FUSION ENERGY SYMPOSIUM

'Commercial Fusion Not Soon Enough' Says NJ State Sen. Joseph Pennacchio

by Marsha Freeman and Suzanne Klebe

June 1—A most extraordinary symposium on fusion energy development took place on Thursday, May 23 in the New Jersey State Senate in Trenton, sponsored by senior Senator Joseph Pennacchio (R-26). It was titled, "What Are the Prospects and Requirements for the Early Development of Fusion Energy, and What Are the Implications for the U.S., New Jersey, and the World?" The symposium brought experts in the field of fusion energy research together with state political representatives, students, and interested citizens.

The invitation announced:

> Achieving commercial development of fusion energy would revolutionize the international economy. It would signal a new era of economic and scientific development world-wide. July 20 is the anniversary of the American achievement of landing men on the Moon. What better time to assess the needs and funding for a new great achievement by the United States, and now with other countries around the world?
>
> Experts from national laboratories, businesses—including three New Jersey businesses working on fusion energy development—and researchers in the field will present their work, and share their knowledge of what is being undertaken, and what lies ahead.

The enthusiastic response by the fusion researchers was clear evidence of the great interest, as well as curiosity, in this invitation to the scientific community from a State Senator to discuss fusion.

Symposium Participants

The symposium was attended by 80-100 people from across the state, despite incredible travel difficulties and problematic weather. Chairmen of physics departments from several universities attended, as well as graduate students in the field. Schiller Institute members, and one class of high school students from a nearby school, were in the audience as well. (The appearance of the students drew comments from the podium.) A faculty member from a college physics department, who could not make it through the traffic chaos, emailed from the road to say she was contacted by her dean, who was attending a fusion conference in Japan, and told to be sure to attend.

Art Murphy

Sen. Joe Pennacchio opening the May 23 Symposium on fusion in the New Jersey State Senate. To his right is Dr. Michael Zarnstorff, Princeton Plasma Physics Lab; to his left is the moderator, Marsha Freeman.

A person with a program that puts scientists on legislators' staffs was there, as was a nuclear energy department chair, who had been the docent of a program in Russia some years ago. Another physics department head said she was very concerned about the lack of understanding by the average American on questions of science.

The vice president of one of the companies partici-

Institute for Plasma Physics, Chinese Academy of Sciences

Support for China's fusion program comes from the top. Here, President Xi Jinping on one of his visits to the Institute for Plasma Physics, in April 2011.

pating in the symposium had arranged a tour of the Princeton Plasma Physics Lab at the conclusion of the symposium. More than 20 people attended the excellent tour. One of those who went on the tour, Jose Vega, from the Bronx, who had recently been a student, noted that the environment of constant experimentation and involvement of students and older scientists together on projects of all kinds was the way education should be pursued.

The responses, questions, and extended discussions with the scientists after the formal presentations, by members of the audience, indicate how quickly the United States could enthusiastically re-establish its "technological optimism."

Senator Pennacchio, minority whip of the State Senate, has been a long-time enthusiast for developing fusion energy. In his opening remarks, Sen. Pennacchio noted:

> What got me thinking about doing this [symposium] was that recently the Chinese landed on the far side of the Moon. And the Chinese did not go there for sight-seeing. Among probably some of the priorities that they had was to look at mining [helium-3] . . . as an intricate part of one of the processes as applied to fusion energy.
>
> For me, [developing fusion] is important because I can imagine a nice clean, safe, source of renewable energy—for which elements can be gotten from our oceans, or even from our Moon, that can supply humankind with an infinite amount of energy. Imagine if this energy—this is special now—imagine if it had bipartisan support; imagine if it had the support of the environmentalists; imagine if countries like the United States, Russia and China and Europe worked together. . . . [T]hat is the promise, and that is what is currently happening with fusion energy. . . .
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> It has been estimated that by 2025 we could have a sustainable fusion reaction, and commercial applications somewhere around 2050. That, in my humble opinion, is not soon enough.
>
> The problems that we have . . . for instance in space travel—we have to get a new propulsion system that can overcome those challenges—one of the ways to allow intergalactic and interplanetary travel in the future.
>
> Imagine the benefits that men and women can reap from its development, and not only the main energy application of fusion, but the ancillary applications, like we had with the space program.
>
> Myself, and the other legislators in this building—we need to know how we can help that; how can we nurture and help this game changer come into being.

