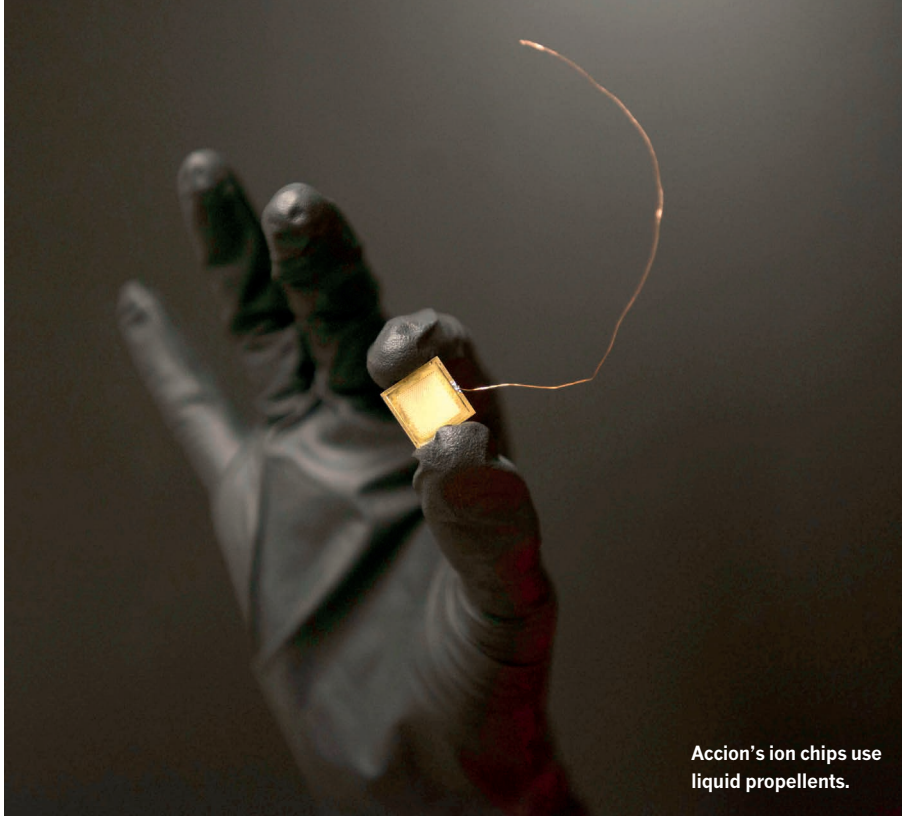


ACCION SYSTEMS

Accion's ion chips use liquid propellents.

ENERGY

Powering change

Innovators are finding better ways to produce, store and use energy, on Earth and beyond.

ACCION SYSTEMS
A new thrust

Massachusetts Institute of Technology, Cambridge

Experimental rockets have a tendency to blow up on the launch pad, destroying their builders' plans in a rain of fiery debris. Rocket companies can be similarly explosive, as Natalya Bailey discovered.

In 2010, while working towards a master's degree in mechanical engineering at Duke University in Durham, North Carolina, she and three other students founded Asteria Propulsion to commercialize a type of chemical rocket technology. But none of the people involved knew much about starting a company. The founding team neglected to discuss the roles, responsibilities and commitment levels of its members. "When we got into fundraising it became very apparent to anyone who talked with us that the team was a ticking time bomb", Bailey says. "We very quickly fell apart — it was a disaster. And I thought, OK, that was my foray into entrepreneurship."

Bailey started a PhD in the Space Propulsion Laboratory of the Massachusetts Institute of Technology (MIT) in Cambridge in 2011 with the intention of becoming a professor, or a researcher in a national laboratory. But when the lab's work on electric space propulsion started to pique the interest of aerospace companies, she decided to try her hand at starting a company again. With fellow student Louis Perna, she founded Accion Systems in 2014.

This time, her planning was more focused. Drawing tips from *The Founder's Dilemmas* (Princeton Univ. Press, 2012), which was given to Bailey by an entrepreneur-in-residence at the Martin Trust Center for MIT Entrepreneurship, her team of five drew up a colour-coded spreadsheet that spelt out everyone's role, and set up a scheme for buying back a person's equity in the company if that person left or didn't fulfil their duties.

