ITER: Fusion Energy Future

An interview with Norbert Holtkamp, PhD, the scientist who, with ITER Director-General Kaname Ikeda, will lead the construction of the world's largest fusion reactor.

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Ministers from the European Union (EU), the People's Republic of China, the United States, and the Russian Federation sign the International Thermonuclear Experimental Reactor agreement at the EU Commission Headquarters in Brussels in May 2006.

The International Thermonuclear Experimental Reactor (ITER, http://www.iter.org) *is a joint international research and development project among seven parties worldwide to demonstrate the scientific and technical feasibility of using the power of fusion—which arises from combining the nuclei, or centers, of two atoms—as an energy source for growing world demand. ITER will be built in Cadarache, France, for operation in or near 2016.*

Courtesy of ITER

Norbert Holtkamp

Norbert Holtkamp, PhD, is ITER's principal deputy director-general nominee and project construction leader. He was born in Germany and has held positions at the Deutsches Elektronen Synchroton in Hamburg, Germany, and the Fermi National Accelerator Laboratory in Illinois. Beginning in 2001, he coordinated and led the design and construction of the accelerator of the Spallation Neutron Source (SNS) at the U.S. Department of Energy Oak Ridge National Laboratory. Completed in May 2006, the SNS is a $1.4-billion accelerator-based source of subatomic particles called neutrons that will provide the world's most intense pulsed-neutron beams for scientific research and industrial development.

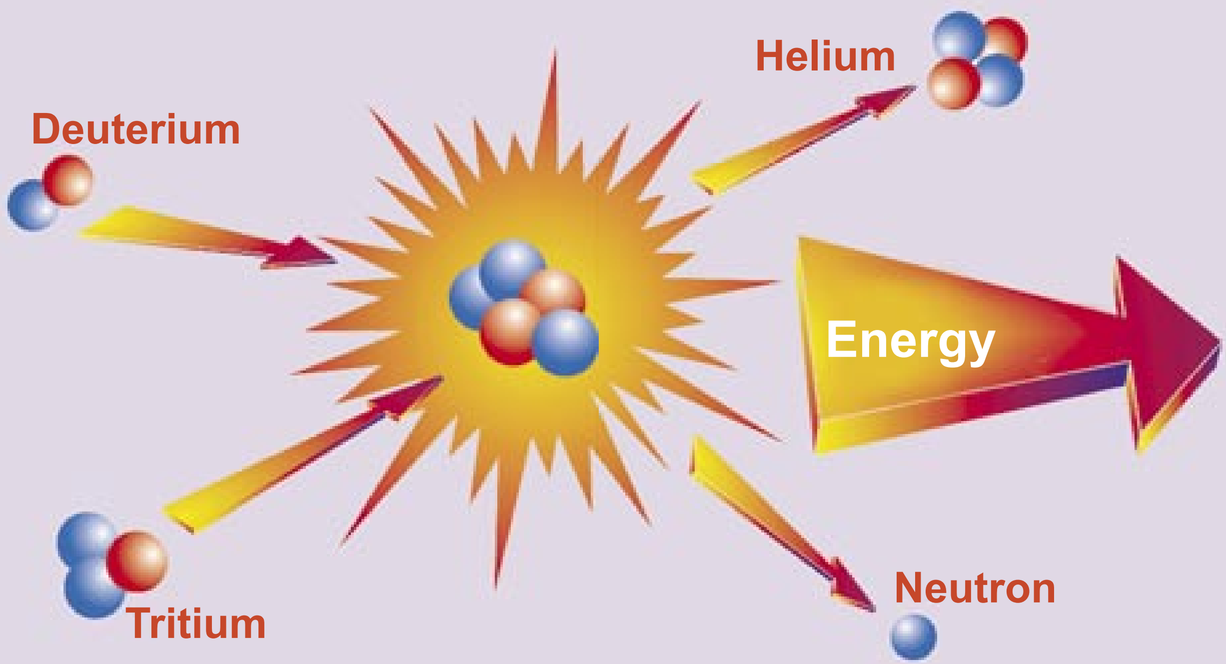
In a world where energy needs are rapidly growing beyond the available supply capacity, scientists from around the world are working to harness the power of the sun and stars and use this resource to meet the planet's rising demands. The European Union, the Republic of Korea, India, China, Japan, Russia, and the United States are forming the ITER Organization to develop this means of energy generation. In this interview, Dr. Norbert Holtkamp, ITER deputy director-general nominee and the scientist who will lead the construction of the world's largest fusion reactor, discusses ITER and the progress of fusion research. Dr. Holtkamp spoke with *Global Issues* science writer Cheryl Pellerin.

