II. The Universe is Knowable

China Is Taking Bold Steps on the Path to Fusion Power

by Marsha Freeman

April 15—In December 2018, China broke ground on a new facility for developing and testing components for its multi-decade science and technology program to develop fusion energy. The Comprehensive Research Facilities project is one of the interim steps toward demonstrating commercial fusion energy in an operating power plant by about 2050. This DEMO reactor will lay the basis for China's industrial mass production of fusion power plants.

Developing fusion energy is an urgent necessity. From a practical standpoint, to bring the world's growing population up to a standard of living in which the majority of economic activity is a creative intervention into nature, and every child has the opportunity to become a genius, requires that energy use per capita be orders of magnitude higher than is available today to billions of people.

The crucial role of fusion energy was developed by economist Lyndon LaRouche, who called for the United States to "Adopt a Fusion-Driver 'Crash Program' " in his June 2014 Four Laws. LaRouche elaborated the steps to reorient the U.S. economy to immediate investment in economic infrastructure, crash programs in fusion, and also space exploration, as "science drivers" for the economy:

> The essential distinction of man from all lower forms of life, hence, in practice, is that it presents the means for the perfection of the specifically affirmative aims and needs of human individual and social life.

That affirmation of the aims and needs of humanity cannot be provided by the low energy-flux dense "renewables" such as wind and solar, which were widely used centuries ago. They cannot support modern civilization. The so-called "Green New Deal," by eliminating fossil fuels as the basic source of energy for the vast majority of the world's population, would create a "carrying capacity" for the Earth of a population size comparable to the Middle Ages, before the use of fossil fuels, when windmills dotted the countryside. The Earth's population did not reach one billion until approximately 1800. What will happen to the more than 6 billion "extra" people alive today, if we were to return to the technological level of the Middle Ages?

Juxtaposed to the current propaganda barrage that resources are limited, and therefore "the world has too many people," China's accomplishment of uplifting

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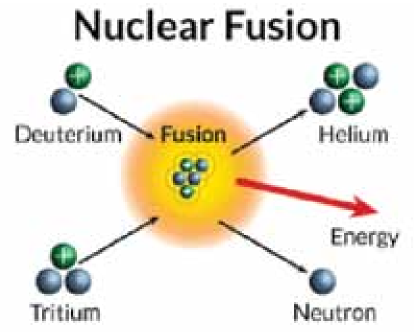
Artist's depiction of the Comprehensive Research Facilities in Support of the China Fusion Engineering Test Reactor.



Fusion, the nuclear process of the Sun and all the stars, is the combining of light atomic nuclei. Most common in today's fusion experiments is the fusing of deuterium and tritium, isotopes of hydrogen, which produces helium, a neutron, and an immense quantity of energy.

hundreds of millions of its people out of abject poverty is stunning. To provide a fruitful future, China has chosen, in the short term, to accelerate its deployment of nuclear fission power plants, with an array of advanced fission technologies, such as high-temperature and fast reactors. For the longer term, the goal is the development of fusion energy.

Besides generating electricity, fusion and plasma technologies will revolutionize industry, chemistry, and materials processing with tools such as the "plasma torch."

As humanity moves out from its ancestral home, fusion becomes a prerequisite for the industrial development of the Moon. In order to provide a livable environment on the airless, radiation-saturated Moon, we will have to create an Earth-like environment. Plasma-based and directed-energy mining, materials processing, and manufacturing will add to the power demand. Energy consumption per capita to live and work on the Moon will be orders of magnitude higher than that of today's highest standard of living on the Earth.

The move from the Moon to Mars cannot be done safely without fusion. Exposing our explorers to as much as six months of microgravity and high levels of radiation using slow chemical propulsion should not even be seriously considered. Nuclear fission propulsion can shorten the trip to a few weeks. But even that becomes unacceptable; fusion propulsion could get crews to Mars in a matter of days.

