

The Promise of Fusion Power

Dr. Dean, president of Fusion Power Associates, of Gaithersburg, Md., prepared this video address for the Schiller Institute's conference on "The Eurasian Land-Bridge Becomes a Reality," in Kiedrich, Germany, on Sept. 15-16. The last four issues of EIR have included other presentations from the conference. This video was recorded on Sept. 11, 2007. Subheads have been added.



Courtesy of Stephen Dean

"I hope to see the beginnings of the application of fusion before I pass from the planet," says Dr. Dean.

Thank you for inviting me to speak at your conference today. I give you my apologies that I was not able to come in person, but I very much appreciate the opportunity to meet with such a distinguished group of people.

I'm going to speak today about the promise of fusion energy. Fusion is a process which is not yet quite commercially available. I've spent my entire career working on this problem, and I hope to see the beginnings of the applications of fusion before I pass from the planet.

Your conference today deals with a number of topics which are going to require new energy sources, or at least extensive

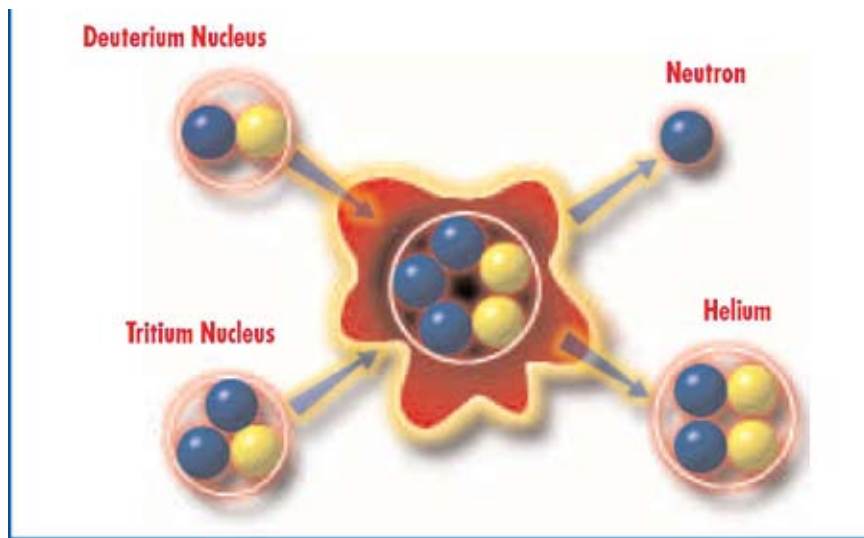
use of the energy resources that are available, and so I'd like to say a few words about why we need new energy sources. There is a lot of energy available in the world today, but there is going to be a growing demand in the world for more and more energy, as we go into the next 50 to 100 years.

Most of our energy today comes from the burning of fossil fuels, like coal and oil and natural gas. Many places in the world still get a lot of their energy simply from burning wood. But as the population grows, and as more and more projects are required for infrastructure and raising the standard of living of people on the planet, there's going to be a growing demand for the resources from which we get our energy.

Now one of the problems that we have in the world today is the uneven geographical distribution of these resources. Wars are being fought, even today, in the Middle East, over the question of who controls the supply of oil. In the burning of fossil fuels, there are many people that have environmental concerns, about the fact that the burning of fossil fuels puts CO₂ and other noxious materials into the environment, and there's a growing concern about the potential for global warming.

There are advanced technologies available, but in many cases these technologies, which do not have some of the disadvantages of fossil fuels, are not always economic, compared to their competition, and in many countries they are not sufficiently technologically advanced to deploy such technologies.

