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SPECIAL REPORT
Startups

A new generation of
IEEE members launch
their own ventures

Limor Fried
Founder,
Adafruit Industries
PAGE 6

REGION NEWS



**REGION
1**

NORTHEASTERN UNITED STATES

- Student branches at the University of Massachusetts, Amherst, and Suffolk University, Boston, form IEEE Power & Energy Society chapters.
- Buffalo (N.Y.) Section forms IEEE Consultants Network affinity group.
- Student branch formed at Roger Williams University, Providence, R.I.

**REGION
2**

EASTERN UNITED STATES

- Dayton (Ohio) Section forms IEEE Women in Engineering (WIE) and IEEE Young Professionals (YP) affinity groups.

**REGION
5**

SOUTHWESTERN UNITED STATES

- Student branch at University of Oklahoma, Norman, forms IEEE Microwave Theory and Techniques Society chapter.

**REGION
6**

WESTERN UNITED STATES

- Student branch formed at University of Arizona, Tucson.
- San Diego Section forms IEEE WIE affinity group.
- Student branch at University of Southern California, Los Angeles, forms IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society chapter.
- Student branch formed at Northwest Nazarene University, in Boise, Idaho.
- Seattle Section forms IEEE Signal Processing Society chapter.

**REGION
7**

CANADA

- Student branch at Simon Fraser University, Burnaby, British Columbia, forms IEEE Systems, Man, and Cybernetics Society chapter.
- Winnipeg (Manitoba) Section forms joint chapter of IEEE Aerospace and Electronic Systems and IEEE Geoscience and Remote Sensing societies.

**REGION
8**

EUROPE, MIDDLE EAST, AND AFRICA

- Student branch at East Sarajevo University, Bosnia and Herzegovina, forms IEEE Industry Applications Society chapter.
- Student branch at University of Sarajevo, Bosnia and Herzegovina, forms IEEE Computer Society chapter.

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BRIEFINGS

IEEE Day Is Just a Month Away

MEMBERS AROUND the world are organizing special events in celebration of IEEE Day on 6 October. Now in its sixth year, the day commemorates the anniversary of the 1884 meeting in Philadelphia where members of the American Institute of Electrical Engineers, one of IEEE's predecessor societies, gathered for the first time to share technical ideas.

IEEE members from every region are planning events including technical and networking meetings, panel discussions, and social gatherings. Last year, a total of 523 celebrations took place.

Visit <http://www.ieeeday.org> to see what other IEEE groups are planning and add your own event to a world map. You can also download this year's IEEE Day logo and T-shirt design.

There are also contests for the best photos and videos taken at IEEE Day celebrations. Cash prizes will be awarded to each IEEE organizational unit that submits a winning photo or video. Winning entries will be displayed on the IEEE Day website.

To commemorate the event, IEEE is offering a US \$30 discount on dues for new members who join between 4 and 10 October. (The offer does not apply to student or graduate student memberships.) New members can simply enter the promo code IEEEDAY15 at <http://www.ieee.org/join> to receive the discount.

—A.D.

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Bringing Electricity and Job Opportunities to Africa 16

ONLINE

Available at theinstitute.ieee.org

TECH HISTORY Read about several IEEE entrepreneurs whose startups went on to become household names.

Calendar & IEEE Events

IEEE-Eta Kappa Nu Celebrates Five-Year Anniversary

IT'S BEEN FIVE YEARS since Eta Kappa Nu (HKN) merged with IEEE to become the organization's honor society. Formed more than a century ago to recognize exemplary college students, it is now known as IEEE-HKN and continues to recognize excellence in scholarship, leadership, and service. Inductees are chosen on the basis of their technical, scientific, and leadership achievements. Since the merger, they must also be IEEE members.

The merger expanded HKN's operations and chapters well beyond North America. Since 2010, IEEE-HKN has grown from 125 to 193 active chapters at universities around the world.

More than 100 years old, HKN itself was founded in 1904 by Maurice L. Carr and a group of nine other engineering students at the University of Illinois, Urbana-Champaign.

Although its original purpose was to recognize academic excellence, its goals expanded over time. Now IEEE-HKN alumni serve as mentors to recent graduates, and many society members give back to their communities by tutoring preuniversity students and organizing science fairs and exhibits. IEEE-HKN also presents a number of awards each year to outstanding students, teachers, practitioners, and leaders in the IEEE fields of interest.

The IEEE-HKN category of Eminent Member is bestowed on "individuals who, by their technical attainment and contributions to society, have shown themselves to be outstanding leaders in the field of electrical engineering and great benefactors to society." Those honored include Internet pioneer Vinton Cerf, 2007 IEEE President Leah Jamieson, mobile phone inventor Martin Cooper, and Intel cofounder Gordon E. Moore.

To learn more about the honor society and find out how to start a chapter at your school, visit <http://www.hkn.org>.

—Amanda Davis

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September

3

1930

The Lackawanna Railroad inaugurates **electric passenger train** travel in New Jersey, between Hoboken and Montclair.

5

1850

Birth date of **Eugen Goldstein**, a German physicist (born in Poland) who would coin the term "cathode ray" for the stream of electrons observed in vacuum tubes.



9

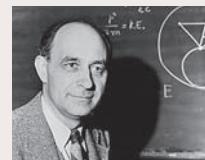
1926

The Radio Corporation of America launches the **National Broadcasting Co. (NBC)**

20

1954

Fortran, a high-level programming language, runs for the first time, on an IBM 701 computer.



29

1901

Birth date of **Enrico Fermi** [above], recipient of the 1938 Nobel Prize in Physics for his work on induced radioactivity by neutron bombardment and the discovery of transuranic elements.



29

1971

October

4

1854

Birth date of **Michael E. Pupin**, who served as president of both of IEEE's predecessor societies: the Institute of Radio Engineers (in 1917) and the American Institute of Electrical Engineers (in 1925 and 1926).

8

1965

London opens its **Post Office Tower** (now the BT Tower), a telecommunications structure.

10–11
Region 8 meeting in Ljubljana, Slovenia.

November



7

1867

Birth date of **Marie Skłodowska-Curie**, who would win two Nobel prizes, one for physics and the other for chemistry, for her pioneering research on radioactivity.

11

1973

The **Ethernet**, a family of computer networking technologies for local and metropolitan area networks, begins functioning at the Xerox Palo Alto Research Center, in California.

13

1922

Birth date of IEEE Fellow **Ambros P. Speiser**, a Swiss pioneer of digital computer design.



18

1963

Western Electric Co. manufactures the first **telephone** in the United States with push buttons instead of a rotary dial.

18–23
IEEE Meeting Series in New Brunswick, N.J.

Historical events are provided by the IEEE History Center. For photos and videos of these engineering milestones, visit <http://theinstitute.ieee.org/briefings/calendar>.

CLOCKWISE FROM TOP RIGHT: MONDADORI PORTFOLIO/GETTY IMAGES; CORBIS; SSPL/GETTY IMAGES; FOTOSTOCK/GETTY IMAGES; NBCU PHOTO BANK/GETTY IMAGES



Startups

ENGINEERING AND ENTREPRENEURSHIP

in many ways go hand in hand. They require imagination, know-how, and the ability to bring a concept to reality. IEEE members have for decades been at the forefront of turning their ideas into successful businesses. In this issue, we present IEEE's efforts to attract more entrepreneurial types to the organization and to support members' ventures through online resources, networking events, and more.

