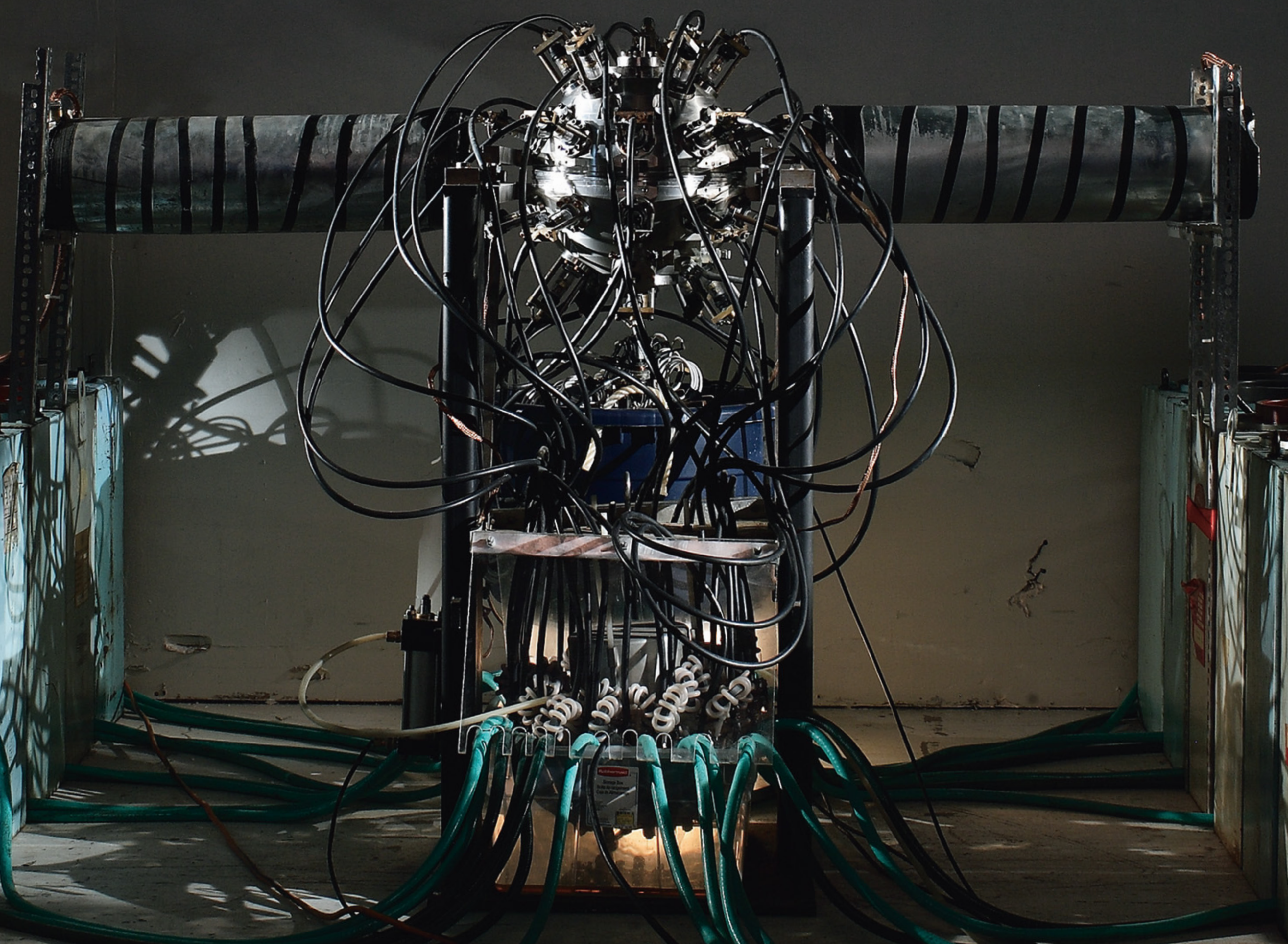
THIS MACHINE MIGHT* SAVE THE WORLD

*THAT'S A BIG, FAT "MIGHT"



TWO DESKTOP-PRINTER ENGINEERS QUIT THEIR JOBS TO SEARCH FOR THE ULTIMATE SOURCE OF ENDLESS ENERGY: NUCLEAR FUSION. COULD THIS HIGHLY IMPROBABLE ENTERPRISE ACTUALLY SUCCEED?

