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The Entrepreneurial Issue

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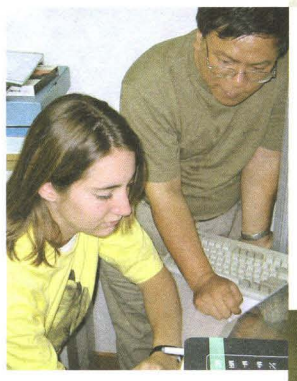

Also in this issue:
Ted Jenkins's early days at Intel; Horace Gilbert's earlier days at Caltech; an alum poses a question in Tech Talk; and a student takes a break (on the back-page poster).

The Entrepreneurial Issue

What are the roots of Caltech entrepreneurism? How is it being nurtured? Who are its players? In this special issue, Caltech News takes a wide-angle and up-close look at the phenomenon, as it affects the campus community and the careers of alumni. Readers may wish to add their voices to the story and are invited to write letters, as noted in Tech Talk on page 14.

On the Cover: Clinical Micro Sensors founders Jon Faiz Kayyem, Tom Meade, and Scott Fraser.

Picture Credits: Cover design-Hillary Bhaskaran; 1,4-9,15,16-Bob Paz; 2-Tetra Tech; 3,8-Clinical Micro Sensors; 5-Ortel, Floyd Clark; 6,7-Rainfinity; 12-Ingeborg Stern/courtesy of Caltech Archives; 13-Kenneth Lambert, AP/Wide World Photos.

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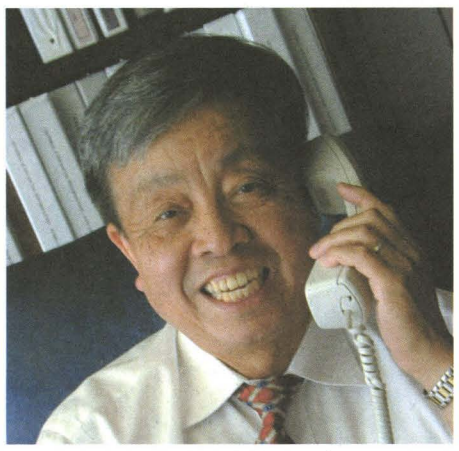
Up Front

Battling Bioterrorism

Where does the U.S. government turn when it needs to decontaminate and secure congressional office buildings, the Supreme Court, and other sites threatened in recent anthrax attacks?

It turns to Tetra Tech Inc., a large Pasadena-based company headed by Li-San Hwang, PhD '65.



Li-San Hwang, PhD '65, is CEO of Pasadena-based Tetra Tech, which has examined and decontaminated numerous anthrax-infested sites on Capitol Hill.

In recent weeks Tetra Tech has snagged new contracts valued at more than $11 million, as the federal government turns to private-sector skill and expertise in combating bioterrorism.

In November alone, Tetra Tech announced two new contracts and more than 50 "task orders" with the General Services Administration (GSA) and the U.S. Department of Labor. The company is working "24-7" as it assists federal agencies, deploying all available staff to affected buildings.

When anthrax was found on the ninth floor of the Hart Senate Office Building, white-suited Tetra Tech biohazard specialists were on the scene. Also in Washington, D.C., Tetra Tech has sampled or decontaminated at least nine other congressional office buildings, along with the Supreme Court and the Department of Labor.

The company also was commissioned to clean up the American Media building in Florida, where the first anthrax contamination was found. Related contract work includes performing security upgrades and training for clients.

Although the counter-bioterrorism work represents a small portion of Tetra Tech's overall business, the niche is growing rapidly in response to current events.

"It is a sad development for the nation," says Hwang, who studied civil engineering at Caltech. "As one of the largest companies in the United States with counter-terrorism expertise, we are making all of our resources available to assist the government, realizing the importance of our rapid response."

Hwang joined Tetra Tech in its infancy. "I was the ninth employee," he recalls. That was back in 1967.

As the company grew, it was purchased by Honeywell in 1982, and then company management executed a leveraged buyout in 1988. After Tetra Tech's stock began trading publicly in 1991, it continued to grow rapidly. Now, the firm employs about 7,500 people in 150 offices worldwide, and expects to earn $1 billion in revenue in 2002, Hwang says.

Although the counter-bioterrorism work represents a small portion of Tetra Tech's overall business, the niche is growing rapidly in response to current events. As of early December, anthrax had killed a total of five people and hospitalized many others since the death of the first victim, photo editor Robert Stevens.

The work was carried out under existing contracts with the GSA, which owns most of the government buildings, as well as with the Environmental Protection Agency. In fact, Tetra Tech holds contracts in eight of 10 EPA regions under the EPA Superfund

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Caltech's Adventures in Entrepreneurism

By Michael Rogers

For much of Caltech's history, entrepreneurship was not exactly a dirty word, but one certainly didn't hear it used on campus much. In the past few years, however, many students and faculty at the Institute have either started a company or are hatching plans to do so. There are numerous reasons—both inside and outside Caltech—for this swelling interest in starting companies. But one thing seems certain. Even with downturns in technology stocks and the deflated prospects of many "dotcom" companies, the interest in starting commercial ventures out of Caltech will not slow down anytime soon.

Investigators at Caltech have always been focused on making fundamental insights and discoveries. While the Southern California aerospace industry grew out of Caltech engineering, Caltech usually left commercialization to others. A steady stream of government funding helped insulate Caltech from the business world, but then the stream started to slow down during the 1990s. And with the high-technology explosion that has erupted since the 1980s, along with a flood of venture capital, the notion that academic science could distance itself from commercial applications changed.

The changes at Caltech have also been student driven, according to John Baldeschwieler, the J. Stanley Johnson Professor and Professor of Chemistry, Emeritus, who has spearheaded many entrepreneurial activities on campus and has started six companies himself. "In the early 90s, the traditional path of going from grad school to teaching and research became less frequent after cutbacks in defense and federal spending. And jobs at industrial labs became harder to get. This was balanced by a huge growth in start-up companies. So students understood the change in career mix, leading to a natural transformation."

In recent years, more Caltech faculty members have become entrepreneurial, translating their research projects into commercial products and occasionally start-up companies. More students are interested in pursuing careers with new business ventures or in starting their own companies than ever before. The Institute has started to adjust.

In 1995, Caltech took a big step toward encouraging the entrepreneurial spirit when it formed the Office of Technology Transfer (OTT) to foster and promote start-ups and licensing activity at Caltech. Before the office was formed, the Institute would receive from its faculty approximately 65 invention disclosures a year. In 1999, the OTT received 143 invention disclosures, and last year, it received 157 invention disclosures.

The Institute has a long history of protecting its inventions through patents, and last year, 115 patents were issued to Caltech, up from 110 the year before. In the past few years, licensing efforts have increased dramatically, and currently more than 50 patent licenses and options are executed each year.

A start-up is a special case of a license, since no company could get off the ground, let alone survive, based on a single product. Caltech's "grubstake" program assists faculty members who may have a project that is commercially viable by providing funds ranging from $30,000 to $50,000 to cover the costs of the project for one year to determine its feasibility. If successful, and if the project supports a start-up, Caltech may aid the faculty member/entrepreneur in seeking funding from venture capitalists, corporations, wealthy private individuals (so-called angels), or groups interested in supporting research in its very early stages to take the project from feasibility to a working prototype.

Since most start-ups are based upon technology developed with federal

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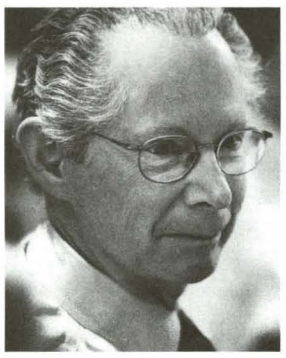


John Baldeschwieler, entrepreneurial mentor.

Larry Gilbert, director of Caltech's Office of Technology Transfer.

Entrepreneurism . . . from page 3

support, the grubstake program serves as a catalyst. Once a company has been formed, the research is done in labs outside Caltech, although some Caltech facilities are available on a fee-for-use basis. When a company is formed to commercialize the project, the expectation is that both Caltech and the faculty member spearheading the project—and possibly the postdocs and students integrally involved—will have an equity stake in the company.

Caltech currently hatches about 10 start-ups a year, a pace that few other academic institutions can match, according to Larry Gilbert, director of the Office of Technology Transfer. "When I came here in 1995, any entrepreneurial activity that was done at all was done out the back door," says Gilbert. "Now, many of the faculty are eager to work with us. And the new programs at Caltech provide enormous benefits to students. They will be better prepared to enter the workplace and can be part of start-ups themselves."

Caltech is good at launching spin-offs, because its basic research leads to new technologies and discoveries, which naturally lend themselves to products and sometimes companies. Caltech is also primed as an incubator for spin-offs because of its interdisciplinary approach to research, where there are no walls within or between departments. So in an area like the biological sciences, where the skills of computer scientists, mathematicians, and control theorists can help modern molecular geneticists make sense out of the huge data sets being produced by the human and other genome projects, Caltech is poised to exploit this information.

Recent Caltech start-ups range from high-tech companies like Xencor, which uses computers to design gene sequences to improve a gene's properties for use by companies to make drugs, industrial enzymes, and agricultural biotechnology products, to consumer-products companies like Materia, which uses a Caltech discovery of a new catalyst to make a plastic with unique properties for use in diverse applications, such as sports equipment and pheromones.

The Office of Technology Transfer helps these companies get off the ground by assisting in filing patents, preparing business plans, finding sources of financing, identifying intellectual property firms, CPA firms, and real estate firms, and assisting in other aspects of launching a company.

Besides offering assistance to Caltech faculty who are starting a company, Gilbert organized a series of seminars in the summer of 1999, geared primarily for students, in which several entrepreneurs outlined the process for starting a company. Prior to that, in 1996, Baldeschwieler created a course in entrepreneurship called Entrepreneurial Development that has attracted more than 50 students each time it has been offered. "I go through the steps of building a company, discussing intellectual property, venture capital funding, accounting, writing a business plan, understanding markets, and other issues," Baldeschwieler says. "We have great confidence in the technological understanding of our students, but business is about other things as well, such as managing people."

Students will be better prepared to enter the workplace and can be part of start-ups themselves.

To get credit for Baldeschwieler's class, students must write a business plan, and some of these projects eventually become actual companies. The class also sponsors the $10K Business Plan Competition—in which two $10,000 prizes are awarded annually—to encourage, appraise, and promote business ideas from within the Caltech community. The prizes are presented by alumnus and entrepreneur Glenn Hightower '72, MS '73. In 1998, Caltech added two additional business classes—one on the management of technology and another on product design.

In 1994, Caltech students formed an Entrepreneur Club to promote entrepreneurship at Caltech. The club has a membership of approximately 250 students and regularly invites Caltech alumni who have formed businesses to speak about their experiences. The club also serves as a support network for budding entrepreneurs, providing job leads and other information about starting a company for students.

In 1997, the Caltech Alumni Association began a mentorship program to give students the chance to talk to experienced alumni about careers and other subjects. It recently evolved into connect@caltech, a program designed to help the Caltech community network with each other and with other people who can provide information about people and careers in science and technology. The Caltech Career Development Center also provides guidance for Caltech undergraduates, graduate students, and postdocs who are considering a career as an entrepreneur.

In addition, the Caltech Industrial Relations Center sponsors a wide range of programs, including seminars with executives of technology-based companies, and the Caltech/MIT Enterprise Forum, in which technology-based companies seeking help with growth and other issues present their cases to a panel of experts. The IRC sets aside a few seats at all of its programs so that students or faculty can sit in for free.

Recently opened on the Caltech campus is Pasadena Entretec, a nonprofit corporation that provides guidance and advice to entrepreneurs, helping them find financing, real estate, liability insurance, and other recources to speed the start-up process, and helping them locate their businesses in Pasadena and the San Gabriel Valley. Although Pasadena Entretec is independent of the Institute, "Caltech is supportive of Pasadena Entretec as a way of helping Caltech spin-offs once they graduate from campus," said Stephanie Yanchinski, executive director of Pasadena Entretec. "We're here to create a critical mass of companies to attract the financing and management needed to help companies grow."

