II. No Limits to Growth

Controlled Thermonuclear Fusion: The Time is Now

by Joel Dejean

This is an edited transcript of a class given by Joel Dejean, an electrical engineer who worked for years in the defense industry, on January 25, 2020, to a meeting in Houston, Texas with LaRouche PAC and Schiller Institute members, and members of the public.

Jan. 25—There are no limits to growth—that is the response we can all provide to Greta Thunberg and her controllers like Prince Charles and Michael Bloomberg. Lyndon LaRouche wrote the book, *There Are No Limits to Growth!* in 1983—that was 37 years ago. He was responding to the idea of "limits to growth"—that all of us were going to have to cut down our consumption, and eventually cut down our population—was being promoted.

Five and a half years ago, LaRouche elaborated his economic views in a rather short statement of principle, known as the "Four Laws." (You've heard of the Ten Commandments that came down on a "tablet," but I don't know what operating system Moses used.) LaRouche came up with his Four Laws for economic revival, survival, and expansion. This starts with the return to Glass-Steagall: we separate commercial banking from investment banking. We create a national bank from which you can issue credit for great projects such as high-speed rail, fission power plants, and small modular fission reactors. LaRouche's Fourth Law presents the idea of using a science-driver policy to drive the economy forward. Similar to the Manhattan Project, and the NASA Apollo project, LaRouche called for a crash program for a revival of the space program and fusion power—controlled thermonuclear power.

What is Nuclear Fusion?

The Universe has already shown us the way. The most abundant power source in the universe is thermonuclear fusion inside the stars. Our star, the Sun, is a perfect example. It has the advantage of having a huge mass, more than 300,000 times the mass of the Earth. At the core of the Sun, you have the conditions to fuse lighter elements like hydrogen into heavier elements like helium, releasing a huge amount of energy in the process. Since we don't have such massive gravity available to us on Earth, we have to use different methods to achieve those pressures. We have had thermonuclear fusion on Earth for about 68 years, in the form of a thermonuclear (fusion) bomb.

The first device was tested in 1952; it was called "Mike." It was about the size of this library, a huge device, and it was triggered by a smaller fission bomb. The yield on the fission bombs like the Hiroshima or Nagasaki bomb was in the range of 10-20 kilotons, or 20,000 tons of TNT-equivalent energy released. The first thermonuclear device tested released over 1,000 times that yield, so it was in the megatons, 10-megaton range. That is not a very efficient power plant—because it blows itself up when you use it! So, the goal since the '50s has been to control the thermonuclear fusion so you can use it as a limitless power source.

The Road to Controlled Fusion Energy

There are two major methods of achieving fusion. While we have not achieved breakeven—more energy released than required to induce the fusion—as of January 2020, we are coming closer and closer. One physicist compared it to the idea that, "if you are climbing a mountain, you go up the mountain until you reach the summit." Well, we're about seven-tenths of the way up. We haven't reached the summit yet. Pessimists keep repeating, "Well, because we haven't done it, that means we'll never achieve it." It's the repeated sour line, "Fusion is 30 years away, and it will always be 30 years away."

Let's look at two examples of what man has done in the past, the first one being man-powered flight. If you think back, man had been dreaming of flying like birds for thousands of years, but it was only 117 years ago that we first achieved powered flight. The Wright Brothers, think back: Where did they get their education? Where did they go to school? Where did they get their aeronautical engineering degree? They were mechanics and they had their own bicycle shop; they observed the flight of birds, and were able to figure it out. But the first engine that they used for powered flight had about 8 horsepower and produced about 90 pounds of thrust. The length of the first flight was about 212 feet. That's less than the wingspan of your average big jumbo jet.

FIGURE 1

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A technician works on a target positioner inside the National Ignition Facility (NIF) target chamber.

Think about what followed after that. Within 66 years, we went from flying the mere length of a football field, to landing on the Moon, almost 250,000 miles away. There were a lot of steps in between. Let's look at one important step. Robert Goddard, from Massachusetts, figured out in the 1920s how to use liquid fuel, liquid oxygen and kerosene to power a rocket. His first major test was in 1926: The rocket lifted off and went up a total of 42 feet. Think of going 42 feet in the air in 1926, and then a mere 43 years later, we're landing on the Moon. This demonstrates that once you make a breakthrough, you can have progress rapidly.

