# U.S. firm, Russians to build modular helium reactor

*The benefits of the gas turbine modular helium reactor developed by General Atomics are enormous, and would draw on Russia's great scientific resources, says GA Vice Chairman Linden Blue.*

*Linden Blue is vice chairman of General Atomics, a San Diego-based company that signed an agreement with Russia on April 1 to jointly develop a modular high-temperature gas-cooled nuclear reactor, which will use an advanced gas turbine to directly convert the reactor heat to electricity. Blue was interviewed in early April by Marjorie Mazel Hecht, managing editor of* 21st Century Science & Technology *magazine.*

**Q:** The recent announcement by General Atomics of the agreement for joint 50-50 partnership with the Russians to develop the gas turbine-modular helium reactor (GT-MHR) is good news for nuclear and good news for world development. Can you tell me about the scope of the agreement that you signed?

**Blue:** First of all, it is an agreement and an alliance that makes all kinds of sense. The Russians have splendid physicists; we have worked with them for many years. Even during the years of the Cold War, we worked on fusion energy together and that's resulted in a broad international fusion effort. There's no reason why we can't duplicate that kind of effort with this fission reactor, the modular helium reactor. The gas turbine variation on that takes the ultimate advantage of that potential.

Additionally, the Russians have enormous infrastructure that is currently unemployed or underemployed and, I think, it's in everybody's interest that these facilities be used and be used for constructive purposes rather than for making weapons for Russia or anybody else.

**Q:** Your agreement is to produce a design and a demonstration plant, but you also talk about mass production, which is tremendously exciting. This is a modular reactor, which lends itself to mass production, and there is such an enormous market in Russia and the former Soviet states because their reactors are terrible by U.S. standards.

**Blue:** That's right, and the Russians do have some good plants and equipment that could be readily adapted to producing these modular reactors.

Saying that it would be in mass production is a little bit misleading, because when people think of mass production they think of the automobile. Production of modular reactors would be at a very low rate. What we're talking about is *serial* production; that is, there would be a constant flow, and you would take advantage of all the economics and controls of factory production. Not only controls that keep costs down, but quality control is much better in factories. So I think a better term is factory production.

**Q:** When would you expect to have the design completed and your first reactor on line, if all goes well?

**Blue:** We would hope to have the first one on line in about 10 years. Frankly, the program will probably be constrained by finances, and 10 years is a very reasonable time period. It could be done sooner, if there were full funding very early on.

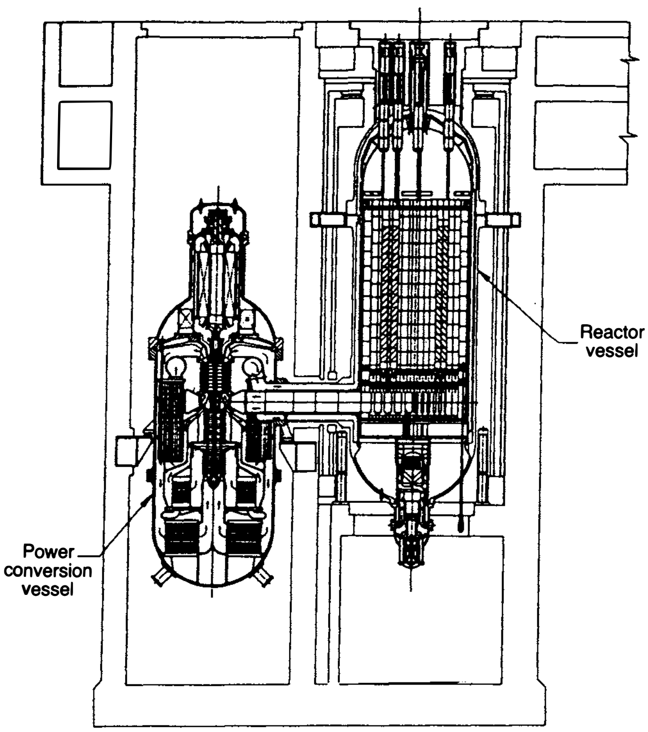
**Q:** If you had the optimal schedule—let's say financing is not a problem and there is a crash program to do this—how fast could it be done and, realistically, what do you expect?