Caltech and Art Center College of Design in Pasadena also recently received a joint grant from the National Science Foundation's Partnership for Innovation. The grant creates entrepreneurial fellowships with the goal of educating science, engineering, and design students about business issues so that they can transfer their skills and knowledge to commercial applications, and successfully develop new start-up business enterprises.

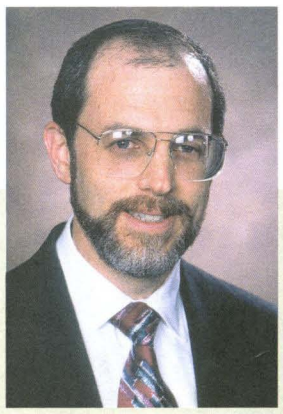
Many companies that originated in Caltech labs set up shop in Pasadena, partly because the founders may already be living here and partly because they often hire Caltech students or graduates. The city of Pasadena is also trying to promote high-tech start-ups by creating areas where new companies are encouraged through reduced red tape, lower fees, and other incentives. Examples include the biotechnology corridor near Huntington Hospital and a manufacturing area in East Pasadena.

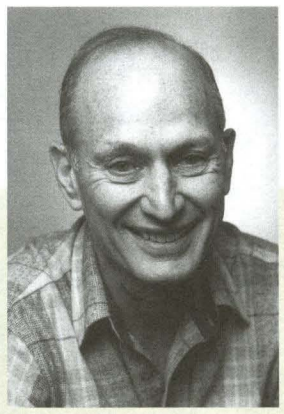
Caltech officials say that when Caltech faculty, staff, or students are involved in new ventures, care must be taken to manage conflicts of interest and commitment. Faculty members might take a sabbatical in the early stages of a commercial enterprise, but they usually return to the Institute. To make sure that they do not compromise their positions at the Institute, faculty must agree not to become day-to-day managers of their company. Most assume advisory roles or board positions. Caltech has put in place an oversight committee to ensure that disclosure and review of potential conflicts are monitored.

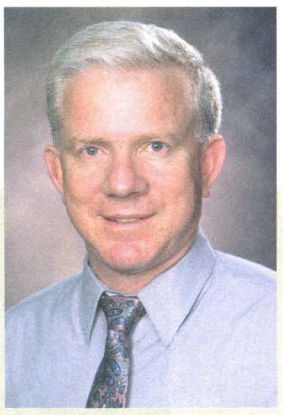
Given the sudden wealth of many entrepreneurs, one would expect that the people behind the start-ups are attracted by the possibility of making money, but Gilbert says that this is not the primary reason Caltech faculty and students start companies. "The majority of the Caltech people who start companies truly believe that they can make a difference by saving lives or providing some benefit through their product. They believe that it will improve the well-being of the community. They usually don't do it to make money. Of course, if the company is successful, they will."

Adds Baldeschwieler, "We hope that the successful Caltech entrepreneurs will ultimately become major supporters of Caltech through grants and gifts to the Institute."

Like the research that is behind the new Caltech spin-offs, the start-up experience of each of these companies has been unique. Take, for example, the stories of Ortel, Rainfinity, and Clinical Micro Sensors. Each story could comprise a separate article, and so it does in this special issue on entrepreneurism. The following three articles are written by Michael Rogers.







Ortel, in three acts

The story of Ortel reads like a three-act play. Act I: Caltech professor and students develop a unique technology and start a company. Act II: After modest success, the company grows dramatically when it discovers that a burgeoning industry is desperate for its product. Act III: The company stalls when the industry's market becomes saturated, but then revives when its product becomes in high demand due to the growth of the Internet. The company's founders attain financial success when the company is bought out by a huge industrial corporation. Curtain.

The author of this story is Amnon Yariv, the Martin and Eileen Summerfield Professor of Applied Physics, internationally known for his contributions to both optics and lasers. These contributions include starting the fields of integrated optoelectronics and phase conjugate optics, which are central to modern fiber-optical communication and to optical computing.

The Ortel story begins in the late 1970s. Yariv's Caltech research group consisted of about 25 graduate students, postdoctoral scholars, and engineers. Two members of the team were Israel Ury, PhD '80, who came to Caltech in September 1976, and Nadav Bar-Chaim, a postdoc who arrived in January 1979. Ury and Bar-Chaim worked on Yariv's research in integrated optics, in which laser light is generated, modulated, and otherwise manipulated in hair-thin layers of semiconductor crystals. These micro-optical-electronic circuits combine lasers and transistors and are used as terminals in optical fiber communications systems. In such systems, laser beams are made to carry huge amounts of information such as computer data or voice channels, either through the atmosphere or over hair-thin glass fibers.

One of the possible applications for this technology was in military communication, and in 1979 the Defense Advanced Research Projects Agency (DARPA) approached Yariv with a project to create high-speed interconnects for radar and computer systems.

Yariv was concerned, however, that what DARPA really wanted amounted to a commercial venture. "We did the basic research on high-speed semiconductor lasers at Caltech, published some papers, and were essentially done with the project, but DARPA wanted a commercial source for these lasers," Yariv said. So he approached Bar-Chaim and Ury in late 1979 and asked them if they wanted to start a company with him. "I chose them," Yariv said, "because they knew the technology, because I thought that they had the talent and temperament to run a company, and because we could not afford, and did not look sexy enough, to attract an experienced manager."

"Starting this company was somewhat of a joke, because the area we were active in was so new that it had no market," Bar-Chaim said. "When I came to Caltech, I thought I'd spend two years there and then go to industry or continue doing research in academia."

"I had a job offer from Bell Labs," Ury said, "but I also had a plan to be involved in a start-up. When Amnon made his offer, I thought, 'Might as well. I can always go to Bell Labs. It doesn't seem too much of a risk. If you lose a year in this, it's not much.'"

So they signed on. Ury became president. Bar-Chaim was the vice president, and Yariv was a consultant. They set up temporary headquarters in Santa Monica in 1980, but soon moved to Alhambra, just south of Pasadena, where the company still maintains operations.

A grant of $180,000 from DARPA helped them pay the bills for a while. During the first few years, the company focused on research and development. It shipped its first lasers for the military in 1983 and then another DARPA project came along.

According to Ury, "With the satellite communications systems then in place, our soldiers in the field were magnets for missiles," because the missiles could follow the transmissions like a beacon, home in on antennas, and kill lots of soldiers. "The military wanted to put their antennas away from personnel. They needed high-speed and high-fidelity links so that you could have remote antennas, and our lasers were able to do that."

By 1987, Ortel began shipping semiconductor lasers for antenna remoting. But by that time, the Cold War was winding down, government defense funding was drying up, and the company needed to rethink its strategy.

Luckily for Ortel, it didn't have to look very long for a new market. In the late 1980s, the cable television industry was on the upswing. As cable channels began to proliferate, more people began subscribing. One major problem, however, was that the coaxial system used to bring the cable channels into homes was subject to failure.

"If one wire broke, tens of thousands of people would lose reception," said

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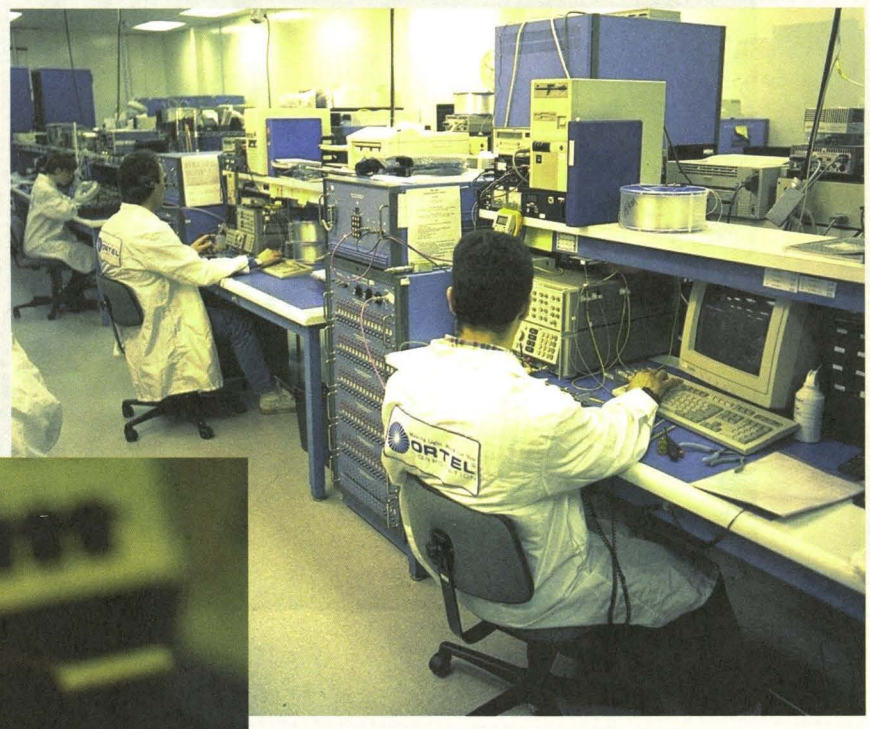
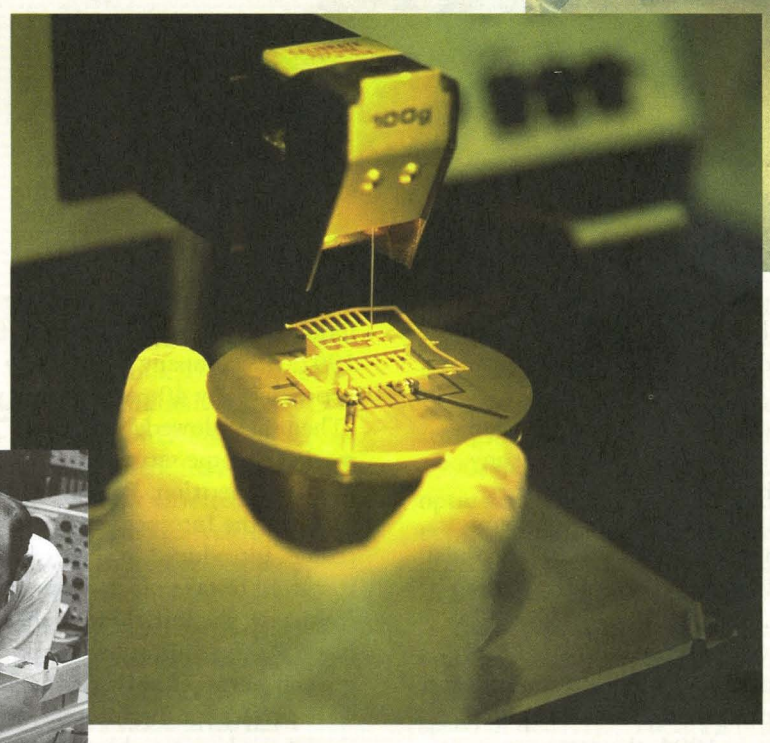
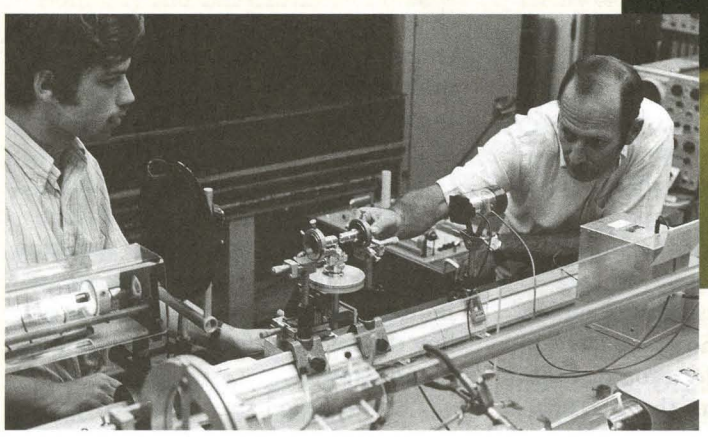
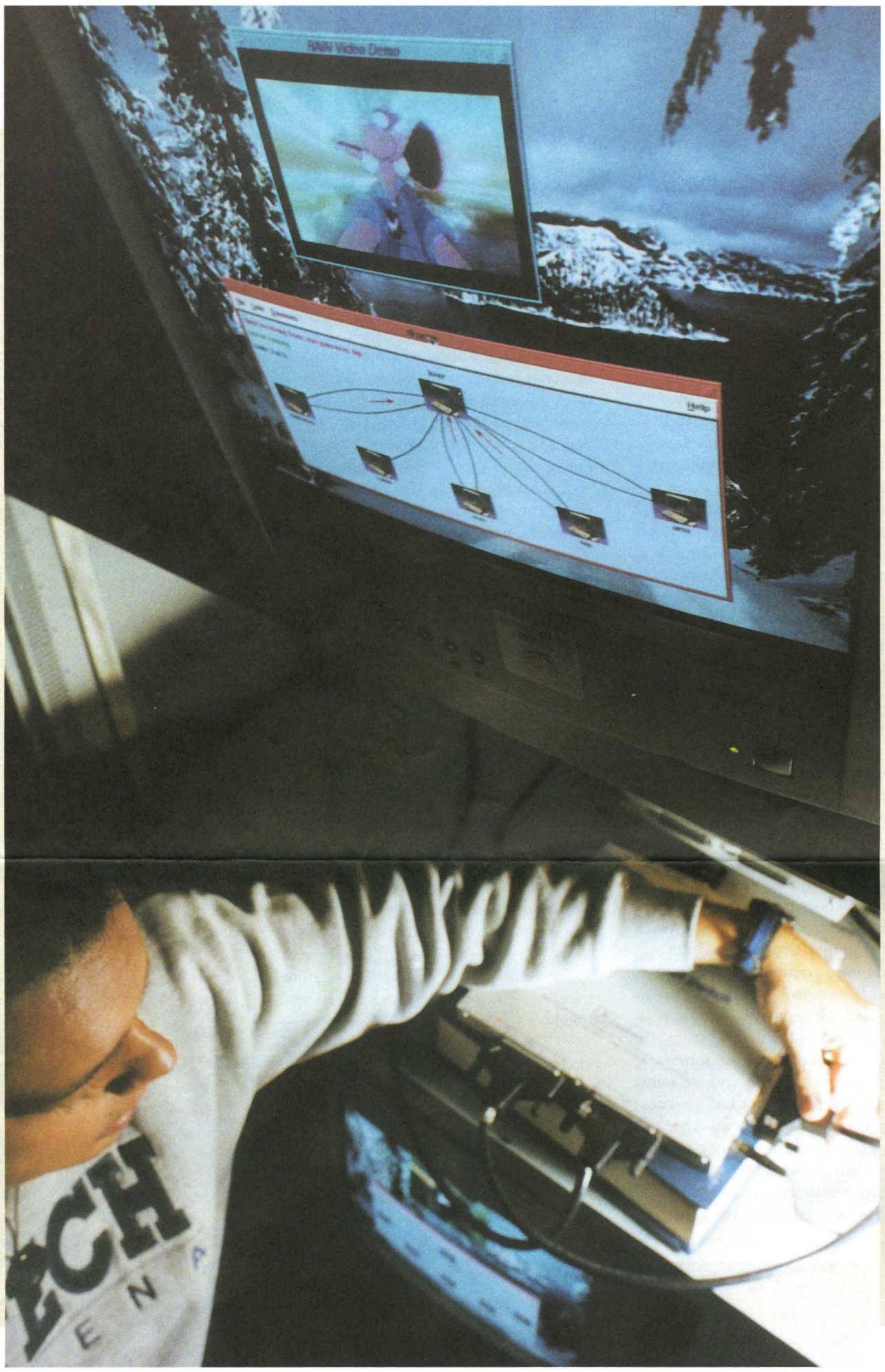






