I. Advance Nuclear Fusion

INTERVIEW: PAUL GALLAGHER

Fusion Power Can Be A Lot Closer Than You Think

Jason Ross interviewed Paul Gallagher for The LaRouche Organization, Jan. 18, 2023, on recent breakthroughs and advances in the development of fusion power. This is an edited version of the video interview; subheads have been added.

Jason Ross: Nuclear fusion is the breakthrough of the future, hopefully the near future, that will do more than any other to transform the potential of the human species. This would mean harnessing the power that creates the light and heat and energy of the Sun, and using it to power our needs, to transform our relationship to mining, materials, water, energy, transportation, you name it. A recent breakthrough at a facility in California known as the National Ignition Facility, has garnered a lot of media attention; there's a lot of excitement about this. So today I'm going to be interviewing Paul Gallagher, who is the Economics Co-Editor of *EIR* and a former Executive Director of the Fusion Energy Foundation.

So let's jump right in about this breakthrough at the National Ignition Facility: What does "breakeven" mean? What happened?

Paul Gallagher: I think the most significant fact here is that this facility at the Lawrence Livermore National Laboratory has been experimenting for quite a long time, and very suddenly, over the past two years, in a series of experiments, achieved a 50 times—not 50%, but 50 times—improvement in its results over just a series of three or four "shots" or experimental operations of its fusion device, or its laser device. That's a tremendous surge of progress towards the achievement of fusion energy. And it included, in the process, for the first time ever in any fusion experiment anywhere in the world, the fact that the laser-and-fuel-target device produced more energy out, more power out, than the lasers put in. So it went beyond breakeven by about 50%—3 megajoules [generated] compared to 2 megajoules of laser power in….

So despite the fact that the facility was built in order to do work for the military, nonetheless this is really a very important signal that fusion power could be coming close—a lot closer than people think. And it's a signal which applies to many fusion R&D lines even though they may not have the same kind of device, the same kind of design that's involved here.

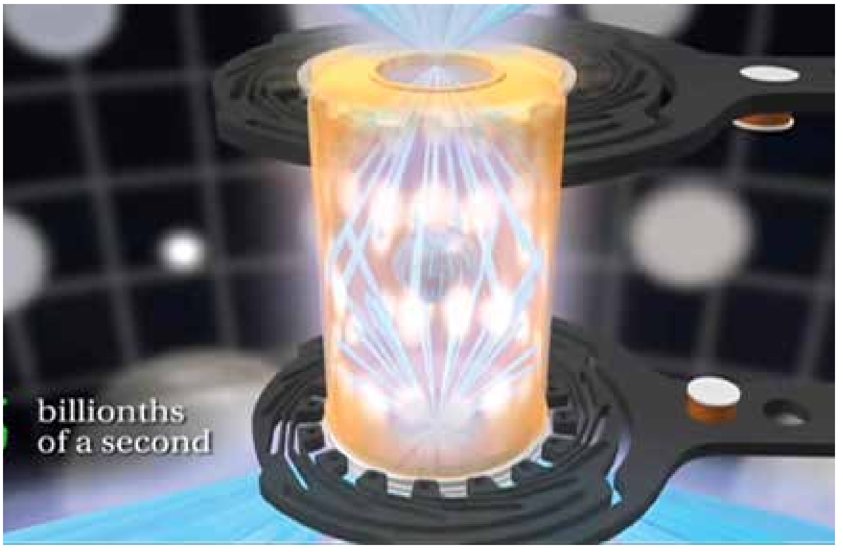
Justifiably, this was reported in scientific press and some popular press around the world, and a press conference was held by the Department of Energy, involving a lot of the team leaders from this National Ignition Facility—the Secretary of Energy Jennifer Granholm, four or five of the Washington agency heads responsible for funding this program, and the overall director of the program. This was, again, unprecedented….

A Transformation of Results

Ross: So, the National Ignition Facility is a California facility where 200 lasers all converge on a tiny fuel pellet, and that's where the fusion happens. What's fusion? What's actually happening inside that pellet? And then I want to ask you what this has to do with national defense.