This January is also the 100th anniversary of an editorial from that so-called great scientific publication, *The New York Times*, published on January 13, 1920, ridiculing Goddard because Goddard had proposed to build a rocket that could reach the Moon and *The New York Times*, in its infinite wisdom, said that Goddard obviously did not know what the average high school student of physics knew, that for every action to get a reaction, you needed something to push on. They ridiculed Goddard because, obviously, you could not get the reaction in a vacuum like space. They only made a correction on July 17, 1969, the day after the Apollo 11 launch. So, while they may not have been right the first time, they do eventually correct the error of their ways.

Two Major Approaches

I want to now go through the two major ways that we are reaching fusion, controlled thermonuclear fusion, in the United States and in the world today. The first one I want to touch on is what is going on at the National Ignition Facility, a part of the Lawrence Livermore National Laboratory, out in the Bay Area near San Francisco. **Figure 1** shows the target chamber. The outside is about three football fields in length, where you have a bank of lasers, 192 lasers, that are amplified hundreds of thousands, eventually millions of times; it starts out with the infrared wavelength and it will go all the way out to the ultraviolet. When they hit the chamber, you have the 192 laser beams converging on a small target.

This capsule is called the *hohlraum* (cavity, referring to its interior) where the lasers hit, and they hit the sides of the *hohlraum*, and produce x-rays that impinge on a small target about the size of an aspirin tablet at the center of the *hohlraum*, and the laser energy put into the target is over a million joules. A joule is equal to one watt of power lasting for one second. Let me give you an example. A superbolt of lightning produces about one million joules of energy.

So, you have a target, the size of an aspirin tablet, with two different isotopes of hydrogen: deuterium (one proton and one neutron), and tritium (one proton and two neutrons) brought up to high temperatures—close to 150 million degrees Centigrade, which is about ten times the temperature of the core of the Sun. You need sufficient density of the isotopes, and you need sufficient confinement time. Given those parameters, you can achieve fusion, and we have achieved fusion using this method. This machine at the National Ignition Facility, which is about ten years old, has been in operation for the last few years; it took about ten years to build.

What we have not achieved yet is to get more energy out of the reaction than it took to trigger the reaction; so it hasn't reached breakeven, or it hasn't ignited the fuel so that the reaction becomes self-sustaining.

The other method of producing controlled thermonuclear fusion on Earth is to generate a plasma and control the plasma with magnetic fields. Plasma is the fourth state of matter. You have solid, liquid, gas, and then plasma, where the particles of a gas are moving so fast that the nucleus and the electrons orbiting the nucleus become separated; so you have positive ions and electrons, called a plasma, which is electrically charged and therefore can be controlled by a magnetic field.

Lawrence Livermore National Laboratory

An inertial confinement fusion fuel microcapsule. It is two millimeters in diameter and contains a central reservoir of deuterium-tritium (D-T) gas mixture, a frozen D-T solid-fuel layer, and an outer ablator layer.

The most famous device for doing that is called the International Thermonuclear Experimental Reactor (ITER), which is being constructed now in southern France by a consortium of 35 nations. France, the European Union, the United States, Russia, China, Japan, Korea, and India all share in the cost of the ITER project. They probably need to recruit the North Koreans and the Iranians to help boost this along.

But it's a combined effort, a worldwide effort, to produce an experimental device that will go beyond breakeven. The goal is that within five years from now, by 2025, to be able to power up this device using deuterium and tritium as the fuel, heat the fuel, and with 50 megawatts of input to achieve 500 megawatts of output, so a gain of ten, for at least ten minutes. That's the goal of the experiment.

The Magnets

The type of magnets they use are not just your regular magnets, they're superconducting magnets. In order to reduce the resistance from running a current through the wires, in which you then generate the magnetic field, they cool the wires to close to absolute zero or close to –460 degrees Fahrenheit or –270 degrees Centigrade, colder than deep space. If you cool the magnetic coils to that temperature, you can have an increased strength of your magnetic field, you can contain your plasma, you can heat the plasma and achieve fusion. This is being worked on: There are machines at Princeton, at General Atomics in San Diego, and in Europe there is the Joint European Torus (JET). The Chinese are building a new machine, so are the South Koreans. This has been worked on all over the world for the last 60 years.

Recently, at the National Ignition Facility, one of the physicists there, John Moody, suggested to his colleagues that to accelerate the ignition using lasers, why don't we combine the idea of magnetic confinement of the target, with the use of lasers to heat and initiate the reaction.

