BUILDING A HOME FOR HARD SCIENCE INNOVATORS

A RETROSPECTIVE ON THE CYCLOTRON ROAD PILOT

2016 ANNUAL REPORT

cyclotronroad

ACKNOWLEDGMENTS

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Biosciences Area
Computing Sciences Area
Earth & Environmental Sciences Area
Energy Sciences Area
Energy Technologies Area
Physical Sciences Area
The Molecular Foundry
Advanced Biofuels Process Demonstration Unit
Berkeley Lab Directorate
Berkeley Lab DOE Site Office
Berkeley Lab Operations
Innovation and Partnerships Office
Public Affairs Office
Creative Services Office

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Front Cover:

Cyclotron Road innovator Kendra Kuhl running an experiment at Berkeley Lab (photo: Winni Wintermeyer)

BERKELEY LAB

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
ADVANCED MANUFACTURING OFFICE

ACTIVATION ENERGY

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LETTER FROM THE DIRECTOR

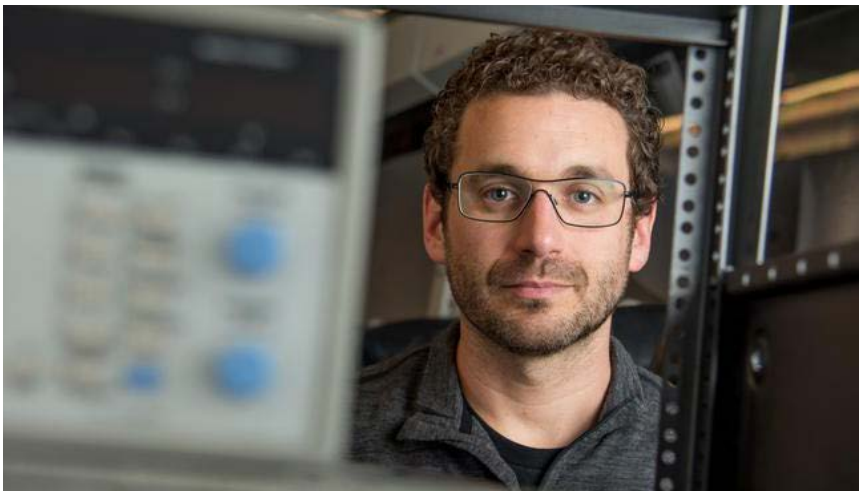


Photo Credit: Todd Johnson, San Francisco Business Times

Dear friends and supporters,

Cohort One will be graduating from Cyclotron Road in the coming weeks, bringing the pilot phase of our experiment to a close. As we approach this milestone, our team has been reflecting on what we accomplished, working to understand what we learned, and sharpening our focus for the next chapter.

This report captures the key outcomes of that reflection. Below you'll find our latest thinking about what Cyclotron Road is and why it matters, a retrospective of what happened during our pilot, and some thoughts on where we go from here.

The bottom line—our first cohort of innovators have blown us away with their vision, drive, and accomplishments. We are humbled by the transformative role Cyclotron Road has played in enabling them to turn scientific concepts into real-world products. Most importantly, we believe their experiences here will set them on course to become global leaders in technology and innovation.

Reflecting on these early successes, we are charging ahead with a renewed commitment to define a new model for hard science innovation, one that empowers the world's most capable innovators to solve society's biggest problems. We hope that you'll join us in that effort.

Onward,

ILAN GUR

FOUNDING DIRECTOR, CYCLOTRON ROAD

WHO WE ARE

CYCLOTRON ROAD: A HOME FOR HARD SCIENCE INNOVATORS

New technologies rooted in the physical and biological sciences will be fundamental to addressing the 21st Century's biggest challenges in energy, water, food, and health. Yet, there are critical gaps in today's research ecosystem that prevent scientists and engineers from maturing new concepts to the point of commercial viability.

Academic research institutions are optimized for scientific discovery, but provide neither the training nor incentives to mature those discoveries into commercially viable technologies. Private industry has both the motivation and capability to guide science toward application, but cannot justify investment in research that is too immature to reasonably gauge its commercial potential. The result is a no man's land between idea and application that keeps some of the most transformative discoveries from reaching the market and benefiting society. Faced with this chasm, even the best science innovators struggle to find the resources needed to mature their research toward application.

Many are even forced to abandon their ideas entirely.