Gallagher: Figure 1 shows a schematic of it. It is a laser array which is huge; it's also old. The laser array was built up in the early 1990s, using 1980s technology. But it produces a tremendous amount of laser power. It's close to 900 feet long, this array of lasers, and it all comes to a focus into the two ends of the cylinder that you're looking at, a very small cylinder wherein there is

FIGURE 1



Lawrence Livermore National Laboratory

beams—but here, definitely by lasers. This effectively is a hybrid of the two. The addition of this magnetic field is only true for the last two years or so and it coincides with the extraordinary advance in the results they got. There was an article [in the American Physical Society's *Physical Review Letters* — ed.] describing this just before the Dec. 5 experiment which achieved breakeven, how the addition of this magnetic field had increased the heating already before this latest test, by 40%, and had tripled the amount of energy actually generated (**Figure 2**). Then with the Dec. 5 experimental shot, the results got still much better than that, and you actually had this 50% above breakeven.

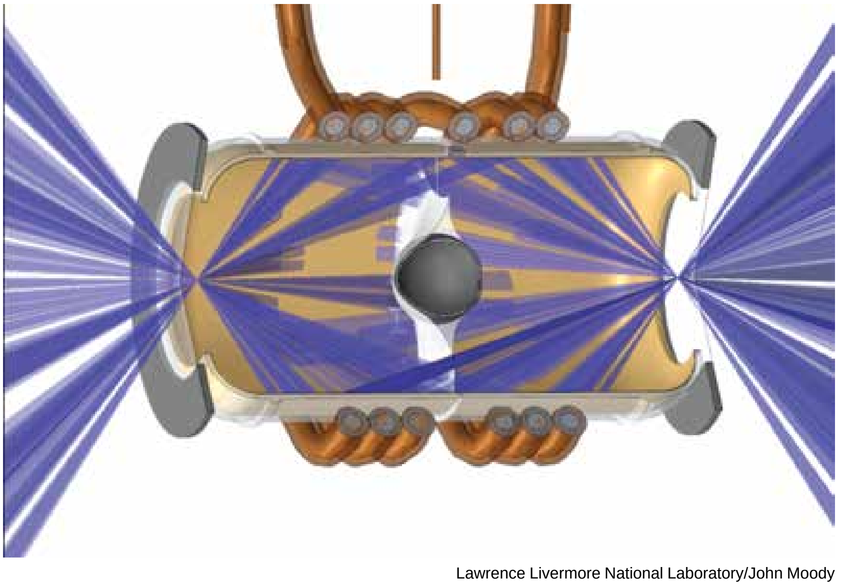
a much smaller pellet of fuel, represented here as white—it's actually silver, it's a diamond pellet—which has deuterium-tritium [isotopes of hydrogen— ed.] fuel in it.

As you can see here, the lasers are not directed on the fuel pellet, but rather on the walls of that little cylinder. And what that does, is it generates an x-ray flux, a very precise and symmetrical x-ray flux from all directions, and it is that which causes the pellet of fuel to shock-compress very, very rapidly, and essentially implode and then explode with energy. In addition, what's not shown here … there was a strong electric coil arrayed around this cylinder in such a way as to create such a strong magnetic field around it, that it further compressed the exploding fuel so that the explosion did not result in the sudden expansion and cooling of the whole superheated fuel [plasma], but rather compressed and kept in that energy.

So, in effect, a *hybrid* of magnetic confinement, that we usually think of in terms of the *tokamak* design, where the superheated plasma is confined by magnets; and on the other hand, inertial confinement where the superheated plasma is confined in a shock manner by lasers or conceivably other kinds of

Ross: You said this was a combination of the two different techniques which have been applied to make fusion happen: inertial confinement fusion and magnetic confinement fusion. In the Sun, the way that fusion happens is that the smaller nuclei are pushed together just by the fact that the Sun is so huge, and gravity pulls everything together. And for the National Ignition Facility, the initial design was pretty similar: The lasers squash everything together. Is this the first experiment, to your knowledge, that's really combined

FIGURE 2



Lawrence Livermore National Laboratory/John Moody these two approaches?

Gallagher: There are a large number of different designs of magnetic confinement fusion. People are generally familiar over the years with drawings and pictures of *tokamaks*, these doughnut-shaped, or lately more spherical-shaped chambers, in which there are magnets on the poloidal direction over the poles and also magnets on the toroidal direction around the *tokamak*. But there are many, many other magnetic confinement designs.