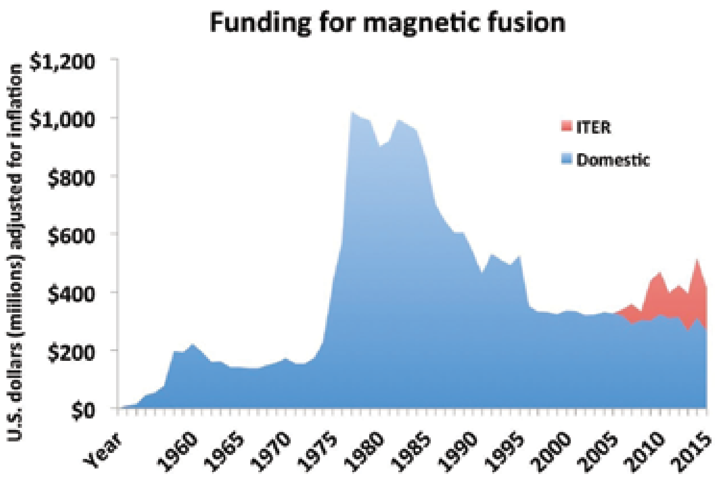
Why Don't We Have Fusion?

The symposium was addressed by a distinguished panel of scientists, who put forward some of the creative solutions—now under development—to the challenges raised by Senator Pennacchio.

Art Murphy

Following the Symposium, approximately 20 people toured the Princeton Plasma Physics Lab.

FIGURE 1



Speakers presented different and sometimes conflicting approaches to fusion development—a point of interest to the audience and members of the panel. Papers, statements, and literature were contributed by the University of Wisconsin's Fusion Technology Institute; MIT's Plasma Physics Department; the founder of the Alcator Project; and the US-ITER office in Oak Ridge, TN.

Marsha Freeman, Technology Editor for *EIR*, was invited to moderate, and also to speak on China's fusion program. Freeman began the session by posing two questions: "Why do we need fusion, and why don't we have it?"

She answered the first question by explaining that fusion, as an energy source, offers an energy-flux density that is orders of magnitude higher than any "competing" source. Fusion also creates an entirely new platform for science and the economy, through plasma applications. This new platform includes creating a new source of fuel with fusion/fission hybrid reactors, new materials processing capabilities, and the fusion torch. Freeman added that we will have unlimited science and exploration opportunities with fusion propulsion, as noted by Sen. Pennacchio.

As to why we don't already have fusion, Freeman showed the graph of federal funding for fusion research from the 1950s (**Figure 1**). For the past four decades, the level of support for research has been on a trajectory so drastically low, that the United States would never reach a viable demonstration of fusion as an energy source. She presented a dramatic picture of what has been lost during these lost decades in a table of fusion experiments and facilities (**Figure 2**) that were planned but not built, halted before completed, or completed but never turned on. The list was compiled by Megan Beets of the LaRouche PAC Science Team.

FIGURE 2

Devices and Capabilities Lost Since the 1990s

Date of Shutdown	Experiment	Location	Description
1990	LSX FRC	Math Sciences Northwest	A brand new facility and experiment at a commercial company under contract to DOE.
1990	Tandem Mirror Machine (TARA)	MIT	A mirror machine experiment at one of the nation's premiere university fusion programs.
1990	Compact Torus Spheromak Experiment (CTX)	LANL	Leading facility in the world looking at the spheromak, a potentially simpler magnetic geometry than the tokamak.
1990	Advanced Toroidal Facility (ATF)	ORNL	The first major stellarator in the U.S. built to study steady-state sustainment of fusion plasmas.
1995	Princeton Beam Experiment-Modified (PBX-M)	PPPL	An experiment using strong plasma shaping to increase the plasma pressure, was developing new methods to control plasma stability.
1995	Microwave Tokamak Experiment (MTX)	LLNL	An experiment to use a free electron laser to generate mocrowaves as an innovative way of heating and controlling the plasma.
1996	Texas Experimental Tokamak (TEXT)	University of Texas at Austin	Dedicated to turbulent transport (maintaining the energy of the plasma).
1997	Tokamak Fusion Test Reactor (TFTR)	PPPL	Largest U.S. fusion experiment, and one of two in the world capable of using D-T fuel to produce >10MW of fusion energy.
Late 1990s	Staged Z-Pinch	UC Irvine	High density pulsed approach to achieving fusion.
2003	Electric Tokamak	UCLA	Very large low field tokamak for innovative confinement and heating ideas
2007	POPS Electrostatic Confinement Penning Trap	LANL	Innovative approach to electrostatic confinement, suppported by theory, with a very compact point neutron source.
2007	Spheromak (SSPX)	LLNL	Innovative fusion confiuration design to achieve a fusion plasma with less engineering and materials.
2010	Field Reversed Configuration (TCS-U)	University of Washington	The only experiment of its kind in the field reversed configuration, using rotating magnetic fields for a simpler engineering approach to a high-pressure plasma
2010	Levitated Dipole Experiment (LDX)	MIT	Explored high-pressure steady-state plasma configurations.
2010	Maryland Centrifugal Experiment	University of Maryland	Examined the effects on plasma confinement of the supersonic spinning of the plasma.
2014	Magnetized Target Fusion (MTF)	Air Force Research Lab and LANL	High Energy Density Plasma (HEDP) experiment combining features of magnetic and inertial fusion