At Cyclotron Road, **our mission is to empower hard science innovators to advance their ideas from concept to viable first product**, positioning them for broad societal impact in the long term. Our aim is to create a new institutional home for application-driven research, supporting our best and brightest as they take the critical first steps toward the market.

Cyclotron Road's approach has three elements:

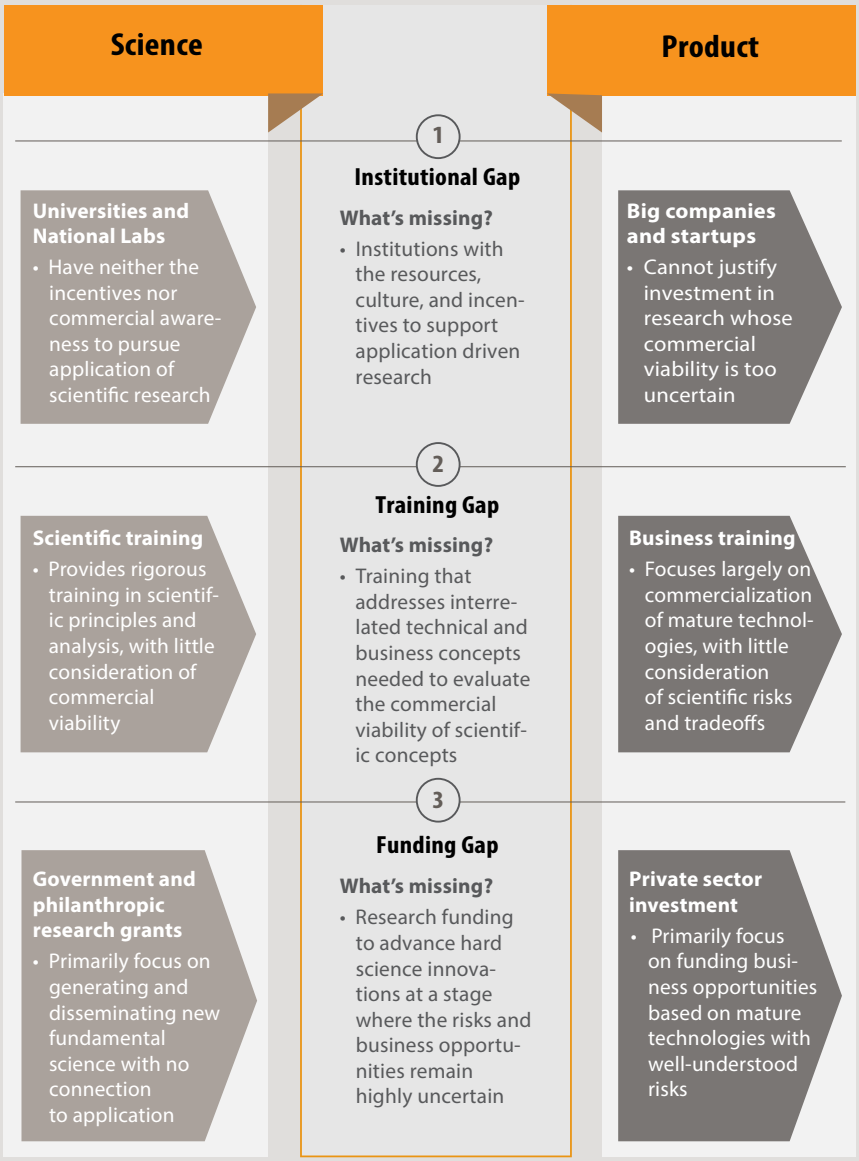
1. **WE RECRUIT** hard science innovators who are determined and able to drive their research to the doorstep of the market. We look for entrepreneurial leaders from among the top scientists in the field—ones with the rare combination of exemplary technical skills, an impact-oriented mindset, and a commitment to build value by solving commercially relevant problems.
2. **WE EMPOWER** our innovators with the credibility and resources to make rapid progress translating their ideas to a viable product, including:

- **A two-year fellowship.** Rapid progress requires an "all-in" commitment. Our program fellowship provides a living stipend and health insurance so that innovators can be 100% focused on their projects.
- **Access to world-class research facilities and expertise.** Science innovation requires sophisticated infrastructure. Cyclotron Road participants receive access to facilities, equipment, and expertise at Berkeley Lab. We provide a small amount of initial research funding to facilitate access and collaboration with the Lab's staff scientists. Innovators fully own or jointly own all intellectual property developed during the program.
- **Training, mentorship and networking.** The Cyclotron Road program curriculum is tailored to support the challenges of hard science innovation. Participants receive intensive training and mentorship covering all aspects of the journey from concept to product. We also expose them to a wide range of leaders from academia, industry, government, and finance that can serve as advisors or partners in support of their effort.