At the same time that fusion propulsion will enable humanity to travel into deep space, the study of plasma science in laboratories on Earth will provide insight into plasma processes in the universe. The stars, including the Sun, are the first-order fusion machines. The study of heliophysics and astrophysics will add insight to scientists' fusion experiments on Earth, and vice versa.

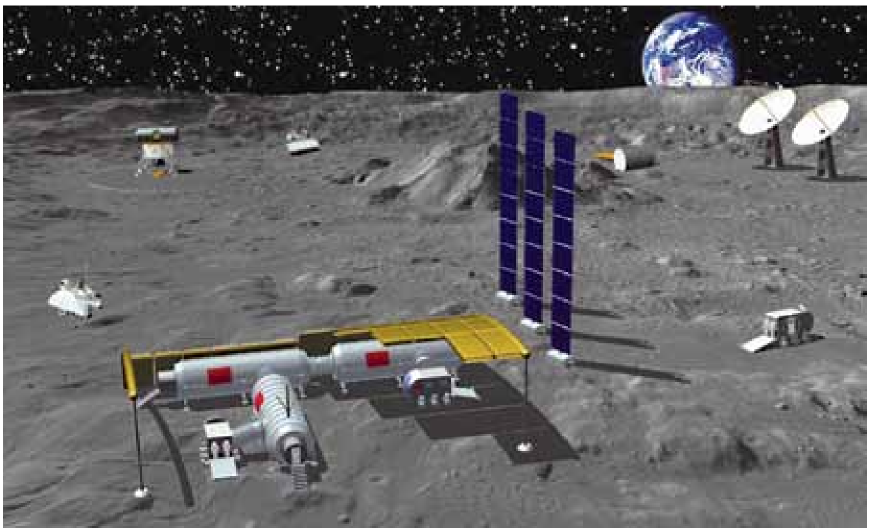
LaRouche summarizes: "A Fusion economy, is the presently urgent next step, and standard, for man's gains of power within the Solar system, and, later, beyond."

China's Fusion Program

China's fusion program is making steady progress, not because it is stealing intellectual property from the U.S., but because it comes under the economic umbrella of that country's Five-Year Plans, which lay out both the overall direction and specific development goals for the nation. The major science and technology projects, such as the Comprehensive Research Facilities in Support of the China Fusion Engineering Test Reactor (CFETR), are included as "mega-science projects" in the current 13th Five Year Plan.

In an interview with this writer in 2014,[1] Dr. Yuanxi Wan, a pioneer in fusion research in China, said that

1. Marsha Freeman, "Asian Nations Forge Ahead in Fusion." *EIR*, January 16, 2015. Pp. 39-40.



China Aerospace Science and Technology Corp.

China's stated intention is to build a manned scientific base on the Moon. One of the purposes is to mine helium-3 as a fuel for fusion power on Earth and the Moon and for fusion propulsion that will take mankind everywhere in our Solar System.

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Xi Jinping gets a briefing on the EAST Superconducting Tokamak at the Institute of Plasma Physics in Hefei China by then Director Yuanxi Wan on April 19, 2011.

when President Xi Jinping visited the Institute of Plasma Physics in Hefei, he told the scientists, "You are doing very important work for the future of human beings." President Xi, Dr. Wan said, "observed that in the last 200 years, America 'developed very quickly because the American government encouraged people to invent something.' " Dr. Wan said that President Xi "doesn't like to take care of small things. He likes [big projects like] the New Silk Road."

The accusation that China is making economic progress only by stealing from the U.S., which has been used to justify banning the export of American advanced technology to China and banning cooperation in civilian space programs, is wearing thin. If China is poised to advance beyond the U.S. in fusion and lunar exploration, it is because China has advanced, while the United States has stood still.

Four decades ago, following impressive progress in fusion experiments in the 1970s, the U.S. Congress passed, and President Jimmy Carter signed into law, the Magnetic Fusion Energy Engineering Act of 1980. The law called for an "Apollo-style" program to develop commercial fusion power, with the interim steps of an Engineering Test Reactor by 1990, and "the operation of a magnetic fusion demonstration plant at the turn of the twenty-first century. . . ." It noted that, "Acceleration of the current magnetic fusion program will require a doubling within seven years of the present funding level. . . ."