FIGURE 3

wnn
world nuclear news

Energy & Environment | New Nuclear | Regulation & Safety | Nuclear Policies | Corporate | Uranium

Chinese tokamak achieves Super I-mode

09 January 2023

A new mode of improved plasma confinement has been demonstrated at the Experimental Adva Superconducting Tokamak (EAST), the Hefei Institutes of Physical Science, Chinese Academy o Sciences announced. It said the new high-confinement and self-organising Super I-mode "repre the reliability and advancement of the machine itself but also offers insights into how to better maintain the plasma operating stably and for long duration".

I think what is really the key here is that even though this is not the first time in which the two methods have been combined—this was something that the Fusion Energy Foundation was writing about and promoting in 1975 within a year after it was founded at the initiative of Lyndon LaRouche….

Perfectly Confined Plasma in China

Ross: One of the other major breakthroughs in fusion was in that magnetic confinement approach. This occurred not in the United States, but in China, in the EAST [Experimental Advanced Superconducting Tokamak —ed.]. They also set records in the past couple of years. What happened there?

Gallagher: Figure 3 shows an article from Jan. 9, "Chinese Tokamak Achieves Super-I Mode." This is an experimental machine which the Chinese developed at Hefei, and is intended to work very closely with the very large International Thermonuclear Experimental Reactor (ITER) in France, a *tokamak* which is being built—with many delays, unfortunately—by a coalition of 35 countries…. This Chinese *tokamak* also has international scientists working on it. It's been acting as a kind of test bed for what's supposed to happen on the ITER. But on its own, with good funding from the Chinese government, and a lot of international participation from scientists and engineers there, it has achieved an extraordinary result.

They have been able to generate a superheated plasma, keep it completely stable with magnetic fields for nearly 20 minutes. In other words, it's been hot enough for more than long enough—it has only not been dense enough, to get breakeven in the way this Livermore experiment just did. That [Livermore] experiment kept that little pellet of fuel hot enough and *dense enough*, for long enough, for the fuel actually to ignite, and to burn on its own and produce more energy out, than in. This *tokamak* has gotten the plasma hot enough—in this case a plasma temperature of 130 million degrees [Fahrenheit, or approx. 70 million Kelvin] was eventually reached for what became an almost 20-minute confinement of a plasma which remained quite calm throughout the entire length of this … pulse.

And it was kept entirely confined. Now, in the past they've been able to keep confinement only of the denser inner part of the plasma, while the edges of it would break away from the plasma and slam into the walls of the experimental machine. This EAST *tokamak* kept that confinement, not only in the center or the "deep plasma" but also around all of the edge of it…. It obviously was "confining itself"; it became a self-organized plasma.

So, this was also very important…. They could have kept going longer if they had wanted to, and they will. This now stands with only the "dense enough" still to be achieved. This EAST *tokamak* is, in a way, beginning to do the job that the big ITER in France was intended to do, and has been delayed, and delayed and delayed.

We have that in terms of magnetic confinement, that's a real breakthrough, too.

Ross: …The opportunity for collaboration with Chinese scientists has really taken a hit for Americans and for the U.S. in recent years, with the FBI going after

Chinese scientists or Americans of Chinese descent working with Chinese scientific institutions. In the space program, with the Wolf Amendment, the Congress has essentially forbidden cooperation on crewed space [missions] between the U.S. and China. How international in scope is the EAST research in China? Is this something that is open to scholars from other countries?...

Gallagher: This is a pretty transparent program. There are scientists and engineers at least from Russia, Korea, India, Australia and Germany working there, and it is also transparent about its results. This is a crucial element of international cooperation in fusion of the kind that the Fusion Energy Foundation put forward already in 1979 and 1980 as the way that fusion could be achieved: Fund it with sufficient funding so that there could be robust experimentation going on as rapidly as possible in many parts of the world; that all of this work be transparent and cooperative in the sense of the results being discussed as soon as they were achieved and confirmed … so that [scientists] could apply what had happened to their own work.

This has not been the case. Especially now, both a great deal of additional funding is required to make these advances real, and it is necessary to break down the absurd barrier that now exists between fusion work in the United States and in China. If the heads of Chinese programs come to an international conference to describe what they have been doing, then U.S. scientists are not supposed to be at that same conference….

