Power Tripping

High-voltage engineer Greg Leyh builds the largest Tesla coils in the world.

By David Pescovitz
Photograph by Jonathan Sprague

GREG LEYH IS A POWER BROKER. VOLTS. Watts. Joules. Amperes. He trades in them all. His aim? Nothing short of lightning-on-demand.

At Maker Faire in May, Leyh premiered his twin Tesla coils, two stately and elegant 10-foot towers that spewed 18-foot arcs between them. Amazingly, the twins are just one-twelfth-scale prototypes for the pair he plans to build at his Nevada Lightning Laboratory. Those coils will fill a football field-sized tract of land with 18 million volts of lightning.

For Leyh, high voltage is a way of life. His company, based just south of San Francisco in the small city of Brisbane, is called Lightning On Demand. In a few years, LOD (lod.org) will be reborn as the Nevada Lightning Laboratory, where, if all goes as planned, he'll open a world-class facility for scientists to study high-power phenomena.

"The higher power you go, the more new physics you uncover," says Leyh, who works days in the Power Conversion Department engineering group at the Stanford Linear Accelerator Center. His personality somehow fits his job. He's quiet, very friendly, a little nerdy, and always willing to explain technical concepts repeatedly until you understand them, or think you understand them. In that way, Leyh reminds me of the best high school science teacher, the kind who still dresses like a NASA engineer from the 1960s — short-sleeve dress shirt, pens in his breast pocket, plain slacks, and dress shoes. But instead of a slide rule on his belt, Leyh wears a calculator watch on his wrist.

If the Nevada Lightning Laboratory can collect just $12 to $18 million in funding, Leyh says he could generate the first arcs in little more than two years. He's just returned from visiting a site 40 minutes outside of Las Vegas that, based on his meticulous surveying, GPS mapping, and Google Earth exploring, would be the perfect spot. Now he just has to finalize a deal with the governmental owners of the property.

Leyh first put his ideas for the Lightning Lab on paper in 1996, but he's been on a power trip since his teens. As a science-minded high school senior in Arlington, Texas, he stumbled upon proto-maker Nikola Tesla's writings about resonance rise, the phenomenon that causes a street light pole to sway wildly at the top from just a small shove at the bottom.

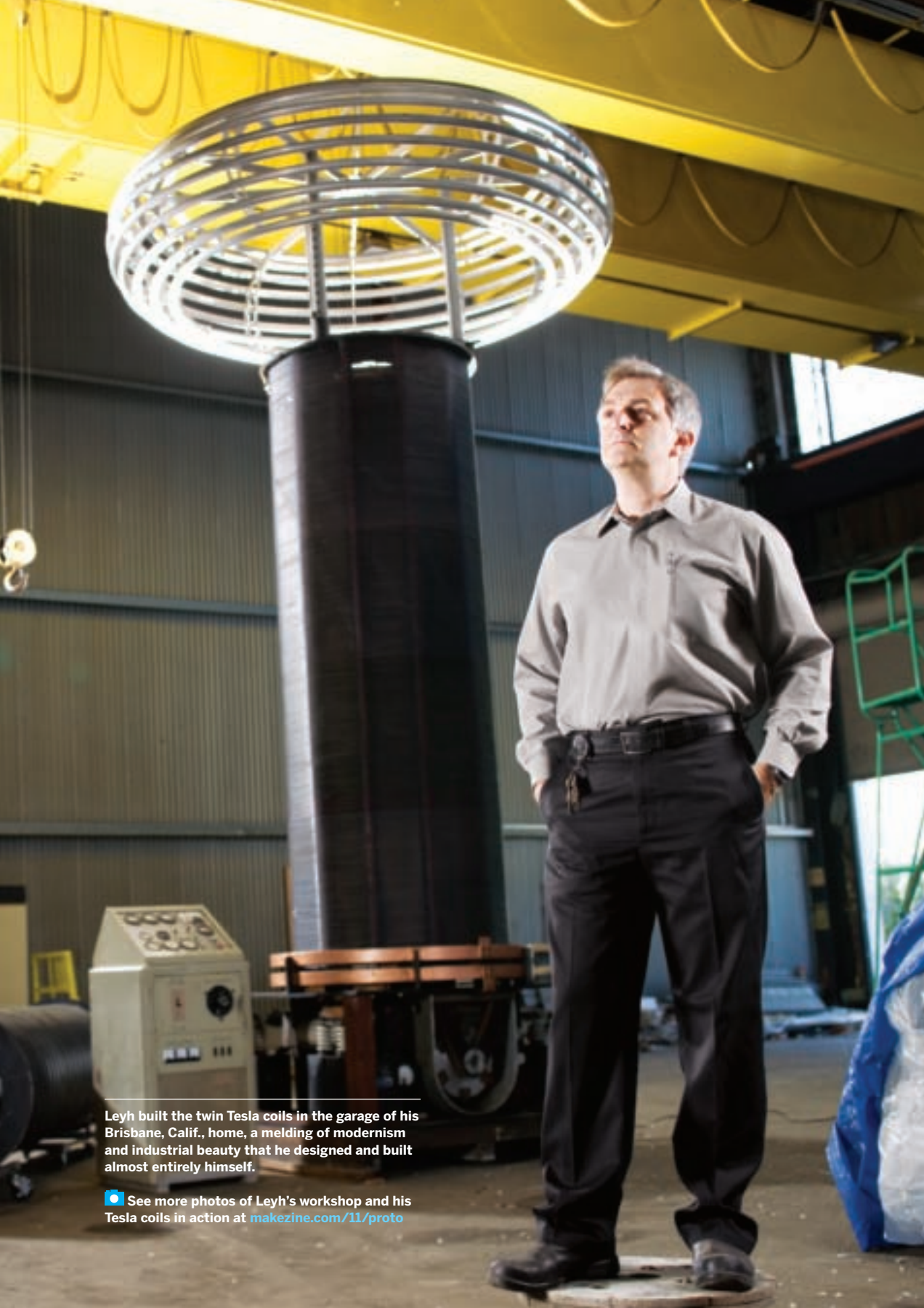
"The whole notion that these physics effects are not only knowable, but can be calculated very precisely, was almost too much to believe at first," Leyh says.