BY JOSH DEAN PHOTOGRAPHS BY JOHN B. CARNETT

THE SOURCE OF endless energy for all humankind resides just off Government Street in Burnaby, British Columbia, up the little spit of blacktop on Bonneville Place and across the parking lot from Shade-O-Matic blind manufacturers and wholesalers. The future is there, in that mostly empty office with the vomit-green walls—and inside the brain of Michel Laberge, 47, bearded and French-Canadian.

According to a diagram, printed on a single sheet of white paper and affixed with tape to a dusty slab of office drywall, his vision looks like a medieval torture device: a metal ball surrounded on all sides by metal rods and bisected by two long cylinders. It's big but not immense—maybe 10 times as tall as the little robot man in the lower right corner of the page who's there to indicate scale.

What Laberge has set out to build in this office park, using $2 million in private funding and a skeletal workforce, is a nuclear-fusion power plant. The idea seems nuts but is actually, he says, not at all far-fetched. Yes, he'll admit, fusion is generally considered the kind of nearly impossible challenge undertaken only by huge universities or governments. Yes, fusion has a stigma to overcome; the image that it is fundamentally bogus, always and forever

HOME-BREWED FUSION General Fusion's proof-of-concept device in the company's austere headquarters, in Burnaby, British Columbia

20 years away, certainly doesn't help. Laberge would probably even admit that the idea of some Canadians working in a glorified garage conquering one of the most ambitious problems in physics sounds absurd.

But he will also tell you that his twist on a method known as magnetized target fusion, or MTF—to wildly oversimplify, a process in which plasma (ionized gas) trapped by a magnetic field is rapidly compressed to create fusion—will, in fact, work because it is relatively cheap and scalable. Give his team six to 10 years and a few hundred million dollars, he says, and his company, General Fusion, will give you a nuclear-fusion power plant.

If (and this is a truly serious *if*) Laberge and his team succeed, the rewards could be astounding: nearly limitless, inexpensive energy, with no chemical combustion by-products, a minimal amount of extremely short-lived radioactive waste, and no risk of a catastrophic, Chernobyl-level meltdown. "It's an astonishing story," says Mike Brown, the founder of Chrysalix Energy, the venture-capital firm that provided the angel funding for General Fusion, and who now leads the company's search for backing. "If Michel makes it work, he's a Nobel Prize winner."

ON THE MAD-SCIENTIST appearance scale, Laberge is maybe a 4 out of 10; he's a little rumpled and wears out-of-style wire-rimmed eyeglasses. But get him a little agitated, and he starts to tug at his hair and slips to maybe a 5 or 6. Discussion of spending money on something other than research will do it. Office supplies! Hotel rooms! Human Resources! These are necessary costs for operating a company but irritating distractions for a physicist with big dreams and limited capital.

Laberge and his business partner, Doug Richardson, an engineer who also studied physics, met at Creo Products, a Vancouver-based developer of prepress-imaging technology now owned by Kodak. They worked together for 11 years on thermal printer heads and other highly precise mechanical devices, making a very comfortable living, until Laberge found himself staring at 40 and had a midlife crisis.

"I said, 'What am I producing here?' " he recalls, leading the way to the warehouse area of General Fusion's small and decidedly unfuturistic headquarters. "I am producing a machine that makes printing so cheap that it can fill your mailbox with lots and lots of junk mail. The main use of my productivity is to cut down the forests. And I look at the energy situation, and it's going down the drain at pretty high speed. So I knew I had to do something. Now, I know about fusion because I did my Ph.D. in fusion physics. So I said, 'OK, we're gonna do fusion here.' "

It was, to say the least, a questionable career swerve. But after some soul-searching, Laberge quit Creo, retired to an island off the coast of British Columbia, and set out to master nuclear fusion. Four years, several failures and $800,000 later (half from friends and family and half from matching government research grants), Laberge surfaced with a contraption that provided a proof-of-concept for his idea. It's a shiny steel orb the size of a basketball from which dozens of cords protrude. Imagine those cranial caps from old science-fiction movies, and you'll get the idea. The cords extend out to two dozen capacitors, and the whole thing is wired up to a tower of controls that could have been pulled from a 1950s battleship. It is the definition of low-tech, and that's precisely the idea.