The IEEE Technical Activities Ad Hoc Committee on Entrepreneurship, for example, is making it a priority to help members start or grow their ventures [this page]. You can also read about IEEE members who launched startups in the past decade. IEEE Member Limor Fried [p. 6] found success with her do-it-yourself electronics company, Adafruit Industries. She turned a simple idea into a US \$33 million business selling electronic kits and parts for hobbyists as well as tutorials for building smartphones, wearables, handheld video games, and other gadgets.

Other members have launched ventures in connected cars, robotics, and mind-controlled technology [p. 8]. An IEEE Fellow who has taken two of his companies public and has invested in six others—none of which has failed—offers advice to members on how they can do the same [p. 10].

Whether you already have a project in the works or are just now toying with ideas, we hope this issue inspires you to take the next step. Remember: You don't have to go it alone. There are related conferences to attend [p. 14] and a number of IEEE resources [p. 15] to help you. Don't forget that Hewlett-Packard founders William Hewlett and David Packard and Medtronic cofounder Earl Bakken started their companies in garages [p. 18].

We'd like to hear about your venture or if you have advice for aspiring entrepreneurs. Write to us at institute@ieee.org.

—Monica Rozenfeld, associate editor

Pictured above: Center: Limor Fried. Clockwise from top left: Jessica Colaço, Devon Ryan, Milton Chang, Mou Riiny, Earl Bakken, Tan Le, Melonee Wise, and João Barros.

Making IEEE a Home for Founders

A new committee is focused on attracting entrepreneurs BY KATHY PRETZ

TODAY'S entrepreneurs have different needs in terms of fund-raising, product development, and social marketing. Often, the startups are not just developing new technologies but also creating innovative software for existing ones. Creative thinkers enjoy going to networking events with like-minded individuals as well as attending academic conferences. And they are likely to subscribe to credible sources that curate content they're interested in, including research articles, videos, and other material related to their product ideas.

Those are just some of the findings from a year's worth of analysis conducted by the 2014 IEEE Ad Hoc Committee on Entrepreneurship. The IEEE Board of Directors established the committee to recommend programs, products, and services that the organization should provide to help encourage more engagement with these individuals. After all, record numbers of young people are starting businesses—just the type of people IEEE wants for future members.

"It's not that engineering research isn't helpful, but today's entrepreneurs are looking to network with other talented and creative people, investors, and entrepreneurs in order to develop their companies, markets, and products," says IEEE Senior Member Ken Stauffer, the committee's vice chair. "These unmet needs are some of the reasons why it's not easy for entrepreneurs to find a home within IEEE."

In 2003 Stauffer cofounded Technology Assurance Labs, an independent laboratory in Orlando, Fla., that provides business-focused solutions and products.

"Forty years ago people looked at you cross-eyed if you came out of college and wanted to be an entrepreneur," he says. "With the proliferation of software that allows people to develop apps, role models like Facebook's Mark Zuckerberg, and easier accessibility to money through venture capital and crowdfunding, starting your own business is much easier and more acceptable for a young graduate." In fact, he adds, in some areas of the world entrepreneurship is a young grad's default occupation because of weak economies and a limited number of corporate positions.

"Additionally, a growing number of large tech companies regularly invest in purchasing and integrating startups, rather than creating an internal R&D department," he notes. "The world of technology business is changing, and IEEE is working to ensure we add value to this changing model."

Stauffer chairs the 2015 Technical Activities Ad Hoc Committee on Entrepreneurship, which has been asked by the IEEE Board to carry out some of the recommendations the committee made last year. Those include the creation of a Web portal to IEEE services and programs relevant to the startup community; holding a global networking event for entrepreneurs, investors, and others; and creating an entrepreneurs section in IEEE Collaboratec, a suite of online tools with which to network, collaborate, and create.

The committee is composed of volunteers who have experience with startups, plus a team of staffers led by Mary Ward-Callan, managing director of IEEE Technical Activities, and Randi Sumner, director of volunteer engagement and strategy, both in Piscataway, N.J.



"If you think about all the pieces that comprise IEEE's mission of advancing technology for the benefit of humanity, we certainly have to engage the entrepreneurial community," Ward-Callan says. "They're an exciting group of people to work with because they're always moving technology forward and pushing ahead with new ideas."

IEEE has been dipping its toes in the startup stream for several years, but getting involved is now a priority.

GEARING UP

The ad hoc committee has been taking inventory of all the entrepreneurial activities scattered

among IEEE societies, sections, chapters, and other groups. The activities will be posted on a new website (<http://entrepreneurship.ieee.org>) along with news and information about resources of value to the startup community.

Entrepreneurs' communities will be formed in IEEE Collaboratec, too, Stauffer says, adding that this virtual way to collaborate will allow the communities to organize globally.

The first IEEE-wide global entrepreneurship event, IEEE N3XT (<http://ieee-n3xt.org>), is scheduled for 14 November, in Toronto [p. 14]. According to Sumner, its three tracks will focus on startup tools,

inspiring stories of successful beginnings, and intrapreneurship, which incorporates startuplike innovative approaches and product development within an existing company.

STARTUP FORAYS

For the past four years, IEEE has held networking events and sessions on emerging technologies for the South by Southwest (SXSW) Interactive Festival. The annual event, a popular venue for introducing new applications of technology, attracts thousands of entrepreneurs.

"Our engagement in SXSW got us involved with its community," Ward-

Callan says. "Most who attend are not setting up traditional companies; they're launching application-oriented businesses. They care less about the invention of technology and more about a creative use of that technology."

IEEE has learned several things thanks to its involvement with SXSW. In particular, Ward-Callan says, it has learned which topics interest creative thinkers and how to present research on emerging areas, like the Internet of Things.

IEEE has also partnered with high-tech companies to inspire innovation and startup activities by sponsoring competitions and awarding prizes, Sumner says, including the Little Box Challenge, sponsored by Google and the IEEE Power Electronics Society. The contest sought innovators who could shrink the size of a power inverter by at least 90 percent and in January will award the winner US \$1 million to see the design through to production. Inverters convert energy from DC sources, such as batteries, solar cells, and wind, to AC.

And the IEEE Engineering in Medicine and Biology Society has been helping to promote the first Qualcomm Tricorder XPrize, a contest to develop a working handheld gadget that can monitor and diagnose health conditions. The top three teams will share a \$10 million prize, which is also to be awarded in January.

Last October, the Toronto chapter of the IEEE Young Professionals group held the Technical Entrepreneurship Mini-Conference, during which entrepreneurs and technologists educated students and early-career professionals about how they can help grow the city's entrepreneurial ecosystem. The upcoming IEEE N3XT includes on its host committee several of the young professionals who helped jump-start last year's Mini-Conference. IEEE N3XT will be a larger and far more diverse event, Sumner predicts, drawing on some of the momentum and experience of the Toronto volunteers.

