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# Fusion in Korea: Energy For the Next Generation

*Dr. Gyung-Su Lee discusses his bold vision for the future, proceeding from the Korea Superconducting Tokamak Advanced Research (KSTAR reactor). Marsha Freeman and William Jones interviewed him in Daejeon.*

In the early 1980s, the Princeton Plasma Physics Laboratory did pioneering work in nuclear fusion research with the construction of the Tokamak Fusion Test Reactor (TFTR), which made significant breakthroughs in the development of fusion power, until it was shut down in 1997. By 2002, the TFTR was disassembled and sent to the scrap heap, and no new fusion programs were brought on line to replace the TFTR. The only two superconducting tokamaks in the world today are in Korea and China.

Today, the engine of advanced scientific and technological development has shifted to Eurasia, toward those nations which Lyndon LaRouche has identified as the key partners for a reoriented United States, in a Four-Power alliance to establish a new world credit system. Those nations, China, Russia, and India, will form the core of this arrangement, to be quickly joined by other developed nations in Asia, such as Japan and Korea.

In 2007, the Republic of Korea completed construction of a tokamak fusion experimental reactor, the Korea Superconducting Tokamak Advanced Research (KSTAR), the newest in its class. It is one of only two such machines in the world using advanced superconducting magnets to confine the fusion plasma. In 2008, KSTAR created its first plasma. It is now preparing for next Spring's campaign to, step-by-step, move toward the requirements of a future commercial fusion power plant.

On Oct. 9, 2009, *EIR* Technology Editor Marsha Freeman and Washington, D.C. Bureau Chief William Jones toured the National Fusion Research Institute, in Daejeon, Korea, the home of KSTAR.

Dr. Myeun Kwon, the director of the KSTAR Research Center, explained that one purpose of the facility is to train Korean specialists, who will contribute to the larger International Thermonuclear Experimental Reactor (ITER), now under construction in France. KSTAR has allowed Korean industry to manufacture high-technology components, such as those needed for fusion, and Korea will be supplying 20% of the superconductor for ITER's toroidal field magnets, a portion of the main vacuum vessel, part of the tritium storage and delivery system, and other hardware.

KSTAR will function as a satellite experimental fusion research facility, once ITER is operational. In addition to trainees from the ITER partner nations (U.S., Russia, Europe, Japan, China, and India), young professionals from Taiwan and Australia work on KSTAR, and Mexico and Brazil have expressed interest in participating.

Next October, Korea's National Fusion Research

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*Dr. Gyung-Su Lee (above), president of Korea's National Fusion Research Institute (NFRI) explained to* EIR *that one objective of the KSTAR fusion program is "to have is a gathering of people, disciples, and followers; and with people, together with industry, you can solve any problem. . . ." Shown: The KSTAR control room, in Daejeon, South Korea.*

Institute (NFRI) will host the 23rd Fusion Energy Conference, organized by the International Atomic Energy Agency (IAEA).

Following the tour of KSTAR, *EIR* sat down to talk with Dr. Gyung-Su Lee, president of NFRI and chairman of the International Fusion Research Council of the IAEA.

## Interview: Dr. Gyung-Su Lee

**EIR:** Today, you are going to be powering up the superconducting magnets of KSTAR. Can you review the history of the project, and its major goals?

**Lee:** KSTAR started construction at a greenfield site in January 1996. We planned to design, construct, and operate almost an ITER-like machine—smaller, but with most of the same features as ITER. At that time, Korea was not a part of the ITER family, because we didn't have anything to show in fusion. . . . [Fusion is needed] due to the energy crisis, and now climate change trouble to come. Whether you believe it or not, it doesn't matter, because climate change is threatening, politically or technically. We started the design of KSTAR in collaboration with many experienced partners, such as the United States, Japan, Europe, and so on.

But then, in late 1997, the famous IMF economic crisis in Asia exploded. . . . The government did not have much money, and they almost cancelled the KSTAR project, because many people talked about how many years you need to complete research on fusion, and the government of the Republic of Korea was on the brink of bankruptcy. Fortunately, they decided not to cancel it, but to put it on hold. That meant that the budget was just sustainable, people were paid, but there was not really any progress.