**Blue:** I would say eight years would be a minimum.

**Q:** Is this eight years to develop the design and get your first reactor on line?

**Blue:** Yes. The reason that I believe it could be done in eight years is that the design is already very far advanced for the

## The direct-cycle gas-turbine modular helium reactor




*GT-MHR will pioneer the development of a next-generation nuclear reactor that is modular, simple in design, and inherently safe (no meltdown is possible). For the first time in a nuclear reactor, it will eliminate the steam turbine, converting its heat, via the helium coolant and an advanced gas turbine, directly to electricity. The great efficiency of the GT-MHR comes from several recent technological breakthroughs: new gas turbines developed for jet engines like the Boeing 747; compact plate-fin heat exchangers that recover the turbine exhaust heat at 95% efficiency; magnetic bearings that are friction free, eliminating the need for lubricants in the turbine system; and high-strength, high-temperature steel vessels.*

*This 300 MW GT-MHR power plant consists of two pressure vessels, both located underground in a concrete containment structure. One vessel houses the nuclear reactor system and the other, smaller vessel houses the power conversion system—a generator, gas turbine, and two compressors.*

*The fuel particles are unique to this type of helium-cooled high-temperature reactor. Uranium or plutonium fuel is fabricated into tiny particles that are coated with layers of ceramic materials that constitute tiny individual "containment vessels."*

*The helium enters the reactor core at 915°F and is heated by the nuclear reaction to 1,562°F. It then converts the heat to electricity and the helium is cycled back to the reactor vessel.*

Source: General Atomics.

reactor itself, and we would be able to take advantage of all the work that's gone on before. All of this work—the latest work—is also on CAD/CAM [computer-assisted design/ computer-assisted manufacturing], which means it's engineered electronically. Thus, changes are much easier to make and you have enormous files that are very easy to manipulate, which in itself reduces the time. So, by taking full advantage of everything that we've done in the past, in my opinion, eight years is quite realistic.

And then it would be a matter of utilizing resources in this country and in Russia, and producing some parts in Russia and some parts in the United States.

**Q:** The news release that General Atomics put out estimated $20 million a year as a budget coming from the United States. How would that work? What do you envision?

**Blue:** We would expect that there would be a program for the development of the reactor—it would probably be administered by the U.S. Department of Energy—and our joint venture would be the contractor which would be asked to do the job. The Department of Energy would oversee the effort.

**Q:** Because the reactor will burn weapons-grade plutonium, do you expect to have funding from the Department of Defense—which, I believe, has already pledged to the Russians $1.6 billion in terms of cleaning up and working with the problems in their nuclear and weapons program?

**Blue:** That's a possibility. First of all, let me clarify one thing. The reactor can either burn low-enriched uranium or plutonium. The thing that has been talked about most recently is the plutonium variation because of the problem we and the Russians have to deal with: plutonium coming out of weapons. Essentially the difference—whether it's burning uranium or plutonium—is in the fuel kernel. . . . It's just a question of what's in the center of the fuel kernel—plutonium or uranium.

The defense authorities in both countries have to be concerned with the plutonium problem. And exactly where the funding would come from is uncertain, but $20 million a year goes a long way toward solving the problem, and, relatively, is not a large amount of money.

**Q:** It's a very small amount compared to development of other large projects like this. I would like to get into some specifics of the reactor design. But first, I am going to ask you another global question. I see this as a tremendous prospect for industrial growth in all of eastern Europe, and also as a boon for U.S. technological capability, because the parts and components of reactor systems that will be needed can be fabricated both here and in Europe.

**Blue:** That's absolutely right, and it's very-high-value-added production. That is to say, after World War II they tried

*The biggest and most important savings of the GT-MHR is the thermal efficiency, but the other is that we are directly driving the turbine from the helium gas as it comes out of the reactor.*

to convert companies that had been manufacturing airplanes to—one case in particular, it was Grumman—making canoes. Well, admittedly, canoes are made out of the same thing—aluminum—that airplanes are, but there's a huge difference in sophistication and value added, so that kind of conversion of a defense industry to commercial products just didn't work.

It's very difficult to convert defense products and defense production capabilities to civilian production, and, in fact, it is very, very rarely done successfully. In this particular case, the same kind of sophisticated equipment and facilities and infrastructure that has produced weapons could also be employed on a very high value-added basis to make these reactors, because these reactors are, likewise, very sophisticated, and it takes the same kind of high-quality plant and equipment that the weapons sometimes require. So, yes, it is a splendid opportunity for conversion of defense facilities to peaceful commercial uses.