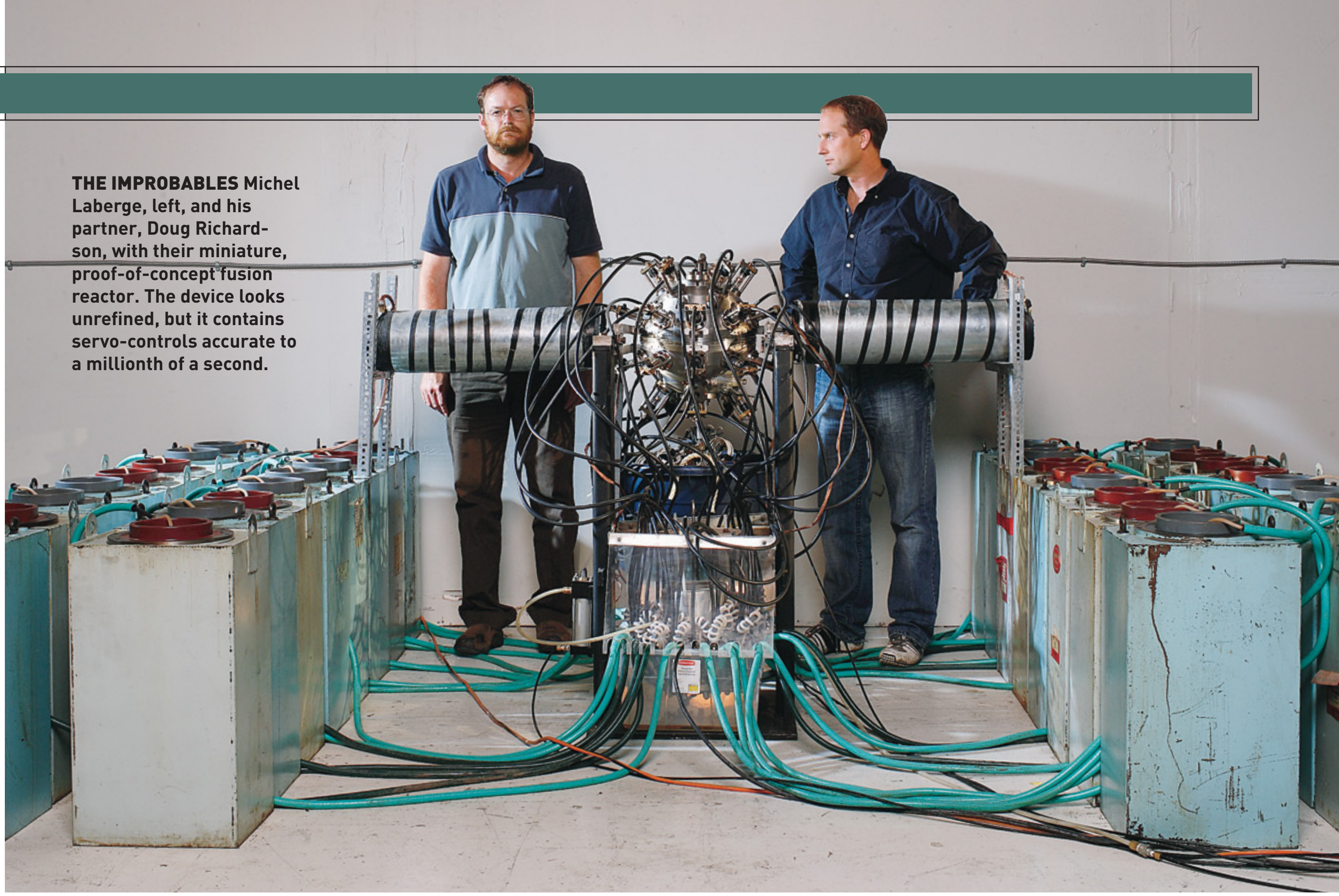
The metal sphere is now mostly a showpiece. Laberge will occasionally fire it up for potential investors, but by and large, it's done its job. In 2006 it proved that a shock wave—created by a massive pulse of electricity, for experimental purposes—can compress a little bit of plasma quickly and violently enough to generate a fusion reaction, however tiny. In place of the hugely expensive high-power electrical systems used to collapse the plasma in more typical MTF experiments, Laberge imagines a set of pneumatic rams colliding with the plasma container's outer shell to form a shock wave. This is where his idea is truly different.