That lasted through 1998, 1999, and 2000. . . . But then the economy rebounded and was booming again, and we started machine construction with the final design in 2001. We completed the hardware in 2007.

The most critical part is that we constructed the machine. But then, whether it will operate as you expect, is a different thing. Not many people trusted or believed that we could do it, because it is so complicated, very high technology, and the risk is very big. We started the commissioning of the machine at the end of 2007, and in 2008 we started checking everything. The main event started in March of 2008.

## Creation of a Plasma

We cooled down the superconducting magnets in a vacuum, [using liquid helium], which is 10 to the –8 millibar, or 10 to the –11 atmospheres, because 1,000 millibars is one atmospheric pressure. The vacuum evacuation was successful. [The superconducting magnet] cooled down from room temperature to 4.5° Kelvin, or –269°C. Even the Large Hadron Collider at CERN in Europe failed last year, with a helium [coolant] leak. When things are cooling down, they get squeezed. And lots of things are squeezing in different directions, although at normal room temperature, it is okay.

**EIR:** When you say the superconducting magnet material gets "squeezed," do you mean it shrinks, or that it twists?

**Lee:** Both: It shrinks and twists. Because it has to be anchored somewhere, so as it shrinks, there is a force, so it twists. Even though we did all the analysis of the design, you cannot be sure this is completely safe, even though inside the vacuum vessel cryostat [which maintains cryogenic temperature], each component is tested. But *in situ* welding is used for assembly, and there are 8,600 points of welding inside. These all have to pass quality assurance. But helium is famous for leaks. It is the worst leaking material.

We did all the welding and tested it at room temperature, but you never know about leaks until you cool down [the magnets]. Because let's suppose this tube is at room temperature, and it has no leak. You check and there is nothing.

But another tube can have very, very minor leakage, which is undetectable. The machine can operate like that, at room temperature, with no problem, with a small leak. But when you cool down, the small leak becomes big, and helium comes out, and you cannot operate. You have to detect this and correct it.

But in order to do that, you have to warm it up so people can get at it, and then the leak closes, so you cannot detect it! Then you operate it again, and it happens again! This is a famous problem of a superconducting machine. No machine yet has proven that this did not initially happen—Japan, Europe—they all had the same problem. The helium leak in the Large Hadron Collider generated an arc which had to be repaired before operation.

So, a leak was the expectation, because Korea was not experienced. I don't know why, but at some point, around 70°K, the shrinkage of normal material stops. This is physics. If you pass through 70, and go below that, it is easy, because there is no more shrinkage. The temperature of the magnet is going down from 300K all the way to 70K, a little more every day; it is slowly going down.

The first time you run the machine, you are slowly going down. Every time you do this, you watch the gas analyzer, looking for helium inside the cryostat, because, normally, there is no helium in this environment. But, if there is a helium leak, you'll see it. Every night, I call up the laboratory, and ask [someone] to tell me what the reading is of the helium. And he says, "not visible yet." [We check] every day; 24 hours a day. Then, when we passed through the 70° level, nothing happened.

**EIR:** So you had no helium leak?

**Lee:** No helium leak. Zero. And it operated without a leak the first time, after a four-month countdown. That was last year. That's why BBC television and *Science* magazine came and did a story about KSTAR.

The reason why we are so proud of it, is not just because it is the Fusion Research Institute's achievement; rather, this is an achievement of the Institute together with Korean industry, in quality assurance of the hardware and manufacture. So this was a demonstration last year of the machine's construction, and it was commissioned.

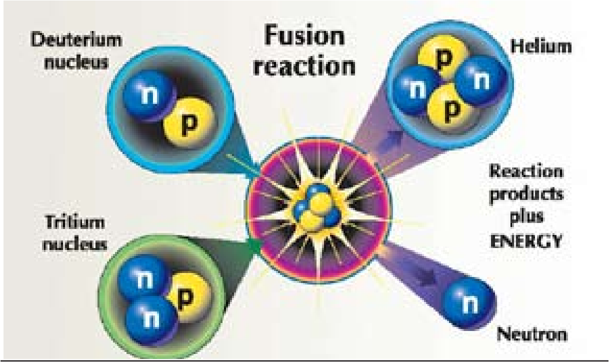
Now, we have to produce something, right? With this beautiful facility that we built, we started research on machine performance and plasma confinement, to see if we can really push this research to better and better [plasma] confinement, [to meet] the requirement of fusion energy, so fusion becomes commercially demonstrated. So that was the next phase.