It's called "magnetized inertial confinement fusion." If you have a coil around the *hohlraum*, you magnetize it by running current through it, and then you hit the *hohlraum* with lasers, and initiate the fusion reactions, heat the fuel elements in the tablet. With the magnetic field around this *hohlraum*, you will be able to contain the alpha particles (helium

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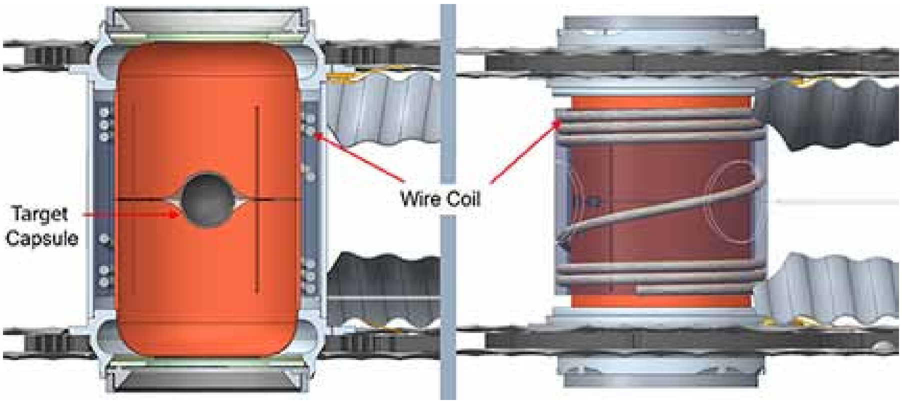
The National Ignition Facility. NIF is the world's largest and highest-energy laser system and the nation's largest scientific project.



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Conceptual diagrams of a NIF hohlraum *fitted with a B-field (magnetic-field) coil.*

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A coil-wrapped hohlraum *target installed at the end of a NIF diagnostic instrument manipulator.*

nuclei) that are generated by the fusion reaction.

And again, just to review, if you have deuterium and tritium—deuterium with two nucleons (protons and neutrons) and tritium with three—if you were to use basic arithmetic you would expect to get five nucleons. But, in nuclear physics, 2 plus 3 does not equal 5. It equals a smaller amount, maybe 4.95. So what happens to that missing mass? Well, it was through the theoretical work of Einstein, and others who followed him, that the conversion between mass and energy was recognized as energy = mass times a constant, namely the speed of light squared, or $e = mc^2$, which gives you a huge amount of energy for a small amount of mass conversion. We have seen that fusion involves a mass-to-energy conversion. So, if you can initiate that, containing it with magnetic fields increases the chance of reaching ignition. At Lawrence Livermore they are scheduling a series of experiments this coming summer to verify that.

So, if you think of all the work that's gone on, even without major crash programs to fund it, we have gone up toward the summit. We have achieved fusion, but we haven't achieved breakeven in any of these experiments—yet.

However, think back to powered flight. We took a major step, but it was a step of about 212 feet. If you think back to Goddard, we had the rocket, but it went up about four stories. You could have said then, "well, that's not success," but we built on those breakthroughs to achieve the aeronautics and the space program we have today.

International Collaboration

So think about LaRouche's Fourth Law. If we were to collaborate like we're doing with the ITER, and accelerate those programs, not only with the tokomak—the magnetic fusion—but also with laser fusion, then we could achieve breakthroughs. The French have a similar laser facility in France in which they have about half of the energy level of the U.S. Na-

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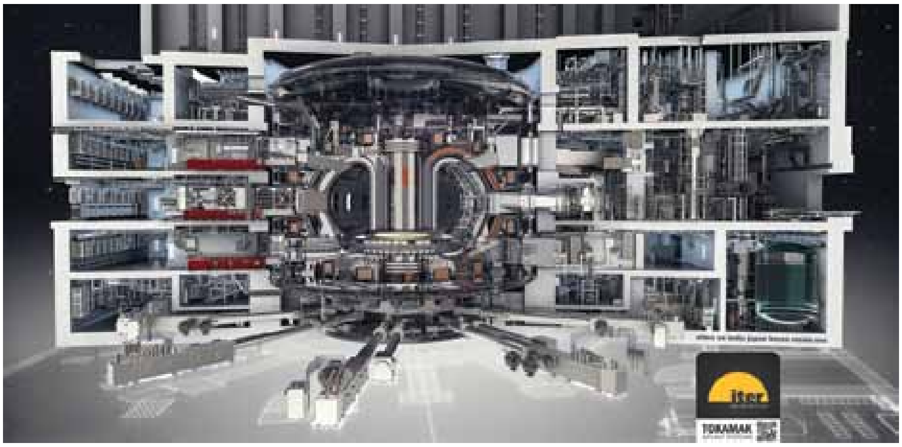
International Thermonuclear Experimental Reactor site at the end of 2019.