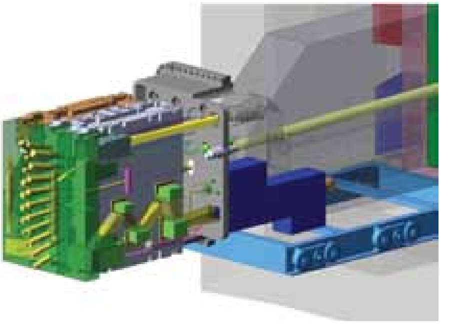
Fusion in the Large . . .

Senator Pennacchio's interest in fusion was evident in his pride in the contributions by New Jersey's Princeton Plasma Physics Laboratory (PPPL). Princeton made ground-breaking advances in the mainline tokamak fusion program in the 1970s and 1980s. The history and current research at the laboratory, and the basics of plasma physics, were reviewed at the symposium by Dr. Michael Zarnstorff, Chief Scientist at PPPL. He was formerly deputy director of research and has been a physicist at the Lab since 1984.

Princeton Plasma Physics Lab

The four-year upgrade of the National Spherical Torus Experiment was completed in 2016.

FIGURE 3



Nova Photonics

Nova Photonics' model of an ITER port plug with several diagnostics integrated into it.

PPPL has 500 of the top U.S. researchers in fusion science and engineering. The Princeton Large Torus and Tokamak Fusion Test Reactor set many of the standards worldwide for tokamak research.

Dr. Zarnstorff reported that the Lab's National Spherical Torus Experiment is now undergoing repairs. When it is back in operation, it will be a powerful experimental and engineering facility. PPPL has an extensive education and outreach program, reaching students of all ages, from K-12 to graduate students. He ended his presentation saying the scientists at the Lab are now working on designing smaller, cheaper fusion power plants that can compete with other energy sources.

By far, the world's largest and most ambitious tokamak project is the International Thermonuclear Experimental Reactor (ITER), under construction in France. Seven international partners, which include the United States, are building ITER, and 27 companies in New Jersey are responsible for providing state-of-the-art components and engineering for the project.

Dr. Fred Levinton founded Nova Photonics in Princeton, New Jersey, in 2000, which is a small business engaged in R&D for advanced plasma diagnostics for fusion, with an emphasis on developing optics and lasers. The complex of diagnostics for ITER provides the window through which to measure the magnetic fields, temperature, other characteristics and activity of the plasma. Dr. Levinton has worked with ITER for almost 20 years on diagnostics of magnetic fields in plasmas, and leads a physics and engineering design team for a diagnostic system that will be installed on ITER.

LPPFusion

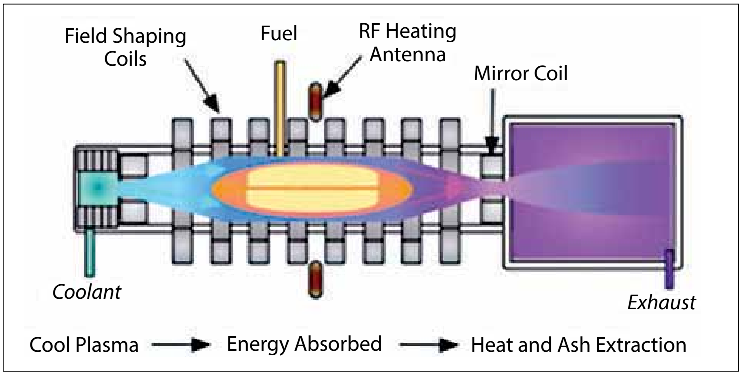
Middlesex, New Jersey-based LPPFusion is developing the Focus Fusion approach to fusion.