That funding never materialized, and today the U.S. magnetic fusion energy budget, in real dollars, is approximately one third of what is was when the Act was passed. Promising experiments have been shuttered and U.S. scientists told to go elsewhere, including to China, to continue their fusion research.

China, on the other hand, understands that their fusion and lunar exploration programs are key science drivers for its economy and, being long-term projects, are at the frontier of science and therefore require consistent government support.

Superconducting Tokamak—EAST

The Chinese fusion energy program got a later start than those in the Soviet Union and the U.S. In an interview with this author in December 2010,[2] Dr. Wan, who has been a leader in fusion research for more than 35 years at the Institute of Plasma Physics of the Chinese Academy of Sciences, related that when he graduated from Beijing University, China was in the throes of the Cultural Revolution. He "got a chance," he said, to go to a mountain area near Tibet. "I became a farmer, and it lasted more than three years."

In 1973, Dr. Wan moved to Hefei, the capital city of Anhui Province, where a new division of the Beijing Institute of Physics was being founded. He was part of a group to set up the new Institute for Plasma Physics.

In discussing the opportunities for Chinese scientists to travel abroad and visit advanced fusion facilities in other countries, Dr. Wan said, "My personal opinion is that former Chairman Deng Xiaoping, the Chairman of our government, made the very important decision to open the door of China."

At that time, China built a small tokamak at the Institute in Beijing, and a series of small tokamaks in Hefei.

Dr. Wan is known as the "mastermind of EAST," China's Experimental Advanced Superconducting Tokamak, at the Institute of Plasma Physics. By the early 1990s, he related, scientists knew that for fusion to become a reality, machines would have to produce the fusion reaction for more than a few seconds. A power reactor would have to operate in a "steady state," able

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2. Marsha Freeman, "China's Ambitious Path to Fusion Power." *EIR*, March 11, 2011. Pp. 47-56.

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After receiving the discarded T-7 tokamak from the Soviet Union, engineers at the Hefei Plasma Physics Institute disassembled the machine (above) and rebuilt it as HT-7 (right).

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to run continuously. "Our Institute said, we must make a contribution to this final purpose." Having decided upon the technology by which they could make a contribution, they asked themselves, "What kind of technical path can we take to a superconducting tokamak?"

The first tokamak in the world to incorporate superconducting magnets was the T-7 at Russia's famed Kurchatov Institute. When the Soviet Union collapsed, Dr. Wan related, "everything was stopped, including some fusion research. This machine [the T-7] was in the garbage. So we discussed this with the Kurchatov Institute, and we shipped this machine to our Institute." At the time, "China did not have enough money to support fusion research," so in the workshops the scientists took apart the device, "cleaned every component" and in 1994 "reassembled all of the equipment."

The renamed HT-7 tokamak ("H" for Hefei) entered service the following year, making China the fourth country in the world after Russia, France, and Japan, with a tokamak incorporating superconducting magnets. HT-7 carried out nearly 20 rounds of experiments, until it was retired in 2013. The Institute of Plasma Physics explained at that time, that most importantly, the refurbished and upgraded Russian tokamak had "nourished three generations of Chinese fusion scientists."

While progress was being made on other machines, the Hefei scientists decided that they would make their contribution to the development of a steady-state operation of a tokamak, by designing a fully superconducting magnet tokamak. After being chosen above competing science and technology projects, EAST was approved by the central government in 1997 and received special budget support for construction. The first plasma discharge was in 2006.

