somewhere between 2 to 2.5 tons per year that could be burned as MOX.

Now, of the material that has been declared surplus, the 34 tons all will be burnt.

Q: Who is funding this part of the project now?
Simon: Our project has one unique characteristic: that in the beginning, GA and the Russian nuclear agency, Minatom, shared the cost. That's how we started.

When the U.S. Congress began to support this program, starting in fiscal year 1999, the Congress required that of the first money it made available (a total of $5 million), $3 million would have to be spent in Russia, but under the condition that the Russians match the amount of U.S. money going into the project.

Well, the Russians have done that, and I'll have to say right now, that this is the only plutonium destruction program with the Russians (and there are several; the light-water reactor program with MOX is still ongoing) where the money is being paid 50-50. The gas-cooled reactor program is, and will continue as, a joint program, which means that for every dollar that the United States puts in, the Russians put in an equal amount. This goes back to the contract we negotiated in 1994-95.

Q: What are the prospects here in the United States for the gas-cooled reactor?
Simon: Earlier this year, GA decided that after the electricity problems we had in California, and the energy plan that came out, spearheaded by Vice President Dick Cheney, that we should move forward here with the GT-MHR on the commercial side. First of all, the U.S. Department of Energy started looking at what to do to get nuclear power back on track. Clearly in the long term, and even in the relatively short term, this country is going to need more power, and this means that new power generation sources will have to be built. Even though a lot of coal and gas will have to continue to be burned, the renewables (solar and wind) will not be able to close the gap.

Q: Hardly.
Simon: And so, nuclear power has to come back. I'm sure you have seen the numbers. They are talking about 100,000 more megawatts in the next 20 years. And so, we decided that we should also follow a parallel branch here, to what we are doing with the Russians. Even though the Russian design is mainly focussed on the plutonium disposition, in the end, it will be the prototype for a commercial unit. That's the way we look at it.

And we have now started to go in a commercial direction, in parallel to the Russian program.

There will have to be some design changes made relative to the plans we are designing with the Russians. One example is that we would not use plutonium, particularly not weapons-grade plutonium, as the fuel for commercial U.S. applications.

We will put together a consortium of companies which, hopefully, will work together and modify the design as may be necessary. The plan is really now to march on toward a commercial unit.

We formed a utility advisory committee, led by Entergy, and including Omaha Public Power District, Nuclear Management Corp., Dominion, PSE&G, and Constellation. We have several additional companies that have joined, but which have not yet been announced.

The bottom line of all this, is that the Utility Advisory Committee represents about 35% of the U.S. nuclear-generating capacity. These people are active. These people are in Washington, D.C., fighting for the gas reactor, together with us, or by themselves. It is quite clear that Entergy, for instance, is very interested in getting the gas-cooled reactor moving.

Q: Is the plan, that you would move forward here in parallel, and perhaps have another prototype built in the United States?
Simon: Yes, in the end we will have to have a prototype in

General Atomics' GT-MHR

The GT-MHR produces higher process heat (1,000°F, compared to the 600°F limit of conventional water-cooled nuclear reactors). This makes it more efficient for a wide range of industrial applications, from making fertilizer to refining petroleum. It uses a direct conversion gas turbine to produce electricity from the flow of superheated gas, thus simplifying the reactor system and increasing efficiency.

The 285 megawatt-electric (MW-e) reactor is small enough to be mass produced in standardized units, thus making the cost very competitive.

How the GT-MHR Works

The GT-MHR reactor consists of two steel pressure vessels, one for the reactor system, and the other for the power conversion system, both of which are housed about 100 feet underground in a concrete building (**Figure 2**). Above ground are the refuelling machine for the reactor and the auxiliary systems for operating the reactor.

Fuel system: Tiny fuel particles that are shaped into finger-sized rods are stacked into a column, and then inserted into the hexagonal fuel element block (**Figure 3**). The GT-MHR is designed to burn uranium fuel, or plutonium.

The cylindrical reactor core is made up of stacks of hexagonal fuel element blocks of graphite (each about a the United States However, the prototype we are talking about for the United States is about a year or so behind the Russian plan. We would go ahead and build the Russian plant, and then, after that, we would start construction on a U.S. plant.