But there is much distance to cover before Laberge's idea leads to a device that generates electricity. "This is not making energy," he says of his machine. "I'm dumping 100 kilojoules of energy, and I'm making about one nanojoule. But it shows that the technique of crushing the plasma to high density has some merit to it, and getting a few fusion neutrons out"—neutrons are a telltale sign of a fusion reaction—"well, I call them my marketing neutrons."

Laberge has the same ultimate goal of every fusion researcher—to achieve "net gain," which means to put out more energy than is put in, and not just, say, 1.5:1. To make a viable power source, you need far more than you put in, anywhere from 10 to 25 times as much. "We must simulate star-like conditions for the fuel" in order to make fusion happen, says Richard Siemon, a professor of physics at the University of Nevada and a former director of fusion research at Los Alamos National Laboratory. The hydrogen isotopes used as fuel have to be held at about 270 million degrees F. The plasma must then be compressed. As you might imagine, this requires an enormous amount of electricity (and an equally enormous infrastructure) or an alternative method of compressing the plasma.

Laberge believes he has a better shot than the competition at creating viable fusion power because his approach is smaller, cheaper and uses so much less electricity. And once his reactor is operating at net gain, it will power itself. Fuel for fusion—deuterium and tritium—is plentiful and cheap. Deuterium is an isotope of hydrogen found in seawater; in theory, one gallon of seawater has the potential energy of 30 gallons of gasoline. Tritium is mildly radioactive and has a 12-year half-life, so it's a little harder to find, but it can be derived from lithium. Conveniently for General Fusion, Canada has the world's largest stockpile of tritium.

LABERGE'S IDEA IS A "THERMONUCLEAR DIESEL ENGINE." COMPRESS FUEL, AND IT BURNS.



THE IMPROBABLES Michel Laberge, left, and his partner, Doug Richardson, with their miniature, proof-of-concept fusion reactor. The device looks unrefined, but it contains servo-controls accurate to a millionth of a second.

Laberge's own energy has now turned toward a long metal tube lying on the floor nearby, a piece about the size and shape of a ship's cannon. That's the first piston housing for the theoretical reactor—step 1 of many in the quest for a commercial fusion power plant. General Fusion's reactor will one day rely on 200 of these housings, each weighing some 2,200 pounds and holding a steam-powered piston that weighs 220 pounds. Operated by servo-controls accurate to a millionth of a second, the pistons will fire simultaneously every second, creating the shock wave that will trigger the fusion reaction. "Somebody described it as a thermonuclear diesel engine," Laberge says, perhaps undervaluing a potentially awesome marketing phrase. "We compress the fuel. It burns."

He walks around the housing and points out the actual piston, which is about a foot thick and roughly the circumference of an LP. When I ask how loud this would be—200 pieces of ultra-hardened steel impacting 200 plates of equally hard steel at extreme velocity—he says we can fire this one up and get a sampling, although admittedly it's not a test at anything close to full power. "This is one third the travel and one one-hundredth the pressure," Laberge says as he flicks a switch. Nothing happens.

"Hmm. Why is there no power here?" He tugs at two extension cords, one of them an orange indoor-outdoor job like the kind you use to plug in a weed whacker. As the cylinder pressurizes, it sounds like a burbling fish-tank filter. "5, 4, 3, 2, 1—0!" Laberge says, and flicks a switch. The piston fires. It's no louder than a kid hitting a tom-tom drum and is . . . underwhelming, not even remotely the kind of far-out experiment you'd expect to see when dropping by a nuclear-fusion start-up. To Laberge, that's exactly the point.

"It's pretty basic, boring stuff," he says. "Look in your car. There's no superconducting magnet in there. There's pipes and pistons and tubes. That's what I want. I want to make a fusion machine at a sort of car level. And that's why we can make it for $50 million and they"—government and university coalitions—"make it for $20 billion. That's the difference."