Question: What is the ITER project?

Holtkamp: ITER is an abbreviation for International Thermonuclear Experimental Reactor, and it also has a Latin meaning—iter means "the way" in Latin. ITER is the intent to build the largest fusion reactor experiment in the world. A much smaller version of it exists now. JET—the Joint European Torus—the largest nuclear fusion experimental reactor device yet built, began operating in 1983 near Culham, England. ITER is the next step toward constructing fusion power reactors to generate electricity.

Q. What are fission and fusion?

Image Courtesy of ITER



Fusion, Briefly: This article discusses the workings of atoms—the tiny particles that make up all matter. Atoms contain three main "subatomic" particles—protons, neutrons, and electrons. Protons and neutrons are heavier than electrons and exist in the atom's center, called a nucleus. Lightweight electrons exist in a cloud that surrounds the nucleus. Each atom's weight equals its protons plus its neutrons. Hydrogen is the lightest element, with one proton and no neutrons. Its atomic weight is 1. Iron is an example of a heavy element, with 26 protons and 30 neutrons; its atomic weight is 56. Fusion in atoms lighter than those of iron produces energy, and fusion in heavier elements requires energy. The number of protons for a given element never changes, but the number of neutrons can change. Atoms of elements that have the same number of protons but different numbers of neutrons are called isotopes. Hydrogen has three isotopes—protium (one proton, no neutrons), deuterium (one proton, one neutron), and tritium (one proton, two neutrons). At ITER, fusion will be the combination of two of these light atoms, deuterium and tritium, to form a more stable heavy atom, helium, and a neutron, both of which carry kinetic energy. Fusing them will release excess energy.

Holtkamp: *Fission* is getting energy from breaking up heavy atomic nuclei. Fission is a process that is controlled in a nuclear reactor and uncontrolled in a nuclear bomb. *Fusion* is fusing two light nuclei together. In the case of ITER, two hydrogen nuclei are basically melded together. When that happens, energy is freed up and comes out.

Q. Why is fusion better for this project than fission?

Holtkamp: Lots of nuclear fission reactors are operational and used to make energy right now, so fission has the advantage that it works today. Fusion is not something that works yet, it's a research project. Both—fission and fusion—are nuclear processes, but they are fundamentally different. The advantage of fusion is that one waste product from the reaction, helium, is not radioactive, and the other, a neutron, is used to make the hydrogen isotope tritium from lithium-bearing materials surrounding the plasma [ionized gas]. In a fission reactor, when you break up these nuclei, the two pieces that are left over are both radioactive. In a fusion process, that's not true—the chamber that surrounds the nuclei becomes mildly radioactive, but the by-products are not.

The big thing with fusion is that the deuterium and lithium, which is used to make tritium, used in the fusion process are available in vast amounts—they are abundant in the earth and in the sea. That's not true for fission reactors, where you have to use uranium, which is in limited supply, or something like it to operate them. But it's not fair to sell fusion as a better process yet because fusion devices built right now are research experiments, not reactors—scientists are trying to find out how to use fusion to create energy. If ITER is successful, it will be the first fusion reactor device that will create significantly more energy than it uses. That's a major step.