There are certain things that we would just take over and utilize. For example, the fuel element here would be loaded with enriched uranium rather than with plutonium. And there will be a few other things that will have to be modified: for example, the whole documentation structure that has been adopted in this country for a nuclear plant. Basically there is a common way of doing that, no matter what type of reactor you build. The Russian rules are different, and the information that will be there, will have to be reworked to meet our requirements.

Secondly, of course, we'll have to start talking with the Nuclear Regulatory Commission (NRC).

Q: Have you begun to do this?

Simon: We had our kickoff meeting in December 2001 in Washington; it's what we call the pre-application kickoff meeting, the first dialogue with the NRC to get this whole thing moving.

Q: The pebble bed modular reactor [PBMR] design has already been brought before the NRC by Exelon, which is working with the South Africans, and it seems to me, just from observing from the outside, that the reaction on the part of the NRC is favorable to these new reactors.

Simon: Fundamentally, I agree with you. These are different types of reactors—the PBMR and GT-MHR. They are quite different from the traditional light-water reactors. I can only go back—and I'm putting a little bit of caution in here—in the sense that we had been dealing with the NRC some years ago on the early modular HTGR [high-temperature gas-cooled reactor], and we had submitted a preliminary safety information document on the design, and we asked for a safety evaluation report and we got all that.

But when the NRC came down in the end, there were maybe something like ten items or so on the table that would apply for both the conventional light-water reactors and the

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foot wide and three feet long), into which fuel rods are inserted in vertical columns. The core is ring shaped (annular). It has 61 columns of graphite reflector blocks at the center, 102 columns of fuel blocks surrounding the center, and a ring of unfuelled graphite blocks near the outer rim. There are also helium coolant channels in the fuel elements.

In the three-year fuel cycle of the GT-MHR, refuelling takes place for half the core every 18 months. (In the Pebble Bed design, the refuelling is continuous.)

Helium coolant: The helium gas flows down through the coolant channels in the fuel elements, mixes in a space below the core, and then carries the reactor heat through the inside of a connecting duct to the power conversion system. It circulates through the power vessel, and returns back to the reactor vessel via the outside chamber of the connecting duct. The helium enters the reactor core at 915°F, and is heated by the nuclear reaction to 1,562°F.

Safety systems: Control rods at the top of the reactor vessel regulate the fission reaction. The rods are lowered into vertical channels in the center and around the rim of the core. If the control rods fail, gravity-released spheres of boron automatically drop into the core to stop the fissioning.

There is a primary coolant system and a shutdown coolant system. If these systems both fail, the reactor is designed to cool down on its own. First, there is a passive back-up system, whereby coolant on the inside of the reactor walls uses natural convection to remove core heat to an external sink. The concrete walls of the underground structure are also lined with water-cooled panels to absorb heat, and should these panels fail, the concrete of the structure alone is designed to absorb the heat. The natural conduction of heat to the underground structure surrounding the reactor will keep the core temperature below 2,912°F (1,600°C), which is far below the temperature at which the fuel particles can break apart, releasing fission products or other radionuclides. The graphite blocks retain their strength up to temperatures of 4,500°F.

In any type of loss-of-coolant accident, the reactor can withstand the heat without any human operator intervention.

Increased Efficiency

The GT-MHR system efficiency is about 48%, which is 50% more efficient than the conventional reactors in use today. Its increased efficiency comes from its use of recent technological breakthroughs: new gas turbines developed for jet engines, like that of the Boeing 747s; compact plate-fin heat exchangers that recover turbine exhaust heat at 95% efficiency; friction-free magnetic bearings, which eliminate the need for lubricants in the turbine system; and high-strength, high-temperature steel vessels.

A more detailed description of how the new fourth-generation nuclear reactors work can be found in the Spring 2001 issue of 21st Century Science & Technology *magazine, which is available at $5 per copy from* 21st Century, *P.O. Box 16285, Washington, D.C. 20041, or online at http://www.21stcenturysciencetech.com.*