NUCLEAR FUSION: It sounds futuristic, and yet it's not. It's a story as old as the sun, literally; fusion is how it fuels itself. Two ions collide at such velocity that the electrostatic repulsion between them is broken. They fuse into a heavier atom and give off energy as heat. In terrestrial practice, the idea is that a man-made reaction would produce heat that would then be captured by a heat exchanger to create steam. The steam would power a turbine as in any coal plant and—voilà!—energy.

The earliest fusion experiments date back to the University of

WITHOUT FUSION, MICHEL LABERGE BELIEVES, OUR ENERGY SITUATION IS DIRE. "IT'S GOING TO BE UGLY."

Cambridge in the 1930s, but the research gained momentum in the 1950s during the Cold War, when both sides were primarily interested in weaponizing fusion. The 1952 American nuclear test Operation Ivy proved that fusion could work as the core of a devastating weapon, when the first hydrogen-bomb test obliterated an entire island in the Pacific.

Two things have conspired to hamper evolutionary leaps in peacetime fusion research. The first is bad press. To the great frustration of people like Laberge and Richardson, fusion's good name has been besmirched by a handful of highly publicized failures, most prominently the cold-fusion experiments of Stanley Pons and Martin Fleischmann and the "bubble fusion" experiments Rusi Taleyarkhan conducted at Purdue University. Pons and Fleischmann announced in 1986 that they had achieved fusion at room temperature, but later review showed that faulty equipment had failed to accurately measure the results. The U.S. Department of Energy all but called them frauds. In 2002, Taleyarkhan published a paper stating that he had used ultrasonic vibrations to make bubbles in a liquid solvent and that, when the bubbles collapsed, they had created fusion. His results, too, would later be discredited, and last year he was stripped of his university chair.

The failures were bad for fusion's public image, but the larger problem, researchers say, is money. Governments just have not seen a need to pour resources into an idea that they perceive as being decades from reality. In 1982, for example, Congress passed a plan calling for fusion energy in 20 years. "What happened?" says Glen Wurden, who heads up the Magnetized Target Fusion program at Los Alamos. "The U.S. didn't fund it. In the 1980s the U.S. was the world leader in fusion research. [Our funding is] a factor of three behind Europe right now and a factor of two behind Japan."

These days, there are several large fusion experiments happening around the globe; the differences among them have to do with how the plasma is contained. General Fusion uses what's considered an "alternative" method, one of a handful of ideas that lie outside the prevailing model, known as steady-state fusion. Steady-state is the form practiced at nearly all the world's biggest test facilities. It's also the model on which the mother of all fusion experiments, the International Thermonuclear Experimental Reactor, will be based.

ITER is funded by a consortium of seven governments: the U.S., Russia, Japan, China, India, South Korea and the European Union. Construction is set to begin this year in the south of France. Like most high-level fusion experiments, ITER uses a plasma-chamber design called a "tokamak," a word transliterated from a Russian acronym meaning "toroidal chamber with magnetic coils." It looks like a gigantic doughnut. Huge superconducting magnets hold the plasma away from the chamber walls. Then they blast the plasma with radio waves and beams of neutrons to trigger a fusion reaction.

Yet aside from reactor design (and obvious contrasts in size and funding), the biggest difference between ITER and General Fusion is a sense of urgency. Conventional wisdom among most in the plasma-physics community—"the tokamak mafia," as Laberge jokingly calls them—is that commercially viable fusion is at least 30 to 40 years away. Richardson and Laberge belong to a splinter cell of the industry that points out that fusion has been 30 to 40 years away for 50 years now and that, frankly, the world can't wait that long. "The s- - - will hit the fan in 10 years," Laberge predicts. "It's going to be ugly. As the gap between fossil-fuel supply and energy demand builds up, we will need to put new energy sources in the gap. We may avoid a disaster if we can do that fast enough, but I don't think so without some serious breakthrough in energy production." They're convinced that this breakthrough has to come from private industry.