Cooperation for Power, or Competition for Weapons

Ross: When you think about the benefits, both from more funding but also from being able to share research, so that there's not unnecessary duplication of effort, or the opportunity to learn from each other—I want to read a paragraph here from a speech at the United Nations, by John F. Kennedy, on Sept. 20, 1963. It's not about fusion, and not about China; but it's about space, and the Soviet Union and international cooperation on it. Kennedy said:

> Finally, in a field where the U.S. and the Soviet Union have a special capacity, in the field of science, there is room for new cooperation, for further joint efforts in the regulation and exploration of space. I include among these possibilities, a joint expedition to the Moon. Space offers no problems of sovereignty. By resolution of this Assembly, the Members [of the United Nations —ed.] have forsworn any claims to territorial rights in outer space or on celestial bodies, and declared that international law and the UN Charter will apply.
>
> Why, therefore, should man's first flight to the Moon be a matter of national competition? Why should the U.S. and the Soviet Union, in preparing for such expeditions, become involved in immense duplications of research, construction and expenditure? Surely we should explore whether the scientists and astronauts of our two countries—indeed, of all the world—cannot work together in the conquest of space, sending, some day in this decade, to the Moon, not the representatives of a single nation, but the representatives of all countries.

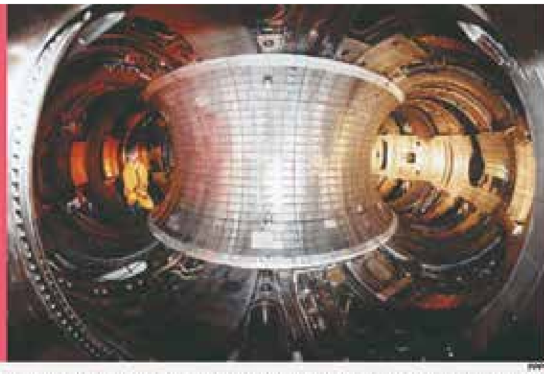
That outlook, I guess, is embodied … in the ITER project in France, which is a large international consortium. Of the projects you've mentioned so far, the National Ignition Facility is related to a weapons project. Is that not where it gets most of its funding?

Gallagher: This is where it gets all of its funding, through the National Defense Authorization Acts and the National Nuclear Security Agency at the Department of Energy…. Fifty years or so ago—people know, perhaps, that if a thermonuclear weapon were to be exploded … when they used to test them, the thermonuclear fusion fuel is effectively surrounded by fission fuel, the fuel for an atomic bomb. The detonation of that fission fuel is what causes the thermonuclear explosion, with such incredible power, to occur. It also means that a great deal of radioactivity is scattered with it.

Initially, 50 years ago, this program began as an attempt to ignite very small thermonuclear explosions with lasers, rather than plutonium…. Then 30 years ago, when the Comprehensive Nuclear Test Ban Treaty was being negotiated, and it eventually was ratified in 1996, … they began converting this program so that it could "virtually" test the reliability of nuclear warheads without actually exploding them…. And that means being able to develop diagnostics of incredible precision and speed, which would enable the condition of these warheads … to be kept reliable.

So that's been its purpose. Now, the scientists there, I am sure, also know that they are getting certain scientific results which have direct bearing on achieving fusion energy…. They are clearly conscious now of the fact that they are showing that fusion ignition and fusion breakeven are not only feasible, but are getting very close to being demonstrated. Even though they know that this huge football-field laser array is not any kind of prototype for a fusion power plant—and will not be—nonetheless, what's occurring right in that compression chamber, where the fuel is actually detonated by the lasers and the x-ray flux, … is very important to the entire worldwide field of fusion development.

FIGURE 4


PPPL

Inside the Tokamak Fusion Test Reactor at the Princeton Plasma Physics Laboratory, while it was in construction. The TFTR set world records for plasma temperature and fusion power produced in the late 1980s and early 1990s. But budget cuts closed it down before all its planned experiments were completed.

The True History of The U.S. Fusion Program

21st Century Science & Technology magazine

And in fact, the Secretary of Energy claimed it in her press conference on this breakthrough, when she said that it was good news for a "decadal" intention of the Biden Administration—that is, within 10 years—to commercialize fusion energy. I'm sure this was news to a lot of people, that they were going to commercialize fusion within a decade with this invisible level of funding. Nonetheless, there's no question in which direction this research is rapidly going now, although its purpose is still testing nuclear warheads.