Oak Ridge National Laboratory

A cut-away drawing of the ITER tokamak and plant systems.

tional Ignition Facility, and they have achieved fusion, but again they haven't reached breakeven. So, if we accelerate these programs and combine them with the use of what's called high-temperature superconductors—there's a team near MIT, of MIT graduates, near Cambridge, Massachusetts, that has designed a smaller magnetic confinement system using high-temperature superconductors—then we could achieve significant breakthroughs.

The idea is that you can reduce the size of your magnets, using high-temperature superconductors. "High temperature" does not mean room temperature; it means you are going from almost absolute zero to 77 degrees Kelvin (minus 320 Fahrenheit), which is pretty warm when you consider that if you could achieve superconductivity at that temperature, you can have the same effect as we've had previously, but only by reaching almost absolute zero. The less resistance in a magnet, the stronger the magnetic field. We're talking about magnetic fields of five to ten tesla. Tesla, besides being a car, and a rocket company, is among other things, a unit of magnetic field strength.

To think about that kind of magnetic field, let's look at the unit used for the Earth's magnetic field, which is the gauss. The Earth's magnetic field strength is about half a gauss. The magnets you may have on your refrigerator door are about fifty gauss. If you go to the hospital and get an MRI, it uses about 50,000 gauss. Ten thousand gauss is equal to one tesla in magnetic field strength units.

So, with these fusion devices, we are talking about huge magnetic fields. If you can shrink the size of the magnet, instead of having an experimental tokomak the size of a football stadium, you could reduce the device to about the size of a truck, a flatbed truck. That's what they are attempting to do in Boston. There are about a dozen companies around the country that are implementing this idea of using smaller compact magnetic fusion devices to achieve what is being attempted with the large ITER. The one in Boston is being funded by the Italian oil company, Eni.

So you have funding for these various smaller experimental compact magnetic fusion reactors. There are a couple of them in New Jersey around the Princeton satellite system. Lockheed Martin, the major defense contractor, is working on a system; in California, you have Tri-Alpha Energy; a company in Vancouver, Canada called General Fusion, which is working on a system in which they compress the gas and use mag-

Steve Jurvetson

Microwave Energy Injector for Commonwealth Fusion Systems.

netic fields to heat the gas. They are experimenting with that to get compact magnetic fusion going. There is a lot of work being done around the country and around the world. The idea is to accelerate it to a crash program, to do what happened with powered flight. What drove us from going just 212 feet in one flight, to crossing the Atlantic, crossing the Pacific, and going around the world? Well, you had something, which came out of World War I. It was actually created before the U.S. got into World War I. It was called the National Advisory Committee on Aeronautics (NACA).

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Cathedral of Santa Maria del Fiore in Florence, Italy.

The Partnership

Before NACA, there were constant squabbles over patent rights. The U.S. government stepped in and created this advisory committee to help, not only to work out these patent disputes, but to promote the science of aeronautical engineering, aeronautical science, such as building wind tunnels. That was the beginning of what eventually became NASA. There was a role for the government in not only coordinating the breakthroughs, but you also had the flight contracts initially awarded by the U.S. Postal Service. Before there were passenger flights, the postal service started using airplanes to speed up mail distribution across the country. So, that was the government coordinating with private companies to promote development of a brand-new technology.

We can use similar methods: If you look at the Apollo project, the government didn't build rockets, but coordinated the construction of the various components that eventually got us to the Moon. That's the model that we could be using. LaRouche, in his Four Laws, shows how we can finance that type of breakthrough. You have to have the leadership to actually push for a real science driver. The dividends from actually funding these crash programs are quite impressive. Look at the spinoffs, the NASA projects, and the civilian nuclear power program, which was a spinoff of the Manhattan Project. We have that positive experience in our history.