FIGURE 1
Fusion Reaction

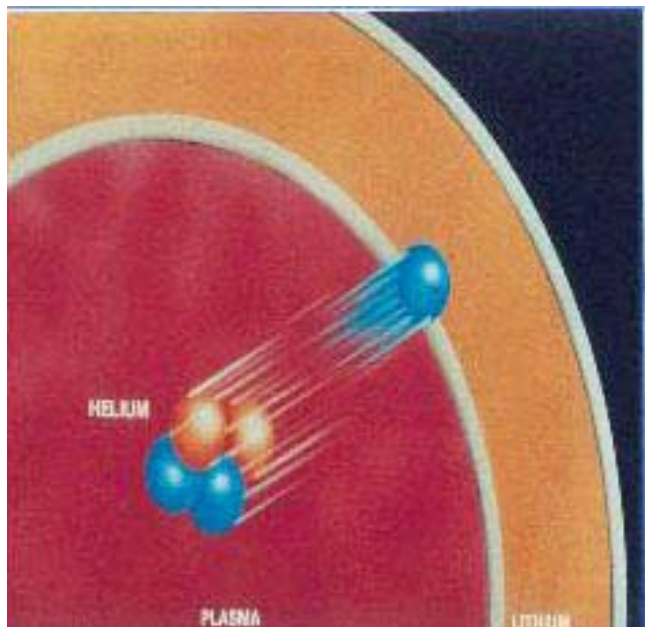


Deuterium and tritium fuse at high energy (10 KeV), producing helium and an energetic (14 MeV) neutron. Mass is converted to energy according to Einstein's formula $E=mc^2$. Fusion fuel releases almost 10 million times more energy per pound than fossil fuels.

DOE

FIGURE 2

Principle of a Fusion Power Plant



Fusion Power Associates

The helium nucleus gives up its energy to the plasma, thus sustaining its temperature. The energetic neutron is captured in a moderator blanket, heating it and reacting with lithium to produce tritium fuel.

What Is Fusion Power?

But today I want to talk about fusion as one of these advanced technologies. Fusion is a nuclear process. We do, of course, have nuclear power today, based on the fissioning of uranium, that is, the splitting of uranium into parts. Fusion is the process that generates light and heat in the Sun, and in the other stars, and, as such, it is the dominant energy source in the universe. It is a nuclear process, but it is the combining of atoms, rather than the splitting of atoms, which is fusion,

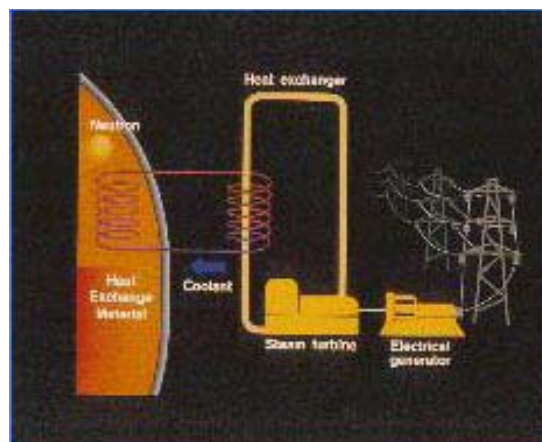
It's most easily achieved on Earth by combining the heavy isotopes of hydrogen, deuterium, and tritium. Hydrogen is the lightest of all the elements. Deuterium is heavy hydrogen. Tritium is three times heavy hydrogen. These isotopes of hydrogen, when combined, form helium, which is the next heaviest element in the Periodic Table.

Deuterium, the heavy isotope of hydrogen, is found one part in 6,000 in ordinary water, and hence it's universally available, and eliminates the problem of the unequal geographical distribution of fuel resources. There will be fuel for fusion as long as there's water on the planet, which means that there will be fusion fuel available to all nations, as long as there's life on the planet.

Let's look at the fusion reaction itself (**Figure 1**). You see deuterium and tritium, the two heavy isotopes of hydrogen, schematically fused, and when they do, they disassemble

FIGURE 3

Fusion Power Plant Schematic



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A conventional heat-exchange system removes heat from the moderator blanket. Heat is converted by a conventional power-conversion system.

themselves into the helium product, and a fast neutron. Mass is converted from the mass of two heavy isotopes of hydrogen, into the products, and in the process, mass disappears and comes out as kinetic energy of the products, according to Einstein's formula $E=mc^2$.