Q. Where did the idea for ITER come from?

Holtkamp: It came from international cooperation in fusion research and was proposed by Soviet President Mikhail Gorbachev in a meeting with French President François Mitterrand and subsequently U.S. President Ronald Reagan at the Geneva Summit in 1985. The three presidents got together and decided to do something about energy resources and see what other energy sources science could make available once we run out of coal and oil. Fusion was always a very international research topic, and at these summits, energy, of course, is a big discussion

U.S. President Ronald Reagan (left) and Soviet leader Mikhail Gorbachev during their November 1985 meeting at the Geneva Summit in Switzerland where they and French President François Mitterrand first agreed to work together to find new energy resources.

point. It drives every economy, every state. It wasn't a scientific discussion, but they came together and said this was something we should be doing. We should be putting the world's brain power together, and do it together, and share the results of the research.

Q. What are ITER's scientific and technical objectives, and what will it demonstrate?

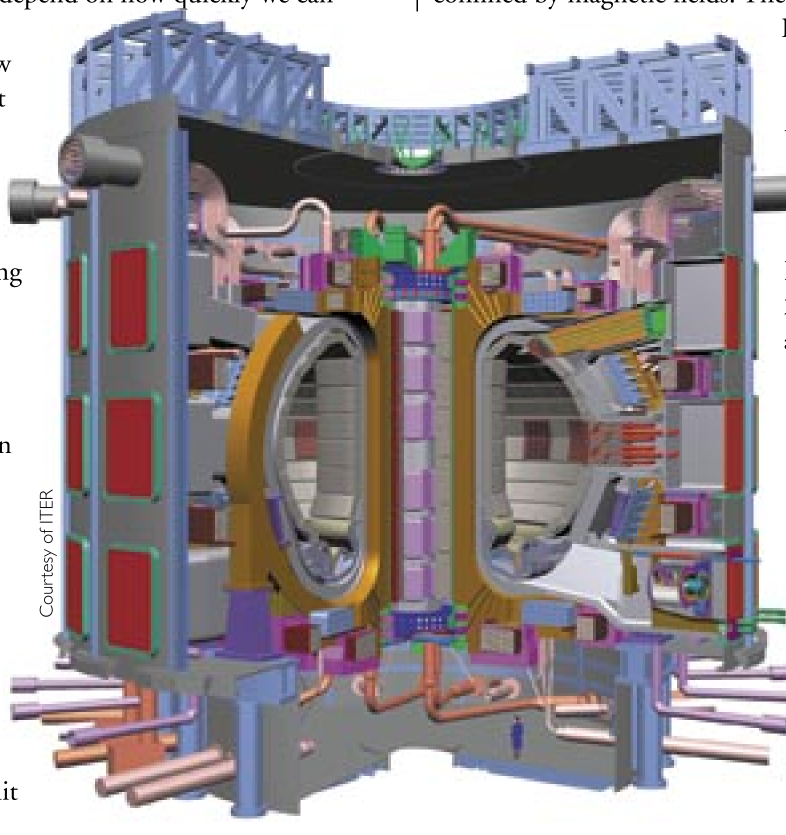
Holtkamp: ITER will be the first fusion reactor to create more energy than it uses. Scientists measure this in terms of a simple factor—they call it Q. If ITER meets all the scientific objectives, it will create 10 times more energy than it is supplied with. The latest device, JET in England, is a smaller prototype that in the final scientific stage reached a Q of nearly 1, which means that it generated as much energy as was put into it. ITER will be the way to go beyond this—a demonstration of creating energy in the fusion process—to a Q of 10. The idea is to put in about 50 megawatts and produce 500 megawatts. So part of the scientific goal of ITER is to first make sure that this Q of 10 can be achieved.

