From the Laboratory to the **WORLD**

THE pathway from national laboratory to marketplace is often impeded by barriers that can prevent Laboratory technologies from meeting their full commercial potential and benefiting as many people as otherwise possible. Barriers can include the time and expense associated with identifying a market need for a technology, scaling up the technology to meet that need, building a business-savvy team of scientists to groom the technology into a marketable product, and finding investors to help make the plan a reality. To overcome these obstacles and accelerate the transfer of national laboratory science from the workbench to the marketplace, Lawrence Livermore's Industrial Partnerships Office (IPO) and the Department of Energy (DOE) provide valuable guidance and resources to educate Laboratory scientists and engineers about business and commercialization.

One resource is DOE's Energy I-Corps (formerly known as Lab-Corps). This program, which aims to accelerate the commercialization of clean-energy technologies, is a rigorous eight-week multilaboratory entrepreneurial "boot camp" where participants dig deep into the nuts and bolts of real-world technology transfer. A team entering the program consists of at least one technical expert, an entrepreneurial lead, and an industry mentor. All participate in a variety of activities designed to advance entrepreneurial knowledge and map out potential paths to commercialization.

Six Livermore teams have participated in Energy I-Corps since its inception in 2014. Yongqin Jiao is the principal investigator of MicroMiners, a project focused on rare-earth bioadsorption, that is, using genetically engineered bacteria to recover rare-earth

elements from sources, such as waste, where levels are so low that recovery by ordinary means would be prohibitively expensive. The rare earths are critical for many U.S. industries, including clean energy, and for national-security applications such as optics at the National Ignition Facility. (See *S&TR*, April/May 2016, pp. 17–20.) Jiao says, "Before we participated in Energy I-Corps, our team did not have the knowledge to successfully transfer our rare-earth recovery technology to industry." The program connected the team to their potential market and even helped them attract funding to better adapt their technology to market needs. In fact, this deeper understanding of the marketplace inspired a shift in their approach to the research. Jiao explains, "Now, when we work in the laboratory, we think of our research in the context of prospective industry applications. This change in perspective bolsters our drive to work more rigorously to push our technology out to the market so it can begin to make a real impact."

Captivating a Customer

Customer discovery represents a major element of Energy I-Corps. During this step, participants are challenged to interview at least 100 potential customers, an experience that helps identify not just a specific application but also specific customers. Sometimes scientists find that their technology will fulfill a different need than originally envisioned. Postdoctoral engineer Congwang Ye and his team designed silicone microcapsules that can capture carbon dioxide (CO_2) from waste gas more safely, quickly, and affordably than other techniques. (See *S&TR*, December 2015, pp. 13–16.) Although the technology was originally targeted for power plants, Energy I-Corps helped Ye's team find an industry application in breweries. The fermentation process that produces alcohol also generates CO_2, which is normally released into the atmosphere. Captured CO_2 could be reused later to carbonate the beer, instead of purchasing CO_2 as breweries typically do. Ye's team proposed providing breweries a CO_2-capturing system comprising a tank filled with millions of the microcapsules to absorb CO_2 from the fermentation gas. When the tank is saturated with gas, the team would collect and replace it. The reclaimed CO_2 could be sold back to participating breweries or other nearby users. Because the current capsule was designed for a different gas composition than brewery fermentation gas, the team will continue their research to adjust the microcapsule design accordingly. The team is in discussions with the University of California (UC) at Davis to validate the system at the university's pilot-scale brewery.

Without Energy I-Corps, Ye admits he would not have thought about applying his technology to the beer industry. Like Jiao, he learned through the program to think about the practical applications of technology in the marketplace, the importance of

Members of multiple Energy I-Corps teams, faculty, organizers, and Department of Energy personnel attend the graduation of the program's fourth cohort in Denver, Colorado, in December 2016. (Photograph courtesy of the National Renewable Energy Laboratory.)

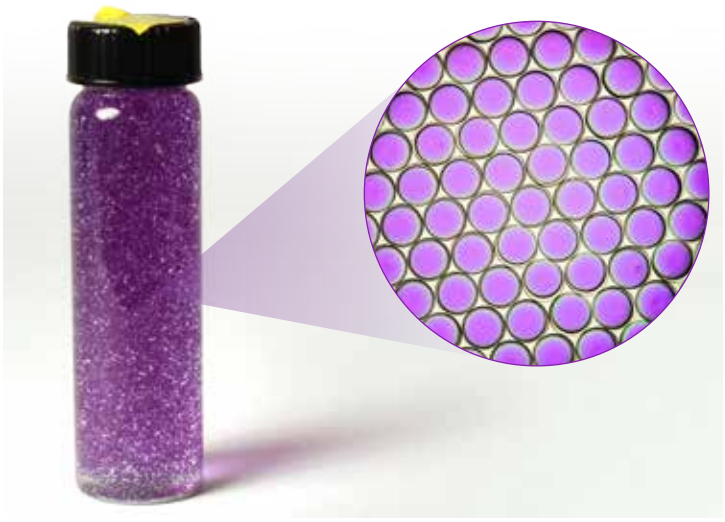
communicating with potential customers, and how to collaborate with seasoned mentors to come up with a successful business plan. Hannah Farquar, Livermore's Energy I-Corps liaison, says, "Our participants come to realize they are no longer addressing a problem unique to national security. Instead, they're using advanced Laboratory capabilities and expertise to provide a solution to a real market challenge."