EAST has recently reached a new mile-

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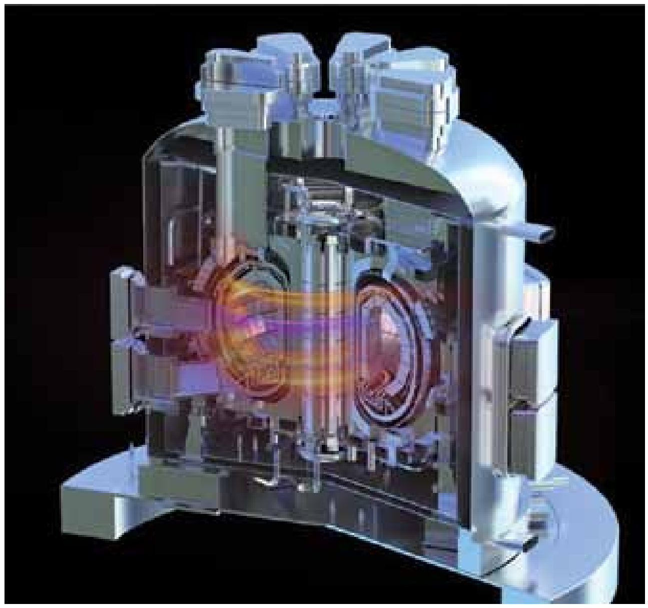
Two views of the EAST Tokamak fusion reactor. Above is the core plasma chamber.

stone. In November, the Chinese Academy of Sciences reported that EAST had achieved an electron temperature of over 100 million degrees in its core plasma, or seven times greater than the interior of the Sun. To achieve that milestone, four months of experiments were carried out, and four kinds of heating power were used.

In a public release issued November 13, 2018, the Chinese Academy of Sciences reported that, "Since it began operating in 2006, EAST has become a fully open test facility where the world fusion community can conduct steady-state operations and ITER-related physics research." Experiments continue on the EAST tokamak, focused on areas of research that will be applicable to ITER, the International Thermonuclear Experimental Reactor, now under construction in France.

But there are numerous challenges to be overcome in applying knowledge gained with the EAST and ITER machines constructed for experimental research, to the development of commercial fusion power plants connected to the electric grid.



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The Comprehensive Research Facilities in Support of the China Fusion Engineering Test Reactor, seen in this artist's drawing, will be in operation in five years, to test fabrication techniques for major fusion experiment components, such as superconducting magnets.

The Next Steps

China is one of the partners in ITER, along with Russia, the U.S., Japan, Europe, South Korea, and India. ITER will be the largest tokamak in the world, with the goal of producing 500 megawatts of fusion power for 400 to 600 seconds. According to the current schedule, ITER will see its first plasma experiment in 2025.

Dr. Wan and other fusion scientists are confident that ITER will be a success, so they do not see any reason to wait for results from ITER to proceed with a demonstration power plant. Although China is committed to cooperation with the international community, it recognizes that a strong domestic program is necessary, both to make important contributions to the global effort, and to ensure that for its own future, fusion is developed as quickly as possible.

This requires tackling the outstanding challenges in both the science and the technology of fusion.

Ten years ago, the Department of Nuclear Science and Technology was established at the University of Science and Technology in Hefei. Dr. Wan, appointed as the Dean of the Department, was asked by China's Ministry of Science and Technology (MOST) to head a national design group to create a road map leading to the next machine for fusion research, the China Fusion Engineering Test Reactor (CFETR).

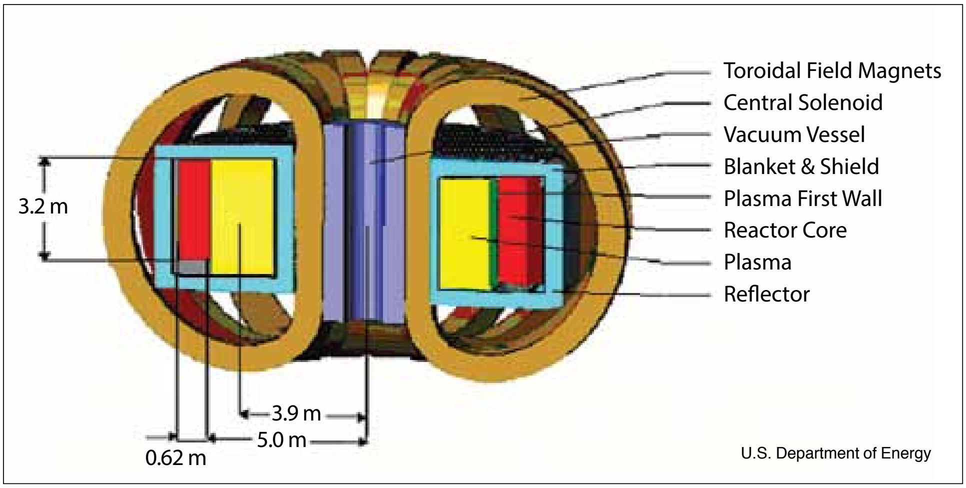
"Just two weeks ago," Dr. Wan told this writer in 2014, "more than 200 scientists and engineers got together to summarize our progress [on] the engineering conceptual design for CFETR," which has been going through continuing iterations. They planned to prepare a more detailed design to be presented to the government, and define additional key R&D requirements.