President Donald Trump went back further than just a mere hundred years ago. He just gave a speech in Davos, and initially we weren't even sure if he was going to go there, because the whole theme of Davos—from Greta Thunberg to Prince Charles and Mark Carney—is the idea that we have to reduce our carbon footprint. We have to stop dirtying up the air and water, that mankind is just a pollutant, which has to be controlled. What's behind all that talk is population reduction.

LaRouche went back to the same period as Trump in his famous book, *The Science of Christian Economy*. It was written about ten years after the first book I showed you, *There Are No Limits to Growth. The Science of Christian Economy* was part of his prison writings. LaRouche was in prison from 1989 to January 1994, and he kept himself busy, by writing one book after another. You see what he chose for the cover of his book was the *Duomo,* the cathedral, in Florence, Italy.

President Trump Echoes LaRouche

Just a week ago, President Trump went to Davos in the middle of this environmental suicide pact; he introduced the thought that a few hundred miles from the Davos Congress Centre in Switzerland, you have examples of what mankind has done, by looking up, instead of digging in the mud, by looking up to the stars. Trump touched on the cathedral in Florence; he said that the cathedral's dome was not built in a day; the construction of this dome began in 1296, and it wasn't completed until 140 years later. In between you had the Black Plague, wiping out whole villages in Europe. Add to that, that the people who initiated this project didn't have any idea how they would actually build the dome.

They began construction nonetheless, and initially built an octagon base that went up to a certain height. But it was Filippo Brunelleschi who figured out how the dome could be constructed without using all the timber in the entire region around Florence as a supporting structure. He used the catenary principle to build this dome, and it was completed. Imagine the President of the United States using this image, and saying that instead of listening to the doomsayers or saying that we have reached the limits to growth and we have to cut back, left and right, that mankind is not governed by the doomsayers, but by the visionaries. While the people who began this project did not have an idea of how to actually complete it, just like today, we don't have the exact method of how we're going to achieve break-even fusion, but we have a goal and we know what it's going to take to get there.

public domain

Visitors stand atop Brunelleschi's dome.

This project, over 140 years, to build the largest dome in Europe, was the center of what Nicolas of Cusa organized as the Council of Florence, which was really the beginning of the Renaissance, the breakpoint from the Middle Ages into the modern era. If you look at the very top of the dome, the sphere at the very top of the cathedral was designed and constructed by Leonardo da Vinci and his collaborators. We can see that the whole of the European Renaissance gave us the science that allowed for a much greater capacity to feed and clothe a larger population, which led to the breakthroughs of Kepler and Leibniz, Riemann, and eventually Einstein and Planck.

The Renaissance as a Paradigm of Creativity

This European Renaissance is what we should use as our model, instead of the flagellants and the doomsayers that we have with the global warming fraud, which seems to still dominate the world of science. Speaking of the world of science, you may have heard that the minute-hand of the Doomsday Clock has been moved up closer to midnight. This was done recently by the Union of Concerned Scientists, which is now headed up by that "great scientist" Jerry Brown, better known as "Governor Moonbeam." You have a pessimism that has taken over the scientific community. What's taught in most colleges now, most universities, as "science" is rubbish; they no longer have civil engineering programs, you have "environmental science," and the whole focus is how to reduce our carbon impact, our carbon footprints. Very little funding, just a small amount, is going towards breakthrough technology for the future.

So, for the President to use this Renaissance example, which LaRouche had used repeatedly over the last 30 to 40 years, shows you that our ability to get the Presidency—and nations like China and Russia and the real thinkers in Europe, Africa, and South America—to collaborate on these great projects, shows tremendous potential. He's showing the way; he might not know how to complete the project, but he's at least pointing you in the right direction. That gives us an idea that we too have a tradition, a Renaissance tradition. We merely have to look back just at the last hundred years, look back at the history of powered flight.

If you think about it today, every day almost 2 million people board an aircraft just in the United States. If you think back to the turn of the 19th into the 20th century, how many people thought we would achieve controlled, powered manned flight? If you think of the steps we took from powered flight to landing and walking on the Moon and returning safely, it was only a mere 66 years. And, think of how long it took to build the cathedral dome: 140 years. I'm sure that if we use the examples of the past, we can get to controlled thermonuclear fusion in the coming ten years, and we can actually beat the record of the building of the dome by a great number of years.