This year, we are cooling down [the magnets] again with no problem. Next, we will put more current in so the [magnetic] field strength will meet the design requirement. Within this week or next week, we will finish all the design checks. The performance requirements of the magnets and of all the active components will be checked. Then the plasma formation and heating starts. That is the issue for this year's campaign.

**EIR:** What do you plan for next year?

**Lee:** Next year, in early Spring, we will put in lots of heating so the plasma gets very hot. We will then

### The Fusion Process



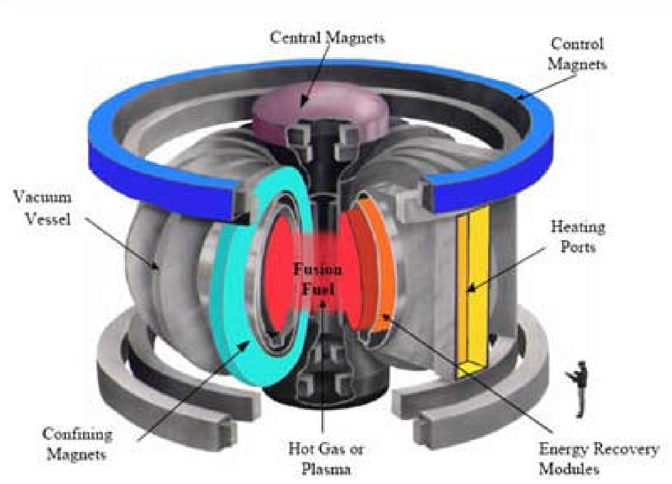
Source: LLNL

*A fusion reaction takes place when two isotopes of hydrogen, deuterium and tritium, are combined to form a larger atom, releasing energy in the process. The products are energetic helium-4 (He-4), the common isotope of helium (which is also called an alpha particle), and a more highly energetic free neutron (n). The helium nucleus carries one-fifth of the total energy released, and the neutron carries the remaining four-fifths.*

*Fusion fuels the Sun and stars, but in the laboratory, atoms must be heated to at least 100 million degrees under sufficient pressure, to produce fusion. Other light elements can also be fused.*

*(N.B.: Dr. Lee describes the work of KSTAR next year, using deuterium-deuterium plasma, not the deuterium-tritium fusion described here).*

### Magnetic Confinement Fusion in a Tokamak



*In the tokamak, the fusion plasma is contained using a strong magnetic field created by the combination of toroidal and poloidal magnetic fields (the first refers to the long way round the torus, and the other, the short way). The resulting magnetic field forces the fusion particles to take spiral paths around the field lines. This prevents them from hitting the walls of the reactor vessel, which would cool the plasma and inhibit the reaction.*

supply deuterium fuel. At the present time, we are using hydrogen, because it has no activity, no fusion. It can be fused in the Sun, but rarely, so we are not producing any fusion energy, just a plasma. We are still using the machine for configuration and studying control, so we don't need to have real fusion happening. But early next year, we will supply deuterium, a heavy isotope of hydrogen, and this will fuse. Deuterium-deuterium [fusion] is easier to handle than fusion with tritium, so we will start with deuterium-deuterium fusion.

This reaction generates neutrons. Nuclear fusion happens, and we measure the neutrons coming out and how much power is produced. So we are trying to put lots of heat [into the plasma], and keep it very high for a long time. Because of the superconducting magnet, we can hold the plasma much longer than normal magnets, such are used in the TFTR and JET [Joint European Torus]. This one is basically the same as the magnet for ITER—a niobium-tin magnet—so we will carry out experiments on how long we can keep this fusion beam controllable and producing neutrons. This will continue until ITER is on line. This is what we are doing.