The goal of the Engineering Test Reactor is to "close the gap" between ITER and the DEMO commercial fusion power plant. This is a large step. Design work on the CFETR began in 2015, and in a presentation the following year, Dr. Wan reported that the design team hoped a construction "proposal could be evaluated and approved in about five years." The plan has been to build the Engineering Test Reactor to operate in the late 2020s.

But it became clear that there was also a gap between ITER/EAST and the Engineering Test Reactor. An R&D program to develop the technologies for the test reactor was needed.

The CFETR project was divided into two phases. In phase one, steady state operation will be a key issue, with a "modest" amount of fusion power produced, of up to 200 MW. In the second phase, the aim is for DEMO-scale power of over 1 gigawatt, with steady-state operation.

And so ground was broken in December to build the Comprehensive Research Facilities in Support of the China Fusion Engineering Test Reactor (CFETR), to help fill the technology gaps.



Interest in developing fission-fusion hybrid reactors as an interim step to pure fusion reactors has increased recently. This concept was included in a report on a workshop on hybrid concepts held at Argonne National Laboratory in 2009.

The Research Facilities involves ten Chinese fusion institutes and universities under the leadership of the Institute of Plasma Physics, which describes the Research Facilities, when completed, as "a comprehensive research platform" that will test reactor-scalable superconducting magnets, reactor heating systems, remote handling and diagnostic technology, and "provide strong support for cutting-edge cross-disciplinary fields, such as energy, information, health, and so on." It is the first project in the future Hefei National Comprehensive Science Center, which will have other science and technology research facilities.

The plan is to have the Comprehensive Research Facilities in Support of the China Fusion Engineering Test Reactor up and running in five years. The general manager of the project, Academician Li Jiangang said that there will be tremendous difficulties in the construction and operation of the Engineering Test Reactor, so it is critical to build this large test platform before its construction is started.

A Different Path to Fusion

There is another pathway that China is considering on its way to fusion power. Professor Yican Wu's prepared presentation for the 2017 Fusion Power Associates meeting featured a chart with two possibilities for the next big step for fusion: A tokamak fusion test reactor and a fission/fusion hybrid test reactor.

When asked in 2010 about the hybrid as a possible interim step to fusion, Dr. Wan said:

> China must develop fission power stations as rapidly as possible. Right now about 70 percent of our energy comes from coal. It is terrible [in terms of pollution]. It is the highest percentage in the world. The government and the public support the rapid development of nuclear power stations. [But in a typical fission plant], you can only use about 1 percent of the uranium so, very quickly there will be a shortage of uranium—in less than 100 years. So that is one problem. The second problem is the waste, which is increasing very quickly, year by year.
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> If the tokamak is successful, you can use the fusion neutrons to irradiate uranium-238 into plutonium-239 for fission fuel. Also, you can use the neutron source to transmute the waste. To do this, you don't need a pure fusion power reactor, which still has the materials problem. If you use the hybrid concept, you can use a little pure fusion in a cold plasma.... You can breed fission material, and treat the fission waste.[3]

This benefits both technologies, Dr. Wan said. "For fusion, you can promote the development of fusion technology, of materials development, so you can get an early application for fusion, while you take care of breeding the fuel and transmute the waste from fission."