Above, from left: Ortel's big three are Israel Ury, Amnon Yariv, and Nadav Bar-Chaim. During the pre-Ortel days, Yariv worked with David Hall, PhD '71 (below), whose experiments on guiding laser beams within semiconductor crystals opened up the field of integrated optoelectronic circuits. Such advances in Yariv's lab caught the attention of DARPA, the government agency that provided early funding for Ortel. By 1987, Ortel was producing semiconductor lasers for military remote communications and introducing fiber optics to the cable TV industry. A laser module appears at right and technicians manufacture CATV transmitters at far right.

The area was so new that it had no market.



RAINFINITY:

Thanks to the Internet, a project involving Caltech and the Jet Propulsion Laboratory has blossomed into a fast-growing company called Rainfinity. Judging by the name alone, one might assume that the company is involved in cloud-seeding or that it sells wet-weather wear on its home page. But unlike many recent start-ups whose primary purpose seems to be peddling everything from socks to salvation on the Web, Rainfinity is helping to make the Internet a more efficient and secure tool for companies that are increasingly dependent on the Web.

Rainfinity traces its origins to 1994, when Shuki Bruck, professor of computation and neural systems and electrical engineering at Caltech, and Leon Alkalai, director of JPL's Center for Integrated Space Microsystems, came up with an idea to improve NASA's computer systems, both on the ground and in space.

"In the past, NASA would customize every computer component—both hardware and software—for each job, which is extremely expensive," says Bruck, an expert in parallel and distributed computing and fault-tolerant computing. "It made sense to us to propose a project to use commercial, off-the-shelf components."

Bruck and Alkalai went to Washington, pitched the idea to officials with the Defense Advanced Research Projects Agency (DARPA), and by 1995 got funding from NASA and DARPA to develop an alternative to the costly, special-purpose computer systems used in space missions. Bruck gathered a team of five graduate students, and by 1997 they had built a prototype of a system called the Redundant Array of

Ortel . . . from page 5

Ury, who stepped down as president in 1985 and became chief technology officer when Ortel hired a CEO from outside the company. "Or if there was a power outage, the same thing would happen. Everything was on one line" and there were no backups.

In late 1987, Ortel's marketing director took a military satellite link to a large cable communications company and demonstrated that the link could be used to transport TV signals. Then, in December 1987, Ortel rented a booth at the Western Cable TV conference, hooked up a 40-channel TV cable system, and demonstrated that the signal could travel several miles on optical fiber. "That got lots of people interested," Ury said. "Our booth was packed."

Ortel quickly changed from a military hardware supplier to a company serving the entertainment industry. Within a few years, all cable systems were using fiber optics instead of coaxial cable and Ortel was one of the leading suppliers.

To serve the cable industry, Ortel needed to expand into new markets and increase production, which required money. So in 1994, the company went public, raising $40 million.

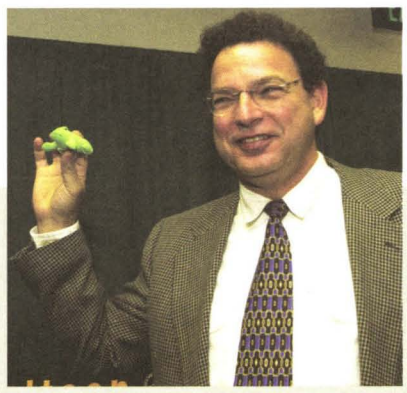
"In 1994, we were one of the first optoelectronic companies to go public," said Ury. "We were on the cusp of that industry." Throughout the 1990s, until 1997, the company's sales grew by approximately 40 percent each year. "Then sales slowed," Ury said. "The market became saturated. There was more competition. Prices declined."

Then the Internet came to Ortel's rescue. Introduced in the early 1990s, it started to take off in about 1997. Ironically, the initial lasers that Ortel made for the military were too fast for general purposes at that time, but they were perfect for the Internet, where users have become obsessed with rapid speed of transmission. So in the late 1990s, Ortel began to focus on making high-speed lasers, an area that had few competitors, according to Bar-Chaim.

In 1999, the cable business represented approximately 90 percent of Ortel's sales. But within one year, the Internet business accounted for more than 50 percent of the company's revenues. Investors took notice. In the middle of 1999, Ortel's stock was trading at about $10 a share. By February of 2000, it was over $170 per share.

Lucent, the telecommunications company that had been spun off from AT&T, had been paying close attention to Ortel's success serving the computer industry, and early in 2000 it agreed to buy the company for $2.95 billion in Lucent stock.

"In the period after the takeover, it



From outer space to interspace

Demonstrating RAIN technology in Shuki Bruck's lab, in the far left photo, graduate student Massimo Franceschetti unplugs one of five interconnected servers that operates an on-screen movie. RAIN software is able to instantaneously reroute connections among the servers to keep the movie playing without interruption. Making a business out of this technology are cofounders (immediately above, from left) Shuki Bruck, Charles Fan, Phil Love, Paul LeMahieu, Vincent Bohossian, and Gil Margalit. Above them, Bruck holds the icon of one of his latest projects, the Caltech–MIT voting technology project, in which a frog represents the casting of a vote. (See more on that at www.vote.caltech.edu.) The frog has yet to spawn a company.

Independent Nodes, or RAIN.

One of the requirements for building an off-the-shelf computer system for NASA is that it must be extremely reliable, since the consequences of a malfunction can be catastrophic in space. In the RAIN system, there are multiple computer nodes and connections that can perform the same function. Rather than design expensive fault-tolerant chips, Bruck and his team designed a system so that if one chip failed, another one would take over. In this system, a component that stores data across distributed processors retrieves it even if some of the processors fail. If part of a system shuts down, the recovery by another part of the system is instantaneous and does not disrupt any operations.

The RAIN prototype was finished at a time when more people had begun going online, to shop or check out companies and products, and businesses began to recognize the Internet as a tool that was vital to their future. Bruck realized that companies that relied on the Web for business were subject to dire consequences if their systems crashed, since competition was now just a click away. And Internet sites crashed often because the computer systems handling Internet connections were not built to manage the Internet onslaught. Bruck figured that RAIN could be applied to the Internet and he began investigating the possibility of starting a company to commercialize RAIN.

In the spring of 1998, Bruck approached the five graduate students who had worked on RAIN and asked them if they wanted to start a company with him. Two opted to pursue academic careers, but three signed on—Vincent Bohossian, PhD '98, Charles Fan, PhD '01, and Paul LeMahieu, MS '96. In addition, Phil Love, PhD '99, then a graduate student in applied mathematics, was recruited for the team.

Bruck, together with his business partners, then found several investors to provide a total of $2 million to launch the company, which they named Rainfinity. With the money, they set up a research office in the Old Town section of Pasadena in September 1998. They then began creating a software product so that companies would no longer have to rely on single Internet gateways to their Web sites. A company's Web site could be accessed faster, and many more people could get into the site at the same time. There would be multiple pathways to route traffic, and the system would also serve as a so-called firewall against outside security breaches and viruses. The system, called Rainwall, was completed in 1999. It sells for $5,000 to $20,000, depending on the number of processors supported.

"RAIN technology is reliable software technology with high availability," says Bruck. "It's like a Borg from *Star Trek*. If you kill a machine it keeps functioning. Others take over. And users don't see the effect of that. We do have competition. But our technology is one generation ahead."

While starting the company, Bruck also negotiated with Caltech, which owned the rights to the RAIN technology since it had been created at Caltech. The Institute got equity in the company in exchange for the rights.

By the summer of 1999, Rainfinity had its first paying customer: the Chicago Board of Trade. Bruck then raised $15 million through venture capitalists, and hired a chief executive officer: Olivier Helleboid, who formerly had run the largest software division at Hewlett-Packard. Rainfinity opened its headquarters in San Jose in the summer of 1999 so that it could be close to a strong employee base and to potential corporate partners. It kept its research arm in Pasadena, since many of its employees continued to have connections to Caltech.

Once Helleboid was on board, Bruck—who serves as chairman of the company—relinquished his involvement in day-to-day operations to focus more on his own research at Caltech. "My role now with Rainfinity is either as cheerleader or pain in the rear," jokes Bruck. The Caltech graduate students who helped start the company with

Continued on page 12 . . .

was nice to see some Ortel employees with new cars and trucks," Ury said. Added Bar-Chaim, "Some people were also able to afford new homes."