"We are learning how to work and play in the startup space," Ward-Callan says, "and it is certainly an exciting place for IEEE to be." ♦

The Do-It-Yourself Entrepreneur

This IEEE member launched a successful electronics company from her dorm room BY MONICA ROZENFELD

MEET IEEE MEMBER Limor Fried. Her do-it-yourself electronics company for hobbyists has carved out a category all its own and is worth millions. Through the new IEEE entrepreneur initiative, the organization hopes to attract more members like Fried who are developing engineer-inspired ventures.

Fried's company, Adafruit Industries, makes hundreds of different kits, including ones for electronics experimentation built around an open-source prototyping platform to make gadgets such as smartphones, handheld video games, and a wearable for GPS-enabled clothing so "you'll never get lost again." The most popular is the US \$19 MintyBoost, a charger for an iPhone or iPad. Its circuit and two AA batteries can fit in an Altoids mint tin.

The company sells more than 2,600 electronic parts, including wire and cable, conductive thread for wearables, multimeters, and breadboards and sockets. It also offers some 800 free tutorials. For the projects, you'll need a soldering iron and a diagonal metal cutter, which are sold separately. Adafruit's mission: to make electronics accessible and understandable to everyone. The company, named in honor of English mathematician Ada Lovelace, is "a wonderland of electronics," Fried says.

As an electrical engineering grad student at MIT in 2005, Fried, now 35, often built her own gadgets, including the smartphone she uses today. Investing \$10,000 she had saved up for her tuition into her company and without ever taking a loan or venture

Posting DIY projects on my website used to be a way for me to kill time until I got a real job

capital funding Fried has grown her business, which earned revenues of \$33 million last year. It now has 83 employees at its 930-square-meter facility in New York City.

HOW IT ALL BEGAN

Adafruit got its start after Fried posted her own DIY projects on her

website. People contacted her about how they could build their own gadgets. "It was something for me to kill time with until I got a real job in industry," she says.

Soon she found herself flooded with orders and making daily trips to the post office between classes to mail the kits. She finally felt she had no choice but to read up on the nuts and bolts of running a company, especially the financial parts. "The idea of crunching numbers didn't scare me. I'm an engineer," she recalls. "I thought, accounting is so easy compared to differential calculus."

For Fried, it was about learning one aspect of the business at a time. When she hired her first employee, she learned to process a payroll. When it came time to file taxes, she determined which forms she needed.

Fried says she wouldn't have been so successful, however, if she didn't offer well-designed goods. "When you have poor-quality products, you need to deal with a lot of technical support, returns, and repairs," she says.

In fact, she tests every product the company sells. "If I don't think a product is good enough," she says, "then I don't put it in on our



website." And her attention to detail shows. *Inc.* magazine last year ranked Adafruit 11th among the fastest-growing manufacturers in the United States and the top one in the New York City metropolitan area from 2011 to 2014.

Fried was also the first woman engineer to be on the cover of *Wired* magazine, and she has been named a top entrepreneur by several leading business publications.



Limor Fried, founder of Adafruit Industries, in New York City, stands with a pick-and-place machine for assembling custom circuit boards.

Adafruit offers open-source code to help people design their projects. "Customers are encouraged to hack into our products to make them their own," Fried says. They could, for example, use the open-source code on GitHub, a platform that lets users access—and, if they wish, collaborate on—coding projects in order to add functions to their devices.

Fried has been influential in the open-source hardware community.

She participated in the first Open Source Hardware Summit and the drafting of the definition of open-source hardware.

COMMUNITY SUPPORT

Fried doesn't rely on typical market research to learn what her customers want. Instead, she gives away products in exchange for feedback. "Let customers teach you about what you're making," she advises.

Adafruit hosts a weekly "show and tell" Google Hangout session in which members of the DIY electronics community showcase the projects they're working on. That provides the company with insight into not only how people use its products but also what they might want in new ones.

Fried has also made STEM education part of the company's mission. To help teachers instruct preuniver-

sity students about electronics and programming, she created a DIY kit for building a smartphone.

And Adafruit produces the YouTube series *Circuit Playground*, meant for children. Each episode covers an electrical engineering concept. For example, one episode is titled "F Is for Frequency." Fried says she wants electronics to be "just as enjoyable for kids as watching their favorite movies." ♦

READY TO LAUNCH

MEET FIVE OF IEEE'S ENTREPRENEURS

BY AMANDA DAVIS

IEEE MEMBERS

are at the forefront of many emerging areas of new technology, including robotics, the Internet of Things, and devices for neurological research. Some members have already turned their ideas into successful companies.



MIND CONTROL

If you attended the Consumer Electronics Show in January in Las Vegas and stopped at the IEEE booth, you may have noticed people moving race cars just by thinking about it. Wearing electroencephalography (EEG) headsets like the one above and concentrating on the task, two people at a time would propel toy race cars down parallel tracks, drag race-style.

The brain behind the headsets is IEEE Member Tan Le. She is cofounder of Emotiv, the company that developed EPOC, the EEG headset. It has five sensors that detect brain waves and transmit data wirelessly to a PC. The headset can be used not just to move objects but also to track the wearer's brain activity. It can measure levels of attention,

Tan Le

Company: Emotiv
Location: San Francisco
Year founded: 2003

focus, excitement, stress, and relaxation. Over time, patterns in the data could help doctors detect the onset of dementia and similar disorders. The headset has been sold for US \$399 in more than 90 countries.

Le told *National Geographic* magazine she wants to keep the price down so the headset is accessible to researchers everywhere: "I want to leverage the creativity of researchers in mathematics, statistics, data mining, computer science, biology, and medicine, as well as the general public," she says, adding, "The brain is the cornerstone of virtually every facet of our lives. I wish we knew more."



Jessica Colaço

Company: iHub
Location: Nairobi, Kenya
Year founded: 2010

Melonee Wise

Company: Fetch Robotics
Location: San Jose, Calif.
Year founded: 2015



NURTURING NEW IDEAS

It takes much more than a good idea to create a successful startup. You need the right people: not just business partners but mentors and investors willing to take a risk on your product. And, of course, you need a physical space to start your business.

IEEE Member Jessica Colaço is well aware of entrepreneurs' needs. She's the director of partnerships at iHub, a workspace in Nairobi, Kenya, that technologists, investors, young entrepreneurs, designers, market researchers, and programmers can use to develop what they have in mind. The company provides budding entrepreneurs with Internet access and matches them with local businesses and mentors. It can also help connect them with venture capitalists.

Colaço courts investors to fund iHub members' tech ideas and companies at the concept stage, before a product even materializes. She says iHub is well placed: "Nairobi is becoming a major technological hub in East Africa. Young Africans are getting trained there to acquire the skills they need to compete globally."

GO FETCH

Ordering items online and getting them delivered to your door the next day is a luxury that many of us enjoy. But those items often have been sitting in huge warehouses—some, like

Amazon's, take up more than 90,000 square meters. There, logistics workers, or "pickers," have the exhausting job of running around the building to retrieve items that have been ordered. It can be difficult to keep up.