3. **WE POSITION** our innovators for market penetration and broad societal impact. Cyclotron Road allows participants to identify the optimal path to market for their technology across a broad spectrum of commercialization models. Many of our innovators look beyond the traditional venture capital community, finding stronger alignment with strategic investors, angel investors, large corporations, or even philanthropy. Our goal is simple: allow innovators to mature their ideas to the point where the most suitable commercial partners can take over. In strengthening this alignment, we enable the private sector to support science innovation more efficiently and successfully, driving better outcomes and greater impact on society.

Bridging the Science-to-Product Gap

Critical gaps in our research ecosystem prevent even the most qualified innovators from advancing hard science concepts to the doorstep of the market.



PROGRAM TIMELINE

2014

May: Berkeley Lab commits to M37 pilot

Aug: 150 applicants registered for Cohort One

Oct: U.S. DOE Advanced Manufacturing Office joins Berkeley Lab to support pilot

2015

Feb: Cohort One launch at 2015 ARPA-E Summit

Oct: Advanced Manufacturing Office commits to support Cohort Two

Dec: Cohort One surpasses $5M in foundational research funding

2016

Feb: First meeting of Leadership Council (see page 20)

May: Cohort Two starts at Cyclotron Road

Sep: Partnership with Activation Energy announced at *Activate 2016* Demo Day

Dec: Cohort One surpasses $10M in foundational research funding and secures first $5 million in private financing.

2017

Feb: Selections for Cohort Three finalized

Activate 2016: Our Inaugural Demo Day

On Thursday, September 29th, 2016 Cyclotron Road hosted *Activate 2016*, our first ever Demo Day, at the Scottish Rite Temple on the shores of Lake Merritt in Oakland, CA. The culmination of many months of work for our innovators and program staff, *Activate* had a simple goal: gather the leading hard tech investors and industry players from across the energy innovation ecosystem to showcase the astonishing progress our teams had made.

Nearly 250 people flooded the Grand Ballroom at the historic Scottish Rite, where they heard five minute pitches from all twelve Cyclotron Road teams, watched live demos of their products, and networked from the afternoon into the evening. Four teams announced the first private sector investments into their companies at *Activate* and the event also served as the public launch of Berkeley Lab's partnership with Activation Energy to support Cyclotron Road.

Photo credit: Paul Mueller. Photos, top to bottom:

1. Guests watching innovator pitches during *Activate 2016*. 2. Etosha Cave makes a case for rewriting the story of carbon dioxide. 3. Deepak Dugar demos his product for Leadership Council member Hemai Parthasarathy. 4. Philip Taynton describing the automotive market for carbon fiber composites.

Cohort One innovator Raymond Weitekamp, founder of Polyspectra, presenting at *Activate 2016*. Photo Credit: Paul Mueller.

WHAT WE'VE DONE

LOOKING BACK: THE CYCLOTRON ROAD PILOT

We founded Cyclotron Road to define a new model for science innovation: embed top science innovators in a world-class research facility for a limited time and with an explicit mandate to bring their ideas to the point of commercial viability. In May 2014, we decided to test our model by launching a pilot program with initial support from Berkeley Lab.

By September, we had recruited nine innovators across six projects into our pilot cohort (Cohort One), all focused on hard science energy innovations. We supported them for two years through a fellowship, small amount of research funding, access to Berkeley Lab's world-class tools and expertise, and mentorship from our program team and network. The funding provided was enough to get innovators started but only a small fraction of what they would need to achieve their vision.

The pilot is now nearing completion and the initial results are in. Below is a summary of what happened during the pilot and some of the key lessons learned. Our interpretation: Cyclotron Road is proving highly effective at enabling science innovators to drive their technologies toward the market.