Both Ury and Bar-Chaim said that they resisted the temptation to splurge. "We both kept the same homes, cars, and wives," quipped Bar-Chaim.

While he remained with the company, Ury cut back his hours and now works only part-time for the company.

"I pulled back in terms of my involvement with the company to pursue personal interests," Ury said. "I have personal community interests that I think are more worthwhile."

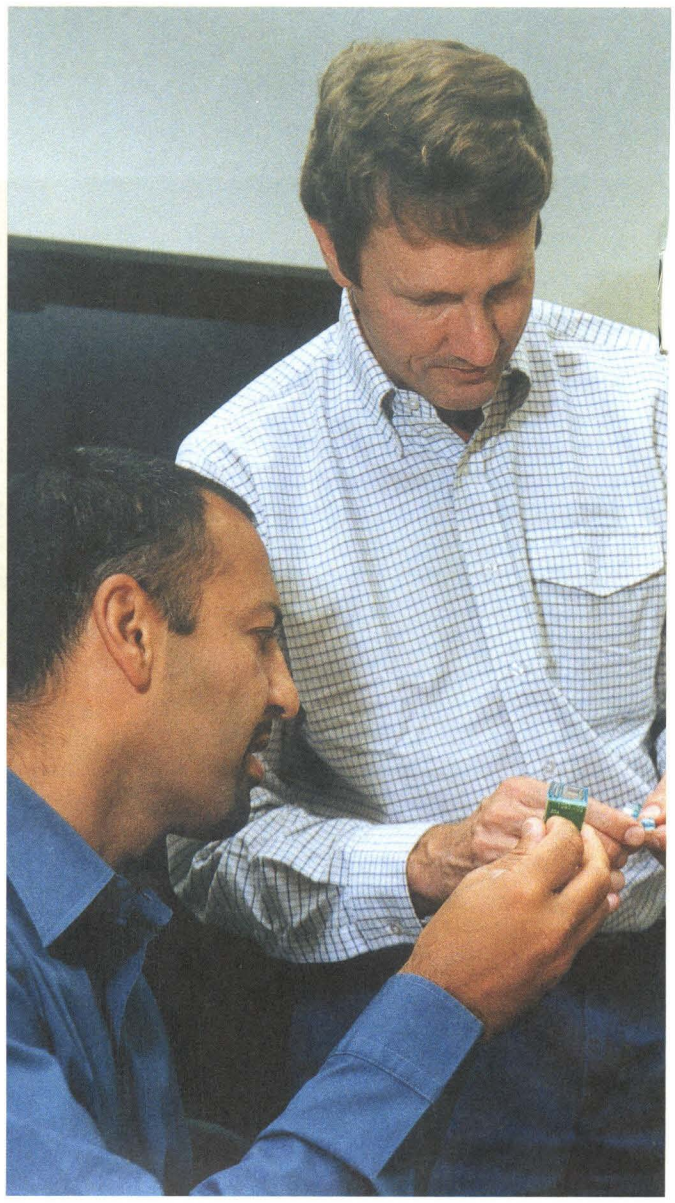
After the deal, Yariv gave $1 million to Caltech to create two graduate fellowships at Caltech. To fund one of those fellowships, Yariv joined with a former student. "Can you think," he said, "of a better way to use a million dollars?" Henry A. Blauvelt, PhD '83, another former graduate student from Yariv's lab who went to work for Ortel, and his wife, Caroline, whom Blauvelt met at Ortel, also used the Lucent buyout to provide funds for graduate support at Caltech, creating the Henry A. Blauvelt Fellowship to support graduate students working in applied physics.

While Lucent's stock price has dropped over the past year and a half like the stocks of other technology companies, Ury and Bar-Chaim say that the future of Ortel—which since the buyout became part of a Lucent subsidiary called Agere Systems—is still strong.

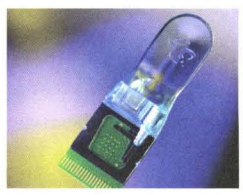
"The cable side of the business will still grow," predicts Bar-Chaim. "In 1990, there were 20 channels per fiber-optic line. Now there are 100 channels per fiber and better quality. We don't expect any slowdown in the next three to five years."

And as far as the Internet goes, Ury says that consumers still have an insatiable demand for information and speed of delivery. "There's a bottleneck as you get to the home, since no one has brought fiber right into the home yet; just to your doorstep," he says. From there it travels via modem or cable, which slows down the speed of delivery. "People want speeds one hundred times faster." Plus, as the speeds of computers go up and more people begin using their computers as a source for entertainment, the speed of information delivery will need to go up, and fiber-optic lines will be the solution.

"People will want to download movies in a few minutes," Ury says. "Fiber into the home is probably where we're heading, and there are a lot of homes."



Clinical Micro Sensors: Star Trek meets the Human Genome



Not too long ago, in the once hyperbolic world of Internet start-ups, it was a common occurrence for thirty-something entrepreneurs to make their fortunes almost overnight. But the riches have always been more elusive in biotechnology, where the development of a proven drug or healthcare product can take several years, which made the market for biotech initial public offerings less explosive than the dotcom IPO market.

But for Jon Faiz Kayyem, PhD '92, the money came surprisingly fast, as Clinical Micro Sensors, the biotech company he cofounded in his garage six years ago, was bought by Motorola last year for approximately $300 million. That deal made Kayyem an instant multimillionaire at the age of 36.

While the buyout may have been big, the primary goal of Clinical Micro Sensors is equally grandiose: to change the way medicine is practiced. The company hopes to do this with a handheld device that will instantly analyze the DNA in a sample of a patient's blood, searching for a wide range of diseases. Kayyem says that when people hear about his DNA detector, they have visions of the palm-sized device that *Star Trek's* Dr. McCoy would use to treat patients with only a touch of a button. But Kayyem's product is based on nuts and bolts science and engineering and not fantasy. He hopes that it will give medical labs a new way of doing business, since—by his account—their expensive and time-consuming methods of analysis will be obsolete once his product becomes commercially available.

Although Kayyem says that he never would have guessed that the payoff for Clinical Micro Sensors would have come so fast, getting there did not happen overnight. Kayyem, who grew up in Los Angeles, came to Caltech in 1986 as a graduate student in molecular biology, after getting his bachelor's and master's degrees at Yale. He worked with Professor of Biology William Dreyer on molecules that help the brain wire up during development and on their relationship to molecules that identify foreign pathogens.

To conduct their research, Kayyem and Dreyer had to develop new methods for detecting molecules. Kayyem, who received his PhD in 1992, says that his work with Dreyer taught him that the tools one develops to make scientific discoveries are just as important as the discoveries themselves.

"When I finished working with Bill, I wanted to make new tools, as opposed to being a leading scientific scholar in the field," he says. Kayyem adds that he was also influenced by Lee Hood, the former Caltech biologist who invented a method for the automated sequencing of DNA, a key to the success of the Human Genome Project. "It became really clear that you could have a highly leveraged impact on a field if you made a tool that everyone used versus making a discovery that may have been an additional piece in a puzzle, but wasn't really helping others put the other pieces together," says Kayyem. "I found that really exciting. And Hood said to me, 'If you want to do anything in this field, just make sure that you've got the Human Genome Project in mind.'

"A lot of people in my class went to work on the discovery process of genes and their functions, and I wanted to work on the testing side," Kayyem says. "I thought, 'If we discover all these important genes, then we can change the way commerce works, we can change the way medicine works, and we can affect environmental issues and food safety issues.' But we couldn't do that without using really expensive tools and highly trained people. So I thought I would try to bring DNA testing down to a level where technicians could do it, perhaps even in the field."

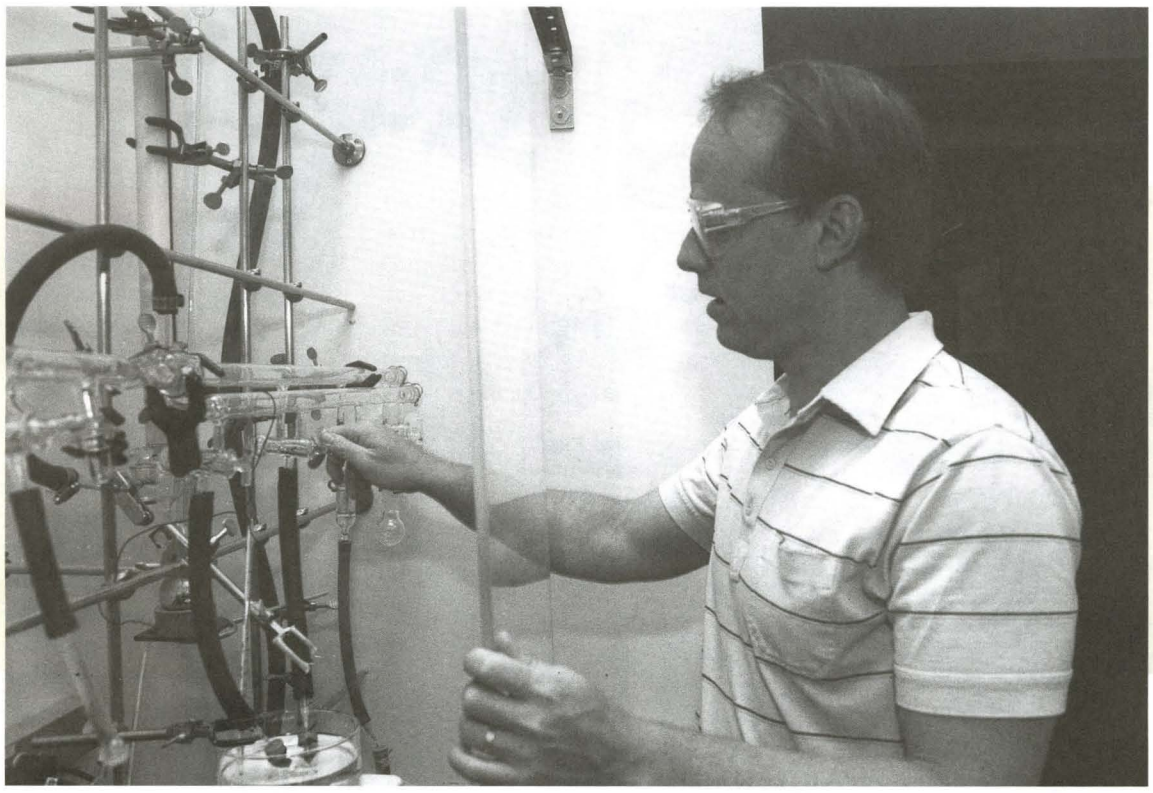
After getting his PhD, Kayyem went to work as a postdoc with Scott Fraser, the Anna L. Rosen Professor of Biology. Kayyem figured it would make sense to develop the DNA testing tools in Fraser's lab, since he thought that the tests would likely involve fluorescent dyes and Fraser was an expert on fluorescence systems.

Kayyem figured that the easiest way to test for a specific DNA sequence would be for a doctor to take a patient's blood sample, stick it in a tube and watch the tube change color if the patient had the sequence associated with a disease, since fluorescent dyes change color when there is a specific molecule in a solution. "I got it to work on proteins and then tried to get it to work on DNA, and it didn't work at all," he said. "It failed so utterly, that I didn't know where to go."

Fraser then sent him to Tom Meade, a senior research associate in biology and a bioinorganic chemist who, like Fraser, works in Caltech's Beckman Institute. Meade is an expert in electron transfer, an area in which Caltech has made numerous discoveries. He had been investigating electron transfer through DNA since late 1988. Meade told Kayyem that the transfer of electrons during DNA binding events was likely preventing the action of the fluorescent dyes. But rather than end the investigation, Meade saw this as an opportunity, figuring that they could study the changing electrical signals as a way to evaluate DNA. At about that time, researchers were putting DNA on silicon chips, so Meade and Kayyem figured that they could take advantage of the electrical properties of the chips to do electronic detection of DNA binding events.