Enter Fetch Robotics, cofounded by IEEE Member Melonee Wise. Its pair of robots, Fetch and Freight, work in tandem to navigate warehouses and fulfill orders. Fetch, a one-armed, wheeled, autonomous robot, finds items on the shelf and loads them onto Freight, an autonomous delivery cart. With an extendable spine, Fetch can reach shelves up to 2 meters high. Freight moves the picked items to another part of the warehouse, where human workers pack them for shipment. The company has also developed Follow Pick, a mobile app for workers to track orders and locate or control any robot or even a fleet of robots, if the company has several.

Fetch Robotics launched in February and began shipping its products in June. It started with a dozen employees, but Wise told *IEEE Spectrum* she expects the staff to double by this month. "If there are developers and



João Barros

Company: Veniam
Location: Porto, Portugal
Year founded: 2012

roboticists out there looking for 'funemployment' with robots, I welcome them to apply," she says.

CONNECTED VEHICLES

You've heard of the Internet of Things—a network of items, each embedded with sensors, that is connected to the Internet. But what about the Internet of Moving Things?

IEEE Senior Member João Barros is behind the idea, in which vehicles connected wirelessly to the Internet act as a network of moving sensors. His company, Veniam, developed NetRider, a device installed in a vehicle that transmits its location, traffic information, and other data about its surroundings to the cloud. It also offers passengers a Wi-Fi connection while they travel—in essence, a mobile hot spot.

In Porto, Portugal, Veniam has equipped more than 600 vehicles, includ-

ing a fleet of some 400 passenger buses, with NetRider, providing Internet access to more than 90,000 commuters each month. The company is installing vehicular networks in Barcelona and Singapore and hopes to deploy NetRider in the United States this year, Barros says.

He urges entrepreneurs to use their time wisely. "Every single decision about how you spend your time can determine whether your venture succeeds or fails," he says.

TIME TO UNWINE

You don't need to be a wine connoisseur to enjoy a glass at the end of the day. That's the idea behind unWine, a mobile app that educates users about wines and encourages them to post reviews of ones they've tasted. The app was developed by IEEE members Devon Ryan and Fabio Gomez. In 2013 they cofounded the software development company Lion Mobile.

Ryan says the app is geared toward young people who want to learn more about wine or simply have fun

without being intimidated by experts or sophisticated lingo. Gomez and Ryan met in a programming class at the University of Texas, San Antonio, where they graduated with bachelor's degrees in engineering in 2012 and 2013, respectively.

Ryan represents the IEEE Young Professionals group on the IEEE-USA Board of Directors. He says the struggles associated with being his own boss have brought out his creativity. "It's such a huge challenge starting something from nothing that it will force you to reach deep inside and bring out your best ideas," he tells *The Institute*. "Even if your company doesn't turn a profit right away, you benefit from the challenge alone." ♦

Devon Ryan

Company: Lion Mobile
Location: Austin, Texas
Year founded: 2013



CAREERS

Getting Schooled on Startups

Milton Chang gives advice on what it takes for engineers to become entrepreneurs

BY JOHN R. PLATT

AFTER TAKING TWO high-tech startups public and helping to incubate nearly a dozen more, IEEE Life Fellow Milton Chang is now an angel investor in Los Altos Hills, Calif. He welcomes new investment opportunities in exchange for equity in the company, of course, but he says most people who come through his door aren't ready to start their own ventures.

"Business is not a game," Chang says. "Most business plans I see focus on technology but lack detail on how to move the company forward and grow. They are based on assumptions instead of verified data."

Chang should know what he's talking about. The first startup he was involved in, Newport Corp., became a leader in photonics technology. Other startups he has invested in—including JDS Uniphase, an optical communications company, and CyberOptics, a leader in 3-D sensors and scanning—have also gone public. He now runs Incubic, an investment firm focused on biotech and photonics companies, where he is currently working with five new ventures.

Six of the companies he personally invested in have gone public, and the rest have been acquired. None has failed—an impressive feat considering that more than 90 percent of startups go out of business.

His self-published book, *Toward Entrepreneurship: Establishing a Successful Technology Business*—available at MiltonChang.com—is used as a textbook in business classrooms at several universities. He writes a monthly business and management column for *Laser Focus World* magazine and mentors aspiring entrepreneurs. Last year, he received the IEEE-USA Entrepreneur Achievement Award for Lead-

ership in Entrepreneurial Spirit, which recognizes an individual who has been instrumental in furthering entrepreneurial growth and enthusiasm in the United States.

How has Chang been able to help startups succeed when so many others have failed? "With an engineering approach," he says.

BECOMING AN ENTREPRENEUR
Coming up with a good business idea is not about jumping on the bandwagon of a "hot" technology, Chang says. Trendy ideas might seem like great opportunities at first, but they often cool quickly. Such startups might also face better-equipped competition.

Instead, Chang suggests using your experience as an engineer to identify an untapped market that you—and perhaps only you—know how to fill. That's how Chang made his mark. He launched his first startup, in Irvine, Calif., after he did research in lasers and holography, which was what he studied as a Ph.D. student at the California Institute of Technology, in Pasadena.

At first, Newport Corp. produced just a few laser and optical components, which Chang knew were needed by research labs. The company expanded slowly until it had an entire catalog of products. All the while, Chang maintained close ties with those in the field, which allowed him to get feedback and understand their needs. He was elected president of both the Laser Institute of America and the IEEE Photonics Society.

"If you use your engineering expertise to identify a need, and it's in a niche market that you know



well, then you're not taking a huge risk," he explains. Serving a relatively small market also means you need less capital to start. And you can take time to hone your business and management skills instead of getting overwhelmed with demands and making hasty decisions.

Once you have identified an opportunity to serve a specific market, do your homework. "Verify who your customers will be and their specific needs, as well as the market size," Chang says. "Walk through every detail of how customers make a buying decision; make sure you know what is required to make your venture a success."

He calls this his "business prototype." Similar to product prototyping, which allows engineers to work out kinks before moving into volume production, business prototyping lets startups verify that their products or services fill a real need by attracting their first sales before investing heavily to build out the business. "It makes it a lot easier to attract the investment capital you need at that stage," Chang says.

CAPITALIZING ON YOUR IDEA
Raising capital for a new business is not easy, Chang notes, adding that contrary to popular belief, "venture

capitalists are not risk takers for risk's own sake. They're smart investors who can quantify risk and determine whether the risk justifies the reward." They don't invest on speculation, he adds. They make an investment only if they're confident that a company is likely to succeed.

Chang and his cofounders at Newport received financial help from family members. He and his team worked long hours filling multiple roles for small salaries while the company established itself.

Most startups, he says, should try to attract at least some financial assistance early on. "Having financial backing can sometimes be more important than technical merits," he says. "Every business makes mistakes along the way; you'll be able to recover from them only if you have the money to keep moving forward."

NEVER STOP LEARNING

Entrepreneurs should always be ready to learn something new, he says, adding, "The secret to success is knowing what you don't know."

You need to stay humble even after you enjoy some measure of success. "Arrogance makes you think you are better than you really are," he says. "That's when you're going to make mistakes."

