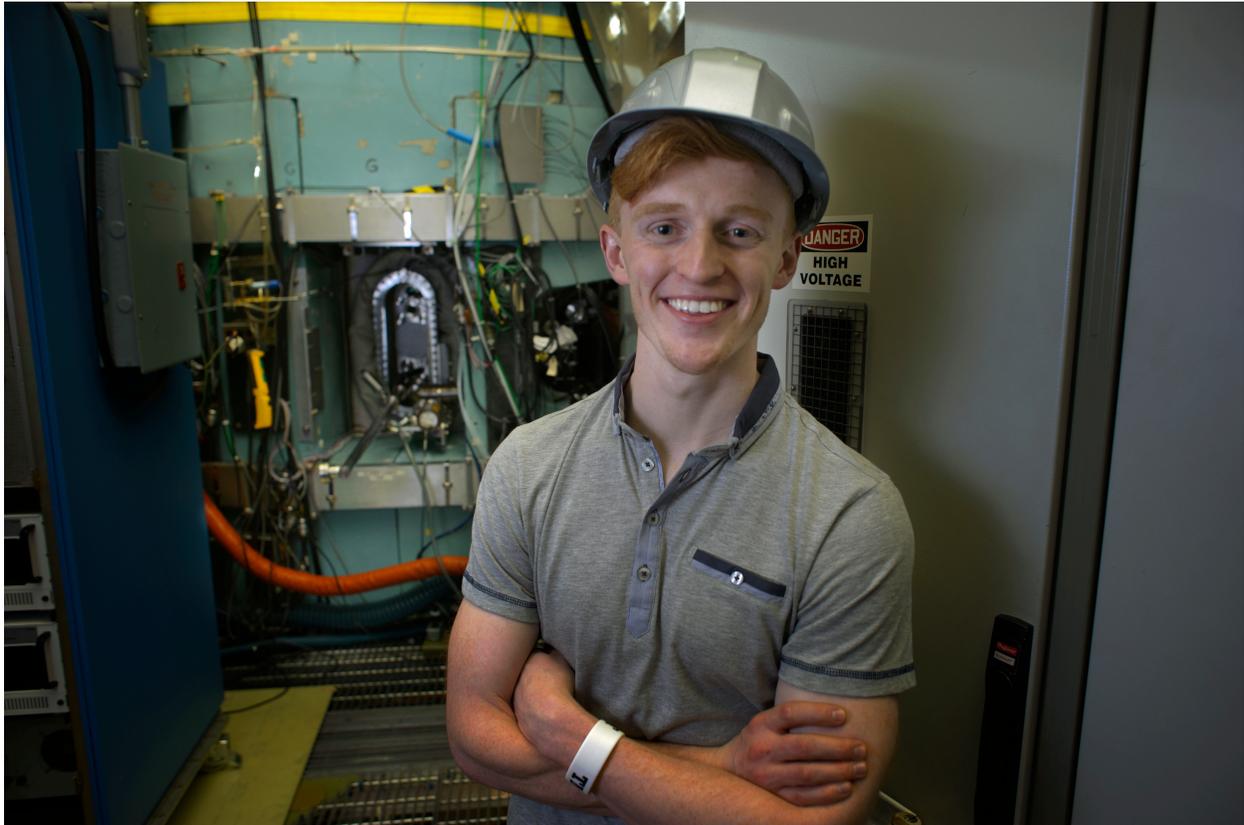


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Article for 8.226 on Alex Tinguely



It's official: our favorite spinning space-rock is in trouble. The Earth is rapidly becoming too hot to handle because we can't stop consuming energy from fossil fuels. But, what if there were a way to unleash oodles of energy from extremely abundant fuel without producing harmful byproducts? A phenomenon so awesome that it lights the sun and every other star in the sky? This process is called nuclear fusion, and the good news is, we can do it here on Earth. The bad news, however, is that there are problems with our methods of harnessing it that make it impossible to use as a viable power source. Solving these problems could mean a bright future for our bleak energy landscape, which is what Alex Tinguely, a graduate student at the MIT Plasma Science and Fusion Center, is working on.

Tinguely is doing research on an impressive machine with an even more imposing name: the Alcator C-Mod Tokamak. It's a device that, against all odds, allows us to achieve nuclear fusion reactions in the middle of Cambridge, MA. A fusion reaction involves taking two nuclei, the cores of atoms, and smashing them together so they become a single nucleus. This releases a

lot of energy, because it takes less energy for hydrogen nuclei to exist bound together than it does for them to exist apart. That said, it isn't easy to convince nuclei to get close enough to fuse, because they are positively charged and repel each other with colossal force.