"I spent three years working with Tom trying to make it work," Kayyem recalls. "Tom wanted the story bulletproof, because there were different theories on DNA as to whether it would be a really bad conductor or an unbelievably good conductor." It turned out to be somewhere in between. Meade and Kayyem discovered in 1993 that electrons can race from one end of a DNA strand to the other as long as the two strands of the molecule are bound together. When a single strand of DNA was used, the electrons didn't travel as fast, and this difference proved to be a key to the development of a DNA sensor.

At the time that Meade and Kayyem were working on electron transfer in DNA in the early to mid-1990's, other scientists were busy discovering the genes responsible for certain diseases. Meade and Kayyem figured that one could identify a disease by taking the



The tools one develops to make scientific discoveries are as important as the discoveries themselves.

In his quest to bring DNA testing down to a level where technicians could do it in the field, Jon Faiz Kayyem (left), PhD '92, worked with Caltech's Scott Fraser (center) and Tom Meade (right). Their handheld prototype is pictured at far left.

section of the DNA unique to a particular disease, splitting the DNA apart, and putting it on a chip. Then if you took a DNA sample from a patient and it matched the DNA on the chip, the two strands would bind together and an electron would speed down the double-stranded molecule. If there was no match, the electrons would travel more slowly. A sensor could distinguish between the two conditions and thus reveal whether a patient was infected or not.

"Every time I thought we had enough to write a paper, Tom would make us go back and measure it a different way," Kayyem recalls. "We had to develop chemistry and test the chemistry to validate that the molecules were stable. The work was time consuming and meticulous and you couldn't have impurities in the system or the chemistry wouldn't work."

After getting it to work in solution, Kayyem says that he decided that it was time "to take a dive and see if we could swim across to a product: a chip." That would be more expensive and would require industrial production techniques, so Kayyem told Meade that he wanted to start a company. Meade and Fraser convinced Caltech to give Kayyem a one-year license to develop the technology and raise enough money to turn it into a product. In exchange, Caltech got royalties and equity in the company, called Clinical Micro Sensors. Fraser and Meade joined Kayyem as cofounders. "This was 1995," Kayyem says. "I started working out of my garage. I wrote a business plan and started looking for money."

Meade played a significant role in finding financing. After he gave a talk on the technology at a conference, a reporter for a science journal wrote an article trumpeting its commercial possibilities. An investor who read the article then contacted Meade, offered to invest in the technology and helped line up other potential investors. Within a year, Kayyem and Meade had raised $6 million.

Kayyem moved the company out of his garage and into a building in the Old Town section of Pasadena. Rather than move to the Bay Area—the location of choice for most biotech start-ups—Kayyem chose to remain in Pasadena, in part, because he wanted to work outside the start-up spotlight.

"I wanted to be a little bit stealthy about this," Kayyem says. "I didn't want word of our incremental improvements going out into the world because then expectations for us would be high. I wanted to show up one day with a system that works. And that's what we did.

"We asked investors to give us 30 months, and told them that we'd build a handheld prototype by then. We then thought we'd raise more money. People say that these companies never turn out the way you lay them out, but by 30 months, we were just about out of money, and we had a handheld prototype."

The prototype includes a sensor and biochips, on which probes of single strands of DNA are deposited. When a sample of DNA is injected onto the chip, binding occurs with the chip DNA if the DNA halves are complementary. The system also contains DNA sequences, called signaling probes, with proprietary electronic labels attached to them. When the DNA binds together, the electronic labels release electrons, producing a signal that can be detected by the handheld sensor when the chips are inserted in a slot in the sensor.

In 1998, Meade and Kayyem showed off the prototype at a conference at MIT. They took prepared samples of blood which were tainted with non-infectious fragments of either HIV or hepatitis C, injected them into the DNA chip, and their handheld sensor indicated the presence of the viruses. Also at the meeting were executives from electronics companies. While viewing the other displays and talking to officials of these firms, Kayyem says that he began thinking that Clinical Micro Sensors was really part of the electronics industry rather than the biotech industry.

"That meeting made me think that life sciences might not be that far removed from electronics if you can do life sciences electronically," says Kayyem. "Our product may not be a consumer electronics device, but it's certainly an electronic device for professionals."

In 1999, when Kayyem started thinking about moving the DNA sensor from the lab to the marketplace, he turned to Motorola, an electronics' industry giant, to forge a partnership. Motorola first invested several million dollars in Clinical Micro Sensors, but then decided to buy out the company. "The whole information worlds and biotech worlds are on convergent paths," says George Turner, vice president and general manager of Motorola Life Sciences. "Motorola thought that Clinical Micro Sensors had the most advanced and well-thought-out plan to create a laboratory on a chip." Turner estimates that the size of the clinical evaluation market could be worth $10 billion a year in sales when the sensors become common tools for medical practitioners, which he says should happen within the next 10 years.

"Our plan is to dominate the biochip sector," says Kayyem. "Motorola is making high-density arrays of DNA chips that are used in the discovery of new genes, and we've got the products that are fairly uniquely positioned to compete on the diagnostic side. I don't see any realistic competition. Other biochip players use scanners and optical systems with lasers that make the tests expensive. You can do an occasional cancer test or an occasional HIV viral load test using fairly expensive equipment, but you're not going to alter widely the way medicine is practiced with those, compared to our method, using very inexpensive scanners and very inexpensive disposable chips. So I can comfortably say that we are uniquely positioned to take advantage of those widespread applications of genomics."

Within five years, Clinical Micro Sensors hopes to make its sensors available to doctors. Kayyem figures that they will cost no more than $200 or $300, and the company may even give them away, since it hopes to make most of its money by selling the disposable chips that will be used to test for

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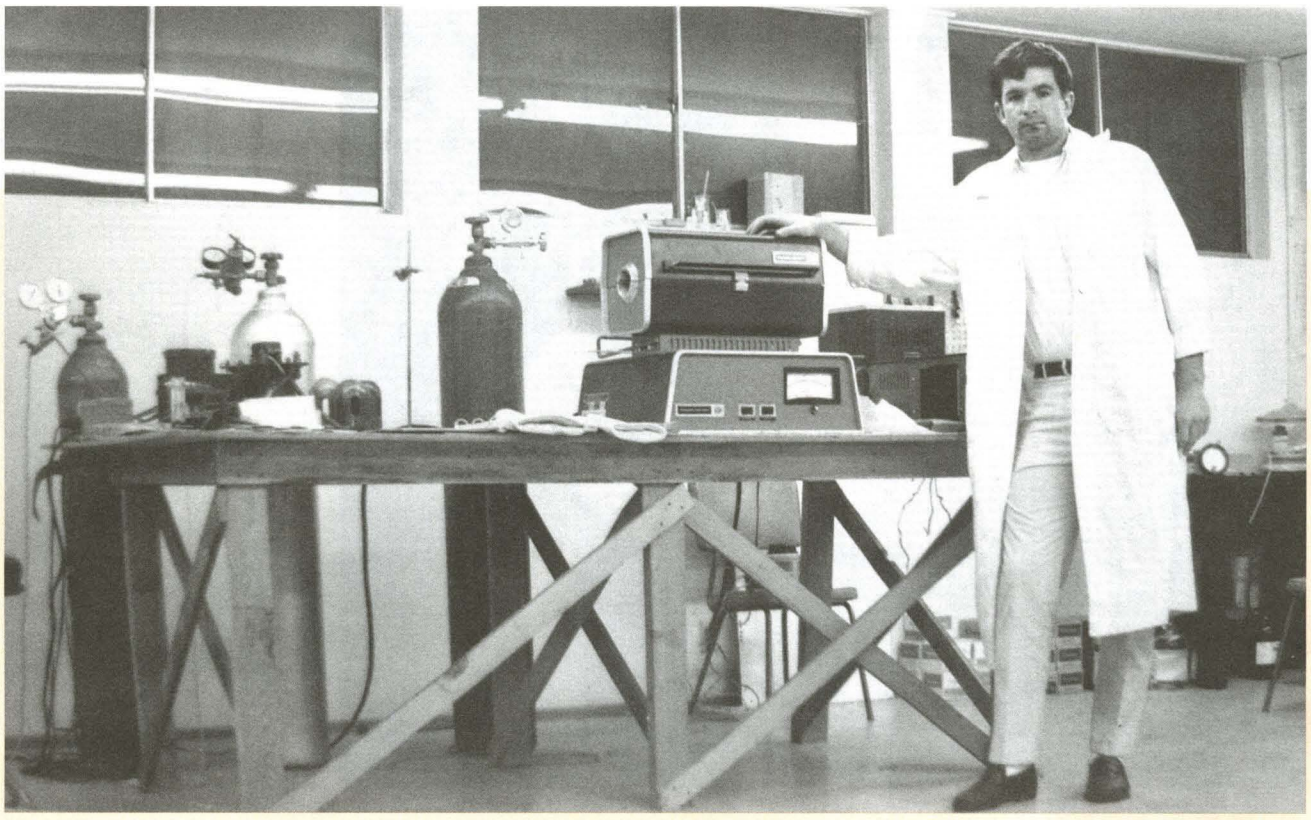


The early days at Intel

By Ted Jenkins, president of the Alumni Association

In 1966, my final year at Caltech, I was fortunate enough to meet Gordon Moore, PhD '54, in the basement of Spalding. Gordon was recruiting for Fairchild Semiconductor's R&D laboratory, which he headed, and Carver Mead, my adviser, had invited him to meet students who were looking for work. I was fascinated by the projects Gordon described, and went to work on semiconductor process technology for linear integrated circuits at his Fairchild R&D lab in the Stanford Industrial Park in Palo Alto.

Later, motivated by the opportunity to work on a different semiconductor material, I followed Gordon, Andy Grove, and Bob Noyce to Intel. I was the new company's 22nd employee. I held a variety of assignments in manufacturing, general management, and patent licensing, and retired in 1999 after 30 years. I spent my entire career in one or another of Gordon's organizations.

My Intel employment had a Caltech connection. I had been working at Fairchild for two and a half years when Andy Grove called and asked me to come work for him and Gordon. They wouldn't tell me what my assignment would be and wanted my recruitment to be kept completely confidential. I asked if I could discuss the offer with Carver Mead, and they agreed. From Carver I found out that my assignment would be to work with him and another guy, but that I would have to make a trip to Southern California to find out what we would be doing.

When I arrived, I met with Carver and Professor Jim McCaldin, who had ideas about how to use zinc sulfide to create diodes with high brilliance and efficiency and the ability to emit light in a range of colors, including the elusive blue hue. I was very excited about the project, mainly because it was a chance to work with something more exotic than silicon.

I remember my preemployment negotiations with Gordon. He said that they were starting people at their current salaries. I indicated that I was making $1,000 a month but was expecting a 10 percent increase shortly. He said he could pay me $1,100 a month, and that Intel would grant me a 1,000-share stock option at $5 per share, vesting over a five-year period. I asked what that might be worth. Gordon estimated about $50K in 10 years. (He was a little conservative. If I still had it all, the original option would be worth over $20M.) When I left Fairchild, I told everyone that I was going to McCaldin Electronics (which was true). Not until several years later did my Fairchild associates realize that I had quit to join a subsidiary of Intel.

So I went to work on the project. I had a lab (Intel south) on Walnut Street in Pasadena, where I worked mostly by myself, except for lunches and meetings with Carver and Jim, and periodic visits from Gordon and Bob Noyce. We were able to develop patentable ohmic contacts and a reasonably efficient injecting metal-semiconductor diode. We found out, however, that the light production was limited at a level lower than we wanted by the recombination rate in the bulk. This appeared to be a fundamental limitation, but we still had fabricated diodes that produced reasonable amounts of light. Gerry Parker '65, PhD '70, followed me on the project, but I had moved back to Northern California to develop Intel's bipolar process for its first memory product. Ultimately the technology was sold to Monsanto, which had a business with light-emitting diodes.

Peter Drucker defines an entrepreneur as one who thrives on change and who looks for opportunities to redeploy resources from less productive to more productive endeavors. I'm not sure that any of us felt like or would have called ourselves entrepreneurs, but we knew we were taking on the next major semiconductor challenge. Primarily as an extension of Andy Grove's personality, our strong suit was execution. We made plans to develop products, technologies, and factories. For the most part we implemented those plans within their forecasted parameters. When we got behind or off track, we knew how to refocus our efforts or form a task force to recover. This was good enough to get us started.