Fusion Program Suppressed for Decades

Ross: On the scale of funding: The National Ignition Facility is like a half-billion-dollar facility, right? Hundreds of millions have gone into this?... In the U.S., what's the level of public funding for fusion?

Gallagher: Well, this is very different from what people think. Everyone thinks that they have read, and that they know, that for 50 years or more, fusion research and development has been failing to meet its goals, and has been constantly very distant in the future, and that despite the money which has been thrown at it, it hasn't achieved much of anything in the way of progress. This is false.

I would refer and rely on one of the leading authors about 20th- and 21st-Century space and fusion technological advances, Marsha Freeman, who was also one of the founders of the Fusion Energy Foundation when Lyndon LaRouche launched it. She has become a very widely published and known author and expert on this. An article that she wrote, now nearly 15 years ago, made clear that there was *never* any serious funding of any serious degree of a fusion R&D program which could *ever* bring commercial fusion any closer (see **Figure 4**).

The fusion energy budget was about $550 million annually of combined Federal funding of R&D—that was in 1978 and 1979. In 1980, through the efforts of Congressman Mike McCormack and the Fusion Energy Foundation and others, an act was passed, the Magnetic Fusion Energy Engineering Act of 1980, which assessed that $20 billion was needed over the next 20 years—that is, until 2000—and a very robust program of international cooperation, transparency of results, and pursuing *all* the different designs and tracks of fusion R&D at once, in order to get to commercial fusion, a demonstration reactor, before the year 2000.

In fact, exactly the opposite happened. That budget of $550 million at the end of the 1970s became $444 million by 1983. It became $325 million roughly at the end of the 1980s and early 1990s; it was $286 million in 2008 just before the financial crash; and in the current fiscal year it is scheduled to be $117 million.

Ross: Wow! That is astonishing.

Gallagher: That in itself, combined with the fact that the Tokamak Fusion Test Reactor at Princeton, for example, which achieved extraordinary results—[plasma] temperatures much higher than you hear about now, 500 million degrees Centigrade—that was shut down after achieving these results. The superconducting experiment in Texas was cancelled without ever operating. What's called the plasma mirror experiment at Livermore was cancelled without ever operating.

Because you had, now, Malthusians, epitomized by James Rodney Schlesinger, who was the Department of Energy head in the Reagan Administrations, Malthusians who wanted deliberately to cover up any achievements in fusion research and wanted to starve fusion of funding. Because unlimited power, to them, suggested unlimited people and unlimited living standards for those people. They were not for that kind of growth. They were for confrontation and war with Russia. And they just killed it. Throughout this entire period of the last 50 years, there has never been serious funding in the United States, which once was by far the world's leading program….

Now, the $117 million for non-military fusion research funding by the Federal government in this fiscal year is going to compare with $641 million for that Livermore National Ignition Facility, because that funding comes under the National Defense Authorization Acts and has the primary purpose of testing the reliability of nuclear warheads on weapons. That's … almost six times the combined support for all the other fusion R&D efforts.

Pushed into the Private Sector

Ross: What a powerful statement of what the intent is. Now, hearing about some of these breakthroughs makes me wonder, as a person who was born in 1980, what should have already happened? These breakthroughs are great, but when you put them in the context that the people running the program in the U.S. … didn't really want fusion power. Those numbers you went through—it's like the only part of the Federal budget that's shrinking!

Gallagher: No, it wasn't the people who were running the fusion program. In fact, some of them, in that period, demonstrably resigned. Dr. Edwin Kintner resigned in the early 1980s, it may have been as early as 1981, because breakthroughs that were comparable to the one I described at the beginning, occurred in the Princeton Plasma Physics Laboratory and in the Tokamak Fusion Test Reactor, [and] were absolutely suppressed by the people controlling the funding at the top of the Department of Energy. They were the ones who wanted to make sure that this kind of progress slowed down to a crawl and then stopped, and that the public didn't know about it….

Here we are 40 years later, and there has been no serious funding and drive to really test the feasibility of fusion since then. So the idea that you've heard, that fusion has been floundering around for 50 years despite money being thrown at it—and I know that President Biden reiterated that when he put out his statement last March and talked about "70 years of public funding of fusion." Seventy years of public *denial of funds* for fusion is what has happened.