In 1953, Dr. Edward Teller and a team from the Lawrence Livermore National Laboratory in

3. According to reports published in August 2015 by the *China Daily Mail*, *Russia Today* and *Science and Technology Daily* (the official newspaper of the Chinese Ministry of Science and Technology), China has set a target date of 2030 for an operational hybrid reactor.

California produced the first proposal in the United States for a hybrid reactor, using a deuterium-tritium fusion reactor's neutrons to produce fissile plutonium from uranium-238.[4] But at that early stage, the scientists were uncertain that creating controlled fusion was going to be successful.

Dramatic results in fusion experiments in the 1970s raised the potential for hybrid development. Fusion researchers at the Princeton Plasma Physics Laboratory estimated in the late 1970s that a crash program based on the tokamak machine design could produce a model demonstration hybrid reactor by 1985.

However, the hybrid and other advanced nuclear programs were not pursued in the United States during or since the 1980s, due to both an "environmental movement" with its anti-nuclear, anti-human "Green New Deal," and failed economic policies that prevent substantial investment in long-term, potentially revolutionary breakthroughs in science and technology.

Regardless of which pathway China takes to full-scale development of fusion power, it will get there. China's scientists have interwoven fusion's long-term potential with another great project before mankind: the exploration of space.

Just below the surface of the Moon lies helium-3, the perfect fuel for fusion, deposited in the regolith over eons by the solar wind.

China—which earlier this year became the first nation to land a spacecraft on the far side of the Moon—plans to establish a lunar base for scientific exploration and to exploit the Moon's resources. Through the use of lunar helium-3 for fusion fuel, the economy of the Earth will be integrated with its celestial neighbor. In the course of living on the Moon, mankind will develop fusion and new technologies to enable humans to further explore our Solar System and beyond.

An International Crash Program

In a 1985 paper, recently republished in *EIR*,[5] Lyndon LaRouche writes:

> The best way to achieve breakthroughs in each and all of the kinds of applications of technological progress over the coming fifty years or so, is to create a mission-oriented, crash-program taskforce, assigned to developing all of the technologies required for beginning the permanent colonization of Mars by some preassigned target-date, such as 2010 A.D. In other words, develop all of the technologies required for the Strategic Defense Initiative, as a by-product of a Moon-Mars-colonization mission-assignment....
>
> Let us henceforth define scientific progress as an ordered succession of ever-more-ambitious grand-scale mission-assignments. Let "science" be defined in such a task-oriented way during each generation. Let "science" signify both the current grand-scale crash-program mission-assignment in progress and the work of defining the successor to such a mission-assignment.

The recent directive by President Donald Trump to NASA to return U.S. astronauts to the Moon by 2024, and to establish a permanent presence no more than five years after that, with the explicit, stated intention that this is a precursor of manned exploration and colonization of Mars, defines what could—and must—become a crash program approach toward manned space exploration. This, in turn, will redefine and refocus both the urgency and the role of fusion energy development for the human race as a whole. As defined by LaRouche, scientific progress is to be pursued not by a timetable dictated by budgetary constraints, nor as separate specialized arenas of individual programs—but rather by the driving necessity of a "grand-scale crash-program mission-assignment," such as was carried out in the 1961-1969 John F. Kennedy Apollo Program.

Such a mission-assignment requires, in turn, the cooperation and the pooled resources of China, the United States, Russia and all other willing partners to accomplish this goal. It will define other, successive urgent goals. It will also place the rapid development of fusion power—as an "Apollo-style" crash program—on the necessary international footing.

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4. Dr. John Schoonover, "The Fusion-Fission Hybrid Reactor." *Fusion*, January 1979. Pp. 18-26.

5. Lyndon H. LaRouche, Jr., "Private Initiative for Colonizing the Moon and Mars" written in June 1985 and republished in *EIR*, April 5, 2019. Pp. 8-19.