in which a large fraction of the confining magnetic fields are generated by currents within the plasma. The spheromak is a form of compact toroid.

Steady-state operation: Continuous operation, without repeated starting and stopping.

Stellarator: A toroidal magnetic confinement device in which the confining magnetic fields are generated entirely by external magnets.

Superconductivity: The total absence of electrical resistance in certain materials under certain conditions. Until recently, superconductivity had only been found to occur in certain materials cooled to within a few degrees of absolute zero. Since late 1986, however, a new class of materials has been discovered that become superconducting at temperatures far higher than the materials previously known. An electrical current that is established in a superconducting material will persist as long as the material remains below its critical temperature, the point at which it loses all resistance to electricity.

System studies: Studies presenting preconceptual designs for fusion reactors that serve to uncover potential problems and determine how changes in design choices affect reactor characteristics. System studies are particularly valuable in guiding the research program by identifying areas where further research and development can have the greatest impact.

Target: In inertial confinement fusion, the structure or object containing the fusion fuel at which the driver beams are directed within the experimental chamber. Targets may consist of simple disks or pellets of fusion fuel or may be complex structures with many parts.

Temperature: A measure of the average energy of a system of particles. Given sufficient time and enough interaction among the different portions of any system, all portions will eventually come to the same temperature. In short-lived plasmas, however, the ion and electron temperatures usually differ because of insufficient interaction between the two. Plasma temperatures are measured in units of electron volts, with one electron volt equal to 11,605 K.

Tokamak: A magnetic confinement concept whose principal confining magnetic field, generated by external magnets, is in the toroidal direction but that also contains a poloidal magnetic field that is generated by electric currents running within the plasma. The tokamak is by far the most developed magnetic confinement concept. The word “tokamak” is a Russian acronym—TOroidal’naia KAMera s AKsial’nym magnitnym polem—meaning torodial chamber with axial magnetic field. See also “Conventional tokamak” or “Advanced tokamak.”

Toroidal: In the shape of a torus, i.e. doughnut-shaped.

Torus: The shape of a doughnut, automobile tire, and innertube.

Tritium (T or ^{3}H): A radioisotope of hydrogen that has one proton and two neutrons in its nucleus. Tritium occurs only rarely in nature; it is radioactive and has a half-life of 12.3 years. In combination with deuterium, tritium is the most reactive fusion fuel.