**Q:** The degree of sophistication, it seems to me, in the machining required will benefit from the skilled labor force that exists both in Europe and here, and is currently going idle to a large extent.

**Blue:** Yes, the problem of keeping Russian physicists and engineers—who are extremely good and talented—productively employed and keeping them from seeking jobs outside of Russia where we might not want to have them working is very important. And I noticed the other day in this country that there's rather high unemployment among physicists and engineers. This would be a great way to put some of these people to work—something that is of enormous value to mankind.

**Q:** Yes, and what they're really missing in eastern Europe is cheap electricity. In other words, what you need for development is electricity, a good source of inexpensive electricity, and once you have that, you can then develop any country. I think you know we've worked on programs for developing eastern Europe, and the bottom line is that you need a transportation grid and you need electricity.

**Blue:** That's right and remember, electricity is the most environmentally benign source of energy there is. So the question is, how do you get the electricity. If you burn coal to get there, you create environmental problems. Nuclear is the cleanest source of energy, other than hydro power. There are no emissions and the radiation levels are actually lower than they are from burning coal. You do have the storage of a small amount of high-level waste. But this amount is about 100,000 times less in volume than the waste from coal. So it really is a problem that can be readily handled, and the fact that you have no emissions into the atmosphere is a great advantage.

**Q:** Especially in eastern Europe, where they burn the kind of coal that has tremendously polluted the entire area. I like your slogan "To Power the World into a New Century," because I think that it is very appropriate. To me, one of the most exciting things about the GT-MHR is that it's a gas turbine. I never have understood why we would want to go with 21st-century new nuclear reactors but use the old steam technology. So, the coupling of the gas turbine, I think, with this new reactor design—the helium reactor—is exciting because this is a technology worthy of the new century.

**Blue:** That's right. The detractors will say, "Well, if it's so good, why wasn't it done before?" And the simple answer is that the technologies haven't been ready before. We haven't had a modular reactor that was sized right for the kinds of gas turbines that are being made now. Gas turbines themselves hadn't evolved to the point of efficiency that we're getting now. And the magnetic bearings make everything easier in terms of the shafts.

**Q:** Are these the frictionless bearings?

**Blue:** Yes, the magnetic bearings virtually eliminate friction, and they have great properties for dynamic dampening of rotating shafts, so they're superior in every way. But with magnetic bearings 10 years ago, you just couldn't do this type of project.

**Q:** There are a number of state-of-the-art developments that made the GT-MHR efficiency possible, as your literature notes.

**Blue:** The recuperators are the final thing. Ten or fifteen years ago, when we looked at this earlier, we could only get recuperators that were 88% efficient and were five times as large as the recuperators we're talking about now. There's been enormous improvement in recuperators. Mostly that has come out of the fossil-energy arena, but these advances are directly applicable to what we're doing. So, yes, the technology has evolved to the point that it is ready to power us into the next century, and the advantages are so great that it is hard to imagine people would consider using steam any more.

**Q:** Can you talk a little about the evolution of the GT-MHR design and about its 50% increased efficiency through the use of the gas turbine? Because that's very impressive.
**Blue:** First of all, the laws of thermodynamics are that the higher up you're able to go in the thermal scale, the more efficient you can become. We've always known that, everybody knows that, and that's always the objective. The problem is, getting heat-exchange mediums and materials that will handle the higher temperatures.

We're able to handle the higher temperatures with our fuel because it's a tough ceramic and, as you know, ceramics can go to very high temperatures. That is number one. Number two is that water is a splendid coolant, but it is corrosive and it limits you to about 700° C in terms of its being an efficient fluid for heat transfer.

Helium, by contrast, is totally non-corrosive and has no thermal limit. It's going to remain a gas whether it's at room temperature or 3,000° C, and that's an enormous advantage. So you can take the helium up to as high a temperature as the other materials will tolerate, and as you do that you are getting greater efficiency.

There's another area where the efficiency comes from: When you have to pass a fluid—be it water or helium—through a heat exchanger before it can do its work, you lose efficiency, and those efficiency losses can be rather significant. The biggest and most important savings of the GT-MHR is the thermal efficiency, but the other is that we are *directly* driving the turbine from the helium gas as it comes out of the reactor. That's also a great source of efficiency, since no heat exchanger is necessary.