As I said, fusion is a nuclear process, and as such, it gives out much more energy per pound than the burning of fossil fuels. Fusion fuel, for example, releases about 10 million times more energy per pound than the burning of fossil fuels, and about ten times more per pound than the fissioning of uranium.

Why fusion? I mentioned that fusion fuel comes from water, and hence is abundant, widely available, and easily extracted from the water at low cost. The fusion reaction itself is environmentally friendly. It produces no CO_2 emissions, no radioactive waste from the fusion reaction itself, although the fast neutron does activate the structure of the fusion reaction; but those products have relatively low hazard potential, and relatively short half-life, and therefore do not require deep geological storage for many, many thousands of years.

Multiple Uses

The primary goal of the fusion program worldwide has been, and is, the production of electricity in a central station power plant. However, that is not the only possible use for fusion. In competition with other energy sources, fusion may also be useful for the production of hydrogen, for the desalination of water, for the production of fuel for fission reactors, and for the deactivation of fission reactor waste.

Figure 2 shows a schematic of a fusion power plant. Fusion is a high-temperature process, as you can imagine, from knowing that it's the primary process in the Sun. In the core of

a fusion reaction is a very hot gas, ionized—it's called a plasma. And when the fusion reaction occurs in this plasma, the helium nucleus, which is the product, stays in the plasma and gives its energy to sustain the process, in a self-sustaining way.

The neutron, being uncharged, quickly leaves the central part of the reactor, and it is captured in a blanket where it heats the blanket, thereby creating the heat that's required for the production of electricity. It also, if there's lithium in the blanket, which we assume there will be, is used to produce the tritium, which is then fed back into the plant as fuel, because a neutron reacting with lithium produces tritium.

Figure 3, which further elaborates on the schematic of a fusion power plant, shows a conventional heat system which picks up the heat from the blanket, which then goes through a turbine, and in a conventional way, produces electricity in a conventional power system.

There are other schemes which people have thought of, such as the direct conversion of fusion reaction products to electricity, but this is the primary, simplest way to think about the operation of a fusion power plant.

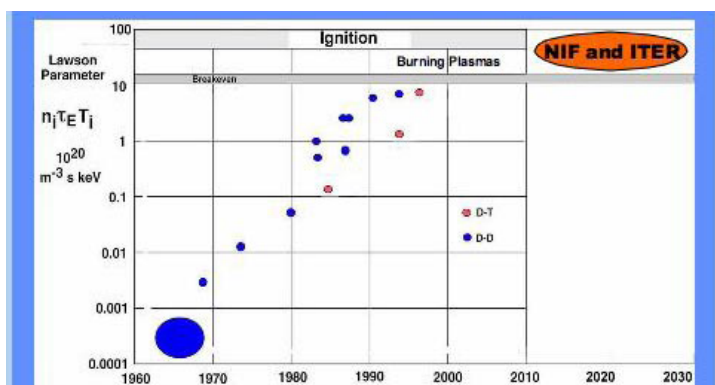
To get a little more technical on you, I show on the next slide some of the technical approaches to fusion. The fuel, as I mentioned, has to be heated, up to temperatures such as exist on the Sun. We've done this many times for many years. It actually turns out to be very simple to do, even though you might think it's not. That hot plasma has to be confined long enough to get net energy, and a useful amount of energy, and there are two main technical approaches to do this: One is called magnetic confinement, in which magnetic fields from superconducting magnets are used to confine the hot plasma, away from the material wall. The other is called inertial confinement, where, for a very brief second, a lot of energy is produced before the plasma disassembles.

In magnetic confinement, the plasma itself is at subatmospheric densities, very low densities. In inertial confinement, the plasma is at very high density.

