Will the United States Join The Helium-3 Fusion Revolution?

The University of Wisconsin Fusion Technology Institute, founded in 1971, has been a leader in fusion and plasma physics research, with a broad range of basic science, engineering, and applications programs. The Institute has done pioneering experimental work using advanced helium-3 fuel to produce fusion energy. Dr. Kulcinski is the Director of the Institute, Associate Dean for Research in the College of Engineering, and Grainger Professor of Nuclear Engineering. He has led a scientific team which has doggedly pursued, and tirelessly promoted, research into the advanced fusion fuels, such as helium-3, which will create the energy for the future.

Dr. Kulcinski joined the University of Wisconsin Nuclear Engineering Department in 1972, having worked in the Nuclear Rocket Program at Los Alamos National Laboratory a decade before. He has participated in government advisory committees, and is a member of the National Academy of Engineering. He was interviewed by Technology Editor Marsha Freeman, on Aug. 21.

EIR: Recently, there have been some very exciting international developments. The Chinese lunar program, most recently the successful landing of the Chang'e-3 lander and rover on the Moon, generated excitement and media coverage around the world. Leaders of the Chinese space program have described the goal of mining helium-3 from the lunar surface, to use as an advanced fuel for fusion energy, as the long-term goal of their exploration program. Although China has now taken the lead in planning to carry out this project, the Fusion Technology Institute has carried out research on advanced fusion fuels using helium-3 for many years, and has even developed designs for machines to mine it on the Moon. But due to the virtual absence of federal support, that work has been stymied since the 1980s.

Support for long-term projects is now on the international horizon. The July summit of the BRICS nations held in Brazil, in which China plays a leading role, laid the basis for the investment of the world's resources to accomplish long-range goals, which could include helium-3-driven fusion energy.

But almost all of the fusion research ongoing today is based on using deuterium-tritium (D-T) fuel, not helium, because it is the easiest fusion reaction to obtain. How did your Institute become involved, quite early on, in pursuing a different approach to fusion research, based on using helium-3?

Dr. Gerald Kulcinski: You're correct. The technology part of our program started in the early 1970s, whereas the total fusion effort here actually started in 1963, with Don Kerst. He had been at the Betatron [particle accelerator at the University of Illinois] and came to Wisconsin to set up a fusion program in 1963. It was mainly plasma physics. It wasn't until the early 1970s that we started to think about the technology. At that time, it was essentially all deuterium-tritium fuel.

In the middle of the 1980s, you remember the SDI [Strategic Defense Initiative] program, that President Reagan had proposed. They were talking about trying to develop power supplies that would run for 30 minutes with 100 or more megawatts electric, in order to power the defensive weapons. We had a contract with the Air Force to develop a pulsed fusion system, to run on a 30-minute time scale, not pulsed for a few seconds; around 300 MW for 30 minutes. We began to think about how you would design a reactor like that, for use in space, and we started to realize that the real problem was the neutrons, because if you had a D-T system you would have to put up so much shielding that the mass of the system would be too large, and it wouldn't be practical.

So we started to look at fuel cycles at that time that

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The Fusion Technology Institute's Inertial Electromagnetic Confinement experiment uses electrical fields to create fusion reactions, unlike a tokamak, which contains the plasma with magnetic fields. Here, Dr. Gerald Kulcinski holds the spherical grid used to accelerate the ions to fuse, which is placed inside the reactor.

produced little or no neutrons. Then we started to think that if you didn't have the neutrons, not only would you not have the shielding, but you could get rid of a lot of the other components. Even if you didn't have zero neutrons, if you went to the D-He-3 system, which drops the neutron production by, on the order of, a factor of 50 from a D-T system, and they're all lower-energy neutrons. You could allow the neutrons to escape, and didn't have to have the shielding. As a matter of fact, you didn't want the shielding, due to the backscatter from the neutrons. So we began to look at these advanced fusion fuels for the SDI program.

We designed a reactor for the Air Force based on the D-He-3 system. It was a one-of-a-kind, or a couple-of-a-kind, but not a real commercial power plant. That was limited, of course, because the amount of helium-3 was classified at that time, for lots of reasons. But anyone can calculate on the back of an envelope, how much was available, and we knew there was enough helium-3 in the United States alone to power these kinds of systems for this short engagement.

After that, in the mid-1980s, we decided, "Well this looks pretty good, but why don't we try to look at how we would provide such a system for Earth and electrical power plants?" Of course, the first thing that you run into is that there isn't much helium-3 around, just from the decay of tritium in nuclear weapons. It all comes from reprocessing the weapons when they bring them in from the field. So we started to look around. We knew the advantages of using helium. That wasn't any secret. The real problem was, where are we going to find large amounts of helium-3 that could satisfy commercial electrical production systems?

