Overview of Progress in Compact Magnetic Fusion Reactors

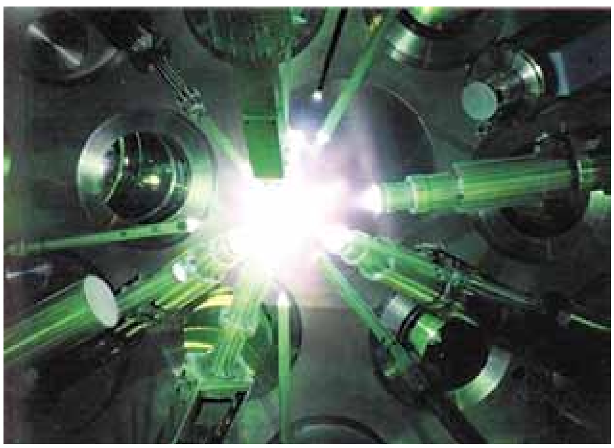
by Joel DeJean

Nov. 10—Fusion powers the Sun, and all the stars in the universe. It is the process whereby lighter elements, such as hydrogen, are fused, to form heavier elements, such as helium. As described by Einstein's $E = mc^2$, the less than 1 percent of mass that is "lost" in the process is converted to a very large amount of energy, over a million times more than is possible in any chemical reaction. According to one standard theory, our Sun has had the great gravitational mass to provide the heat—15 million degrees Celsius at its core—density of plasma, and containment time, to allow this process to continue for over 4.5 billion years.

LLNL

The National Ignition Facility at Lawrence Livermore Laboratory.

For the last 66 years, Man has been able to achieve fusion using isotopes of hydrogen, deuterium and tritium, and, by providing sufficient heat and plasma density-containment time, using a fission bomb as a trigger, to release great amounts of energy, but in an uncontrolled manner. In 1961, the Russians tested a thermonuclear device, the Tsar Bomba, that released over 50 megatons of TNT equivalent, more than 3,000 times the energy released by the bombs dropped in 1945 on Hiroshima and Nagasaki, Japan.

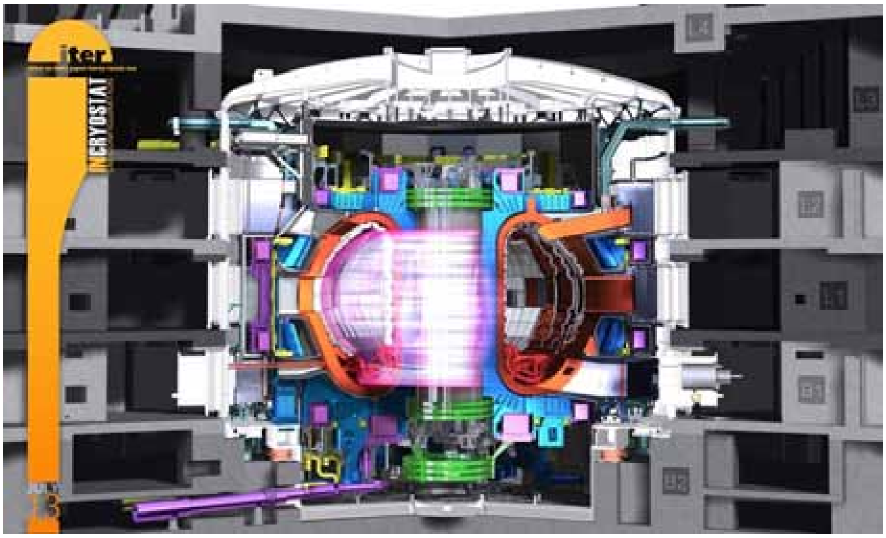


NIF

This past June, the National Ignition Facility, part of California's Lawrence Livermore National Laboratory, reported that it had produced 19 quadrillion fusion neutrons in a test shot using a deuterium/tritium capsule. Fifty kilojoules of energy was released, bringing the plasma to within only one order of magnitude of what will be required to reach ignition and breakeven.

Our goal, however, is to achieve controlled thermonuclear fusion, using magnetic fields to create and contain a plasma of deuterium and tritium—or alternatively, to use high-powered lasers to heat and compress a capsule of deuterium and tritium. We need temperatures of around 100 million degrees Celsius, plus plasma densities and containment times that allow us to exceed breakeven—the point at which the output energy exceeds the input energy required to start the fusion process.