As I mentioned, the plasma must be confined at whatever density it's at, whatever temperature it's at, for a sufficient length of time to get a useful amount of energy out, and this product, the density times the temperature times confinement time, is called the Lawson criterion, and it's a figure of merit for progress.

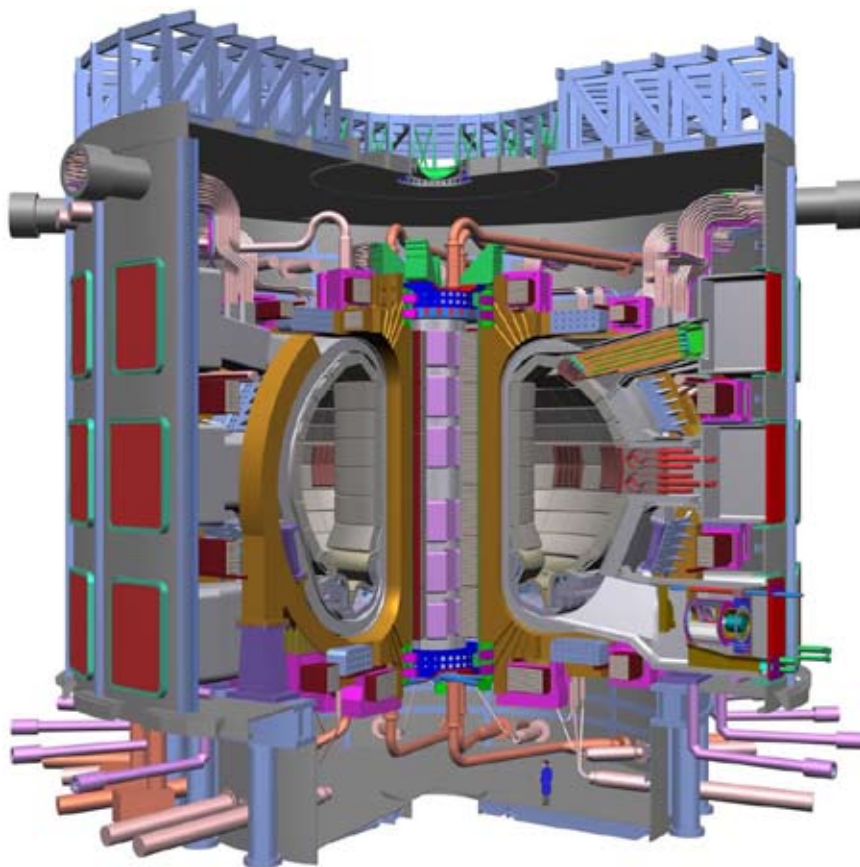
Progress over the years is shown on

FIGURE 4
Fusion Progress and Projections



the next slide (**Figure 4**). Going back to 1960, you can see that the product of the density, the confinement time, and the temperature, was quite low. Over the years, in experiments around the world, that product has gradually gotten higher and higher and higher. Today we are very close to the regime we need to be in, called the burning plasma regime, and there are two fa-

FIGURE 5
The International Thermonuclear Experimental Reactor (ITER)