Cohort One innovators

Kendra Kuhl, Cofounder OPUS 12
Ph.D. Chemistry, Stanford

Etosha Cave, Cofounder OPUS 12
Ph.D. Mechanical Engineering, Stanford

Marcus Lehmann, Cofounder CALWAVE
M.Sc., Mechanical Engineering, TU Munich

Ray Weitekamp, Founder POLYSPECTRA
Ph.D. Chemistry, Caltech

Jared Schwede, Cofounder, SPARK THERMIONICS, *Ph.D. Physics, Stanford*

Dan Riley, Cofounder, SPARK THERMIONICS, *Ph.D. Physics, Stanford*

Tom McDonald, Cofounder, MOSAIC MATERIALS, *Ph.D. Chemistry UC Berkeley*

Steven Kaye, Cofounder, MOSAIC MATERIALS, *Ph.D. Chemistry UC Berkeley*

Deepak Dugar, Founder VISOLIS
Ph.D. Chemical Engineering, MIT

Snapshot: Review process and selection criteria

Our review process is designed to provide our staff with rigorous insights while being efficient and beneficial for the candidates. Applicants are asked to submit a simple five-page application describing their personal goals, technology vision, and alignment with our program. This is followed by a four-month selection process that includes input from industry and academic experts, phone interviews, and two in-person visits to Berkley Lab, including a final presentation to our Leadership Council. Throughout the process, we aim to identify potential advisers and collaborators for the applicants.

Our **selection criteria** are intended to identify the best candidates for our support and filter for the projects most aligned with our mission.

Project Leader: We look for the very best outcome-oriented, entrepreneurial technical founders who have the drive and ability to build a foundational technology vision and lead a team in its development. The ideal candidate would exhibit exceptional technical strength, outcome orientation, and professional excellence.

Project concept: While ideas may evolve, we want to ensure that the initial project concept is technically sound, reasonably differentiated, and addresses a well-framed problem with significant long-term impact potential. The ideal project would exhibit exceptional impact on the U.S. energy economy, technical merit, and fit with Cyclotron Road's goal of providing transformative support to hard science innovators.

RECRUITING
TOP ENERGY INNOVATORS TO JOIN COHORT ONE

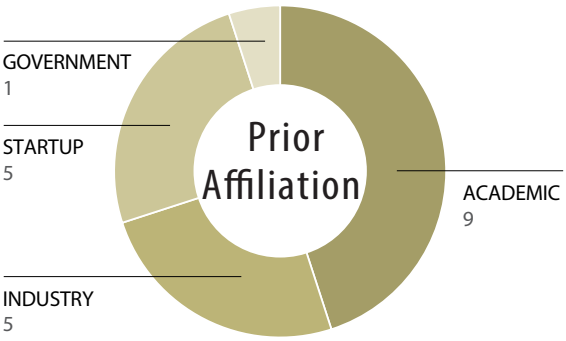
First and foremost, the Cyclotron Road pilot provided the opportunity to validate our motivating hypothesis: that a critical science-to-product gap in the research ecosystem was preventing top science innovators from developing their ideas. If the gap existed, we would expect a strong response from high-quality innovators. Otherwise, the program would be a non-starter.

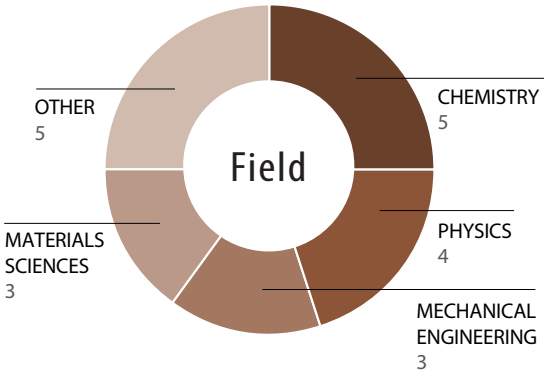
Recruitment of Cohort One began in July 2014, when Cyclotron Road's first application website went live under the codename 'M37'. An overwhelming response from interested applicants forced us to close the application portal after only three weeks. The website had received over 15,000 page views and 150 innovators from across the country had registered to compete for an anticipated five slots.

Ultimately, we received complete applications from 100 innovators, covering a broad range of technology concepts based in the physical and biological sciences, and targeting a variety of industrial energy markets. Innovators hailed from all backgrounds: academia, industry, startups, and government. Most were looking to use Cyclotron Road to jumpstart their first commercially oriented hard science endeavor. Many were recently graduated Ph.D. students and postdocs seeking an opportunity to develop products based on their academic research. As we learned their stories, it became clear that nearly all of these prospective innovators had no other place to pursue their vision.