Meanwhile, over the last 20 years, several private companies have been designing compact magnetic fusion reactors, using cylindrical vessels employing the magnetic field-reversed



ITER

The International Thermonuclear Experimental Reactor (ITER) is being built in southern France by a consortium of 35 nations, including the U.S., Russia, the European Union, China, India, Japan, the Republic of Korea, and others. Its goal is to produce 500 megawatts (MW) of power for 10 minutes, from an input power of 50 MW—an increase by a factor of 10. The testing of ITER is scheduled to start in the early 2020s. ITER is the world's largest tokamak—29 meters high, 29 meters wide, weighing over 23,000 tons, and employing the largest superconducting magnets ever designed.

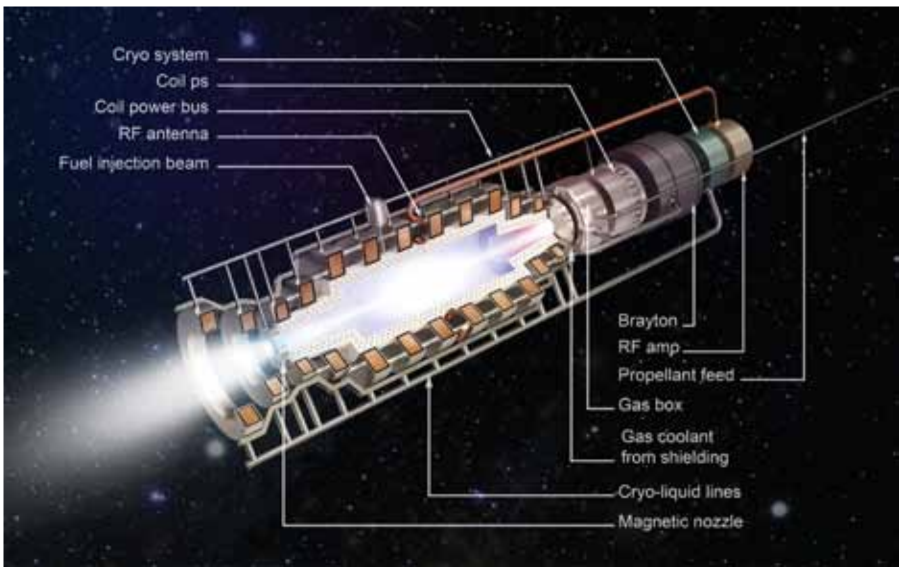
configuration (FRC), in which an axial magnetic field, created by poloidal magnets around the cylinder, is reversed by toroidal currents in the plasma, producing a self-stabilized rotating plasma, which is then heated by radio-frequency fields or particle beams. These designs produce a high beta (a high ratio of plasma pressure to magnetic pressure). Their outputs are designed to be in the 10 to 100 MW thermal range.

Three of the most advanced projects follow.

Aneutronic Reactions

Princeton Satellite Systems has been working on a Direct Fusion Drive (DFD) reactor, under a NASA Innovative Advanced Concepts contract. Working closely with the nearby Princeton Plasma Physics Lab, and using the field-reversed configuration for cylindrical shaping, plasma is created using superconducting magnets both around and inside the cylinder. The company is using deuterium and helium-3, producing an aneutronic reaction, that is, fusion in which neutrons carry no more than 1% of the total released energy, plus an alpha particle (that is, two protons and two neutrons—a helium-4 nucleus) and a proton that can be used as propellant by way of a magnetic nozzle. Since aneutronic fusion greatly reduces problems associated with neutron radiation such as ionizing damage and neutron activation, biological shielding may be lessened, remote handling becomes easier, and the overall environment is safer. Output will be in the 10 MW thermal range. PSS has proposed using a cluster of 6 DFD engines to send a crew onboard a Deep Space Habitat module on a flyby of Mars.

Last July, this author visited Michael Paluszek, president of PSS, and his staff. You can watch an interview with Paluszek conducted July 26 by La-