Accion Systems is developing miniature ion engines that can manoeuvre small satellites. Ion propulsion is not a new concept: NASA launched the experimental ion-engine spacecraft Deep Space 1 in 1998. But Bailey says Accion's ion thrusters are the first to use a liquid propellant — a more-efficient design than a conventional thruster that requires no valves, pipes, pumps or separate ionization chamber.

Their fuel is a salt solution. To generate thrust, it is spread across a grid and an electric field is applied. The field plucks ions from the fuel and shoots them through the grid into space in streams thinner than a human hair. Each stream provides a miniscule thrust, but together they are able to accelerate spacecraft to a high velocity.

The advantage of electric-propulsion engines over chemical rockets, Bailey says, is that they use much less fuel. Although that means electric rockets accelerate more slowly, they also weigh a lot less. Bailey says that Accion's thrusters are ideal for an emerging class of smaller, lighter satellites that are used for applications such as communications and imaging. Older satellites are about the size of a single-deck bus and carry an engine the size of an average family car, but these are giving way to satellites that take advantage of the shrinking size of electronics in general, and weigh between 100 and 200 kilograms, she says.

Accion's smallest complete system, including storage tanks, electronics and thruster, is about the size of a packet of chewing gum. The engine for a 200-kg satellite would be larger — about the size of a medium pizza. And whereas previous ion engines were custom-built, Accion relies on established microelectromechanical-systems technology for mass production, which brings manufacturing costs down. Bailey hopes that Accion can deliver products by the end of the year.

Gaining initial funding was a challenge. Potential investors were generally more familiar with life sciences or information technology, and Bailey found being a woman in a male-dominated field a challenge. "People make awful comments, and it can be tough," she says. "On the other hand, being a woman with a PhD from MIT starting a space company, I stand out — I can at least usually get the meeting." Seed financing came from the Founder's Fund, a venture-capital firm set up by Peter Thiel (the founder of online-payment company PayPal), which is a major investor in the private rocket company SpaceX. Since then, the company has raised US$8.5 million in series A round — the first significant round of venture-capital funding — and received $6.5 million from the US Department of Defense to develop the thrusters.

With demand growing for the type of satellite that Accion's thrusters are designed for, Bailey is optimistic about the start-up's future. But burned by her previous experience, she is determined to follow a conservative course. The company is initially focusing on working with established aerospace buyers — Lockheed Martin, Boeing and the US government — rather than riskier newcomers.

Bailey found the process of starting a company much smoother this time, partly because of the resources that MIT offers budding entrepreneurs, from the steady supply of ramen and espresso at the centre, to seminars on how to interview potential customers, and

networking opportunities with established businesspeople. Bailey and Perna also took part in MIT's Global Founders' Skills Accelerator programme and entered the institute's $100K Pitch competition, which offers the chance to practise pitching in front of a panel. "If there was a service on campus, we used it," she says.

It was helpful to have experienced people to ask questions of, Bailey says. "You run into a lot of silly things and you can Google them, but sometimes it's nice to talk to smart, real people who have been through it before." ■

Neil Savage *is a science and technology writer in Lowell, Massachusetts.*

AMBER KINETICS
Flywheel freedom

University of California, Berkeley

There's no such thing as a perpetual-motion machine. But a 2,300-kilogram steel rotor that spins for a few weeks without losing a significant amount of energy is the next best thing.

Amber Kinetics in Union City, California, is commercializing flywheel energy-storage systems that can absorb excess electricity from the grid when renewables such as wind and solar are producing more energy than is needed. When demand peaks in the late afternoon, the kinetic energy stored in the spinning rotor can be harnessed — the rotor can be used as a generator to provide up to four hours of electricity.

Flywheels have been around for hundreds of years. In the past, they could store energy for tens of seconds or a few minutes — good enough to provide a quick burst of power, but not long enough to store energy on the electric grid.

"The conventional wisdom about flywheels was that they were not suited to energy storage," says Seth Sanders, an electrical engineer at the University of California, Berkeley, and co-founder of Amber Kinetics. But his research indicated that this was not necessarily the case, and Sanders thought that flywheels could address a major need — and market — on the electric grid. The spinning discs inside flywheels lose energy to drag from air and to friction. To address this, Amber Kinetics applies a vacuum and magnetically levitates the flywheel — technology that Sanders has been working on at Berkeley since the mid-1990s.