Accelerating Advancements

Seeking to expand on the success of Energy I-Corps, DOE issued a call to the national laboratories for ideas. IPO proposed a broader and more ambitious business education system based on one already in place at Livermore. Similar to a business school, the system trains budding entrepreneurs in relevant business skills, including market research, customer discovery, and product development. Roger Werne, IPO's deputy director, says, "Through this system, scientists and engineers come to understand more about industry and are therefore more likely to find a successful match for their technology in the outside world." DOE eventually decided to expand the Livermore approach to all DOE laboratories. The new, larger program is dubbed the National Laboratory Accelerator Program.

Participants in the National Laboratory Accelerator Program first attend the National Laboratory Entrepreneurship Academy, a three-day course at UC Davis that drills participants in basics such as business model, value proposition, and customer discovery. A firm grasp of these steps allows scientists and engineers to better develop, analyze, and validate the commercial potential of their work. They also learn how to communicate with the business world, becoming familiar with industry terminology and learning to rely less on technical language. Werne states, "Our scientists and engineers are comfortable explaining how their technology works to colleagues and sponsors, but the key to success in this process, rather, is clearly communicating what their technology can do for industry."

Livermore researcher Congwang Ye (left) visits with professors at the University of California at Davis at their pilot-scale brewery to learn about fermentation tank operations as part of his adaption of a microcapsule technique for trapping carbon dioxide (CO_2) to commercial breweries. Ye hit on this application through his participation in Energy I-Corps.



Silicone microcapsules contain a sodium carbonate solution that traps CO_2. Although originally designed to capture CO_2 from flue gas, the capsules could also be used by breweries to capture CO_2 released as part of the fermentation process.

After this initial training, each budding entrepreneur pairs with an experienced non-Laboratory business mentor who aids in further developing the initial concept. This collaboration steers the concept's maturation while fostering a close working relationship with the entrepreneurial community—important for establishing connections with related markets and potential partners. In some circumstances, the mentor may see great potential in a protégé's technology and become even more involved in the project, even to the point of becoming a partner or investor.

The rare-earth element extraction technology developed by Jiao greatly interested Jim Kiles, Jiao's industry-savvy mentor. Kiles is founder and chief executive officer of Ystrategies Corporation, a business development and venture capital firm that invests

Accelerating Innovation

Hybrid-electric vehicles, fluorescent lights, large wind turbines, and other clean-energy products all rely on small quantities of rare-earth elements. However, these elements are often expensive, with demand exceeding supply because of the difficulty of extraction with conventional methods. The combination of scarcity and high cost creates an urgent need for new approaches to efficiently and cleanly recover these materials from ores and recyclable products.

Livermore staff scientist Yongqin Jiao and colleagues are leading a project to develop an environmentally friendly bioadsorption strategy for rare-earth recovery using a genetically engineered bacterium. Attached to the bacterium's outer cell wall are lanthanide-binding ligands, which attract rare-earth atoms with 1,000 times greater affinity than for other metals. Rare earths adsorbed by the bacteria can be washed off with a solution of citrate, a derivative of citric acid that is harmless to the bacteria, allowing the organisms to be reused many times. Applications originally envisioned for this novel technique include the processing of low-grade waste materials such as mine tailings, coal byproducts, and geothermal brines.

Jiao's team participated in the Department of Energy's Energy I-Corps program to further develop their technique for the U.S. clean-energy industry. Through the program, the team identified geothermal and coal mining companies interested in adopting the technology. The Livermore team and the companies are now working together to commercialize the technology and thereby supply the nation with a more secure source of the important materials.

Livermore's Yongqin Jiao (left) and Suzanne Singer, members of the MicroMiners team for rare-earth recovery, engage with industry expert Tim Heaton as part of the Department of Energy's Energy I-Corps program. The program pairs national laboratory researchers with industry professionals who can help enhance a technology's commercial potential.

in advanced clean-energy technologies designed to minimize disruption to business processes. Clean-energy technologies using rare earths fit that bill but lacked market appeal because of the elements' costs. (See box above.) Kiles explains, "Because of the scarcity of rare-earth elements, the demanding market for the materials is suffering. However, this Livermore extraction technology can potentially solve a major industry issue and propel the success of related businesses."

The next step in the National Laboratory Accelerator Program is for the scientists, engineers, and their mentors to participate in Energy I-Corps or a similar program for intensively studying customer discovery, product–market fit, and business model development. After this step, some participants continue working until their business concept is deemed ready to unveil to investors. Those whose technologies demonstrate exceptional potential are invited to a competition where the most promising team from each of the 10 participating national laboratories pitches their technology to actual investors ready to offer seed funding to the right team.

Access to the advanced technologies and intellectual property of a national laboratory helps industry partners to develop products with the potential to improve society. In return, these partnerships help the national laboratories develop and sustain the very capabilities that further their national security mission. Energy I-Corps and the rest of the National Laboratory Accelerator Program promote this mutually beneficial partnership, combining the expertise and resources of the national laboratories, collaborating universities, and business partners to accelerate the commercialization of promising national laboratory technologies. The successes already achieved demonstrate that these public–private collaborations add value to both the national laboratories and the nation's economy. Werne states, "The question is, can we boost the nation's economic competitiveness? We can. We do. We have."

—Lanie L. Helms

Key Words: carbon capture, carbon dioxide (CO_2), clean-energy technology, commercialization, Energy I-Corps, Industrial Partnerships Office (IPO), MicroMiners, National Laboratory Accelerator Program, rare-earth elements, technology transfer.

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