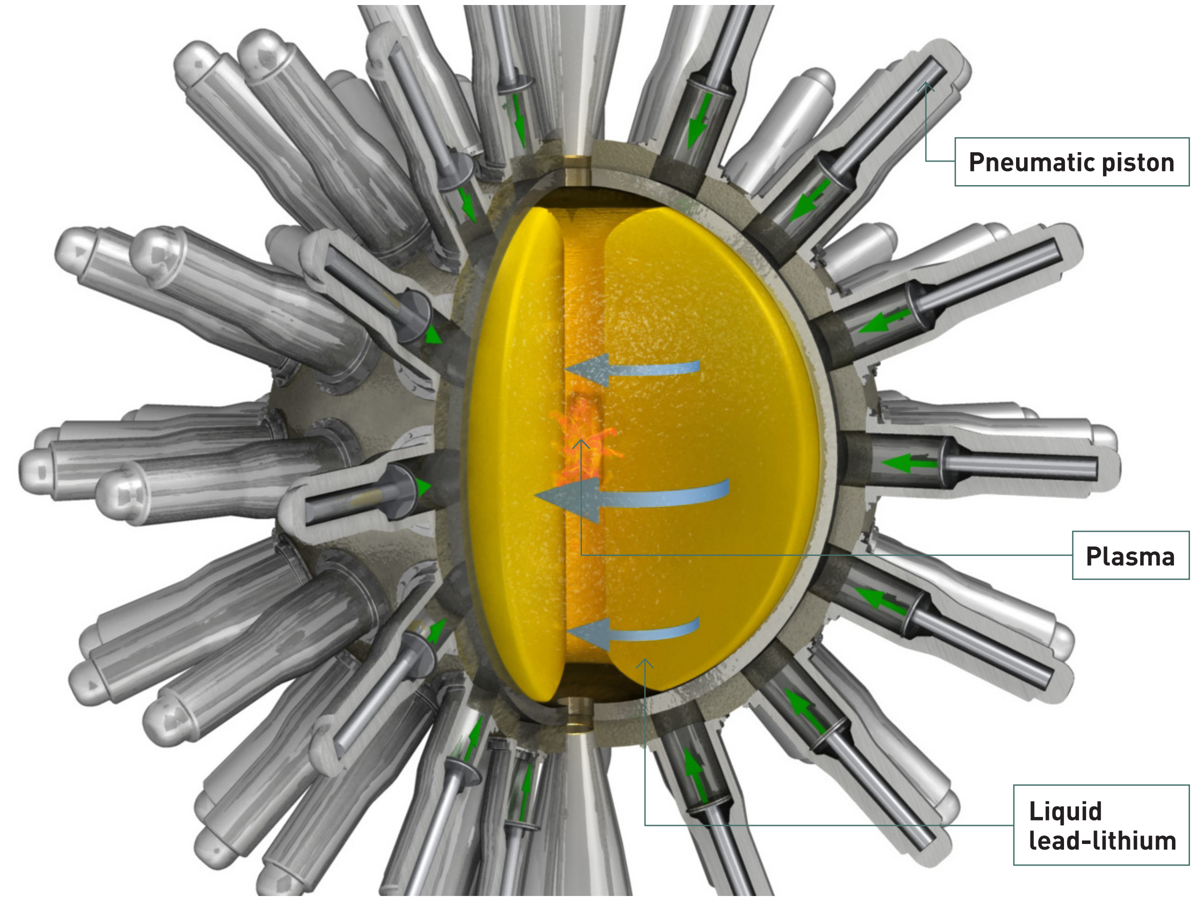
It's certainly not going to come from ITER anytime soon. The experiment has been delayed innumerable times and is now not expected to go online until 2018. If projections are correct, sometime after that, it will produce 500 million watts of fusion power for a period of 300 to 500 seconds, a gain of 10 times the energy put in to create the reaction. Yet ITER is only a demonstration. A workable power plant is yet another monumental project that will take at least 20 more years.

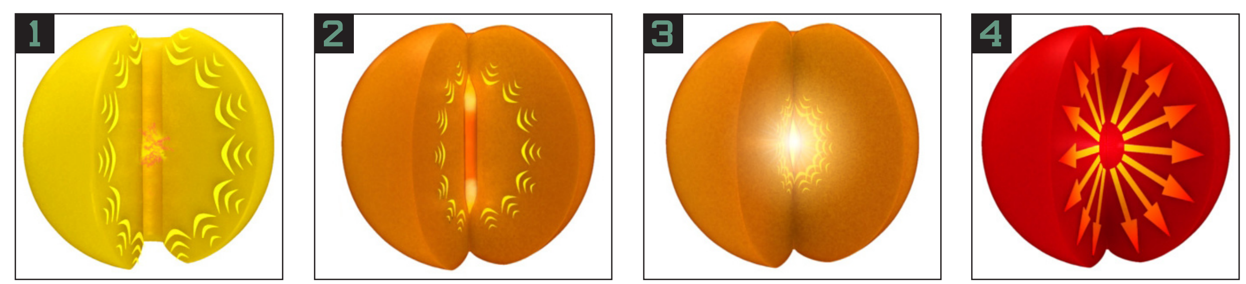
That's plenty of motivation to pursue other approaches, and General Fusion isn't alone. Wurden, for example, is working on a model akin to General Fusion's: He fills a container about the size of a large beer can with plasma and uses electrodes to "crush" the can and condense the plasma. Scientists at Lawrence Livermore National Laboratory are at work on a project known as NIF (National Ignition Facility), in which the world's biggest laser blasts tiny balls of plasma encapsulated in glass.