As a college freshman at UT Arlington doing work-study in the machine shop, Leyh decided to conduct his own mechanical resonance experiments. He built a mechanical oscillator from an old Camaro's blower motor. Essentially, the machine repeatedly lifted itself up and then dropped back to the ground, at various speeds controlled by a rheostat. Leyh attached it to various objects to determine their resonant frequencies. His most, er, successful field study took place on a wooden footbridge.

"I adjusted the dial until I found the sweet spot where the bridge was bouncing a foot and a half up and down," he says. "Then I heard a very satisfying crack and I couldn't find the right frequency again."

Through college, Leyh devoured Tesla's writings, eventually building his first small Tesla coil. The coils also exploit resonant rise, but with electrical energy rather than mechanical. A Tesla coil steps up the power from an input source by taking it through several transformer and driver circuits until it reaches incredibly high voltages. That energy is then discharged in zaps of radio frequency (RF) energy.

After graduating with an electrical engineering degree, Leyh landed a job working in Stanford's physics department. In 1988, a friend sent him a grainy, fourth-generation video of San Francisco machine performance group Survival Research



Leyh built the twin Tesla coils in the garage of his Brisbane, Calif., home, a melding of modernism and industrial beauty that he designed and built almost entirely himself.

See more photos of Leyh's workshop and his Tesla coils in action at makezine.com/11/proto

Laboratories. Intrigued, Leyh eventually located SRL director Mark Pauline's legendary machine shop and the two became fast friends and collaborators.

Shortly after his first meeting of the minds with Pauline, Leyh noticed that the scraps from a decommissioned particle accelerator at Stanford were headed for the dumpster. Digging around in the big-science garbage, Leyh pulled out transformers, copper stock, basically "80 percent of the makings of a big Tesla coil." He hauled the detritus to the SRL shop and set to work. In 1990, Leyh's 40,000 Watt Experimental Coil made its debut at an SRL performance in Seattle. At the time, it was the largest Tesla coil in the world.

"The Lorentz Gun creates a 40-foot section of a real lightning bolt."

Leyh and Pauline also developed several other machines, the most infamous being the 110,000-volt Lorentz Gun, formerly known as the Taser. The name change was spurred by a nastygram sent to LOD several months ago from TASER International. The company claimed copyright infringement even though Leyh built his device years before TASER trademarked the word.

The guts of the Lorentz Gun are 4,000 pounds of capacitors that SRL intercepted on their way from Lawrence Livermore National Laboratory to a waste management facility. Wired together in a bank, the capacitors produce 110kV at 100 kilojoules, enough to blow a big divot out of thick steel. The gun fires a thin wire into the target, and the capacitors are instantly discharged. Within the first 100 microseconds, the wire melts into plasma. Even with the wire gone, the current is contained within a magnetic field and delivered to the target.

"The Lorentz Gun essentially creates a 40-foot section of a real lightning bolt," Leyh explains.

As SRL featured both the Lorentz Gun and the Tesla coil in shows, Leyh's reputation grew as a high-power researcher with, well, unusual application ideas.

In 1996, Leyh met Eric Orr, a Los Angeles artist known for large sculptures involving fire and water. A wealthy art patron in New Zealand had commissioned Orr to build a "fountain for lightning." Generating lightning was Leyh's specialty, so a mutual friend introduced the two. Two years later, Leyh, Orr, and a team of assistants, mostly from SRL, set up camp on the patron's property and installed *Electrum.* The 38-foot-tall sculpture generates 40- to 50-foot lightning bolts against a sweeping backdrop of coastal waters. To this day, it is the largest Tesla coil in the world. Leyh has never been called back to New Zealand for maintenance.

While Leyh's projects have charged crowds around the world, to him they're all incremental steps toward the Nevada Lightning Laboratory. He conceived of the facility a decade ago when testing new simulation software for the Stanford accelerator. To put the software through its paces, Leyh built a virtual Tesla coil. And then a bigger one. And so on.

"I found that two 120-feet-high coils operating in opposite phase is right before the point of diminishing returns," he says. "So it follows logically that a facility of that scale should exist."

The coils will open a window onto uncharted areas of mega-scale electrical physics, providing scientists with the opportunity to get up-close and personal with lightning. For example, Leyh expects research groups will value fresh data that may deepen our understanding of how lightning is related to global temperature changes. Yet while the business plan counts on research dollars, the bulk of the financial support is expected to come from tickets to public educational demonstrations, some of them seen from the top of one of the coils.

Each 12-story-high tower will be topped with a 55-foot-diameter electrode. Amazingly, the operator and observers will be inside the electrode. According to Leyh, "That's actually the safest place to be." If visitors get nervous, they can always sidle up to the bar that Leyh designed for the east tower. The west tower's electrode will include living quarters for experimenters or, Leyh points out, a donor's apartment.

Right now, though, the Lightning Lab exists only on paper and in Leyh's hard drive. "It'll never be done. Once it's constructed, there will be an endless stream of questions that need to be answered," Leyh says. "Anytime you devise a truly new scientific instrument, you find things you could never have imagined."

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Photograph by Terry Leonard

Leyh takes measurements from inside *Electrum* before it's shipped to New Zealand. Alberta Chu's film *Electrum*, shown on PBS, documents the project. asklabs.com/electrum