BOOK REVIEW

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Search for the Ultimate Energy Source

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In the summer of 1958, Stephen Dean decided to make a career in fusion after reading A. S. Bishop's book titled *Project Sherwood: The U.S. Program in Controlled Fusion*. Dean earned a master's degree from the Massachusetts Institute of Technology and then took a position at the office of the U.S. Atomic Energy Commission's Division of Controlled Thermonuclear Research in Washington, DC, before receiving a PhD from the University of Maryland in 1971. During his fusion career of more than 50 years, Dean has been connected with U.S. national laboratories and industries. In August 1979, Dean formed Fusion Power Associates to mobilize private organizations, hoping to start the fusion engineering development activity that, he predicted, could eventually lead to the first fusion power plant construction by the turn of the century.

In *Search for the Ultimate Energy Source*, Dean provides a personal perspective on the U.S. history of fusion research with a balanced view between magnetic and inertial fusion energies. He answers the pertinent questions of how and when fusion might contribute to the U.S. energy market, why it always seemed to be out of reach, and whether it rightly can be called "the ultimate energy source." He also covers in great detail the history and evolution of the U.S. fusion program, beginning with the struggling years of the 1960s, followed by the glory years of the 1970s, the successes and disaster years of the 1980s, and the hope for resurgence in the early 1990s—which, to the contrary, ended with the financial crises as the twentieth century drew to a close. Instead of a U.S. fusion renaissance (as happened in many other countries), the turn of the century witnessed a significant restructuring of the U.S. fusion program to meet lower funding levels: shutting down the Tokamak Fusion Test Reactor (TFTR) experiment, withdrawing the United States from ITER, and emphasizing a fusion *science* program while abandoning its *energy* mission. Several groups of U.S. fusion experts responded by holding a Symposium for Pathways to Fusion Power (Aug. 27–29, 1997), a Forum for Major Next-Step Experiments (Apr. 27–May 1, 1998), a meeting on Cost-Effective Steps to Fusion Power (Jan. 25–27, 1999), and a Snowmass, Colorado, meeting (July 11–23, 1999) that involved the entire fusion community. In addition, several panels convened to review the newly structured Fusion Energy Sciences Program.

The new millennium gave a boost to the hopes of the U.S. fusion community when President G. W. Bush established the National Energy Policy Development Group (NEPD). NEPD's 2001 report recommended the development of next-generation fusion technology. Nevertheless, during the following decade, the study of burning plasma physics became more and more stated as the focus of the U.S. fusion effort, rather than a balanced science and technology effort aimed at development of a fusion power plant. In early 2003, the United States did rejoin ITER but called for a lesser role for its national fusion program. Worse, the 2004 U.S. budget eliminated all domestic energy-oriented fusion technology programs, claiming that funding for energy-relevant technology research and development (R&D) should wait for the results of ITER and National Ignition Facility (NIF). More cuts to the U.S. fusion domestic budget were made in 2006 and beyond, bringing that budget below $300 million/year. In the early 2010s, ITER continued to face cost increases and schedule slippages, with a projected doubling of the cost and delay of deuterium-tritium operation until 2027.

Dean notes that a conflict has always existed within the magnetic fusion program on the issue of how many alternate concepts to pursue and support. During the first decade of the 2000s, the title of this category was changed to "innovative concepts" (IC), and it included tokamak-related work, spherical tokamaks, and stellarators. Later, the IC program placed increased emphasis on exploring improved pathways to practical fusion power from tokamaks by addressing critical problems that hinder the tokamak concept, such as disruptions, heat loads, maintenance schemes, etc.

In the early 2010s, a committee was convened to assess the prospects for generating power using inertial confinement fusion, identify the scientific and engineering challenges, and develop a roadmap aimed at creating a conceptual design for an inertial fusion energy (IFE) DEMO plant. The committee's report states that despite numerous advances made during past decades, many of the technologies needed for an integrated IFE system are still at an early stage of technological maturity and that there remain critical challenges associated with an IFE DEMO plant. An intense national campaign is under way to achieve ignition on NIF, and planning should continue to make effective use of NIF as one of the major program elements in an assessment of the feasibility of IFE.

Chapter 14 of Dean's book presents personal perspectives of several persons who have played key roles in fusion R&D over many decades: for instance, "Is the USA Serious About Fusion Energy?" by C. C. Baker, N. A. Davis, and W. R. Ellis; "Perspectives on Inertial Fusion Energy: 2012," by R. McCrory; "Time for the Fusion Community to Focus on the Future," by D. M. Meade; and "Recollections and Perspective from 40 Years of Magnetic Fusion Research," by F. L. Ribe, J. Sheffield, K. Tomabechi, and A. Trivelpiece. In Chapter 15 on "The Ultimate Energy Source," Dean says, "Currently, governments fund most fusion research. In the USA, progress has been severely constrained by the availability of federal research dollars and the absence of policy decisions to construct new fusion facilities. The US Department of Energy has to balance priorities among many competing programs (weapons, basic science, and energy technologies and efficiency). The priorities change as new administrations take office based more on political agenda than on national need. The US fusion budget remains stagnant on a track that does not lead to a US DEMO plant. Even after ITER and NIF have advanced the fusion quest, there will still be much engineering and technology development required before a commercial fusion power plant can operate."

In Dean's opinion, fusion will ultimately become a practical source of energy because fusion will ultimately be required to fulfill society's energy needs. Estimates of when fusion will be ready for commercialization vary widely, depending on the optimism of particular advocates and assumptions on how much funding will be available for development. It is more likely to occur in the 2050 time frame and more likely to be in Europe or Asia than in the United States. It is fortunate that the world is not likely to run out of energy sources by then. Issues associated with the cost of electricity and climate change will likely become more and more important as time goes on. At some point in the future, fusion will enter the energy mix, at which point we will be able to truly assess its right to be called "the ultimate energy source."

Dean's book covers the history of the U.S. fusion research since its inception in the early 1950s. I highly recommend it to those interested in the evolution of the U.S. fusion program, to those searching for answers regarding why the United States views fusion as a science program—not an energy program—and to those curious about how and when "the ultimate energy source" could join the electric grid.

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