In fact, General Fusion isn't even the only private-sector start-up. For a few days in May 2007, the fusion world was abuzz over a rumor that a company called Tri Alpha, associated with a noted physicist from the University of California at Irvine named Norman Rostoker and reportedly backed in part by Paul Allen, had received $40 million in venture-capital money to pursue a method called "proton-

HOW GENERAL FUSION'S PLAN COULD WORK

General Fusion uses a variation on an approach called magnetized target fusion. Inside a metallic sphere measuring approximately 10 feet in diameter, a liquid lead-lithium mixture spins around the tank fast enough that a cylindrical-shaped empty spot opens in the middle of the tank. Two injectors send plasma—ionized gas—into the void at the center of the swirling liquid metal. Two hundred pneumatic pistons, accelerated to approximately 100 meters per second by pressurized steam, slam the outside of the sphere simultaneously. Then, if all goes as planned, the magic happens (see below).





1. The impact of the pistons sends a compression wave reverberating through the liquid metal and toward the the plasma suspended by a magnetic field in the center.

2. The compression wave picks up speed as it hurtles toward the center, quickly becoming a shock wave powerful enough to compress the plasma quickly and violently.

3. The shock wave hits the plasma, a highly energetic stew of the hydrogen isotopes tritium and deuterium. The force is so great that the ions merge to form helium.

4. The fusion reaction hurls neutrons and alpha particles out through the liquid lead-lithium, creating heat that generates steam to power an electricity-producing turbine.

KRIS HOLLAND

SPARE PARTS From left: The interior of the proof-of-concept fusion reactor; the reactor's low-tech-looking control tower; General Fusion plasma specialist Stephen Howard works on one of the 200 pistons that will power the scaled-up reactor.

boron fusion." Then the company went into stealth mode.

Laberge thinks that proton-boron fusion, if that is in fact what Tri Alpha is up to, is a valid idea, but that it requires much higher temperatures—generated, most likely, with the same extremely expensive superconductive magnets used in tokamak reactors—and has other theoretic flaws he feels are far more challenging than the ones in front of him. "I used to say, [proton-boron fusion] is like learning to run before you walk. And I was talking to physicists at some conference, and they say, 'No, no, it's like learning to fly before you walk.' You think we're ambitious? I think they're ambitious."

"BASICALLY, THEY QUIT their jobs to answer one of the most complicated problems in physics," says Mike Brown, whose venture-capital fund, Chrysalix, allowed General Fusion to get to its so-far very callow state. Brown's fund has concentrated on alternative energy for years. He was the first investor in Ballard, a Canadian company that helped perfect the fuel cell. And even now, at age 69, he cares not so much because of the money, though the potential there is obviously significant, but because of what fusion would mean for a planet in rapid decline.

At an age when most successful businessmen would be retired, Brown is more enthusiastic than ever. "I think it took someone with exceptional talent to do this combination of mechanics and physics, which is really unusual," he says of Laberge (whom he tells me was also once a high-speed downhill skateboarder and a member of Canada's national hang-gliding team). "Europe is particularly ITER-focused. It's as if [MTF] never existed. But when you bring in experts—not a single expert hasn't said, you know, you guys have a real shot of doing this."