I was fortunate to have held a variety of assignments throughout my Intel career that kept me interested, engaged, and productive. Over time I've found that it is important to reinvent one's self periodically. Once you've solved the same problem several times, it gets harder to attack similar problems with the same vigor. This isn't good for employees or for the enterprise they work for. Employees tend to bring the most vitality to their jobs when they are learning something new. The only way to maintain this level of interest and energy consistently is to introduce new challenges into the work environment from time to time.

In my early years with Intel, the company's business plan was straightforward, even simple. Integrated circuit technology was maturing to the point that it would support competitive memory arrays. Product planning wasn't a mystery—the objective was simply to make the largest economical memory array possible. The company's subsequent success in memories, then with the microprocessor, is well known. In the May 2001 issue of *Technology Review*, Gordon talked about the two key elements of a successful business strategy: "Really understand what your market needs and what your advantages are," and "Surround yourself with the best people you can possibly find."

All but Albert Yu '63 are retired now, but there was a time when Intel had more corporate officers from Caltech—Gordon Moore, Gerry Parker, Albert, and myself—than from any other university. While Caltech graduates don't have a monopoly on intelligence, management skills, or entrepreneurship, they do have training that uniquely prepares them to manage technology-intensive businesses. The Institute has always focused on a comprehensive grounding in scientific fundamentals, even for those students in engineering and the applied sciences. Its economics and business courses and student entrepreneurial clubs offer further support to entrepreneurial endeavors.

One way to maintain lifelong contact with this network of unique and talented people is through the Caltech Alumni Association. Most of our activities are designed to promote interaction between both Caltech and its alumni and among alumni themselves, often in a learning context. To give a recent example, in the last year the Bay Area has held two mixers and an alumni-led tour of the Stanford Linear Accelerator Collider (SLAC), each of which attracted roughly 200 people. Only time will tell what new enterprises driven by Caltech alumni had their genesis at these events.

Above: Intel's 22nd employee in the company's early days.

A GRAD STUDENT ROAD-TESTS BUSINESS BASICS

By Rhonda Hillbery

Maybe the best glimmer of a future entrepreneur can be found in the anything-is-possible outlook of a person like Jessica Stumpfel, a second-year graduate student in computer science.

As she explores the interface between art and science in computer graphics, this 23-year-old's future may plunge her into a high-tech start-up, a PhD program at Caltech, or something completely different.

Exemplifying a newer breed of student not confined by a single vision of research or business, Stumpfel isn't troubled by the notion that her research area may not mesh with current commercial opportunities, and she has no interest in fitting into a predetermined job description at a large company. She describes her motivation this way: "Whenever I'm not doing something that's not a great adventure, I am looking for something that is."

Stumpfel started fall term just days after returning from a summer internship in Beijing, where she worked for Microsoft Research China. She landed her summer internship in classic networking fashion—after meeting a Microsoft China researcher at a computer graphics conference. "China was an incredible opportunity. They had a place for me to stay, food for me to eat, and fun people for me to hang out with." Though she doesn't speak Chinese, Jessica was able to draw upon the bilingual language capabilities of Chinese roommates, and to see the countryside as widely as possible.

It wasn't uncommon to take 13-hour train rides on "hard-seaters," with people lying underfoot. Despite the rigors of sometimes-questionable-but-often-outstanding food, she loved the chance to visit natural wonders, including the vast grasslands of Bashang, north of Beijing near Mongolia. In the west, she saw Hua Shan, a legendary mountain near Xian, and Qing Hai, a huge salt lake. Also west of Beijing, she trekked to see the immense Buddhas carved into caves in Datong, which was China's capital 1,600 years ago. She even found herself treated like a celebrity of sorts, especially in the countryside, where Westerners are a novelty. People would hand her their babies to hold for snapshots that would become vacation-trip mementos.

Any tremors of culture shock were taken in stride. "I didn't find it stressful at all. It was an adventure—that's what life is all about."

During the summer Jessica also was able to jump-start her research concerning how to leverage the computer to help animation artists. The idea behind her work involves finding "artistically intuitive ways for artists to interact with the computer while allowing the computer to take care of the busy work.

"My current project attempts to interpret 2-D sketches of articulated figures so that 2-D sketches from new viewpoints and skeleton poses can be created automatically. I'm trying to have an artist draw a character from a few angles and in a few different poses and be able to create an animation of that character walking around the room." She's carrying on her research under the supervision of adviser Jim Arvo, associate professor of computer science.

This marriage of art and science is intentional. As a Duke University undergrad, Jessica completed a double major in computer science and art in 2000. "I couldn't decide between the two, so I did both."

Among campus computer science majors, she was one of the few who went on to graduate school. In fact, when she announced her plans, she found herself getting quizzical what-are-you-thinking? stares from fellow graduates. During those go-go days when venture capital seemed as abundant as would-be entrepreneurs' ambition, the question wasn't whether to join a start-up, but rather which one.

Jessica Stumpfel, left, was supervised by Ying-Qing Xu during a summer internship in computer graphics with Microsoft Research China.

A group of Stumpfel's close friends decided to ditch senior year in favor of moving to Boston to launch their own dotcom, called buyerIQ.com. "They were all extremely talented individuals and worked 80 hours a week on their idea for close to six months. And, still, before they could really get off the ground, an established company moved in on their target market. My friends were back at Duke in time to see the rest of us graduate and to start their senior year a bit late."

She didn't pity them, however. She admired them. "Of all things, I marveled most at their amazing timing. If they had waited until graduation, they would have missed the chance to experience the dotcom phenomenon." As she sees it, her friends gained invaluable life and work experience in a few short months.

Jessica opted for graduate school out of a sense that there was much she needed and wanted to learn about computer graphics. Caltech seemed like the right place to do that. "What's pretty beautiful about Caltech is that you can work in your own area and be supported."

China is only the latest stamp in her passport since coming to campus.

Last spring, Jessica and Caltech electrical-engineering graduate student Craig Cameron represented Caltech at the fourth annual MIT $50K Global Startup Workshop, in Melbourne, Australia. The educational workshop about business plan competitions drew students from all over the world. "Craig and I tried to represent how things are done at Caltech, and we came back with a world of ideas and inspiration, not to mention an international network of people with entrepreneurial interests," she says.

The workshop tied into the entrepreneurial development class Stumpfel attended on campus last winter term. Students come armed with an idea or the hope of developing one, and then work up business plans for their technology-based ventures. They learn about initial public offerings, hiring challenges, and business plans, and have the chance to chitchat over cheese and crackers with high-tech executives. The course is taught by John Baldeschwieler, Johnson Professor and Professor of Chemistry, Emeritus, who has himself founded or cofounded several start-ups.

Intended to introduce the basics of launching high-tech businesses, including early-stage patenting, marketing, legal, financial, and organizational challenges, the course touches on feasibility research, taking a company public, mergers and acquisitions, and dealing with Wall Street analysts.

"It really gives you an idea of what it would be like to start a business," Stumpfel says. "It's not going to be you and your buddies—it's you and your legal team and a whole bunch of other people." To her mind it also reveals another side of Caltech, the one where bright people launch businesses, some of which become hugely successful.

"If you just sit there and think creatively it's amazing what you can come up with," she said.

She and her partners came up with an idea for something they called a money clip—a new way of exchanging money via cell phones or PDAs (personal digital assistants). They were deep into the details of developing their business plan when Palm launched a similar product.

That was the end of an experience that for a time had Jessica contemplating quitting school and going into business. "If this thing had worked, I would have gone for it." On the one hand, the fact that a major company brought something similar to market was a huge validation of their idea. On the downside, of course, the idea was now unmarketable. But it was all part of a learning curve that proved to be highly educational. "It just means that your idea has to be that much stronger."

Stumpfel doesn't doubt that another entrepreneurial venture will beckon sooner or later. "I think it is the way to do things here in America, as opposed to working for a huge company." In these newly turbulent economic times, she has adopted the idea that now must be the mantra of would-be entrepreneurs: keep trying.

It really gives you an idea of what it would be like to start a business.
It's not going to be you and your buddies. It's you and your legal team and a whole bunch of other people.

How it began: Horace Gilbert and Caltech's business roots

When Horace Gilbert came to Caltech in 1929, he already had established a reputation as a Harvard University economist and as the author of a successful textbook, Introduction to Business. *These accomplishments had caught the eye of Caltech's president-in-all-but-name Robert Millikan, and he offered Gilbert a job. As Gilbert recalled in later years, he was surprised that the Institute would be interested in business training, but Millikan told him that "he had observed that a good many graduates of Caltech were going into industry, and . . . they ought to know something about it."*

So, for the next 40 years (he retired in 1969), Gilbert taught students about "it"—industrial finance, business manufacturing, and other topics that would prepare them to function as effective scientist-managers in an industrial or corporate setting.

Although students of his day were more likely to join big industrial labs than to launch their own companies, there is little doubt that Gilbert would have been pleased to see the Institute striking out so successfully in a direction that he pioneered on campus more than 60 years ago. In this excerpt from his 1979 oral history, Gilbert talked with interviewer Mary Terrall about his role in introducing Caltech students to the world of business and finance.

Horace Gilbert: I would say that when I came here, I had the advantage of high expectations on the part of the engineering faculty that their students would benefit from a course in business economics. So the various options assigned entering graduate students to my course. This kept on right along, and I would say it existed right up to my retirement.

Mary Terrall: Now, when you first got here, would this have been just because the [engineering division] thought it was a good idea, or did you go and talk to them about it?

HG: No, I didn't talk with anybody. They thought it was a good idea. I remember Franklin Thomas, after whom Thomas Lab is named, saying it was a great relief to him to find someone on the campus who was teaching these engineers something about the money and capital that is involved in great irrigation projects, water supply projects, and so on. I also asked the engineering faculty for introductions to people in industry with whom I could make contact. I knew that aircraft was a big industry here, so I started going to the aircraft companies every year to talk with them about things that I was interested in. . . .

MT: In your contact with the aircraft industry, were you then using information you got from them in your course?

HG: Yes, but only lightly, because it would have been out of proportion. While there were always quite a few aeronautical engineers in the class, I was broad-minded, and I talked as much about automotive and civil engineering as I did about the airline industry.

MT: Did the students in this class have any economics or business background?

HG: No, and I told them that I didn't care very much whether they had had economics or not, because in a way I began at a different point. The courses in elementary economics as they are taught are an interesting part of a liberal education, but they aren't very relevant to a course in business economics. . . .

MT: How did the students react to the course?

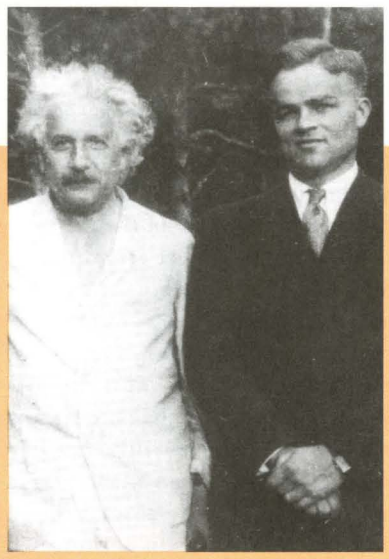
HG: This is difficult for me to say. I can point to the record, namely, that when I first came I taught four days a week, and I always had two or three sections—very few students dropped out between Econ. 100 a, b, and c. In other words, they continued their interest. Actually the course began with an emphasis upon industrial finance, then it went into advanced manufacturing practices. Throughout the course I brought in business economics topics, especially as they were hitting the headlines. So there was a flow-through in the three terms that apparently held their attention. I have had many graduates comment that they were very happy with it.

MT: Did you have . . . students in later years who came back and said it was useful?

HG: Oh, yes, from all over the world. Do you know the story that T. Wilson told when he was named a Distinguished Alumnus? He came to Caltech in 1948 . . . [and when he learned] that among the [graduate] courses he would be taking was business economics, he said, "I don't want to take business economics. I came here to study aeronautical engineering." As he told this story, the first term he got an A in aeronautics and a C in my course, but at the end he got a C in aeronautics and an A in business economics. This indicated what his field of interest was, and so it ended up. He led the Minuteman [R&D project], for instance, at Boeing, and then the B-47, the B-52, and the 747. . . .