Chang suggests that technologists learn the whys and wherefores of business practices long before they start their own ventures. He did so before launching his first company by taking classes, attending seminars, and reading as many business articles and books as he could find. He suggests enrolling in business and management courses at a college or online and taking on entrepreneurial challenges that turn up in your current job before you set out on your own.

Learn from people in your company, including those in finance and marketing, and understand how products are commercialized. "That way," he says, "when you launch your startup, you will already know many of the aspects of how to run a business."

To be successful, Chang advises, you must be practical, understand the market, and fulfill a customer's need. "This approach is proven and empirically verified," he says. "This is the formula for starting up your own venture and having it succeed." ♦



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Steven Kotler: Is Silicon Valley Ageist or Just Smart?

The *Forbes* contributor writes that although people do get wiser with age, they lose an essential skill at the core of entrepreneurship: risk taking. Facebook and other companies have been criticized for hiring mostly young employees, but Kotler suggests that this might be a smart strategy, helping an organization innovate quickly and take more chances.

CHIME IN Tell us what you think by commenting online at <http://theinstitute.ieee.org/opinions/question>.

Sparking Conversation

In June, *The Institute* described what's needed to make wearable fitness trackers accurate, secure, better equipped to monitor vital signs, and more enjoyable to use. The conversation continued on our website.



with a background in experimental psychology;

M.C. Schraefel, professor of computer science and human performance at the University of Southampton, in England; **Jesse Jur**, assistant professor

of textile engineering, chemistry, and science at North Carolina State University, Raleigh; and **Kevin Curran**, assistant professor of computer

science at Ulster University, in Northern Ireland.

Q: Users don't seem worried or even aware of the need for data privacy and control over their personal data, even when related to their health. How can we make them more committed to protecting their data?

Churchill and Schraefel: Research suggests that people do worry about their data but take little action

ASK THE EXPERTS
Answering readers' questions about wearables were **Elizabeth Churchill**, a specialist in user experience

until there is a breach that forces them to think about its security. There are several reasons for their inaction. For example, service agreements are written in language that makes little sense to us; most devices, websites, and applications are not transparent about what data they collect and how they use it; and such services don't make it easy for people to access and manage their own data.

We will see an even greater need for secure logging and sharing when wearables become part of our clothing and accessories, collecting data about us all the time. A call for transparency can help change how users manage their data.

Q: What are designers of wearables doing to make products user-friendly and more accurate?

Jur: A primary issue for wearables is the perception that they're a hassle to use. These concerns include short battery life and their form factor, involving, say, having to clip them somewhere on the body or wear them on a wrist. Strategies for reducing power consumption are rapidly developing in low-power communications, which includes Bluetooth, sensors, and data algorithms.

The ASSIST center at North Carolina State University is working on the next big step: self-powered devices that use body heat and motion to provide power for the wearable so that the user never needs to worry about a battery.

Q: At what point will wearables become synonymous with clothing and not be seen as gadgets?

Curran: As the technology grows smaller, more connected, and more integrated with our environment, it will eventually disappear into our surroundings so that only the user interface is visible. Integrated with our clothing,

wearables will communicate via the interfaces in our smartphones. The market for wearable devices is growing and will ultimately lead to a revolution in our everyday garments.

MEDICAL DATA ACCESS

We asked readers whether patients should have the right to access their electronic medical records or if it is better to leave them in the hands of their doctors.

"The federal government of Australia has set up a countrywide electronic health record system in which both doctors and patients can enter information. Not enough patients and doctors are using it yet, but the current opt-in system will soon become an opt-out system, meaning everyone living in Australia will have an e-health record. However, several problems remain, including security concerns and doctors struggling to find the time during the day to upload data."

—Helen Robertson

"Patients go to doctors to have their data interpreted; however, the data unquestionably belongs to the patient. On a personal note, the hospital that I frequent recently updated its medical records system and ended up losing all my medical history. Because I had no copy and my physician had left the practice, I had to explain my case from scratch."

—Sarah Z.

"The bottom line is that any personal health information is owned by the patient. For physicians to state that patients cannot comprehend the meaning of the information is quite pretentious. It implies that the medical community is thinking about liability but hiding behind some higher power. Transparency is good and exposes bad behavior, so just hand over the records."

—Gregory Gogates

the institute

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IEEE Operations Center
445 Hoes Lane, Piscataway, NJ
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DARREN CARROLL

IEEE: A 131-Year-Old Startup

Entrepreneurs founded the organization's predecessor societies

HOWARD E. MICHEL IEEE PRESIDENT AND CEO



IN 1877, Edward Weston founded the Weston Dynamo Machine Co. to explore possibilities within the expanding field of dynamo machines. He would later move on to establish the Weston Electrical Instrument Co. in 1888.

In 1878, Thomas Edison founded the Edison Electric Light Co. In 1879, Elihu Thomson and Edwin Houston founded the Thomson-Houston Electric Co., which later merged with Edison's company to form the General Electric Co.

ENTREPRENEURIAL ROOTS

Those four giants, together with a few other leaders in their respective fields, in 1884 started one more organization of note: the American Institute of Electrical Engineers, one of IEEE's predecessor societies.

Think about that for a moment: Today's IEEE is the second-generation creation of a startup, founded by entrepreneurs. Actually, both of IEEE's parent organizations were startups; the 1912 creation of the Institute of Radio Engineers was the direct result of Robert H. Marriott's desire to create a unified association to support technical professionals in the burgeoning field of radio and wireless communications.

Technology giants of the modern era—Texas Instruments, Qualcomm, Intel, and Hewlett-Packard (see p. 18), among many others—were started by entrepreneurial AIEE, IRE, and IEEE members. Those companies began with an idea and some solid thinking about how to turn that idea into a commercial enterprise.

When we think about today's entrepreneurs, we think about garages, dorm rooms on college campuses, or any one of countless locations where individuals and groups have pursued their passions, chased their dreams, and changed our world.

But we also need to think of the people behind each invention. Behind every new invention you will find one person with an idea or a small cluster of people working to find a solution to a problem or create a tool we didn't have before. Regardless of how an entrepreneurial idea starts, it needs a community within which to grow—and that's something that IEEE has been providing for more than 130 years.

*No matter how
an idea starts,
it needs a
community in
order to grow*

Diverse communities, ones that allow technical professionals to pursue their ideas in any direction, are the cornerstones of innovation. They are so critical that the current IEEE Board of Directors and the IEEE in 2030 Ad Hoc Committee have made the fostering of such communities one of four key strategic areas of focus in the coming years.

Providing the right conditions for forming startups isn't just a good thing to do—it's critical. We live in an era in which technical progress is measured by the year and month; in the coming decade, it's likely that progress will be measured by the month and week. If IEEE neglects to encourage the growth of communities that seek entrepreneurial outlets for their efforts, it does so at its own peril.

THE NEXT 130 YEARS

During recent industry outreach efforts by the IEEE Board of Directors, we met with industry leaders in Shenzhen, China. Years ago,

these leaders were entrepreneurs, armed with ideas, sound thinking, and a desire to bring something new to the global marketplace. And they did. In 1990, Shenzhen had a population of less than 900,000; today, it boasts more than 10 million people.