In late 1985, I took the fusion technology group on a retreat, around Christmastime. Classes were out, and we wanted to figure out how to get larger amounts of helium-3. We went off campus and spent at least a week, maybe a little more, coming up with all kinds of crazy ideas, none of which seemed to work. Until two of our scientists, almost simultaneously, came up with the idea that there is a source of helium-3 in the Solar System, from the Sun. Helium-3 is a component of the solar wind, and there are a lot of bodies up in the sky that might have collected the helium-3. But the problem is that the solar wind, being [electrically] charged, is deflected by any body that has a magnetic field.

If you look at the closest planet to the Sun, Mercury, it has a magnetic field, so it didn't collect any. Venus has no magnetic field, but it has a hell of an atmosphere! It couldn't collect any. We've got both on Earth, so we didn't collect any. So you could march through the Solar System and you'd come back, and you'd say, "There is a body that is close to the Sun, and that's our own Moon." It has neither a magnetic field nor an atmosphere, and, in theory, it should have been collecting the solar wind for 4.5 billion years or so, depending upon what the age of the Moon is. If that was the case, using the composition of the solar wind as we know it today—and probably it was different then, but that's the only one we know—we calculated that 500 million metric tons should have hit the Moon before that time period. Then, the question was, is there any of it up there still?

So right after New Year's in 1986, we went down to the Lunar and Planetary Institute in Houston, and started to go through all of the records of the Apollo program. Every rock that was analyzed had helium-3 in it. We kept finding this, but we weren't quite sure we were reading it correctly, so we literally walked down the street to the [NASA] Johnson Space Center, talked to some of the lunar geologists, and said, "Here's what we've been finding. Is this correct?" And they said, "Yes." They knew where the helium-3 was, but they didn't know what it was good for. We knew what it was good for, but we didn't know where it was. That was in 1986. We did not discover, but we rediscovered, the large amount of helium-3 on the Moon. So that started another program at Wisconsin, which was to retrieve the helium-3. We had several NASA projects, where we designed miners that could extract the helium-3 which is very shallow, buried in the regolith. And then Harrison Schmitt, who was an Apollo astronaut, joined our team.

Harrison Schmitt Joins the Team

EIR: When did Harrison Schmitt come on board?

Kulcinski: This is a rather interesting twist. I was at a meeting in Albuquerque at which he was the dinner speaker. Jack [Schmitt] is a very good speaker, and he gave an inspiring talk about Apollo 17, and space travel, and the Moon, and so forth. And after the talk, when people gathered around to talk to the speaker, I had a couple of seconds to describe this to Jack, and he got very, very interested, and he contacted us after that. One thing led to another and we started to collaborate after that speech [Schmitt became a consultant to the Fusion Technology Insitute in 1986—ed.]. We published an article in *Fusion Technology* at that time, and that was the kick-off for all of this work.

Jack, of course, brought an enormous amount of knowledge to the team, about the lunar surface and the regolith, and the fact that they had actually taken samples about two meters into the lunar surface and found helium-3 all the way down to about two meters or so. It's probably deeper than that in the regolith. That then gave us an idea of how we could actually mine the helium-3. We designed several miners which went through NASA review. The bottom line was, the folks from NASA said, "Fine. We can get the helium-3 if you need it, but you're never going to make fusion work." Well, if you went down the street and talked to the Department of Energy folks, at that time, they'd say "That's fine. We can make fusion work, but you're never going to go back to the Moon." We could not get NASA and DOE together to work on this project, which was no end of frustration for us. Both thought they could do their part, but the other agency wouldn't be able to do it. That's what we've been up against for the last 30 years, trying to get NASA and DOE to work together on this.

Advanced Fuel Cycles

EIR: You then developed an experimental approach and an apparatus optimized to be able to use this advanced helium-3 fusion fuel?

Kulcinski: Later on, we got into this area of inertial electrostatic confinement [IEC] devices, to actually show fusion with an advanced fuel. D-He-3 has to be heated up to about 60 kilovolts, which is on the order of three times higher than a D-T system [which requires a temperature of at least 100 million degrees].