## Moving to Commercial Fusion

**EIR:** What were your reasons for building KSTAR?

**Lee:** When we started KSTAR, the United States, Europe, Japan, and Russia had been doing fusion research for a long time, and had spent a lot of money and used a lot of people, and were trying to build ITER. In 1991, when I came [back to Korea] from the United States, this whole place was rice paddies. Can you believe that? Rice paddies. Nothing here. So we started. When we started, many people could not believe us. They were skeptical, at first: "This guy is crazy." It is very understandable. We aimed very high, to do what ITER is supposed to do, but on a smaller scale. Then we trained our engineers, and trained with our industry and factory, together.

So, when ITER expanded its family, and accepted us, in 2003-04, Korea jumped in, with a *real* capacity to [help] build ITER. ITER is now under construction,

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*Dr. Myeun Kwon, director of the KSTAR Research Center (left, with* EIR*'s Marsha Freeman and William Jones), explained that one purpose of the facility is to train Korean specialists, who will contribute to the larger International Thermonuclear Experimental Reactor (ITER), now under construction in France.*

and you need ten years to construct it. During those ten years, engineers and construction [workers] have lots of headaches, and lots of work to do. But during these ten years, scientists who want to do experiments and research, have no machine. Machines that you want to play with you have already played with for 20 or 30 years. But new machines—there are none.

So, we built KSTAR. First, we proved that we can be a worthwhile partner for ITER. Then, during the ten years of construction of ITER, we would provide this machine to the ITER family. Young scientists can prepare for ten years with this machine. So for ten years you play, work, do research. Then, once ITER operates, these people move to ITER, and ITER is no longer a "new" machine, because they have all this experience. You don't need to repeat using trial and error, so they can do much better, and exploit the machine very easily, in a short time. This is the reason why we built KSTAR.

**EIR:** And you see this as one step on the path to one day having a commercial fusion reactor?

**Lee:** Sure. They need to put in the money to [develop it] commercially. With government money alone, we are not going to make it. Because the government decides very poorly; sometimes it says, "Bye, bye," and sometimes it comes in again. And today we have lots of trouble in the economy so, [people may say], "How about delaying it five more years?" In this way, fusion progress will be slow. This is how it has happened for 45-50 years. . . .

**EIR:** I have a quote from you that was in the *Korea Times* two years ago, in which you said: "Should the world accelerate spending on nuclear fusion, its commercial launch will be possible in about 15 years."

**Lee:** . . . Fusion, if you don't need it, never comes. If you need it, you just need the willingness of human beings working together, and resources and leadership, I believe, not for the commercialization of fusion in the whole world, but the initial demonstration of fusion power on the grid. That is possible within the years 2030-40. . . .

This can be seen in Korea. It is a resource-poor country. And on green grass, and with just a few people, we built KSTAR. So why not Japan, why not the U.S., why not Europe, with science and an economy hundreds-fold bigger, and so many people—why not? We rocketed to the Moon in ten years. With this kind of resolution and passion we can do that. But without it, just pushing poor scientists, with no power; criticizing; giving them just a few dollars, forget it. We have technology and we have people. If we put them together, we can do that. Of course, it's not easy, but it's possible, for sure. We demonstrated it.

So I believe, as you quoted me, that *definitely* I can do that. Seriously. You can quote me.

**EIR:** The question is, how quickly can we convince the governments of the world to do it? Today, many of them are foolishly building solar panels, and not funding fusion.

**Lee:** We have to do all of this. But this is not sufficient. When you have cancer in your stomach, you drink medicine every day to make you feel better. We are facing a big problem, but what they do is drink some pain killer. We have to do it because until we really solve the problem, we have to take a pain killer, of course. But a painkiller alone cannot remove this cancer.

All of these ideas, I give to my students in my lectures, and even go to the young students in Kindergarten through grade 12, and I tell them: Jesus Christ came 2,000 years ago, and look at [the changes in] 2,000 years. The history of the human race is short, but look forward to 2,000 years more. We know this is a short time, but if you try to extend our lifestyle 2,000 years more, what solutions do you have? What imagination do you have to sustain human behavior and the quality of life we are enjoying? How will this problem be solved? This is very important. I am not negative on nuclear; I am very positive on nuclear, because without it we will have to cut out everything, now. . . .