This exponential growth in just 25 years was made possible by a commitment to fostering a community that values innovation and entrepreneurship. Today the city is one of the fastest-growing technology centers in the world, with a population that averages 30 years of age and is engaged in a dizzying array of entrepreneurial endeavors.

This is the cohort where I truly believe that IEEE will see a blossoming of entrepreneurs—especially within the ranks of our Student and Young Professionals communities. It's in these two groups that we find countless engineers working together to solve problems or to invent the next "must have" product or application. In the next few years, I believe we will see these efforts ratchet upward at an incredible pace.

I'm not going to close this article by asking for your ideas about the startup you're working on. I suspect my in-box would be flooded with tens of thousands of great ideas, all in various stages of exploration. No, asking you what you're working on is a little too easy.

I prefer to offer a challenge instead: Send me your thoughts regarding what role you believe technical professional organizations like IEEE can play in creating the conditions in which startups can not only form but also flourish. It can be a reimagining of something that's already in place or a wholly new construct never tried before, but it's something you believe holds great promise.

Reach out to me at president@ieee.org. Your input is vital as we look toward IEEE's future. As an organization, we've been a seedbed for startups our entire existence. Let us together develop those efforts and accomplish even greater things. ♦

BENEFITS

Conferences for Budding Entrepreneurs

Upcoming events cover innovating within a company and crowdfunding



Rock Stars of Tech Startups

SAN FRANCISCO; 10 NOVEMBER

TOPICS: Business strategy, digital marketing, crowdfunding, risk management, cybersecurity, product design, talent acquisition, venture capital funding, scaling a startup, and mergers and acquisitions.

SPONSOR: IEEE Computer Society
VISIT: <http://www.computer.org/web/rock-stars/tech-startups>

■ IEEE Women in Engineering Summit USA East
PHILADELPHIA; 6–8 NOVEMBER

TOPICS: Mentoring the next generation of female business leaders; leadership development in education, industry, and government; boosting written communication and public-speaking skills; and maintaining a work-life balance.
SPONSORS: IEEE Regions 1 and 2, IEEE-USA, and IEEE

Women in Engineering
VISIT: <http://sites.ieee.org/wie-summit-usa-east>

■ IEEE N3XT
TORONTO; 14 NOVEMBER

TOPICS: Technical and entrepreneurial skills, business development, innovating within a company, transforming ideas into inventions, and successful startup models.
SPONSORS: IEEE Toronto

Section's Young Professionals affinity group and IEEE Technical Activities Ad Hoc Committee on Entrepreneurship
VISIT: <http://ieee-n3xt.org>

■ The eChallenges e-2015 Conference
VILNIUS, LITHUANIA;
25–27 NOVEMBER

TOPICS: Entrepreneurship and innovation in information and computer technology, smart cities, the smart grid, cloud computing, mobile applications, security and identity management, e-health, e-learning, digital libraries, and social implications of technology.
SPONSORS: IEEE Society on Social Implications of Technology, IEEE Lithuania Section, and the European Commission
VISIT: <http://www.echallenges.org/E2015>

■ World Conference on Futuristic Trends in Research and Innovation for Social Welfare
COIMBATORE, INDIA;
29 FEBRUARY–1 MARCH 2016

TOPICS: Health care entrepreneurship, information and communication technology, food security, economic development, agriculture, education, infrastructure and telecommunications, and renewable energy.
SPONSORS: IEEE Robotics and Automation Society, IEEE Madras (India) Section, and Karpagam College of Engineering
VISIT: <http://startupconclave.org.in/2016>

■ International Conference on Teaching and Learning in Education
KUALA LUMPUR, MALAYSIA;
1–2 MARCH 2016

TOPICS: Entrepreneurship within higher education institutions; e-learning; quality assurance and learning; and educational resources.
SPONSORS: IEEE Education Society and IEEE Malaysia Section
VISIT: <http://www.uniten.edu.my/icitle2016>

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ISTOCKPHOTO



Kick-start Your Business With IEEE Resources

BY MONICA ROZENFELD

MBARKING ON A NEW business venture can be intimidating, but IEEE provides a host of tools that can help entrepreneurs launch their companies.

TIME TO NETWORK

It's important for new entrepreneurs to forge connections with like-minded people, and IEEE's countless networking events around the world are, of course, an integral part of many of its conferences. In particular, IEEE has groups to help members launch and grow their ventures.

The IEEE Cyprus Entrepreneurs Network, formed in January 2013, helps members in Region 8. The group offers workshops on many entrepreneurial topics, including financing a business, protecting intellectual property, and leadership styles. It also matches members with potential angel investors as well as mentors who can help them evaluate their business plans.

On the other side of the globe is the IEEE Boston Entrepreneurs' Network. Founded in 1991, the group organizes more than 15 events each year. Topics have included why startups fail and low- or no-cost ways to promote a business. The group holds "open mic" nights so members can pitch their startup ideas to experts and peers to get their feedback. And like the Cyprus group, it holds sessions where angel investors, CEOs, and other entrepreneurs share their advice and experience.

IEEE Young Professionals has made it its mission this year to focus on entrepreneurship. The group is holding sessions on starting a company, in conjunction with IEEE conferences its members may be attending. Find the Young Professionals' latest events and webinars on its Facebook page at <http://www.facebook.com/ieeeyp>.

Throughout the year, IEEE holds events to encourage members to take steps

toward entrepreneurship. IEEE Standards, for example, offered two startup events, including one at this January's Consumer Electronics Show, in Las Vegas. It focused on helping budding companies develop products and services for the Internet of Things.

BOOK SMARTS

IEEE-USA has published five *Starting Your Start-Up* e-books, which cover developing a business plan, market size and strategy, competitive analysis, pricing strategies, and launching a business. It has also published four e-books in a series on *Doing Innovation: Creating Economic Value*. Those titles, which explore what it takes to be an innovator and how to develop a product or service, are available at <http://ieeeusa.org/communications>.

QUESTIONS AND ANSWERS

The IEEE-USA website offers services for entrepreneurs in the United States or those companies that already do business in the country. The website provides a form to submit questions to the U.S. Small Business Administration on topics such as registering a new company, getting a business loan, hiring employees, and filing taxes. IEEE-USA's salary service can help businesses calculate pay and determine benefits for their employees based on the field they're in, years of work experience, and geographic location.

A page on the site dedicated to career management offers a list of workshops and webinars on such topics as business ethics and

setting career goals. The page also has a section for consultants that helps them with landing clients and tips on working for themselves. The site also offers a TechMatch service IEEE members can use to submit their business plans for review at no charge by seasoned entrepreneurs.

INNOVATING IN INDIA

The IEEE Kerala Section is helping women and young engineers start their own companies. Its IEEE Women in Engineering affinity group launched an initiative in 2013 to encourage women in India to create tech companies and provides mentorship and access to seed funding. The section is also involved in India's Startup Village, a business incubator that hopes to launch 1,000 tech startups in the next 10 years. The village's amenities include office space for new businesses and access to the Internet, legal services, and funding sources. Find out more by visiting <http://www.ieeekerala.org>.