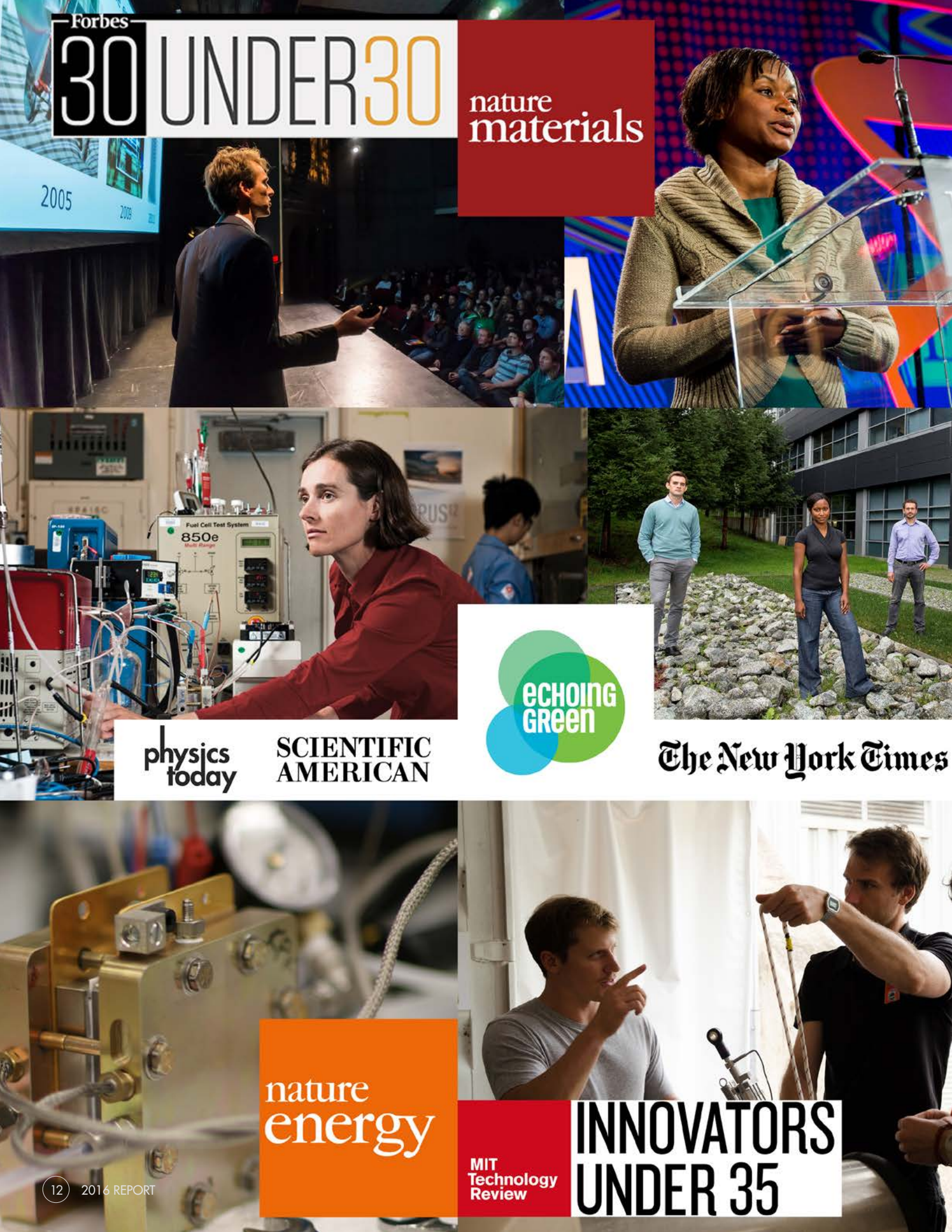
After a rigorous selection process with input from a panel of industry and academic experts, nine innovators across six projects (see opposite page) were admitted to Cohort One and began work at Cyclotron Road in early 2015.

The size and quality of the Cohort One applicant response gave initial validation that we were meeting a significant need in the research ecosystem. Impressed and hoping to further validate this need, the US Department of Energy EERE Advanced Manufacturing Office partnered with Berkeley Lab to support the Cohort One pilot in Fall 2014.