**EIR:** What is so impressive about Korea is how quickly the country moved from where it was 50 years ago, to where you can now export nuclear reactors. Also, in space and in fusion, you took advantage of what had been developed around the world, and now your country is at the frontier of nuclear, fusion, and space.

**Lee:** I think it is an important lesson of a small country. . . .

## The Challenges Ahead

**EIR:** What are some of the challenges you see?

**Lee:** All of our energy, besides small hydro or biomass, we import. So this is a risk, with the fluctuation of the oil price, from $100 to $30, and all the politics. In this environment, we have to exploit our human capital. It is the only way, intensively thinking and working, and that's how we did it in the past 40 years. If we keep this intensity, then, even as a small country, we can prolong our growth and be a better country. But we are still at a crossroads.

**EIR:** Korea is becoming an important factor in new technology and econmic growth in Asia. You have a lot of very big neighbors, who are also very active in fusion, and in space. . . .

**Lee:** Also, army! Our neighbors are—Japan is a good friend; Russia, China, Mongolia, a very good friend in America. They are strong and we are small. . . .

**EIR:** We know that you studied in the United States. It has been a long, hard battle, to make progress in fusion research in the U.S.

**Lee:** Initially I studied at the University of Chicago. I worked for Marshall Rosenbluth, at the Institute of Advanced Study. Then, I worked with him at the University of Texas, when he moved there, doing theoretical work. Then I moved to Oak Ridge National Laboratory in machine design. At the time, Oak Ridge built the Advanced Toroidal Facility, the stellerator, a very complicated machine. Then I relocated to MIT, and I worked at the fusion center. I spent 12 years in the United States.

**EIR:** That was when we had a fusion program!

**Lee:** Yes, they had boosted the fusion program. But suddenly the oil price went down, and will power went down.

**EIR:** And stupidity goes up. It's an inverse relationship.

We began publishing *Fusion* magazine in the 1970s, and helped Congressman Mike McCormack get a bill through Congress in 1980 for a Manhattan-style crash fusion program. But this was never implemented, which led to drastic cuts in funding, and stagnation in much of the U.S. fusion program.

**Lee:** That was because of a miscalculation. The solution is the human being. That is key. The United States invested billions of dollars in fusion and built PLT [Princeton Large Torus experiment], and so on. Look at that [investment] now. What is the value of this? It has minus value now.... Where did this value go? Into people.

Machines can stay around for 30, 40, 50, 60 years, but a human being goes 60-something years; he can continue, but he decays physiologically. This is not something you can avoid. And some day, you go. But if the human time created by this machine has value, it is much bigger than the investment of the hundred million dollars in hardware. That's how science wins. You invest one hundred million here, but people's knowledge has a value of 500 million, or a billion.

But this guy disappears, he dies. Then this knowledge in the brain and the heart disappears. Then, how do you continue it? You transfer [knowledge]. This is how you teach. But to do this, you have to build continuously, for people to be able to teach.

## The Importance of Human Capital

**EIR:** And you lose this transfer of knowledge, when the programs start and stop?

**Lee:** You are not attracting new people. They look at it, and say, "it's unstable." Good people come in, but there are lots of other good job opportunities. So this is the normal sequence of destroying this program. This was my "lesson learned," because I was watching, just as an interested party, all this history, and not just in the United States. So in order to build KSTAR, we had to have a very compact scenario of people teaching. That's why we start with young people.

At the time I started [fusion research] in Korea, when I was hired, I was 35 years old—and I was the oldest member. I was very realistic: I have only 30 years to go, I recognized. Even though I would survive longer, my scientific education tells me the mean value of your effectiveness is, at best, 30. So you have 30 years.

We needed engineers to build KSTAR over ten years. I had students who finished PhDs and Masters degrees. I had all young people in their early 20s. We worked together to build KSTAR. Now, they are in their early 40s and late 30s, and they already have full experience in machine building, with KSTAR.

They will have to work harder with ITER; literally, harder. So here they are learning ITER construction. And along the way you are hiring scientists, in their late 20s and early 30s, to operate the machine.