My thought had been that the first job that these students take will be in their engineering options, but as time passes, they see opportunities in the broader fields of management decision-making. This has been the story of so many. The vice president of Volvo was one of my students. The vice president of Flygmotor, the big Swedish company making jet engines . . . was one of my students. All over the world there are people who have had my course who have broken into the broader field of decision-making in industry. It gives me very great satisfaction.

Horace Gilbert died in 1990. This excerpt from the Horace Gilbert Oral History is printed by permission of the Caltech Archives. Copyright © Caltech Archives, 1979.



Einstein and economics

As a social scientist, Gilbert was very much in the minority at Caltech, but he relished the campus environment and counted a number of scientists among his close friends. He got to know Albert Einstein and his wife rather well when they were all living for several months at the Athenaeum. In 1931, he stayed with the couple at their home outside Berlin, scene of the photo above.

Gilbert recounts that, on one occasion, the genius behind general relativity sought to bring some order to the universe of economics.

"Einstein . . . asked me, 'What are economists concerned about? What is one of their principal problem areas?' And without hesitation I said, 'The division of income among the factors of production: land, labor, capital, and enterprise.'

"Well, he understood that. He was silent for a few moments, and then he shook his head, and he said that he was afraid that he couldn't help me.

"Which I think is an interesting observation. I believe that this is the basic difference between the exact sciences and the social sciences."

Rainfinity . . . from page 7

Bruck now have a variety of engineering and managerial roles with Rainfinity.

For Charles Fan, director of technology at Rainfinity, who came to the United States in 1989 from China and started his career in business as a paperboy while in high school in Indiana, helping start Rainfinity has been exhausting but thrilling. While developing Rainfinity's products and refining the technology, he has also been responsible for recruiting and hiring technical employees—many of whom have come from Caltech—and managing the engineering side of the business.

Once customers started buying the product, Fan also found himself flying around the country and the world at a moment's notice to install systems or assist in troubleshooting. Adding to his hectic schedule, he got married to Fang Wang, PhD '98, and they had a baby daughter in September 2000.

"I'm extremely proud of the technologies that we've created at Caltech and at Rainfinity," said Fan, who took a leave of absence from Caltech to work at Rainfinity before receiving his PhD in 2001. "Ten years from now, I hope people will see that we created something useful and solved people's problems."

Rainfinity, which had less than 20 employees in 1999, has now opened offices in England, Germany, France, and Brazil, and has more than 200 customers, including Dresdner Bank in Germany, Boise Cascade, and Qantas Airways.

The financial implications of this expansion only partly motivate Fan. "Making a lot of money is one of the excitements of the start-up experience, but it is not the only motivation," he says. "It would be a big mistake if we were driven by money in terms of company strategy. The company must remain focused on customer needs."

Indeed, given the fluid nature of the Internet, there should be a continued need for Rainfinity's products. Fan predicts that new Internet issues will arise involving security, reliability, speed of service, and versatility.

"As the Internet evolves, there will be new needs and solutions that address these needs," Fan says. "There will be holes and bugs in those solutions that create new problems. Then there will be new solutions to solve these new problems. It's a continuing cycle and a continuing process in how the Internet grows. When I came to Caltech, I was young and wanted to learn as much as I could. This is more than I hoped for, and I'm having a blast."

Clinical Micro Sensors . . . from page 9

diseases and viruses. "If a doctor is testing for strep throat or influenza, that's a simple test, so maybe we'll charge only $20 a test," he says. "For other diseases, the chips may cost more."

Another application for the sensor is helping doctors determine which drugs will work best on specific patients. "If you have a pain in your stomach, your doctor—in addition to doing an oral history and an external examination—is going to test you to see if you have signs of any genetic disorders or signs of any infection," Kayyem says. "We can test to see if you have a bacteria in you. The doctor can also test you to determine what your likely response will be to one of the different medications that he has. He's got everything from antacids to Tagamet to Pepcid to Zanax. People respond differently to those, so he's going to do a test with our chips that will tell him which drug you're going to respond best to, because it's actually all in your genes.

"We're starting to be approached by research labs that are telling us that they have patients with a particular genetic makeup, who do really well when they are put on a particular Alzheimer's medication. But others, with a different genetic makeup, didn't respond to it at all. So now, before they deliver this medication, they will want to test people first. So that's exactly what we're going to do. That's a perfect test for us."

Often, doctors prescribe many medications based on trial and error, and that can be time consuming. "It's a huge cost to society and on health care for doctors to get people on the right drugs," Kayyem says. "For example, in the case of depression, it turns out that certain doctors always give Prozac first and then wait a few months. It works on some people but not all. If not, the doctor may suspect that the patient is not taking the medication regularly, since compliance is often bad. So the doctor has to take forever before he can really figure out if the patient is responding or not. Six months may go by. The patient may be the same or may have an adverse response, so the doctor may put the patient on something else. Some people do great on Prozac, but what if you could have saved the six months? By the time of the last decision, the doctor may have sent the patient to a psychiatrist. It can take a year before a patient is on the right medications. There's no reason for this."

Kayyem says that the sensors can also be used to test for pathogens in the environment, to test for the presence of fungi and bacteria in crops, and for use in animal health applications. And Meade says that the product is being considered by NASA to test for water contamination aboard the space shuttle. Two current projects are in animal husbandry, where companies want Clinical Micro Sensors to test for a particular genetic code so that they can determine which animals to breed.

A doctor could instantly test to see if you have a bacteria in you . . . or which drug you're going to respond to, because that's in your genes.

"In livestock, the code might signal a healthy cow or a fast rate of growth or a low fat content of the meat," Kayyem says. "Companies have identified these codes and want ways to test for them. Current tests cost up to $1,000, which may be more than what the cow is worth. These projects will give us practice making chips for under $20 and will allow us to sell them at the same time that we're gaining experience learning how to adhere to FDA guidelines for manufacturing. Then we will be well positioned to address the clinical markets."

Over the next year, Clinical Micro Sensors will be perfecting its chips and sensors so that its detection system can eventually handle dozens of tests simultaneously. "Once you've got a critical mass, it becomes more likely that people will start wearing these things around on their belts," Kayyem says. "If a computer only runs one piece of software, you're not going to buy that computer. You want to buy a computer that has an operating system that allows lots of different programs to run on it.

"We're now changing from an R&D company to a manufacturing company," he adds. "We're trying to establish our chip technology as a platform in the industry by getting it in the hands of users, so that by 2002 or so, we can have a number of tests and good manufacturing practices for the FDA. And hopefully, all of these genes that everyone's been discovering will start to filter down into the healthcare community.

"We're already seeing it in infectious disease detection where DNA-based testing has really replaced antibody-based testing. All these infectious disease organisms, like chlamydia and HIV and herpes and gonorrhea, have a DNA component. So I think that by 2002, doctors will call us saying, 'I think I'm giving half my patients the wrong medication. I heard that there are genes that will tell me which drug I should be giving. Do you have a product that tests for that?' Hopefully I'll be able to say 'Yes' by then."

Tetra Tech . . . from page 2

Technical Assessment and Response Team (START) program.

"We are fully utilized. Everybody who has that type of training is currently working on that type of project, at many buildings," says company spokesman Mike Bieber.

In the wake of the anthrax threat, Tetra Tech has entered into about 50 smaller contracts to survey buildings for federal and state governments and for large companies, including General Electric. The work often calls for conducting vulnerability assessments of building security and heating ventilation and air conditioning (HVAC) systems.

Tetra Tech also operates a terrorism-response training school in Cincinnati, Ohio, for the EPA. Police and fire departments as well as federal agencies are lining up to attend, Bieber says.

The attacks of September 11 and the as-yet unsolved anthrax cases brought into sharp focus the nation's need for higher levels of bioterrorism expertise.

"It's very tough for a society to be able to evaluate and accept the true cost of security, both economically and from the standpoint of personal freedom," says Hwang. "It's going to be debated for a long time." And while the nation can take steps to ratchet up security measures, nothing is infallible, he says. "My feeling is that we can't be perfectly safe."

Hwang grew up in Japanese-occupied China during World War II, living in an atmosphere of fear, uncertainty, and deprivation. (After the war, his family went to Taiwan, where he completed high school, later moving to the United States to attend college, first at Michigan State.) Maybe that partially explains why the September 11 terror attacks, and the anthrax letters that followed, surprised but did not traumatize him.

"I'm not as terrorized as some people are by this situation. Certainly I'm very surprised. In my mind and everyone's mind, the United States is a land that is very well protected. We don't expect these things to happen. It's very much psychological warfare, and terrorist warfare."

Investors looking for shelter in an otherwise weak economy have turned to companies like Tetra Tech, which recently reported net income up about 25 percent for fiscal year 2001, to $47.2 million. Overall, it offers "specialized management consulting and technical services" in three areas: resource management, infrastructure, and communications.

Around the world, it oversees work in water resource and environmental management, and the building of roads and schools, as well as wireless communications networks. Highly variable in nature, projects include building a custom heating and cooling system for the Guggenheim Museum in Bilbao, Spain, designed by architect Frank Gehry.

"What we originally were in was resource technology," Hwang says.

"Now essentially what we are doing is working on how to enhance the quality of living for people, in terms of comfort, security, and enhancing the quality of life. That's really the thing for Tetra Tech."

RHONDA HILLBERY

On the evening of November 5, Tetra Tech biohazard workers suit up to enter an anthrax-contaminated congressional office in the Longworth House office building on Capitol Hill.

AUDIT ALERT

Audited Caltech Alumni Association financials will be available on the Association Web site as soon as they are complete. Go to http://www.its.caltech.edu/~alumni for more details.

Tech Talk

Dear Editor:

Just a few more stories about the late and wonderful Professor Feynman:

1. When I first began my graduate studies at Caltech, I would receive humorous telephone calls at my Pasadena apartment from my non-Caltech friends asking (jokingly) for such notables as Professor Gell-Mann and the "late" Professors Einstein and Millikan, among others. One day, I got a call from a woman to speak with Professor Feynman, but was unable to recognize the voice of the caller (a great imitation of an older woman, I conjectured). I played along with this one and simply took a note from her for Professor Feynman to return her call. Since there were no follow-up calls from my friends, I took the liberty of looking up Professor Feynman's number in the White Pages. To my surprise, our telephone numbers were almost identical, differing only by a single digit, the "least significant," seventh (last) digit. I will therefore always feel proud and honored that Professor Feynman and I differed by only one part in about 10,000,000 (actually, a little less), which, as my friends point out, turned out to be extremely significant!!

2. I attended my first Caltech physics colloquium and found that the lecture hall was nearly filled (I got there a few minutes before the talk). However, I noticed that the first row was completely vacant, without any notes or ropes to reserve these front-row seats. I thought, "Boy, am I lucky. I get to see my first Caltech seminar from the best seat in the house!" A minute or two later, down the stairs from the rear entrance comes none other than Professor Feynman, followed by Professors Gell-Mann, Delbrück, and other Nobel Laureate Caltech faculty, all to be seated in the first row of honor. Even though I received a courteous smile from Professor Feynman, it was a very long and embarrassing trip for me to face the entire audience as I squeamishly walked up the staircase and became a standing-room-only viewer beneath the Exit sign.

3. One day, I was at HRL Labs, formally Hughes Research Labs, attending a Feynman physics lecture (we had the honor of having Professor Feynman visit the labs periodically). During coffee breaks, he would share with us interesting (nonscientific) stories, many of which later appeared in his popular books. In one of his stories, Feynman reminisced how he loved to do physics at Caltech and then travel to Chicago to spend time there and entertain his lady friends. I suggested to him that if he were to meet a female scientist in Los Angeles, then he could simultaneously do physics with her and also entertain her, without having to commute between Pasadena and Chicago. I reasoned that in the process, he could essentially kill two birds with a single stone. He turned to me with that wonderful grin and said, "Obviously, you don't know the first thing about women!!"