It may be helpful to think of fusion like trying to get two people who hate each other to carpool: As difficult as it may be, once you manage to get them both in the same car, you save a lot of energy. Analogously, once you manage to get the hydrogen nuclei to fuse into a single nucleus, energy is saved by the combination. You can then use that extra energy to do useful things, like generate electricity.

Tinguely gets nuclei to smash into each other by getting them moving fast enough to plow through the barrier of electrical force. For hydrogen atoms in a gas, this means heating them to such a high temperature that the electrons are ripped from their nuclei, resulting in a plasma, a gas full of free charged particles. As exotic as they may sound, plasmas are common. Here on Earth, they're responsible for the glow of fluorescent lights, the brightness of a flash of lightning, and the awe-inspiring shimmer of the polar aurorae. They're even more mundane in outer space, where they make up much of the matter between stars, and the stars themselves. In fact, most natural fusion reactions occur in plasmas at the hearts of stars.

This gives us an idea of how hard it is to make fusion happen on Earth: We need to create conditions comparable to the inside of a star. Great for dramatic flair, but also great for melting expensive scientific equipment.

Unsurprisingly, hot star-stuff can't be allowed to run amok on Earth: It would dissipate and never produce any useful reactions. "You have to somehow confine it," explains Tinguely. "The Sun produces fusion energy, and it's confined by gravity. If we wanted a reactor like that, we would need something the size of the Sun in order to have it confine itself, and we can't have that on Earth, because Earth is like a million times smaller than the Sun, right? But what we can do is confine it with magnetic fields."

That is exactly what the tokamak was designed to do<sup>1</sup>.

A tokamak, such as the Alcator C-Mod, consists of a donut-shaped vacuum vessel that contains the plasma, which is prevented from touching the walls by powerful magnetic fields. The plasma interacts with the magnetic fields due to its abundance of charged particles. Jolts of current heat up the plasma to the necessary temperatures.<sup>2</sup>

So, to recap, we have a clever setup of magnetically-confined plasma whizzing around at temperatures hot enough to produce fusion reactions. Why aren't we using this to power the world? Unfortunately, there are problems that arise when you confine such an energetic material, and Tinguely's goal is to solve them.

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<sup>1</sup> Culham Center for Fusion Energy. "Fusion Energy: The Tokamak." *Culham Center for Fusion Energy*. UK Engineering and Physical Sciences Research Council, 2012. Web. Mar. 2016.

<sup>2</sup> Ibid.

One of Tinguely's research objectives is to predict events called plasma disruptions in the tokamak. A plasma disruption is, in Tinguely's words, "the death of a plasma," in which it rapidly loses energy and deposits itself on components of the machine. Disruptions often render the tokamak unable to continue generating power without undergoing expensive repairs. Tinguely is looking at measurements of parameters of the plasma, such as its position, velocity, and trajectory in the vacuum vessel as well as the current. "Just by looking at all the data we have, trying to create some sort of algorithm that, given another shot, would predict another disruption," he says.

If Tinguely is successful in creating an algorithm to predict disruptions at Alcator C-Mod, it would be a ray of hope for the future implementation of tokamaks. When it comes to a plasma disruption, "if we can predict it, then we can try to prevent it or mitigate it," he says. That would mean less damage to the equipment and a greater possibility of using it to generate usable power.

Another problem that arises in tokamaks is the issue of runaway electrons. Electrons are extremely light compared to the nuclei of atoms, so they move much faster in the plasma. If the electrons reach relativistic speeds, they can escape confinement and harm the device. The vessel and other components of the device can experience "in a sense, very small explosions just from being hit by a beam of really high energy electrons," says Tinguely.

Using spectrometers inside the tokamak, Tinguely is measuring the radiation emitted by the accelerating runaway electrons in order to determine under what conditions they arise. If he can figure out the formation mechanisms, it might become possible to stop them from occurring or prevent them from damaging the device.

For both plasma disruptions and runaway electrons, figuring out how to prevent them or compensate for them is crucial for creating larger-scale fusion experiments, because it would be wasteful to spend so much time and money building a tokamak that's going to destroy itself. Tinguely says, "if we can solve that, then we're one step closer to having a fusion power plant producing net energy that you can put on the grid for the world to use."

With regard to the awesome potential of fusion and the bright prospects of his current work, Alex Tinguely is optimistic. "I really think that it will be the energy of the future," he says. "But hopefully, the near future, within our lifetimes."