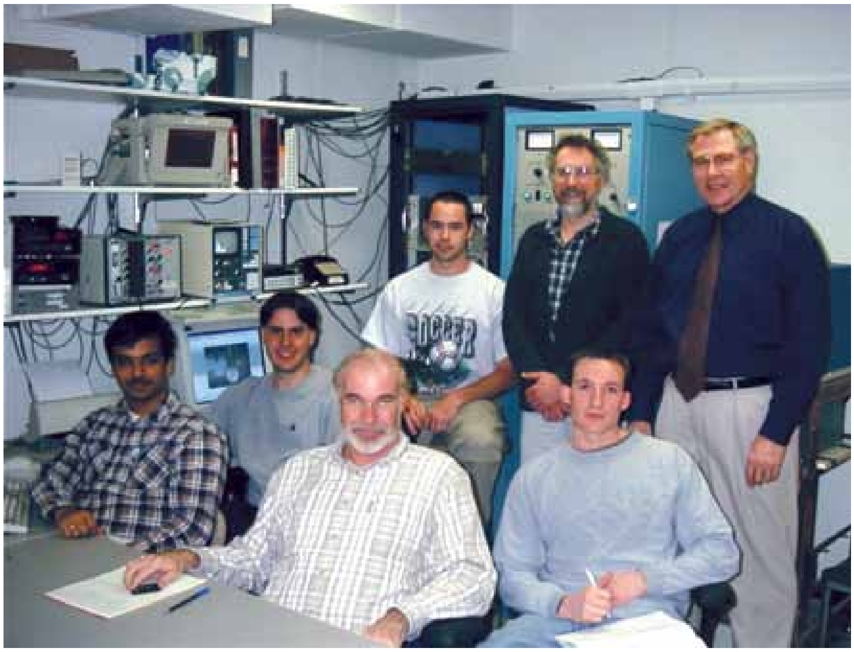
We looked at two advanced fuel cycles. If you also look at the helium-3/helium-3 cycle, that is one that has *no* residual radioactivity associated with it—there is some radioactivity when you have the nuclear reaction, gamma rays, but they're easy to shield and they don't cause radioactivity to be induced in the structures, whereas, neutrons do.

So we looked at those two fuel cycles, D-He-3 and He-3/He-3, and said we had to find some confinement concept that has better operational efficiency and high energies compared to a tokamak, or anything that's a Maxwellian distribution, where you have ions with a [wide] range [of energy distribution]. That's how we got in to the inertial electrostatic confinement area. That research all started with Philo Farnsworth, who invented television, and Bob Hirsch, who did the initial experiments, way back in the 1960s. But the research dropped off because they didn't know about helium-3 at that time.

So we have been pursuing both arms of this: one, the extraction of the helium-3 from the Moon, which is an engineering issue, not a physics issue. It looks like that could be done. The harder part, is to demonstrate being able to burn helium-3 with anything close to a break-even number, and that's where we've been concentrating most of our efforts. We have actually run D-He-3 routinely in the laboratory, and we've also run He-3/He-3 systems, but we're a very, very long way from a q=1 [energy breakeven]. It's only a small university program, so it's not surprising that we're not at any high level.

In the 1990s, we did a little twist, because we realized that fusion power plants seemed to be a long way in the future, and slipping further. We asked ourselves, how could you have an impact with fusion in the next five to ten years? If you didn't make electricity, what would you use fusion for? We got into this whole area of using fusion to make near-term products that could benefit society, while you learn about the physics, and scale up larger and larger, to eventually have a power plant. That has also been a very major part of our program now.

These near-term projects are making isotopes for medical diagnostics, or using these small portable systems for detecting nuclear weapons, explosives, IEDs, and a few other commercial products that we're working on now that have very near-term applications, within five years of commercialization. These systems won't be making electricity, but some will be using helium-3 to make products.



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Since 1971, the Fusion Technology Institute has graduated 164 Ph.D. candidates, creating the next generation of fusion scientists. In this 2000 photo of the first group of students and staff studying advanced fusion fuels are (back row, l. to r.): Dr. Greg Peifer, Shine Medical Technologies, Prof. John Santarius, and Prof. Kulcinski.

For example, two of my graduate students started a company called Shine Medical Technologies. There was a big problem with molybdenum-99, which is used for diagnosing cancer and other medical procedures, when the Canadian nuclear reactors producing it went down. These students came up with the idea of using fusion neutrons to drive a fission reactor, to produce the radioisotope. They are building eight fusion-driven fission systems which will produce half of the U.S. need for moly-99.

Other Fusion Applications

EIR: Are there other fusion experiments being carried out using helium-3?

Kulcinski: I wish there were. I know the Japanese have done some. We have a collaboration with Japan that is a university-to-university collaboration, not government-to-government collaboration. I know the Japanese work with the same IEC devices that we do, and they have watched our experiments and duplicated some of them in Japan. I expect the Chinese are doing this, but we don't know, we don't have any inside information on that. I don't know of any in Europe, or in Russia.