SPEAKING OF STARTUPS

The IEEE Communications Society hosted a Startup Speaker event in December. Built around panel discussions, it covered such topics as determining whether starting your own company is right for you, how to measure a market's potential, and best practices when it comes to developing products. Visit the society's website at <http://www.comsoc.org> for upcoming startup events.

BENEFITS FOR THE SELF-EMPLOYED

Recognizing that entrepreneurs need support in many other ways, IEEE offers discount programs to help offset the cost of health, life, and auto insurance, and it supplies low-interest credit cards plus special prices on travel and computers. The offers are available on the IEEE Member Discounts website, <http://www.ieee.org/discounts>.

AND THE AWARD GOES TO...

IEEE-USA gives an annual IEEE-USA Entrepreneur Achievement Award for Leadership in Entrepreneurial Spirit. The award recognizes an individual who has been instrumental in furthering the growth of entrepreneurship in the United States. Last year's winner was IEEE Fellow Milton Chang [p. 10]. ♦



Powering Africa: It Takes a Smart Village

An IEEE Foundation program helps entrepreneurs bring renewable energy to their communities

BY MONICA ROZENFELD

F THE 20 countries with the shortest supplies of electricity in the world, 19 are in sub-Saharan Africa, where on average fewer than one in three people have electricity. Instead, for light they use candles as well as kerosene lamps, which are harmful to health.

And once the wax or fuel runs out, they sit in darkness. According to a 2014 report from the International Energy Agency, growing the energy sector in that region would be the key to its prosperity.

The IEEE Smart Village program, formerly the IEEE Community Solutions Initiative, has some bold ideas on how to bring electricity to millions while also providing jobs to their communities. The IEEE Foundation has made it one of its signature programs, whose goals are to provide funds for projects that can yield an immediate and broad impact and are also sustainable over the long term.

Smart Village volunteers work with local entrepreneurs in several countries to help them set up local electricity businesses using renewable energy technology like solar panels to power nearby homes, businesses, and schools. Depending on resources, they could serve dozens of customers or up to tens of thousands, charging them monthly fees comparable to the cost of kerosene or candles.

IEEE grants the initial investment for buying the equipment as well as providing mentoring and training. So far, since development

of the microutilities began in 2011, the program has supplied electricity to some 15,000 people.

"Our goal is to provide electricity for 50 million people in 10 years, and that's conservative," says IEEE Fellow Robin Podmore, cofounder of IEEE Smart Village. Podmore believes it's doable because the right

shown support for Smart Village and its mission. In April, it was named a finalist for the Bloomberg Energy Finance Summit's Finance for Resilience initiative, which recognizes powerful ideas and actionable interventions for clean and sustainable energy. And Alstom, an international electricity generation company with headquarters in Paris, awarded a US \$28,000 grant to Kilowatts for Humanity, an initiative supported by IEEE Smart Village.

A SUSTAINABLE MODEL

The earthquake that struck Haiti in 2010 was the genesis for what was then IEEE's Community Solutions Initiative. IEEE volunteers worked to develop a reliable source of low-cost electricity there. They came up with the SunBlazer community charging stations.

Using six silicon photovoltaic 250-watt solar panels, the trailer can collect more than 4 kilowatt-hours of energy per day, or enough to charge 80 portable battery packs.



Entrepreneur Mou Riiny, a former refugee from war-torn South Sudan, returned to his village, Thiou, where he is installing 13 community charging stations powered by photovoltaic panels.

entrepreneurs and partners are out there. He adds that in the last few years, philanthropists and investors have realized that helping locals form their own businesses is the key to lifting them from poverty and is far more sustainable and effective than donations alone.

Recently, a number of companies and organizations have

These packs can then be used to power LED lightbulbs in homes and are equipped with USB ports to charge cellphones—which many in remote regions now depend on for exchanging money as well as for education and health services. Locals pay \$6.50 a month for unlimited charging. Since 2010, community charging stations have

been set up not only in Haiti but also in Cameroon, Kenya, Nigeria, and South Sudan.

IEEE volunteers help train operators to install the technology and mentor them on how to run a profitable business, including managing payments from their customers. IEEE Smart Village awarded a \$150,000 grant to the Torchbearers Foundation to establish three microutilities that will provide electricity for thousands in Cameroon.

IEEE Smart Village is also supporting efforts in South Sudan with IEEE Member Mou Riiny, a former refugee from that war-torn country (see photo). Riiny was brought to the United States as a child and raised by foster families. He earned an electrical engineering degree from the University of San Diego. He recently returned to his village, Thiou, where he is installing 13 community charging stations powered by solar panels. Each station will serve 100 portable battery kits, which will be up and running this year.