Prior affiliations and technical backgrounds of final 20 candidates for Cyclotron Road Cohort One.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echoing green
The New York Times
nature energy
MIT Technology Review
INNOVATORS UNDER 35

EMPOWERING COHORT ONE INNOVATORS FOR RAPID PROGRESS

To effectively bridge the science-to-product gap, Cyclotron Road was designed to support coupled technology and business exploration. We sought to validate the effectiveness of this support by tracking Cohort One's progress within our pilot. Our hope was that we could help our teams reach the doorstep of the market, equipped with a first prototype, initial customer, and business model hypothesis.

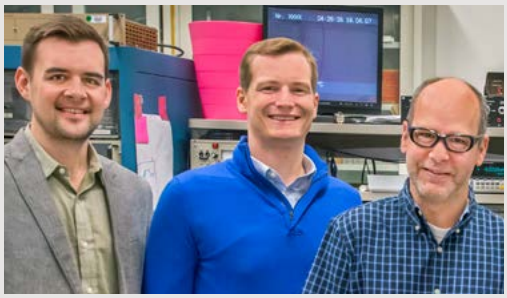
Cohort One made astonishing progress over their two years at Cyclotron Road. They made scientific discoveries, scaled materials from flasks to giant reactors, broke world records, identified market applications, and engaged customers. They secured the foundational research funding needed to advance their ideas, ultimately founding six companies that are already supporting 30 high tech manufacturing innovation jobs. Their work received national recognition in *The New York Times*, *Chemical & Engineering News*, *Fortune*, *Forbes*, *MIT Technology Review*, and *Physics Today*, among other outlets. And, critically, all six Cohort One teams will cross the science-to-product gap, having succeeded in building a first customer prototype or securing the financing to do so during the next phase of their effort.

This progress was due in no small part to successful collaborations with Berkeley Lab scientists. During their tenure, Cohort One innovators have worked closely with researchers across the Lab, developing publications and intellectual property, as well as new scientific methods and tools that help to support the Lab's basic research goals.

In retrospect, Cohort One's results may not be all that surprising: we took best-in-class innovators, provided the resources and credibility of a top research institution, motivated them with a two-year cliff and the expectation to make rapid progress, and immersed them in an entrepreneurial culture with strong mentorship and training. Cohort One's results provide strong validation that these elements can form a bridge from hard science concept to product.

SNAPSHOT: COMPANIES FOUNDED BY COHORT ONE

SPARK THERMIONICS



Dan Riley and Jared Schwede, *Cofounders, Spark Thermionics* with Berkeley Lab scientist Andreas Schmid

Spark Thermionics

- **Background:** Compact solid-state heat engine concept with high power density and efficiency developed during Ph.D. in Physics at Stanford University.
- **Key milestones achieved at Cyclotron Road:** Identified first target application, won $2M+ from ARPA-E and DARPA, and built technical team.
- **Status upon graduation:** Raised seed financing from venture capital investors, 5 employees.

mosaic

Tom McDonald, *Cofounder Mosaic Materials* and Chemist Zoey Herm

Mosaic Materials

- **Background:** New sorbent concept developed at UC Berkeley using metal-organic-frameworks (MOFs) to reduce cost of industrial chemical separations.
- **Key milestones achieved at Cyclotron Road:** Developed low-cost synthesis and engineered MOF pellets, won $1M grant from California Energy Commission for pilot demo at biogas plant, built technical team.
- **Status upon graduation:** Raised seed financing from industry investor, 4 employees.

OPUS12

Kendra Kuhl, Nicholas Flanders and Etosha Cave, *Cofounders OPUS 12*

OPUS 12

- **Background:** New nanostructured catalysts and reactor concept for conversion of carbon dioxide into commodity fuels and chemicals.
- **Key milestones achieved at Cyclotron Road:** Built prototype reactor and demonstrated dramatic improvement in performance over state of the art, won four SBIR awards, DOE small business voucher, and Shell Gamechanger award. Built technical team.
- **Status upon graduation:** Raised seed financing from angel, strategic, and philanthropic investors, 7 employees.

POSITIONING
COHORT ONE INNOVATORS FOR MAXIMUM IMPACT

Hard science innovators face a unique financing challenge. While new software and consumer products can be easily financed by the private sector, significantly more time and funding are needed to mature a hard science concept into a validated industrial product. As a result, innovators are often forced to seek large institutional investment while still at the research stage. Given a high level of technology and business uncertainty, early-stage investors are either unable to justify an investment, or risk investing in a concept that might ultimately prove incompatible with their goals.