**Q:** It also gives you a very compact design, it seems to me, with your two modules side by side.
**Blue:** Very compact and very simple, and any engineer will tell you that the simpler you can keep a design, the better it is.

**Q:** Some of the other advantages mentioned are that the cooling towers can be smaller, which saves cost, and that they're air-cooled, which to me is a very big selling point, because that means you can locate the reactor in places that are deserts or don't have the water availability.
**Blue:** That's right, and there are so many places where there may be a little bit of water, where it's very precious—it's a shame to use it to cool electricity-generation facilities. So the GT-MHR is ideal from that standpoint also. It is possible because of the higher temperatures. It tells you that throughout the GT-MHR design, you're gaining economics that are extremely attractive, and you're getting rid of the traditional problems and resistances to reactors of the past.

**Q:** Can you say a little bit now about the inherently safe aspect of the reactor? In particular, I think what is attractive is that the containment of this reactor is actually the ceramic layers surrounding the tiny fuel pellet.
**Blue:** Yes, we believe the right place to confine the radionuclides is at their source, and that's exactly what the tiny fuel particles do. They are in actuality tiny containment vessels. We have a lot of other things that could contain the radionuclides as well, but the essence of the safety is the tiny-fuel-particle containment at the source. That leads us to a reactor that can't melt down. That's a big contrast to the kind of fuels that we've seen in reactors in the past, which required the presence of coolants at all times.

The helium reactor can have an accident where you lose all the coolant and you still don't have a meltdown. We're the only reactor that can do that.

This isn't to be critical of light-water-reactor safety. I think in this country we've done a fine job and have had a fine safety record. It just points out that in the case of the helium reactor, even if you have human error as we had at Three Mile Island and Chernobyl, you can't have a meltdown. Even if you were to have a major structural failure, you can't have a meltdown. It goes right back to that microscopic fuel particle that contains all the radionuclides right there and the low-power-density reactor that simply can't reach temperatures which would fail the fuel.

**Q:** I noticed also that this reactor makes 33% less high-level waste than the ordinary light-water reactors do. Why is that?
**Blue:** Let me clarify that. The light-water reactors today produce 50% more waste. It takes them 50% more neutrons to produce heat and 50% more fuel to produce the neutrons, and that results in 50% more waste. It is strictly a function of our high thermal efficiency, where you don't have to pass the coolant through a heat exchanger.

**Q:** So, all of these advantages add up to a lower cost per kilowatt hour of electricity produced?
**Blue:** That's correct.

**Q:** What is your estimate of electricity cost with the GT-MHR?
**Blue:** We estimate that we will be very close to about $.03 per kilowatt-hour, and that's a big improvement.

**Q:** The current light-water cost is closer to $.05 per kilowatt-hour, I believe.
**Blue:** Yes, it's sort of all over the ballpark, depending on when the reactors were built, but the recent ones are certainly at $.05 or more. . . . Natural gas combined-cycle gas turbines are very low—I think in the neighborhood of 3½¢. But that's with low gas prices, and one of the things I noticed the other day in the paper was that natural gas future prices have gone from $1.50 in January to $2.25 now; that's a 50% increase in three or four months. That just tells you how subject to change anything is that involves natural gas.

We think natural gas is a fine fuel, but it should not be the only one that we rely on for production of electricity. Of course, coal has its environmental disadvantages. Natural gas has environmental disadvantages also, but from the environmental standpoint, it's better than coal.

**Q:** But both coal and natural gas have the limitation that they are natural resources that we are depleting.
**Blue:** They are natural resources we're depleting that ought to be used for transportation and home heating.

**Q:** And also for making plastics and other things that cannot be done without having the fossil fuel as a source.
**Blue:** The other thing that people must remember about natural gas is that it is a fossil fuel. It does have emissions—they're lower, yes—but they're only about 40% lower than coal; you still have 60% of the emissions to deal with.

**Q:** Well, I'm sold on the modular helium reactor, no question about that.
**Blue:** There's another advantage that I would like to talk about, and that is the whole relationship of energy availability to world improvements in standards of living, and that means political stability. It also means less fighting and killing.