Just think of the amount of funds that are thrown into defense—$850 billion per year now, $112 billion already authorized and more than half of that already appropriated and spent for Ukraine in the NATO war against Russia. And here we're talking about $117 million. This is awful.

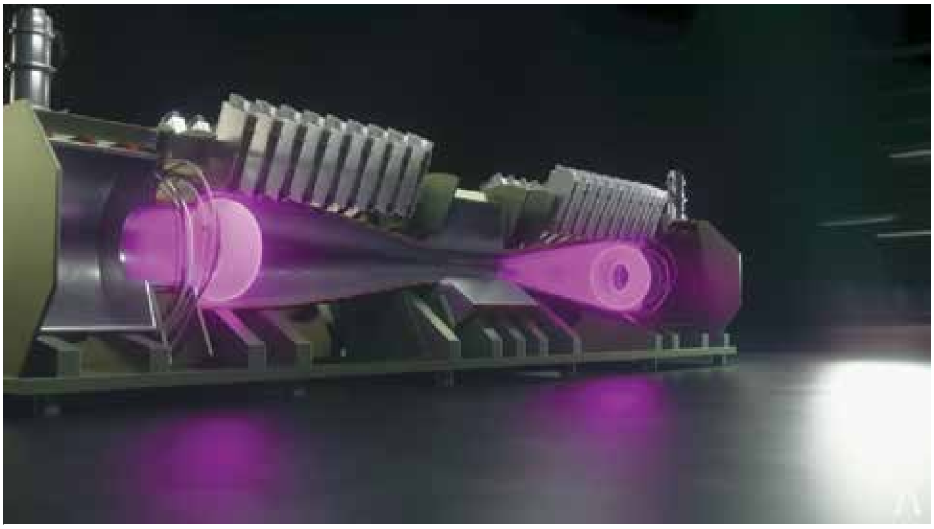
Ross: But you think about defense: How about defense against energy poverty and everything that that entails, against malnutrition, under-development, undernourished people around the world, the lack of access to health care, clean water, all of this.

Let me ask you: There are a lot of people who are extremely excited about this field, who are gripped by an impassioned sense of the potential that fusion holds; and a lot of these people are not necessarily waiting around for public funding. There are private companies getting involved in this as well—if you could make a breakthrough on this, this is maybe a potential way to make a fortune, among other things, as well as really contribute something to humanity. What's the status of private investment in fusion research?

Gallagher: In the last couple of years it has dwarfed public funding, on the order of $5 billion in new investment that has gone into more than a dozen private companies working on fusion designs of many different kinds, and funded by venture capitalists, by billionaires and so on…. They are making these investments in a whole series of lines [of research].

There was—I think as part of the aftermath and the

FIGURE 5



Real Engineering/Brian McManus

excitement on the breakeven and 50% better than breakeven that was achieved in the National Ignition Facility program—a video released just a few days after the [Dec. 13 —ed.] press conference about this. It was *Real Engineering* magazine that made the video, but they made it with a company called Helion Energy in Everett, Washington. This is one of a number of these private efforts which are not pursuing laser fusion, and they're not pursuing *tokamak* designs either. They're pursuing other kinds of designs which have been around, and have been—let me put it this way: They're as old as the Fusion Energy Foundation! These designs have been worked with since the pioneers of fusion research.

Another Design: Magnetic Pinch

One of these designs is given a number of names: I would call it a reversed-field magnetic pinch. **Figure 5** is one picture from that video. This video has been seen now most recently by about 4 million people. It's 30 minutes long and extraordinarily detailed; and this is new for the private fusion programs. They are proprietary; they are not set up to share their results in detail with other fusion companies and fusion programs; they are pursuing what they hope will be commercializable results within a short period of time. So it's extraordinary, I think, that a video involving a very detailed interview and demonstration of all parts of the facility by the CEO of it, that that would appear and get such wide circulation. That's a very good thing.

What you're seeing here is a long—perhaps it's 20-30 meters—cylinder with two symmetrical ends, two shrinking ends of this cylinder. And these coils are generating very strong magnetic fields, and particularly here in the middle. And what you're seeing here is plasmas which have been generated at either end by fuel being injected and trapped and heated magnetically—to relatively low temperatures for this, a million degrees [Centigrade —ed.] or so. At this point in the video, these two are just beginning to be accelerated towards each other at millions of kilometers per hour speed until they collide in the middle.