By providing innovators a research environment in which to mature their technology and evaluate its market applicability, Cyclotron Road can enable the private sector to more properly evaluate the risk and fit of potential early-stage investments. This should help prevent misalignment and lead to more successful investment decisions. Our pilot sought early indications that our support could unlock aligned sources of private sector funding for our innovators for their next phase of development beyond the program.

Over their two years at Cyclotron Road, Cohort One innovators raised more than $15 million to support their projects. This included attracting more than $5 million in initial private funding commitments to their companies at the back end of the program. Notably, private financing came from a broad spectrum of investor types with varied goals and expectations, ranging from philanthropic funders and angel investors to traditional Silicon Valley venture capitalists and industry-backed strategic investors. This diversity of investors helps to validate our hypothesis that the support provided at Cyclotron Road can enable innovators to successfully secure aligned private sector support.

Our hope is that this alignment leads to better outcomes for our innovators and their partners in the future. By enabling the capital markets to support science innovation more efficiently and successfully, we can encourage greater private sector support for science innovation, have greater impact on society, and create stronger incentives to drive the next generation of world-changing innovators.

WHAT'S NEXT

Beyond the pilot: laying a foundation for Cyclotron Road's future

Moving forward, we aim to build upon the success of our pilot to establish Cyclotron Road as the world's foremost home for science innovators to bridge the science-to-product gap. Though Cohort One validated our model, we see tremendous opportunity to enhance our impact by increasing the number and type of innovators we support, and by better addressing the most critical pre-commercial gaps they face.

Bridging critical gaps

In working with our innovators over the past two years, we have come to appreciate the breadth and severity of institutional, educational, and financial gaps in support for hard science innovation. Recognizing that the solutions to these challenges often lie at the intersection of public and private innovation ecosystems, Berkeley Lab issued an open solicitation in 2016 seeking non-governmental organizations to support Cyclotron Road in addressing the most critical issues facing hard science innovators. This resulted in a partnership with the non-profit organization Activation Energy that provides deeper private sector engagement and a versatile platform to begin systematically addressing the challenges faced by Cyclotron Road innovators as they move from concept to first product, and beyond.

The first area of focus in this partnership has been addressing a critical knowledge and educational gap for hard science innovation. While resources to support software or consumer product innovation are abundant, there are few existing educational tools or curricula tailored specifically to hard science innovation. The scarce resources that do exist can be difficult to find and hard to interpret without guidance from experienced technologists. We have found that the lack of such educational resources and guidance can lead to costly, unproductive, and unnecessary diversions and delays for our innovators.

To address this need, we began piloting our own innovation framework and corresponding training curricula and mentorship programming this past year. Our framework (see Appendix) builds upon elements of various traditional and modern innovation models to systematically provide hard science innovators with the tools they need for success at the concept-to-prototype stage. Unlike other models, our framework provides a strong coupling between technical and business development, and supports a wide range of commercialization pathways.

Looking forward to Cohort Three, we plan to refine and expand this program with a more formalized educational curriculum, mentorship program, and resource database. Ultimately, we aim to provide our innovators with every tool they need to maximize their chance of success. We plan to share these resources openly in hopes of more broadly accelerating the translation of hard science into commercially viable products.

Supporting more innovators

To achieve our mission, Cyclotron Road must continue to attract the nation's top hard science innovators. Since launching the pilot, the DOE EERE Advanced Manufacturing Office has supported two additional energy manufacturing focused cohorts. Cohort Two came aboard in May 2016 and Cohort Three will begin work at Cyclotron Road in May 2017. The number of high-quality applicants has risen each year, such that we are now only able to accept a small fraction of qualified candidates. There is unquestionably a strong need for programs like ours.

Toward the end of 2017, we plan to pilot a complementary program for hard science innovators focused specifically on the electric power system in partnership with the California Energy Commission. Through this pilot, Berkeley Lab and Activation Energy will seek to validate the potential for Cyclotron Road to serve as a home for experienced innovators looking to develop their next transformative technologies and businesses.

Meanwhile, innovators and research managers from across the globe have approached us to explore how Cyclotron Road can support them in sectors including biomedicine, water management, and defense. One thing is clear: there is no lack of opportunity ahead.