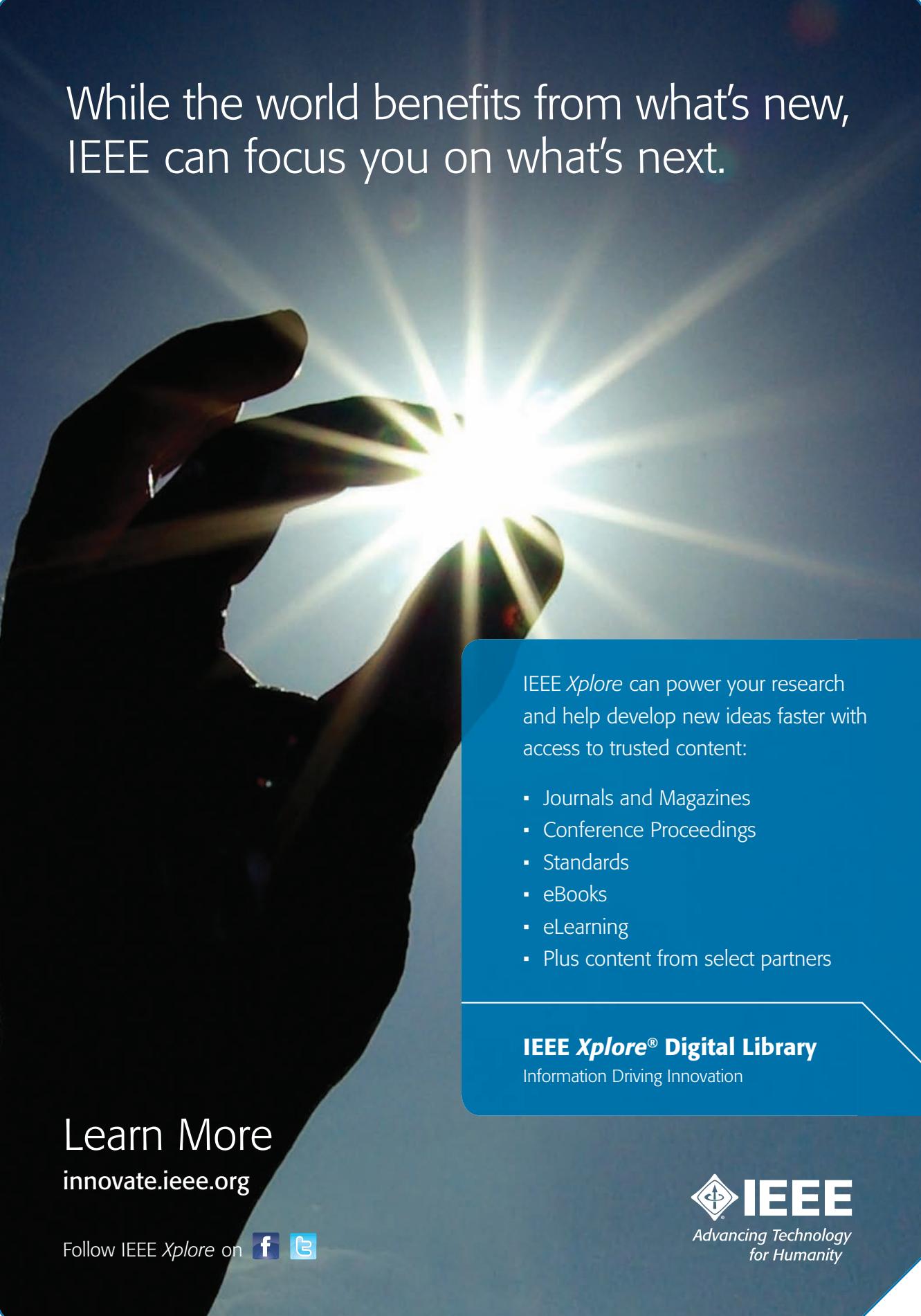
THE NEXT ROUND

Local entrepreneurs can apply to get funding through the IEEE Smart Village website (<http://ieee-smart-village.org>) later this year. Applicants must submit a detailed business plan that includes how they will make their utilities sustainable after IEEE's initial contribution. They must also describe how their profits will be reinvested to create jobs in their local communities.

"Providing electricity can help others in the community to form businesses and allow existing ones to stay open longer, which will help shopkeepers and farmers sell goods into the evening," Podmore says. "By creating jobs, we're preventing people from having to leave their families and villages to make money."

The tide is turning, he adds. Instead of leaving, people are now moving to remote regions in Africa to start businesses, particularly in the power and energy sector. "There is just far less competition and a lot of opportunity," he says. ♦

This article originally appeared online in our February report on global development, which highlighted IEEE's efforts in using technology to help advance developing and underserved regions.



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From the Garage to

A pair of billion-dollar companies started by IEEE members had humble beginnings

BY KATHY PRETZ



IEEE Fellows David Packard [left] and William Hewlett stand in front of Hewlett-Packard's original headquarters in Palo Alto, Calif. In 1939 the two started what would become a multibillion dollar company out of Packard's garage. The photo was taken in 1989.

William Hewlett David Packard *Hewlett-Packard*

MOST CONSUMERS ARE FAMILIAR WITH Hewlett-Packard's printers, computers, and ink, but many don't know that the company was formed by two engineers in a garage workshop on Addison Avenue in Palo Alto, Calif. IEEE Fellows William Hewlett and David Packard launched their business in 1939 in Packard's two-car garage, which is now a U.S. National Historic Landmark.

According to the Engineering and Technology History Wiki (ETHW), which contains content from the IEEE History Center as well as articles from six other technical societies, Hewlett and Packard were old friends and classmates from Stanford. Hewlett, a bachelor, was living in a back room of the house where Packard and his wife lived when the two decided to follow their dream of starting a company.

Its first product—built by Hewlett—was a resistance-capacitance audio oscillator, an instrument that generates a pure tone, or frequency. The two partners' initial capital for their company was US \$538, though by the end of 1939 they had sales of more than \$5,000, with a profit of more than \$1,500 (greater than \$25,600 in today's dollars). HP is now one of the world's most valuable brands. The company earned some \$109 billion in revenue last year.

HP oscillators were used to design, manufacture, and maintain telephones, radios, and audio equipment. Hewlett and Packard called their first oscillator the Model 200A to give the impression that it was the latest offering of an established company, rather than the first from a startup. Sales took off after the Walt Disney Co. paid \$71.50 (equivalent to \$1,214.50 today) for eight modified versions—200Bs—for its production of *Fantasia*. Disney engineers used the oscillators to test audio channels, recording equipment, and speaker systems in the dozen specially equipped theaters that showed the movie in 1940 and 1941.

The order of names in the original partnership was determined by a coin toss. Hewlett was a quiet, self-effacing man; Packard was more outgoing. Packard concentrated on the nuts and bolts of production, while Hewlett was more proficient in technical innovation.

the Fortune 500

The two received the 1973 IEEE Founders Medal for "leadership in the development of electronic instruments, for creative management of an industrial activity, and for their unselfish public service."

Packard died in 1996, Hewlett in 2001.

Earl Bakken *Medtronic*

IT WAS WHILE REPAIRING electronic medical equipment in his Minneapolis garage for the University of Minnesota Hospital (where his wife worked) that IEEE Life Fellow Earl Bakken [right] got the idea for his startup, according to the ETHW. Bakken was fascinated by electricity from an early age, figuring out how the wiring in his house worked and building electrical devices, including a robot that could smoke cigarettes and wield knives.

At the time, there were no companies in the city that designed or repaired specialized medical equipment. Seeing a need, he and his brother-in-law started Medtronic in 1949, just a year after he received a bachelor's degree in electrical engineering from the University of Minnesota. They struggled until October 1957. That's when open-heart surgeon C. Walton Lillehei, who was familiar with Bakken through his work at the hospital, approached him about making a better pacemaker than those being used. Lillehei, a professor in the department of surgery at the University of Minnesota, had pioneered open-heart surgery.

Within four weeks, Bakken produced a small, self-contained, transistorized, battery-powered pacemaker that could be taped to a patient's chest. Insulated electrodes sutured to the heart passed through the patient's chest wall. When pac-

ing was no longer needed, doctors could withdraw the wires without having to reopen the patient's chest. The pacemaker liberated patients from their power-cord tethers and was a significant step in the evolution to fully implantable units. Bakken's device was honored with an IEEE Milestone in 1999.

Bakken described the process in this excerpt from his autobiography, which is published on the ETHW:

"Back at the garage, I dug out a back issue of *Popular Electronics* magazine, in which I recalled seeing a circuit for an electronic, transistorized metronome [a device that produces regular, metrical ticks such as beats and clicks]. The circuit transmitted clicks through a loudspeaker; the rate of the clicks could be adjusted to fit the music. I simply modified that circuit and placed it, without the loudspeaker, in a 4-inch-square,



inch-thick metal box with terminals and switches on the outside. And that, as they say, was that."

Bakken successfully used a pacemaker on a dog at the university's animal lab. He intended that prototype to be used only experimentally on laboratory animals, but shortly afterward Lillehei implanted it in a

human patient. It was produced commercially as the Medtronic 5800.

Today, Medtronic remains a leading developer of medical technology. Its products—including catheters, coronary stents, and heart valves—are used to treat nearly 40 medical conditions. Its revenue last year was \$17 billion. ♦



IEEE Life Fellow Earl Bakken [above] was repairing electronics in his Minneapolis garage when he was inspired to found Medtronic—now a leading developer of pacemakers, catheters, and other medical equipment.

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