FIGURE 6

Office of Science

Department of Energy Announces $50 Million for a Milestone-Based Fusion Development Program

SEPTEMBER 22, 2022

This new public-private partnership program is the first step toward realizing the Administration's bold decadal vision for commercial fusion energy

WASHINGTON, D.C. – Today, the **U.S. Department of Energy (DOE)** announced up to $50 million to launch a new milestone-based fusion development program as authorized in the Energy Act of 2020. This program will support for-profit entities, who may team with national laboratories, universities, and others to meet major technical and commercialization milestones toward the successful design of a fusion pilot plant (FPP) that will help bring fusion toward technical and commercial viability. The program is informed by recent reports from the Fusion Energy Sciences Advisory Committee; the National Academies of Sciences, Engineering, and Medicine; community workshops; and input from private industry.

U.S. Dept. of Energy

And as they collide with each other they are very strongly compressed by the magnetic field in this center area, and also by the fact that the cylinder itself is shrunken in that area. The magnetic field lines become more and more and more compressed and they, in turn, compress the plasma—the electrons and positive ions in the plasma.

What you're trying to do here is combine a very strong magnetic field with an ionized plasma which is, in effect, a current, and therefore to create another electrical current *directly*—not to produce neutrons which produce heat which produce steam which produces rotation of a turbine around a magnetic field, which then produces a current—rather directly to produce a current in this central "combustion chamber," if I may call it a combustion chamber here….

The more frequently you could achieve this collision of the two plasmas, while they're being very rapidly heated from a million degrees up to 100 million degrees and more; the more frequently you could do that per minute, per second, the more "piston-like" production of energy and electric current from that central chamber could take place.

In addition, they're using a fuel combination of deuterium and helium-3, which in itself has been known for many, many years to be the best fuel for fusion reactions, because of all of the charged particles that are in that plasma, and the relatively low energy involved in neutrons in that plasma. That means that those charged particles can be easily confined by magnetic fields, and can be directed.

So this kind of magnetic pinch, I would call it, is characteristic in one way or another, I think, of a number of these private companies. I think you can begin to see a certain similarity between the lasers coming in at the two ends of the cylinder in which that tiny pellet of fuel is contained in the … National Ignition Facility, and the way in which the two plasmas are being accelerated to smash into each other and be magnetically confined in this central chamber. Especially now that the Livermore experiment has included a strong magnetic field (see **Figure 2**) to confine that exploding fuel.

I think we're really getting somewhere here. And if these things were simply being shared widely and had the funding to accelerate what they're doing—given the fact that they are private companies—nonetheless, if enough effort is given to that, it accelerates it further….

'Worthy Goal for All Humanity'

But again, it's almost laughable to think of the venture capitalists and billionaires having put almost $5 billion in the last two years into this, while the Federal government is putting $117 million.

And let me show you one other thing. This (**Figure 6**) is in September of last year, just before that latest breakthrough. This is also the Department of Energy. And they're announcing "a milestone-based fusion development program" of $50 billion? Nope, $50 million—and it's not clear from this, over how many years that $50 million is supposed to be disbursed. And as it says:

> The program will support for-profit entities who may team with national laboratories, universities and others to meet major technical and commercialization milestones.

That is definitely the right way to do it, if you confine yourself to the United States. But these universities are all over the world, and so are the national laboratories of laser energetics and plasma physics all over the world and in what is probably the most dynamic program at this point, that of China. This approach needs not $50 million, but at least the $5 billion—a year—of this private venture capital in the last two years. And it must be a global, international cooperative program.

I'd like to read you, again, this comment from Marsha Freeman, whom I cited earlier. She said about this, just today:

> For decades, men of science and engineering and people of vision have been imagining what the harnessing of fusion power would mean for the future of mankind. It was recognized, that with a fusion-propelled spaceship, an explorer could study any and all of the planets *in situ* over the course of his single lifetime, and achieve that goal of the father of all human space travel, Hermann Oberth, who said the goal was "to make all worlds habitable." That, as further breakthroughs are made in fusion power, is a worthy goal for all of humanity.

I think that's as good as I can say.