ITER

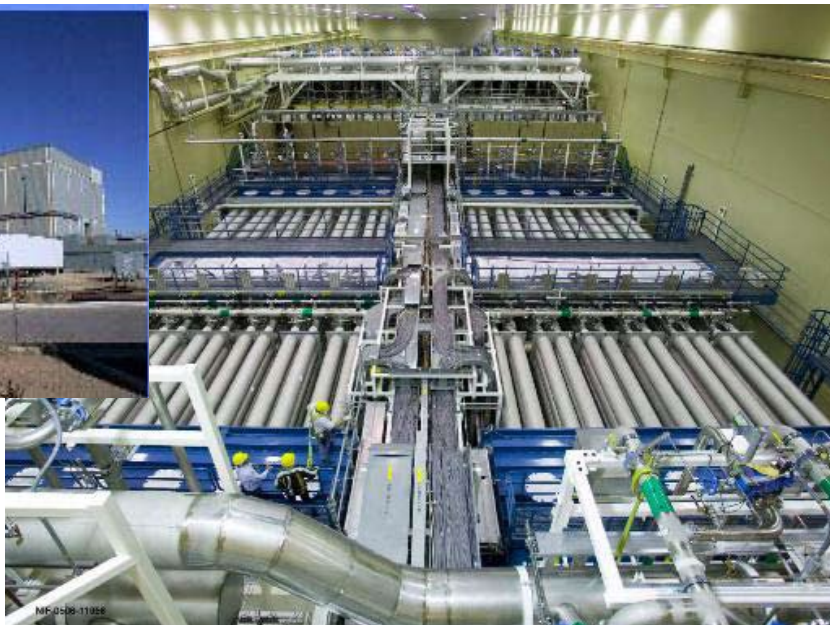
FIGURE 6

National Ignition Facility (NIF)



Fusion Power Associates

The laser-based NIF, under construction and in partial operation at Lawrence Livermore National Laboratory, is aimed at beginning ignition experiments in 2010.



cilities, three actually, that are under construction now, that will produce net amounts of fusion energy for the first time. One is called the National Ignition Facility (NIF), the laser-based inertial confinement facility, which is being built in California. And a similar facility called LNJ is being built in France. And the other is called ITER, the International Thermonuclear Experimental Reactor, which is also being built in Cadarache, in France. And those two facilities will operate with net fusion power, sometime over the next one to two decades.

The ITER and NIF Projects

Looking at ITER, I note that it's a joint venture of the Europeans, Japan, Russia, the United States, China, India, and Korea—seven parties banding together, working together, to be sited in France. Construction will be initiated shortly after the beginning of 2008. The agreements have all been signed; the details have been worked out. The people are starting to assemble as a team in Cadarache. The projected operational date for ITER is 2016. The important point to note is, there's going to be about 500-700 megawatts of thermal fusion power produced in this reactor, initially, for about 300 seconds at a time, but the facility itself is upgradable to produce this power in steady state.

Figure 5 is a schematic of the ITER. The only thing that you really need to know is, if you look down very close to the bottom, you might see a shadow of a person, to give you an idea of the scale. The schematic shows the superconducting magnets that are used in the facilities, and the plasma goes in the very center.

In this area of magnetic confinement, the U.S. is about one-sixth of the world effort. The Europeans are about 45% of

the world effort, Japan is 25%, and others are 13%. If we look at the dollars that amounts to, the world effort is about \$1.5 billion, per year, of which the U.S. spends \$260 million.

Figure 6 shows a photograph of the building in which the NIF, the inertial confinement facility, is being built at the Lawrence Livermore Laboratory in California. The facility is in partial operation now, but it's aimed at beginning its ignition experiments in just a few years, in 2010.

Below is a photograph of the interior of the building, showing some of the laser beams. This facility has 192 laser beams. They'll all be focused down on a very small pellet, containing deuterium and tritium, fusion fuel, and about once or twice a day, it will ignite these pellets and produce net fusion energy.