Nova Photonics has developed a number of spin-off applications from its research, including an optical filter that is being tested by the U.S. Navy for underwater laser communications (**Figure 3**).

Referring back to the chart of the decline in fusion funding (Figure 1), Dr. Levinton pointed out the irony that since 80% of the U.S. funding for ITER goes to companies like his, cutting the budget for U.S. contributions for ITER only reduces research right here in the United States!

. . . And in the Small

Whereas ITER demonstrates the conventional tokamak approach, in which increase in size is central to an increase in performance, a number of New Jersey companies are developing fusion "in the small," as needed for certain applications—most definitely in space.



Princeton Fusion Systems

Princeton Fusion Systems is working with scientists from PPPL on the Princeton Field Reversed Configuration, a small compact fusion system, ideal for space propulsion.

Princeton Fusion Systems, a subsidiary of Princeton Satellite Systems, is working with scientists at PPPL on the Princeton Field Reversed Configuration (PFRC) experiment. It is a magnetic confinement fusion design, "which is a step in producing a compact nuclear fusion reactor that would fit on a truck," explained Michael Paluszek, President of Princeton Satellite Systems. [See article by Michael Carr in this issue of *EIR* for more about the PFRC experiments and the Direct Fusion Drive.]

LPPFusion

LPPFusion's President Eric Lerner with a Focus Fusion experiment.

"It would be ideal for space propulsion, emergency power, remote power for mines and resource extraction, and for military forward power," Paluszek said. The fuels for the PFRC will be deuterium and helium-3, "which dramatically reduce neutron damage and radioactivity."

Princeton Fusion Systems is currently working under grants from the Department of Energy and NASA for advanced technology development, and in the past had funding from NASA to develop the Direct Fusion Drive for a number of space missions, including a proposed Pluto Orbiter.

Other Alternative Approaches

At Lawrenceville Plasma Physics Fusion (LPPFusion), in Middlesex, New Jersey, an entirely different approach to fusion is being pursued. A complex experimental design attempts to "use the natural instabilities of plasmas, rather than fighting them." In nature, plasmas can form "disruptions," such as filaments and other structures. (Look at such phenomena on the Sun.) LPPFusion is developing the Focus Fusion approach to take advantage of this self-organizing characteristic of plasmas.

Eric Lerner, President and Chief Scientist of LPPFusion, reported that the company has already published the highest confined temperature of any fusion device, and using a hydrogen-boron fuel, the reaction produces no neutrons. Electricity can be produced directly from the fusion plasma.

Lerner reported that the inadequate federal funding for fusion has all but eliminated support for non-tokamak research. "The fundamental mistake made in the government fusion program in the 1970s was to prematurely focus all research on the tokamak and laser approaches." This became an irreversible policy with the budget contraction starting in the 1980s. Instead, Lerner argued, "what is needed today is a crash program that funds all approaches that can't be proven impossible."

It is noteworthy, in this connection, that one of the attendees at the symposium was a venture capitalist, who heads a new fusion 501(c)(3) (tax deductible) organization. He said his organization is connecting donors to start-ups in this field. The lack of adequate federal funding for fusion and space research is increasing the role of "private" investors, whose support was welcomed by the researchers, who have nowhere else to go. This change in source funding will change the character of U.S. science to "proprietary control" by a group of investors who are filling the vacuum left by the lack of governmental and public support for a federally funded, mission-oriented crash program for fusion energy.

Another approach to fusion being developed at the Fusion Technology Institute at the University of Wisconsin, Madison, led by its director, Dr. Gerald Kulcinski, is Inertial Electrostatic Confinement (IEC). As Dr. Kulcinski could not attend the symposium, he sent recent papers and graphics, which were summarized by Marsha Freeman.

Gerald Kulcinski

In this photo taken at a fusion meeting in Japan in 2002 are, left to right: Apollo 17 astronaut, Harrison Schmitt; Prof. Masami Ohnishi, from Kyoto University; FTI Director, Dr. Gerald Kulcinski; and Robert Hirsch, past leader of the federal fusion program.

Gerald Kulcinski

Artist's impression of the Mark II lunar helium-3 miner.

population. So in addition to being one of the partners in ITER, China has a very ambitious domestic program, to take the next steps.

Last December, China broke ground for a Comprehensive Research Facilities complex, which will develop the manufacturing technologies for the most challenging components of China's future Engineering Test Reactor (ETR).