Throughout history men have fought over the resources, the wealth they perceived that they needed for a good or improving life. There's been incredible killing for that reason. Right now, today, we see so much evidence of that in the volatility in the Middle East because of the concentration of hydrocarbons in that area.

To continue world reliance on those resources is almost certainly a formula for continued violence, destruction, and death. While there is no way we can get away from using those resources, we should certainly not increase our reliance on them, and the only way we can decrease the reliance on them is to have other sources of energy. The kind of reactor that we're talking about is the best source of alternate energy I know of, unless and until solar makes dramatic improvements in economy which, I hope and trust, it will over a long period of time. But, right now, today, this is the only thing that's really economical.

**Q:** I think that you're absolutely right. The strife and devolution that we're seeing is extremely dangerous. If you look at the 21st century and look at the way things are going now, unless we are able to turn that around and do exactly what you say—provide the energy so that nations can develop and can improve the lives of their people—it seems to me that we're looking at the Third World War.
**Blue:** I think that's very likely, and if not a Third World War, just more and more conflicts like Iraq.

**Q:** There are so many hot spots now—in the Middle East, throughout Africa, Iraq, and Iran. Certainly I think people would prefer to build instead of destroy, and to do that you need a source of energy. And a source appropriate for the 21st century would be nuclear fission or fusion. I disagree with you on solar, because I think solar is inherently limited and will never be able to provide the quality of energy—the energy density—needed for industrial economy.
**Blue:** I don't disagree. I'm only saying that I would be hopeful on solar, but that it would be crazy for us to rely on the expectation that it will happen. I just hope that it will come along and make what I think will be a very modest contribution. But it's not going to provide the huge amounts of energy that nuclear and/or use of fossil fuels can provide.

**Q:** What do you think the next step is, looking ahead? You signed the agreement as of April 1; what kind of a timetable do you think you can have?
**Blue:** I think the Russian scientists need employment now; this is a problem now. I would hope that this will be a program that will be expedited and that maybe some funds would start to flow in a few months. The need is there, the people are there, the resources are there. The capability is very much in place, and we have the capability in this country of contributing enormously to the technical effort as well. So, I hope that we would be under way in a serious way within a few months.

**Q:** And what are the indications from the new administration that you had about the project?

**Blue:** I believe it is one of the projects that was discussed at the summit, and I believe it was favorably discussed, and is being considered now.

**Q:** That is good news. What do you think the prospects are for General Atomics to work out similar joint projects with other nations?

**Blue:** I think they're very good, because there is a need for this modular type of power plant where power can be added in, say, increments of 300 MWe rather than four times that amount, which the big water reactors require. That's needed almost everywhere. It's also needed to have the economy, of course, that the modular reactor gives you, and the freedom from the huge infrastructure that's required to assure the safety of a light-water reactor.

Our reactors are so simple, so forgiving, they can be put almost anywhere in the world and you wouldn't have to worry about it from a safety standpoint.

**Q:** I think that that's a big selling point, and I think there would be other nations in Ibero-America and elsewhere in Asia that realize that they need nuclear in order to grow, and that would be interested in this.

**Blue:** One of the areas in which it could be very desirable is for the stimulation of heavy-oil production. Right now, in order to get heavy-oil production you need to burn about a third of the deposit, and that's a terrible waste of the oil and has all kinds of environmental negatives. So, any place that has heavy oil should be very interested in this source of stimulating that production . . . along with all the other reasons. And there's a lot of heavy oil in the world—Venezuela, Indonesia, Russia.

There's always resistance to anything that's new. But there comes a time when the technology is so overwhelming—in terms of its advantages—that it can't be resisted, and I believe that's what we have now, because we have a reactor that is not only dramatically more efficient, but dramatically less polluting, dramatically less expensive (in terms not only of building, but its product), and dramatically safer. In a time when the world does need energy, this confluence of technologies gives us an enormous opportunity, and I think that those people who are pessimistic about what science and technology can do for the good of the world, just haven't been exposed to this particular project.

**Q:** That's a good optimistic note to end on! Can you say a little about the history of General Atomics?

**Blue:** General Atomics was founded nearly 40 years ago for the peaceful uses of nuclear energy, and it has been dedicated to that purpose ever since. It is a world leader in production of training, research of isotope reactors, in fusion energy and it is the world leader in the fission helium-cooled reactor technology.