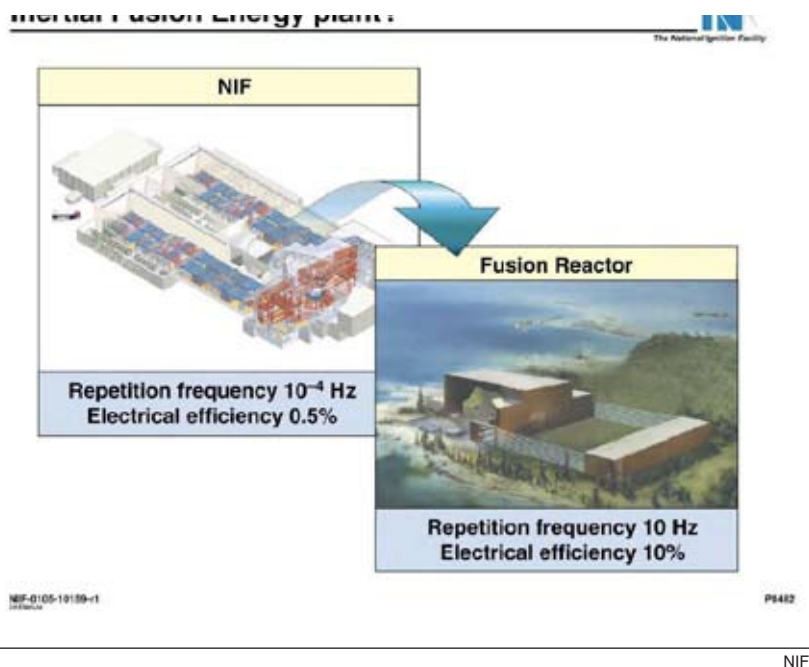
Figure 7 comments that NIF itself is a precursor to an inertial fusion energy plan. The NIF facility, and also the LNJ facility of France, are single-shot facilities. They do this once, they're shut down for a few hours, new experiments are set up, and then they'll do it again. For an inertial fusion power plant, as shown in the corner, you must do this on a repetitive basis. For example, you must do it at like 10 Hertz, which is like 10 times a second, with an electrical efficiency of about 10%, from the wall plug to the energy that irradiates the fusion pellet. Right now, the lasers that we have are much lower efficiency, and only operate at one pulse at a time, but development is under way at a variety of facilities to up this repetition rate to the required frequency.

Commercial Fusion

Beyond the NIF and ITER, one has to look at going from those facilities which are experimental, to a fusion power

FIGURE 7

Is NIF a Precursor to an Inertial Fusion Energy Plant?



plant. One of the problems that fusion has had over the years, is that the governments of the world, even though they support the development to varying degrees, have not had a serious commitment to a schedule for bringing the development to fruition, and operating a fusion power plant. Back in 1976, I was involved in preparing a long-range plan, which aimed at producing fusion power in a demonstration power plant by the year 2000. The year 2000 has come and gone. All I can say is that the governments have not built the facilities, or provided the funding required, to meet that schedule.

Today, there are still large uncertainties as to when we will actually have a fusion power plant on the grid, based on not only technical unknowns, which still require significant R&D—research and development—but also due to lack of firm funding commitments, and to a lack of a firm schedule on the part of world governments. The projections that are made by the advocates of the various proposals of how we can get from here to the end, range from 15 years on the optimistic side, to maybe 50 years on the conservative side, with a mean of around 30 to 35 years.

As I mentioned, the governments have no firm commitment to any particu-

lar schedule, but the advocates do have a schedule, and I show you on my final slide, the European Magnetic Fusion Roadmap (Figure 8). It shows the ITER project, which I mentioned, and then it shows the other R&D, down at the bottom, that's required. And then in the middle, it shows the construction of a demonstration power plant. The schedule shown is in terms of the number of years after start of ITER construction, which, as I mentioned, would start early in 2008. And it shows the operation of a large-scale demonstration power plant about 30 years from now.

I hope that that meets with your own time scale. I know that many of the projects that you're talking about at this conference are aimed at 50 to 100 years kind of payoff. You're looking at the long term for the benefit of the people on this planet. And I think that fusion will come along in plenty of time to meet some of the demands, and in the meantime, we have a lot of other energy sources, like nuclear

power, which hopefully will fill the gap until fusion can come in, and add its contribution to the energy mix. I think, in the long run, we're going to need lots of energy sources, for a lot of different applications, and each one will have its niche, and hopefully, fusion will play an important role in the long term. Thank you for your attention.

FIGURE 8

European Magnetic Fusion Roadmap

