The race to make the world's strongest magnet

By **John D. Sutter**, CNN
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(CNN) -- George Hadjipanayis' assistant came to him with perplexing news: Some incredibly strong magnetic field had caused their lab instruments to go haywire.

"You're out of your mind," Hadjipanayis recalls telling him in the early 1980s. "You have something wrong; go back" and try the experiment again.

Nothing was wrong, though, and Hadjipanayis soon realized that his team accidentally had created what was then, and continues to be, the world's strongest magnet -- made of a strange and little understood "rare earth" element called neodymium. That magnet would help revolutionize technology, powering wind turbine motors and giving juice to electric cars.

But the luck wouldn't last.

Accessible supplies of neodymium and 16 other rare earth elements -- which occupy those two orphaned rows at the bottom of the periodic table -- are running short. China, which controls supplies of 97% of these materials, doesn't like sharing them with the West. And the only U.S. mine for rare earth elements went out of production after a radioactive waste accident in the 1990s.

Throw in the fact that rare earth elements are important to all kinds of technologies -- they're the reason smartphones vibrate, why TVs have vivid reds and greens, and how computer hard drives are able to etch data -- and you've got a recipe that scares many technologists and researchers.

What would happen to our technological landscape without these rare earths?

Hadjipanayis, chairman of physics at the University of Delaware, and researchers from two other institutions, the Ames Laboratory in Iowa and GE Global Research in upstate New York, are preparing for that day.

They're in a race to make an even stronger magnet than before -- an essential component in green technologies, which use magnets to transfer electrical energy into motion. And they're trying to do it by using as little neodymium as possible, since that element is getting harder to come by.

For Hadjipanayis, this is a professional as well as personal struggle. He's trying to recreate the accidental success he had with magnets in the 1980s.

"I have pressure," he said. "Look, this is not easy. I mean, you need also a little bit of luck. We have the concept here, but there are many, many obstacles that we need to resolve before we succeed."

Rare earth mysteries

Rare earth elements possess strange magnetic and conductive properties aren't found anywhere else in our cabinet of elements.

Understanding precisely why this is the case would require graduate degrees in both chemistry and physics, but the for-dummies version goes something like this, according to Frank Johnson, a materials scientist at GE Global Research:

"In a magnetic material, the magnetic ions are connected by springs."

To keep that metaphor going, a typical rare earth element is full of super-powerful springs, but they're all jumbled up, facing various directions as if they'd been thrown onto the floor of a closet.

Something magical happens when a rare earth element like neodymium is combined with specific other elements: They form crystals. And if the shape of those crystals is just right, all of the super-powerful springs align, and -- bam! -- the springs amplify each other, and you have the very powerful magnet.

"They are very unique elements, and the science of them is fascinating," Johnson said.

Metallic recipes

Hadjipanayis didn't know that boron was the missing ingredient when he asked his lab assistant to add that gas to the metallic mixture they were working with.

All he knew was that the experiments were going wrong because the metal kept crumbling and falling apart. He thought boron might do for this metallic solution what eggs and milk do for cake batter. It would smooth things over.

The unexpected result: He discovered the neodymium-iron-boron magnet, which was far stronger than anything that preceded it.

"For me, that was kind of a very exciting experience," Hadjipanayis said.

He keeps several of these nickel-sized magnets on his desks to show visitors.

Scientists measure the strength of magnets with a unit called the "maximum energy product." A typical refrigerator magnet has a rating of 3 or 4.

Current neodymium magnets register 57 to 60.

Several years ago, Hadjipanayis recalls going to an airport with a neodymium magnet tucked away in his coat pocket.

He walked past a metal object near security, he said, and got temporarily stuck.

Hadjipanayis was able to free himself from that situation. But if two neodymium magnets get stuck together, "you have to slice it into two parts."

"If you're an ordinary person, you can't separate them" by pulling, he said.

Now, Hadjipanayis and researchers at GE and the Ames Laboratory in Iowa are trying to create magnets that are nearly twice that strong.

A world without rare earths

In addition to trying to invent magnets that don't depend as heavily on rare earth elements, mining companies are trying to harvest new supplies.

This carries environmental risks, however.

China has become the world leader in rare earth mining and production in part because it's more willing to put up with these risks than the United States, which faced them head-on in the 1990s. A rare earth mine now owned by Molycorp Minerals was fined in 1998 for leaking hundreds of thousands of gallons of wastewater containing low levels of radioactive material.

Molycorp's mine in the California desert, near the Nevada border, is set to reopen this year. A U.S. Department of Energy report from December says the country needs to ramp up its rare earth production in order to ensure that technology companies here maintain a supply of these vital elements.

A spokesman for Molycorp, Jim Sims, said the reopened mine and upgraded processing center will put the U.S. back in the rare earth business -- and will do so safely.

"America will have the most environmentally progressive and technologically advanced rare earth processing capability," Sims said.

Starting a rare earth element mine is an expensive, long and arduous task, however. The elements aren't especially rare in nature, but they're usually found in relatively small quantities, mixed in with other materials, which makes them both difficult and somewhat uneconomical to mine and process.

Consequently, the Department of Energy also says we should look for alternatives. And that's where the magnet researchers come in.

A wing of the Energy Department called the Advanced Research Projects Agency-Energy, or ARPA-E, has put $6.6 million into grants for programs to develop a magnet that is stronger than any that exist on earth today -- and uses much less neodymium.