In the meantime, in addition to ITER, China's Experimental Advanced Superconducting Tokamak (EAST) is laying the foundation for the more advanced experiments to come. EAST began operation in 2006 as the world's first fully superconducting tokamak, which has set records for plasma temperature and confinement time.

A hallmark of China's fusion program has been international cooperation. Chinese scientists travel to fusion experiments abroad, and American scientists and scientists from other countries meet in China, and even carry out experiments on EAST.

Now, China is in a position to help developing countries learn how to start their own education programs, and where possible, help with experimental experience and hardware.

Like the Kulcinski group, which is concentrating on

In 1986, the Wisconsin team identified the presence of helium-3 in the lunar regolith and their experiments in IEC have the goal of investigating the use of advanced fusion fuels. To investigate further the presence of helium-3 and other resources on the Moon, Apollo 17 astronaut and geologist Harrison Schmitt joined the faculty of the Wisconsin institute.

The Fusion Technology Institute has designed a second-generation lunar helium-3 miner, the Mark-2, which will undoubtedly be updated as we learn more about the distribution and concentration of helium-3 on the Moon.

China's 'Long View' Fusion Program

"Why is it the case that China can carry out a long-term fusion program over decades, without the vagaries of annual budget fights, and continuous re-evaluations and changes in direction?" asked Marsha Freeman.

The answer is that China's fusion program, like its space program, is not seen as an isolated line item in a budget, but as an important contribution to that country's economic growth, which is based upon on fundamental breakthroughs in science and applied technology. Fusion and space exploration play important roles, therefore, as "science drivers" for their entire economy. And that national policy is expressed in the requisite financial support and in the attention paid by the top leadership of the country.

China has determined that it will need fusion power at least by mid-century, if not sooner, to support a rising standard of living for its growing

Institute for Plasma Physics, Chinese Academy of Sciences

China's Experimental Advanced Superconducting Tokamak (EAST), the first fully superconducting tokamak in the world.

using the advanced fusion fuel helium-3 and mining it on the Moon, the father of China's lunar program, Ouyang Ziyuan, the creator of cosmochemistry in China, is a premier promoter of mining helium-3 on the Moon. Ouyang Ziyuan said in 2006:

> Currently, fusion technology is not mature, but once it is commercialized, fuel supply will become a problem. . . . Each year, three Space Shuttle missions could bring back enough fuel for all human beings across the world.


Art Murphy

The Symposium is for the young people, said Sen. Pennacchio, at the conclusion of the event. Here, Jose Vega, a recent student from the Bronx, New York, addresses the panel during the question and answer period.

German-American space visionary Krafft Ehricke pictured a city on the Moon that he called Selenopolis, where thousands of people would live and work, and the helium-3 mined there would power the city, its transportation, mining and manufacturing, and would open the rest of the Solar system to mankind.

'This Symposium Is for the Young People'

In his closing remarks at the end of the symposium, Sen. Pennacchio said that most important and helpful for him was hearing the divergence of opinions on how we will achieve fusion:

> In my 64 years, the thing I know absolutely, is that there are no absolutes: Ulcers come from stress, right? No, take an antibiotic. The Earth is flat—No, the Earth is round. Well it is not actually really round, but sort of punched in. When I grew up, the atom was the absolute smallest element known to man, now we are way beyond quarks. So science is changing.
>
> The main point is to engage the public, let them know what is out there. And the young people who came in—this symposium is for them more than for anybody else, because they are the ones who will benefit from what we are discussing today. I hope you found it helpful and informative. It was helpful to me, and will be for my grandson.


Art Murphy

New Jersey State Senator Joseph Pennacchio.

In remarks to the speakers after the symposium, Sen. Pennacchio said he thought the presentations were well received, as most of the people in the audience stayed until the end. Asked about possible follow-up to the symposium, he said:

> I am working with staff to see how we can incentivize and nurture fusion research and industry in New Jersey. I may draft a resolution in support of increased funding at the federal level. It has been estimated that by 2025 we could have a sustainable fusion reaction, and commercial applications are somewhere around 2050. That, in my humble opinion, is not soon enough.
>
> The President has accelerated the timetable for the manned landing on the Moon. Now it is time to bring fusion up front and do the same.

During the question and answer period at the end, Jose Vega asked the panelists how to change the culture of people his age, who have grown up with drugs and school shootings. Members of the panel, as well as of the audience, related how the space program had encouraged them to pursue a life in science, bringing optimism to their generation.