Our vision: science to societal impact

We are thrilled by the results of Cohort One, but the obvious question is: "to what end?" This is the long-term experiment that remains at the heart of Cyclotron Road. Time will tell whether transformative support for hard science innovators at the early stage will in fact lead to bigger impact on society in the long run. We believe that it will. But our ultimate success will be measured on the scale of gigawatts, tons of CO_2, billions of dollars, and millions of lives.

In the meantime, as we continue to learn, improve, and grow, we express our deepest appreciation for the remarkable group of men and women pioneers that blazed the trail for Cyclotron Road. Thank you Cohort One: for helping us build our model and establish our core principles. Your efforts have set a high bar for those to come. Above all, thank you for inspiring us day in and day out to work ever harder on this important mission. As Cyclotron Road's first graduates, we are eager to see to what great heights you will climb.

APPENDIX

CYCLOTRON ROAD INNOVATION FRAMEWORK

We have created a comprehensive program curriculum over the past two years tailored to meet the needs of hard science innovators at the concept stage. Some of the unique elements of this program include:

- **Coupled technology and business exploration.** Cyclotron Road gives innovators the opportunity to evaluate the strengths and limits of their technology and explore market applications *before* committing to a costly development plan. We promote a hypothesis driven, iterative approach to probe alignment of key technology, finance, market, and stakeholder considerations.
- **A hard look at manufacturing cost.** For hard science innovation, widespread impact depends on the ability to manufacture new technologies at enormous scale and competitive cost. Yet scientists lack the training to evaluate manufacturing costs for a concept-stage technology. To address this gap, we created an eight-week course, covering everything from back-of-the-envelope viability assessment to detailed technoeconomic modeling. The goal: equip our innovators with the key tools needed to prevent them from developing a solution no one will be able to afford.
- **Formal advisory board reviews.** Our program staff is committed and experienced, but no single team can adequately cover the broad technology and application space represented by our innovators. Therefore, we help our innovators recruit top-tier industry advisors with domain expertise and professional connections that are essential for their success. We require our innovators to hold quarterly advisory board meetings, which provide a formal mechanism to maintain accountability and offer strategic feedback.
- **Examples of excellence.** Our first cohort struggled to find role models and resources geared toward hard science innovation. Responding to that need, we developed a speaker series to provide examples, inspiration, and actionable knowledge from successful hard technology innovators and entrepreneurs. We also created a comprehensive online library that archives curated resources and examples of excellence across all aspects of hard technology and business development.
- **A "people first" philosophy.** At Cyclotron Road, we believe that people are the drivers of innovation. That's why we select for and support people, not companies or technologies. Starting day one, we help our innovators articulate and stay true to their big picture personal goals. Alignment with these goals always comes first.

From Concept to First Prototype

Cohort One Results at End of Pilot

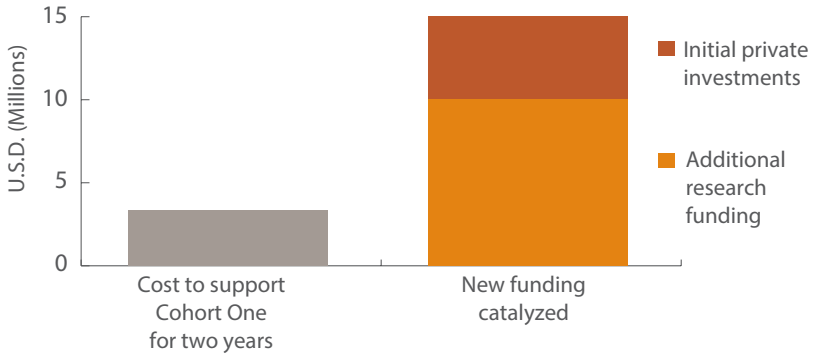
PROTOTYPES: 100% of teams have built a first prototype or secured funding to do so

JOBS: 30 high tech manufacturing innovation jobs already supported by new companies founded by Cyclotron Road innovators

FUNDING: Cohort 1 has catalyzed over $15 million of foundational research funding and initial private investments

RUNWAY: All teams are funded for their next stage of development beyond the program

Top innovators + world-class R&D support:
A catalyst for public and private investment



OUR LEADERSHIP AND SUPPORT

Cyclotron Road is a program of Berkeley Lab funded by the DOE EERE Advanced Manufacturing Office and supported in partnership with Activation Energy.

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Lockheed Martin

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Silicon Valley Bank

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Cyclotron Road innovators, staff and supporters after *Activate 2016*, our inaugural demo day. (Photo credit: Paul Mueller)

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