Ronald Kirkpatrick, a guest scientist at Los Alamos and someone who has spent much of his career contributing to the American fusion program with a particular emphasis in MTF, was one of the handful of independent scientists who vetted General Fusion's plan. And although he's not ready to say it *will* work, he certainly thinks it could. "I see no problems in principle, but I do see a lot of technical challenges ahead," he says. Among them: the potential for instability between the plasma and the lead-lithium liner, which could cool the plasma and prevent it from reaching fusion temperatures. "It's worth pursuing, but investors have to know it's a high-risk affair."

Richard Siemon hasn't studied General Fusion's plan but knows enough about MTF to say that he's more optimistic about it than any of the tokamak projects. "MTF in particular has the potential to be an approach that could be done on a small scale by a small group," he says. "I think it's an exciting thing. And there's an efficiency to the private sector that just isn't comparable to government-funded approaches."

Given another round of financing—roughly $10 million, $7 million or so of which has been procured—Laberge says he will build two dozen of those unassuming pistons and use them to impact a cylinder full of liquid lead-lithium. This will allow him and his team to study the shock waves as well as the synchronization of the pistons. That's two years. A third, $50-million influx of capital, Brown says, gets them a test reactor. "By the end of 2012, we'll have done net gain." ITER will still be six years away. "Nobody will have done net gain at that point. If we do that, we'll attract a significant amount of attention." After that comes the first power plant. That will cost another $200 million to $500 million, but after net gain, the money should be easy to raise.

"If the world is waiting for energy from ITER, it's a lost cause," Brown says. "I think sooner or later it could work. But it's going to be later, and it's going to take a *lot* of money. If we could do for $500 million what they'll do for $50 billion—in six years versus by 2035. For electricity!" There's no need, really, to complete the thought.

ON THE AFTERNOON of my visit, Doug Richardson leads us out the back of General Fusion's offices and through some trash-strewn woods to a Subway sandwich shop. While we're there, he points to a newspaper headline about fuel prices. "Every day it's the same thing: cost of fuel and climate change," he says. "I think a revolution is coming. I believe it'll be for conservation of resources."

Back at the office, Richardson shows me a climate-change mug someone gave him. When you add hot water, the places that will someday be submerged by ocean water if Greenland's ice cap melts turn blue. Farewell New York, London, Paris, Vancouver and the entire Amazon basin. Outside the door, Laberge is updating the company's Web site, and the team's plasma specialist, a young postgrad named Stephen Howard, is tinkering with the design of the plasma injector that they are right now trying to decide if they can afford. Richardson shows me chart after chart on energy demand, as well as existing technology that backs up almost everything they're building or plan to build. The global demand for power, he points out, is nearly 4,000 gigawatts today. According to projections, it will be 7,000 by 2030. The world can't possibly meet that number using existing sources.

Does General Fusion really have a chance of filling that gap? There is the way Glen Wurden sees things—that the idea is plausible but that the implementation will require far more work, not because of technology but money: "Imagine it's 1910 and you want to fly a 747, and someone gave you the plans. You're screwed. You don't have the materials. You don't even know what a jet engine is. You're stuck. Having ITER work is like the Wright brothers. Having a fusion power plant—it's like having a 747."

Richardson, not knowing what Wurden had told me, spun the 747 example a very different way. Flight went from paper and wood to the 747 in 65 or so years. Laberge adds that nuclear fission went from proof-of-concept to power plant in a decade. And that was the 1940s. The difference, of course, was money. "If we were proposing some funky new microbe or algae to go down and eat oil in tar sands or something and then burp it up later?" Richardson scoffs, "I'm sure we would have been financed by now. Even though it's probably a more difficult task than what we're proposing."

Sitting around twiddling your thumbs when you could be building your experimental fusion reactor can make you bitter. And to step into that room and talk to slightly bitter—or rather, frustrated—scientists, it's easy to read them as crackpots. Guys in rumpled khakis sitting in an office-park warehouse monkeying around with a piston hooked up to extension cords can easily look like crackpots. But as Kirkpatrick points out, compared with ITER or any other current fusion experiment, "the closest to a potential reactor scheme is what General Fusion is proposing."

"People"—in particular, politicians and moneymen—"have to get used to the idea that maybe this is possible," Laberge says. How could they fail? Well, they could run out of money. Or "the laws of physics might fight back in ways we don't know about yet," Brown says, smiling. "We have to find that out."

Josh Dean is an editor at Play *magazine and writes for* Outside, Inc., Fast Company *and* Best Life. *This is his first story for* Popular Science.