There have been a few places in the United States, for example, at the University Illinois, by George Miley, who has worked on these systems. There was a system at Los Alamos National Laboratory; there was one at Idaho National Laboratory; one at NASA's Marshall Space Flight Center; there's one now at the University of Maryland. There are some small efforts, people looking mainly into the physics of what is going on. The nice thing is that they're small, they're cheap, so students can really get a lot of effort out of them, as opposed to being part of an army working on a big tokamak. . . .

EIR: As long ago as 1987, I talked with John Santarius in your Institute about using polarized fusion fuel. What advantage would that have for fusion? What has been the development since then?

Kulcinski: The advantage is that you increase the reaction rate for the same temperature of the ions. Polarized fuel has been demonstrated in some experients, to have a higher fusion rate at any given temperature. That all has to be proven, to show that you can do that. I think the idea is sound. We discuss it. It hasn't gone away.

If you're asking have we done anything with it, the answer unfortunately, is "No," but it comes up every once in a while. We just don't have the facilities to be able to do the experiments. John's ideas, I think, are sound, but we don't have the resources.

EIR: John Santarius also mentioned fusion applied to space propulsion.

Kulcinski: John is working on electrostatic devices for space propulsion, which I think may be closer. You can get extremely high specific impulse units, a million seconds of specific impulse, in contrast to chemical rockets, which are 400 seconds, or nuclear rockets, which may be 800 seconds. These are a million seconds of specific impulse, which allow you to go to a star and back without having to breed people [i.e., to wait through the lifespans of many generations of people].

EIR: And for manned missions farther away than the Moon, fusion propulsion is a prerequisite. Almost every day there are reports of yet more deleterious effects on astronauts from the long-term exposure to microgravity.

Kulcinski: I think the physics are sound, and that it's a demonstration issue. We can get to Mars and back in less time than it would take to [just] get you to Mars with chemical rockets. That, the astronauts would be very much interested in. But you have to have the resources to demonstrate that and show how it would work. We're certainly not going to do that at a university, in terms of building something that large. That's a program for NASA or a federal agency. A big company could do that—like Boeing or Lockheed.

Mapping Helium-3 on the Moon

EIR: In 1993, your group published a fascinating paper on "Remote Sensing of Astrofuel." It was a proposal for a lunar orbital mission using gamma ray spectroscopy to map out the concentration of helium-3 on the Moon. The only definitive data we have are from the Apollo and Soviet Luna samples that were returned to Earth. Helium-3 is very dispersed, only a few parts per billion in the lunar soil, and is not something you can measure using the tools and instruments that we have either orbiting the Moon now, or roving on the surface. What was the design of this proposed mission?

Kulcinski: I think it is still a valid idea, because there is a neutron background on the Moon, from the cosmic rays hitting the surface, a small flux of neutrons on the surface of the Moon. The whole Moon is covered with neutrons that are being generated there, on a very low level, not damaging to humans. But those neutrons are moving around, interacting with the lunar soil, and with any helium-3 embedded in the soil. And those reactions, which emit 10 MeV gamma rays—which is the key to this—would stand out from all the other gamma rays that are emitted on the Moon.

So what you need is a detector to detect 10 MeV gammas. If you have an orbiting system that could detect 10 or 20 MeV gammas, in that range, then you would be able to light up the areas where the concentrations are higher than other areas. I think that is still a valid idea. The problem was that the detectors for that energy gamma are not things that are in the open literature. So we sort of left that, because we were not doing classified work here. We don't do classified work on campus.

EIR: Maybe you should suggest to the Chinese that they should do the mission.

Kulcinski: They wouldn't classify it. They would just do it!

I've got to believe, as you indicated, with their strong fusion program, their strong need for power in the future, and their strong interest in space, that helium-3 would be one of the things that they're doing, but I haven't seen anything that I can really put my finger on and show that they are actually doing that.

EIR: Chinese space officials have been very forthright in stating that mining helium-3 on the Moon for fusion is a goal. So I think one would assume that they must also be looking at what the requirements are from the fusion side, to be able to use such advanced fuels. Although there is no government-approved manned lunar mission, it is stated by scientists and visionaries in their space program that manned missions, with the goal of living and working on the Moon, will follow the Chang'e series of robotic missions. With facilities for industrial production and mining, they would be well placed to be transporting helium-3 back to Earth.

Kulcinski: Now, they are following us, so they know it can be done. But once they get to the Moon and set up a base, then *they* will be in the front, and they will have to be more careful, because they will be venturing into technology that has not been demonstrated by the U.S. or the Russians. But they have a very impressive program.

By the way, their fusion program is also very impressive. I believe there will be a connection at some time.