Another piece of the scientific goal is that ITER will have a very extended burn—an extended pulse of up to one hour. ITER is a research experiment reactor and cannot create energy all the time. When ITER starts operating, it will be on for up to one hour, then you have to turn it off. The importance of this is that, so far, typical devices we build can only have burn times of several seconds or tenths of seconds—that's the maximum. JET achieved its Q of 1 with a burn of about two seconds in a pulse length of 20 seconds. But several seconds is not really constant. Like starting a car—cranking the motor up and then turning it off is not really operating a car. When you drive your car for half an hour, it's constantly operating and demonstrates that you can actually drive.

So what ITER will provide technically and scientifically is a Q of 10 and an extended burn.

Q. What is the schedule for the ITER project?

Holtkamp: That will depend on how quickly we can put the team together in Cadarache, and how successful the different parties will be in constructing the components they have to deliver. That goes along with funding the project adequately on a yearly basis, so the funding needs to be agreed upon. The general intent is that in 2016 ITER will begin operation. I cannot promise you that this is realistic because the detailed planning process during the next year will have to confirm that. Therefore, I'm not quite willing to commit to 2016 yet. When complete, ITER will run for 25 or 30 years.



Courtesy of ITER

An artist's cutaway image of the ITER fusion device. The device is based on the tokamak concept, in which a hot gas is confined in a torus, or donut-shaped vessel, using a magnetic field. The gas is heated to more than 100 million degrees Celsius and will produce 500 megawatts of fusion power. A person at the bottom of the image gives an idea of the device's size.

Q. Could you describe the phases of ITER?

Holtkamp: Phase 1 is Before Construction. Officially, ITER doesn't exist yet as an organization because the seven parties have not signed and ratified the documents. That's supposed to happen by the end of the year. The parties have agreed upon what ITER as an international organization is going to look like. This is a real success story. It took four years or so to finalize the negotiations on how this is supposed to be done and that ITER will be built in France. At the same time, if you look at what the parties have said, the entire agreement document is less than an inch thick. It's impressive that seven parties can agree on founding a new international laboratory with less than an inch of paper.

We're launching the Construction Phase right now—constructing the device, building the buildings and pieces of the tokamak [a doughnut-shaped (toroidal) chamber used in fusion research in which a plasma is heated and confined by magnetic fields. The term tokamak is from the Russian words for "toroidal chamber in magnetic coils"], and then putting the tokamak together and getting it up and running.

The Operation Phase is the following 25 or 30 years, when all the experiments will be done. Because it's an experimental device, ITER will not achieve its performance the day after it's built. People have to learn how to operate it, where the tricks are, where the problems are, and they will have to push to achieve the ultimate scientific goals and maybe even go beyond.

Then the Decommissioning Phase starts; part of the construction and operation phases is to plan for decommissioning. I mentioned earlier that the fusion by-products are not very radioactive, but the chamber—the place where this process happens—is very radioactive. That needs to be decommissioned and disposed of in an environmentally compatible way, like any other radioactive piece of hardware. That's part of the decommissioning phase, which will last about five years.

Q. Why is international scientific cooperation critical to ITER?

Holtkamp: Energy is a problem for everybody in the world. If you look at the seven parties—the European Union, the Republic of Korea, India, China, Japan, Russia, and the United States—and count the people who live in these countries, they account for more than half of the world's population. The interest part is clear and can easily be explained. The scientific cooperation is just as clear in my view. There is expertise all around the world in fusion devices, and a complicated device of that magnitude absolutely needs the smartest people we can find to be successful. Plus, there's a big benefit in international cooperation because people of different cultures bring different ideas to the table, and in a scientifically competitive environment that leads to a better scientific device.

Q. What will happen at the end of the ITER project?

Holtkamp: The fusion program is very international, very widespread. People are already anticipating that ITER will be successful and are thinking about the next step—a prototype commercial fusion reactor called DEMO. In order to build that, ITER has to work. You have to achieve your scientific goals because that means the concepts you're putting forward are feasible. Nevertheless, I agree that one should always think ahead. Also, while ITER is operating over 25 to 30 years, the knowledge will gradually improve and grow, and the next step can be better defined. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government or the ITER parties.