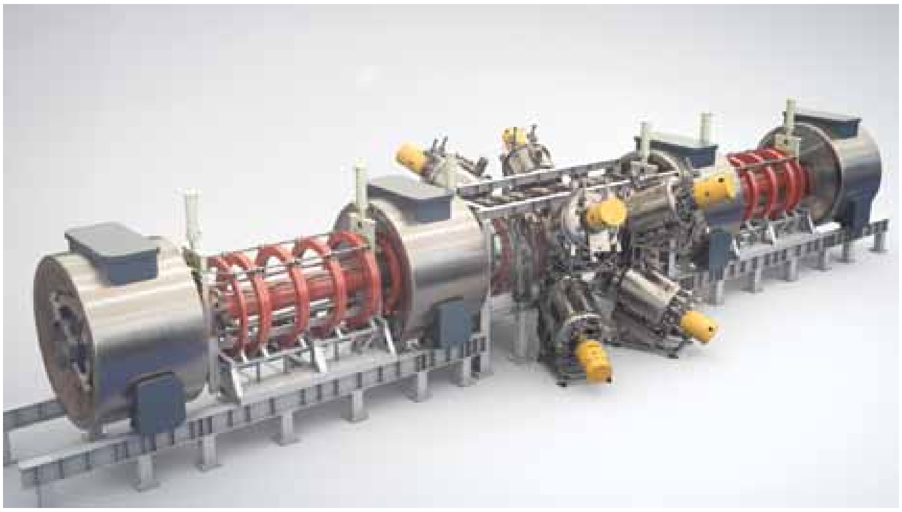


Princeton Satellite Systems

Artist's rendering of the Princeton Satellite Systems' direct drive fusion propulsion engine, with interior exposed to show detail of the magnetic coils. This engine uses radio-frequency heating to reach fusion conditions, with helium-3.

Rouche PAC Science Research Team member Megan Beets.

A second aneutronic concept, that of TAE Technologies (formerly Tri Alpha Energy) was presented to the July 1, 2018 Schiller Institute conference in Germany by Dr. Armin Azima of Hamburg University. Its latest generator, called "Norman," is named after the company's late intellectual co-founder, Dr. Norman Rostoker. Unveiled in 2017, over 3,000 experiments have been performed on Norman. TAE is using Boron-11 and a high-speed proton, resulting in an aneutronic reaction of 3 alpha particles. This concept is more complex, using colliding FRC plasmas, requiring plasma temperatures of 3 billion degrees Celsius. TAE has backing from Goldman Sachs, Google and a Russian company. Its goal is also in the 100 MW thermal range.

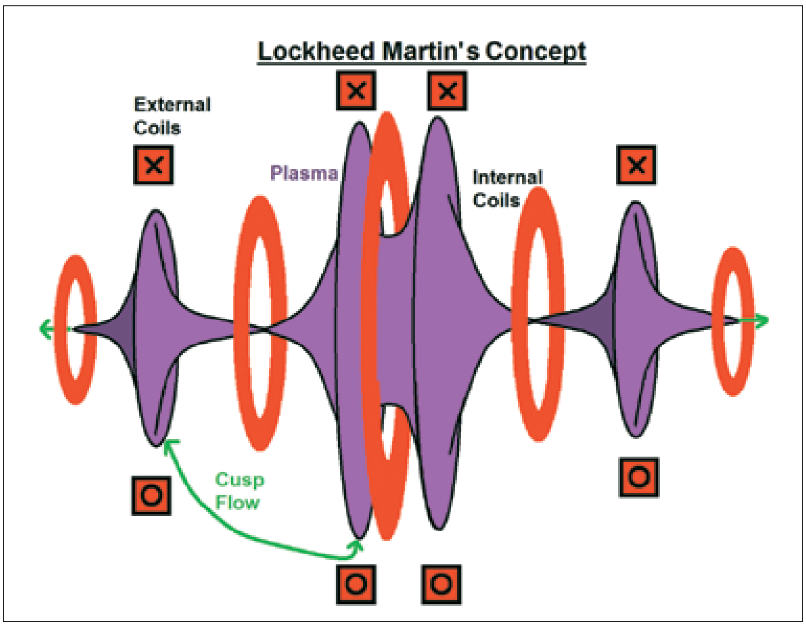


TAE Technologies

Using its latest generator, known as "Norman," TAE Technologies is focussing its current work on plasma merging and field-reversed configurations (FRCs) to achieve optimal, scalable conditions for clean, safe fusion.

Neutron Heating

The Skunks Works unit of Lockheed Martin has been working on a compact magnet fusion reactor since 2014. Its motto is "No mission is impossible." Its approach is also a high-beta concept, using a high fraction of the magnetic field pressure, or all of its potential, to make devices ten times smaller than previous concepts, perhaps replacing devices that must be housed in large buildings with one small enough and light enough to fit on the bed of a truck! The team is using deuterium and tritium, with a lithium blanket to generate tritium and heat transfer. Its goal is to attain 100 MW of thermal output. Using a cylindrical shape and FRC, lead design engineer Thomas McGuire is hoping to have a working prototype by 2019.



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Conceptual schematic of Lockheed Martin's truck-sized high-beta compact fusion reactor.

None of these three designs has reached breakeven, but if incorporated into a crash program, with the open patents concept as used during the Apollo program, one or more of them could lead to a breakthrough in the next five to ten years, providing the world's economy with the largest leap in energy flux-density since the Manhattan Project of World War II and fulfilling LaRouche's Fourth Law.

Reference

"The Promise of Fusion Rocketry," by Joel DeJean, *EIR*, July 21, 2017.