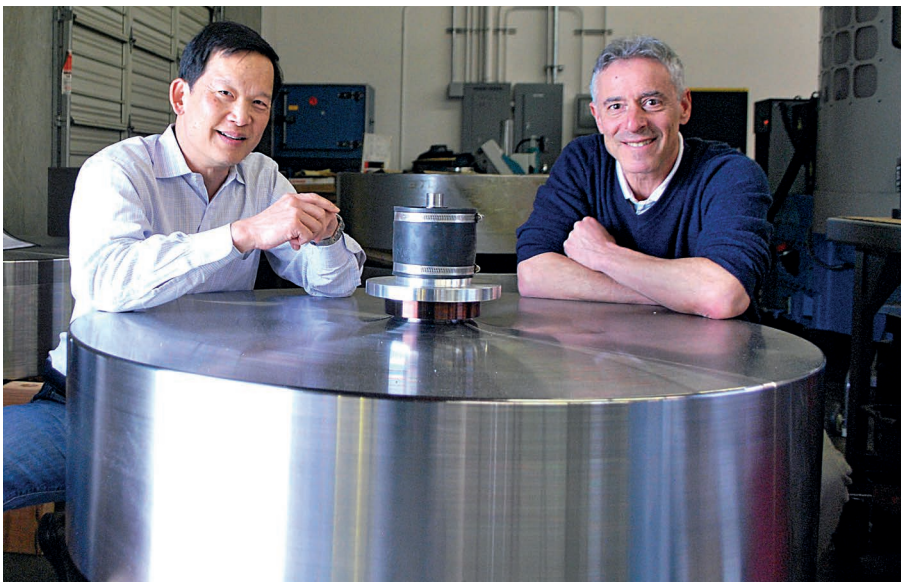
The company's current model can store 32 kilowatt-hours of energy. Individual flywheels can be connected like cells in a battery for greater storage. Because the flywheels can store energy for longer than can previous devices, and then release it over a sustained period of about four hours, they can help stabilize the electric grid, says Sanders.

Pacific Gas and Electric, which serves central and northern California, will be the company's biggest customer. Californians have long had to endure blackouts in the summer, when many homes and offices switch on the air conditioning. Sanders thinks that Amber Kinetics' technology can help smooth out peaks in demand.

The company is in the planning stage for the installation of a flywheel plant in Fresno, California, that can provide 20 megawatts of power for use during peak demand. It has already installed a smaller-capacity system in the Philippines and has a contract for another pilot facility in Hawaii. ■

Katherine Bourzac *is a freelance journalist in San Francisco, California.*

AMBER KINETICS



Chief operating officer Wei-Tai Kwok and chief scientist Seth Sanders with an all-steel flywheel rotor.

SOLID POWER
Advancing lithium

University of Colorado Boulder

Rechargeable lithium-ion batteries have powered major changes to the way we live. They have been used in lightweight laptops and smartphones, as well as in sleek electric vehicles. But no major changes have been made to the chemistry of these batteries since they came on the market in the 1990s. They still store the same amount of energy in a given volume and they still have a propensity to catch fire.

Sehee Lee, co-founder of Solid Power in Louisville, Colorado, thinks that new types of lithium battery can change this. The start-up is developing batteries with a solid, instead of a liquid, electrolyte.

Lithium-ion batteries have two electrodes and an electrolyte, which is typically a flammable liquid, through which ions and electrons travel. Lee, a mechanical engineer and battery specialist at the University of Colorado Boulder, works on solid-state batteries, which use a less-flammable solid or glass as the electrolyte. In 2012, his lab spun out Solid Power to commercialize the work.

The hope is that solid-state batteries will need less packaging, and so take up less space and weight in electric vehicles and be less expensive. Batteries in electric cars are surrounded by a metal case to contain fires, cooling systems to keep them in a safe temperature range and a control system to shut them down if anything goes wrong, says Lee. Because solid-state batteries can be charged more quickly than can those that use a liquid electrolyte, they would make electric cars more convenient.

Lee has limited involvement in the company's operations, preferring to pursue academic research rather than iron out the engineering and manufacturing details of the battery. "If I were involved in the daily business, I'd be stressed out," he says.

So far, Solid Power has relied on federal funding, including grants from the US Department of Energy. Now, the company is raising private funds and sending prototype batteries out for evaluation. Lee says that it has built standard-size cylindrical batteries of the kind that can be assembled for use in a car. But the manufacturing processes need refining, and it will be a few years before the batteries make their way under the hood of a car. ■

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