There are two tiers: one is engineers now in their late 30s, who did the KSTAR construction, and the younger people come along as their disciples. When the construction of ITER is finished, [the first tier] will be in their late 40s, early 50s, and the younger guys will be in their late 30s. The first group were the leaders. This system can generate [successive generations], and history tells me it's possible. We may not be so successful, but this is why we built this kind of tiered scheme: recognizing the importance of the human capital, not the money. If it is successful, then what we want to have is a gathering of people, disciples, and followers, and with people, together with industry, you can solve any problem....

**EIR:** That was the lesson of the space program in the United States. What we built was not a rocket, but a capability, and we could have done anything after Apollo. But we destroyed that.

**Lee:** And also, this happened in the fusion program. Smarter people always have high mobility, and can be successful in anything....

**EIR:** Then people complain that nothing is being accomplished. They say, "all of this money was spent on fusion research, but we still don't have it."

**Lee:** Money is always being spent, because you hire people, but they do nothing, just maintain [the facility]. Spending $100 million per year is easy, just to pay them. Multiply that over 20 years. Now there is $2 billion gone, and then they claim, that after $2 billion, nothing happens. This is a dishonest, political statement.

But if you had built the machine, and put it together in a package, and had done exciting research, giving people the money, in less time, you would have already met all of the requirements for fusion. If you look at the energy produced from fusion [experiments] over 30 years, it is an exponential curve. But certainly, after TFTR, nothing happened. They say, over 30 years,

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*Dr. Lee compared Korea today, to the U.S. consumer society, in which "people want to be safe . . . and make money." But, he said, "they have to figure out what they want to commit their lives to. If you ask about fusion, why am I, myself, here? . . . What kind of incentive do you have in daily life to work with this intensity, for so many long years? You have to understand what is at stake, and what you're committing to. Otherwise, this will never happen." Shown: the KSTAR tokamak, under construction, June 2007.*

nothing happened. But what they intentionally overlook is that they put nothing in over 30 years; they just waited. This is unfair. So if you want to kill it, kill it, so people can do something better with their lives. But if somebody wants to do it, do it with intensity. I hate the delay approach, not because money is spent, and wasted, and the total costs rise, but most importantly, because of the human waste.

Let's say that ITER is built over 20 years, rather than 10 years. Then the people you hired are working and are paid an enormous amount, but this is a relatively small price, since they each waste ten years of their lives. They could complete it 10 years but it is extended to 20 years, so half the total human capital involved is lost.

## Understanding What's at Stake

**EIR:** In the space program, you lost a whole generation of people, because there were 20 years without bringing in new people or building new vehicles. So today you have people in their 20s and 30s, and then in their late 50s and 60s in the space program.

**Lee:** And the new people never build anything; they just play with the automatic CAD [Computer Assisted Design] program, and create beautiful pictures.

**EIR:** There was also a cultural degeneration in the U.S. from the mid-1960s. The shift was away from the belief in progress, with the hippie phenomena and the Baby Boomers. Instead of advancement in science and technology, and increases in productivity and infrastructure, we became a consumer society.

**Lee:** In Korea, it was the same thing. We are now more or less prosperous, compared to the old days. These people want to be safe, easy-going, and make money; the same behavior. We have to tell them, not just lecture them, but they have to figure out what they want to commit their lives to. If you ask about fusion, why am I, myself, here? Because I can do other things, too. But I do this, which so many people criticize, so many people don't understand. What kind of incentive do you have in daily life to work with this intensity, for so many long years? You have to understand what is at stake, and what you're committing to. Otherwise, this will never happen.

People with vision and intensity always try to see something that normal people don't see. Sometimes if you see it, and you believe, people believe you are crazy, because they don't see it. Then one day, there is a storm gathering, and they all see it, and they complain: "Why didn't you tell me? You are a scientist. You must have known this many years ago!"

So we have to tell them the choices. This is how we make progress. As human beings, we all have different interests and different ideas and they are honest, and all of them believe they are correct. So we cannot lecture, but communicate, and steer in the right direction, so they see the storm. . . .