—David Pepper, PhD '80

How were Techers doing in the struggling young intellectual phase of their careers, which seems interminable to me at this point?

As alumni reminisce about their Caltech experiences (see "A Scroll Down Memory Lane" and "Tech Talk" in the past two issues of *Caltech News*), one aspect of Tech life stands out in my mind. Over the past several years, starting while I was still a student at Caltech and continuing to this day, I've realized how long most Caltech undergraduates have identified themselves by the House they were in. For example, I have had a chance to encounter several Caltech alums in graduate school at Cornell as well as at academic conferences. When they find out that I am a Caltech alum, the first question that around 90 percent of them have asked is what House I was in. This includes several people who graduated thirty to forty years ago, which really indicates how much of an institution the House system is at Caltech.

It's also interesting to meet fellow Techers who have already had lots of success when I'm still a newbie. I find myself thinking curiously about how they were doing in the "struggling young intellectual" phase of their careers, which seems interminable to me at this point. Was success easy for them or was it elusive? This is quite difficult to discern merely by reading someone's list of accomplishments and the periods of time between them.

—Mason Porter (Lloydie) '98

Please send letters to hillary@caltech.edu. We welcome comments on Mason Porter's comments; past and present perspectives on your career experiences; and thoughts on entrepreneurism. Caltech News reserves the right to select and edit letters. Thanks for writing.

For the Record

In the previous *Caltech News*, former Jorgensen Scholar Bharathi Jagadeesh was incorrectly described as a faculty member at Northwestern University. She is in fact assistant professor of physiology and biophysics at the University of Washington, in Seattle.

Class Notes

1953

John Pollet
jpollet@aol.com

Bruce Scott (blscott@csulb.edu) went to the University of Illinois for graduate study and married his high-school sweetheart, Betty Moore. The couple moved to Southern California, where Bruce completed his physics PhD in 1960 at UCLA, and, after spending five years at USC, joined Cal State Long Beach as an associate professor. "I spent 31 years there, semi-retiring in 1996. I served as department chairman from 1988 to 1994 and in 1995 was named the University's Outstanding Professor and also received the Distinguished Teaching Award. I have three wonderful children, two boys and a girl, and two grandchildren (one of each). Betty died in 1996 after nearly 42 years of marriage, and I occupied my time with travel (spent a month in India), hiking (hiked the High Sierra Camps loop—40 miles—in 1997), reading, listening to music (mostly classical—have season tickets to the opera), playing a little tennis, and teaching one semester a year. In addition, I am a big rose fan and grow them for fun and for exhibition. I have won lots of ribbons and a few trophies for them! Can you believe that there are such nuts?

"Then my life took another wonderful turn. I attended my high-school-class 50th reunion, where I met a wonderful woman, Barbara Woodard Lezin, a professional violinist. We hit it off immediately and were married only two months later. It has been an amazing experience, feeling youthful romance again at my age! I have had fun and am still enjoying life. Last year I went to Alaska on a Sierra Club cruise and rented a house in Hawaii for a month. My entire family came over for a few weeks. I saw the solar eclipse in Bucharest with the Alumni Association tour. A recent hip replacement has made it possible to get back in the mountains."

Arthur Stasney (astasney@earthlink.net) has retired from working at Optical Disc Corporation and is now living quietly on the edge of Eaton Canyon, some four miles northeast of the Caltech campus.

Herb Henrikson (henriks@earthlink.net) retired after 50 years at Caltech as a Member of the Professional Staff.

1959

Phil Harriman
Jefh38@aol.com

In October of 2001, I retired from my job as program director for genetics at the National Science Foundation in Arlington, Virginia. My wife and I have moved to Northern California, where we're closer to our son and other family members. I'm planning to do some part-time teaching at nearby Sonoma State University, but right now I enjoy having the time to do something other than science.

News from a number of classmates indicates that many of us have retired or soon will retire. **Walter Cribbs** plans to retire next semester from his job as instructor at City College of San Francisco. This will allow him to devote more time to his main hobby of hiking in the area just north of San Francisco.

Frank Childs III retired two years ago after working for Aerojet Nuclear and now spends time doing Alpine ski patrolling in the areas where he's been living (Idaho and Wyoming).

Ron Forbess retired in 1994 and is still involved with Scouting, helping out as a hike advisor for his local troop in Palos Verdes, California. He recently received the Silver Beaver (appropriate for a Caltech alum) award for his contributions.

Ralph Owen has been retired for seven years. He lives in the Seattle area and enjoys hiking and traveling.

Several classmates have told me that they don't see themselves retiring soon. **Gerhard Klose** finds time to race sailboats with his wife and to take part in planning for future space missions at JPL.

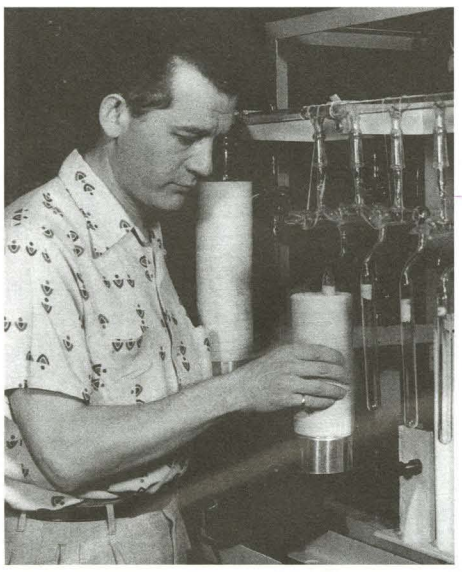
Tony Leonard has been working as a Caltech faculty member since 1985, and still enjoys teaching and doing research in computational fluid mechanics as professor of aeronautics, and serving on Caltech's freshman admissions committee.

And this from **Michael Milder**, "I'm enjoying a Corporate Fellowship at Arete Associates in Sherman Oaks, one of the better companies nobody's heard of. Its principal founder, **Frank Fernandez**, PhD '69, is better known as the recent director of DARPA. It has provided a very satisfying mix of fundamental and applied research in ocean physics over the last 25 years, which my Harvard degree in astrophysics prepared me for better than you might think. Our classified work for the Navy is giving way to movie special-effects software—the ocean exteriors in *Titanic* are 'Arete water.'

"I met my wife, Mo McGee, in a semi-pro (we took money, when anybody would pay) ethnic folk-music chorus, 'Song of Earth,' run

Obituaries

Samuel Epstein 1917–2001



Sam Epstein in 1983 (right) and (left) shortly after coming to Caltech in 1952.

Samuel (Sam) Epstein, Caltech's William E. Leonhard Professor of Geology, Emeritus, died on September 17, 2001. He was 81.

Epstein was born near Kobryn, Poland (now Belarus) in 1919. In 1927, his family moved to Winnipeg, Manitoba, Canada, where Epstein received a BSc in geology and chemistry from the University of Manitoba in 1941, and an MSc in chemistry in 1942. In 1944 he received his PhD in chemistry from McGill University.

Epstein then worked on rare gas fission products for the Canadian Atomic Energy Project in Montreal, where he met his wife, Diane Vool. He was recommended to Nobel laureate Harold Urey as an ideal research fellow to work on the oxygen isotope paleotemperature project that Urey was then initiating at the University of Chicago.

Seizing this opportunity to work with a famous scientist on a fascinating problem, Epstein moved with his family to Chicago in 1947. Within several years, he and his research team made what is widely regarded as the most significant contribution in the history of stable isotope geochemistry: they measured the temperature coefficient of the oxygen isotope exchange reaction between $CaCO_3$ and H_2O and developed extremely precise methods to measure oxygen isotope ratios of marine carbonate fossils. This allowed them to calculate what the temperatures of the ancient oceans had been more than 70 million years ago.

When geochemist Harrison Brown moved from the University of Chicago to start a geochemistry program at Caltech in 1952, he invited Epstein to join him. At Caltech, Epstein explored a variety of new scientific terrains, applying the newly developed techniques and principles of stable isotope chemistry to almost every aspect of natural science. He applied oxygen, carbon, hydrogen, and silicon isotope studies to problems of botany, plant and animal physiology, photosynthesis, biochemistry, meteorology, Pleistocene climatology, glaciology, ore deposits, and igneous, metamorphic, and sedimentary petrology. He also carried out important research on the Antarctic and Greenland ice sheets, on isotope geothermometry, on modern geothermal systems, and on the origin of meteorites, tektites, and lunar rocks and minerals.

Epstein's many graduate students and postdoctoral fellows have established their own laboratories all over the world. He is particularly remembered by his students and colleagues for his intuitive ability to investigate and solve important but seemingly intractable problems, for his refusal to become bogged down in extraneous and unimportant details, and for the rigor and precision with which he handled the data used to decisively determine given measurements

Widely recognized for his scientific achievements, Epstein was honored with the Goldschmidt Medal of the Geochemical Society in 1977, the Day Medal of the Geological Society of America in 1976, the Wollaston Medal of the Geological Society of London in 1977, and the Urey Medal of the European Association of Geochemistry in 1995. In 1976, he was elected to both the National Academy of Sciences and the American Academy of Arts and Sciences, and served as president of the Geochemical Society in 1978–79. In 1980, he received an honorary LLD from his alma mater, the University of Manitoba, and in 1997 he was elected a fellow of the Royal Society of Canada.

Epstein retired from teaching in June 1990, but continued to work a full schedule in the laboratory until just a few months before his death. He is survived by his wife, Diane; sons Reuben and Albert; and three grandchildren.

Nominate an alum

The Alumni Association is now accepting nominations for the 2003 Distinguished Alumni Awards. Alumni interested in submitting a nomination can request a nomination packet from the Association by calling 626/395-6592 or by e-mailing molly@alumni.caltech.edu to receive a packet in the mail. The deadline for the 2003 nominations is March 29, 2002.

by the late **David Helfman** '64. We toured locally and actually performed at the class reunion in 1979. Mo and I have two sons, Sam, 18, and Max, 11, who are delightful and capable kids, and evidently determined to stay as far away from science as they can. They are both enthusiastic soccer players, which partly explains why I have taken up soccer refereeing so late in life. It is a weirdly fulfilling hobby, though hard on my '38-model knees."

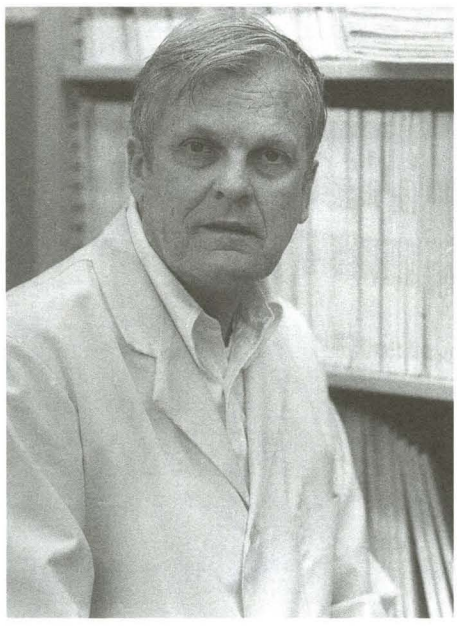
Hope to see some of you at the next Caltech reunion in Pasadena.

Alumni personals and obituaries will return in the next Caltech News.

James McCaldin 1922–2001

James (Jim) McCaldin '50, PhD '54, professor of applied physics and electrical engineering, emeritus, at Caltech, died November 23. He was 79.

A graduate of the University of Texas and Caltech, McCaldin spent the early decades of his career in industry. He worked in telemetry at Arabian American Oil Company of New York in 1952, in physical metallurgy at General Motors from 1954 to 1956, at Hughes Aircraft as head of the semiconductor materials department from 1956 to 1961, and at North American Aviation Science Center as semiconductor leader from 1961 to 1968.



Jim McCaldin, in his campus office in the 1970s.

He joined Caltech in 1968 as an associate professor of applied science, retiring in 1983.

McCaldin was a widely recognized expert in electronic materials and their device applications. He did early work on the planar construction for silicon devices and on the ion implantation doping of silicon, which have been of great practical importance.

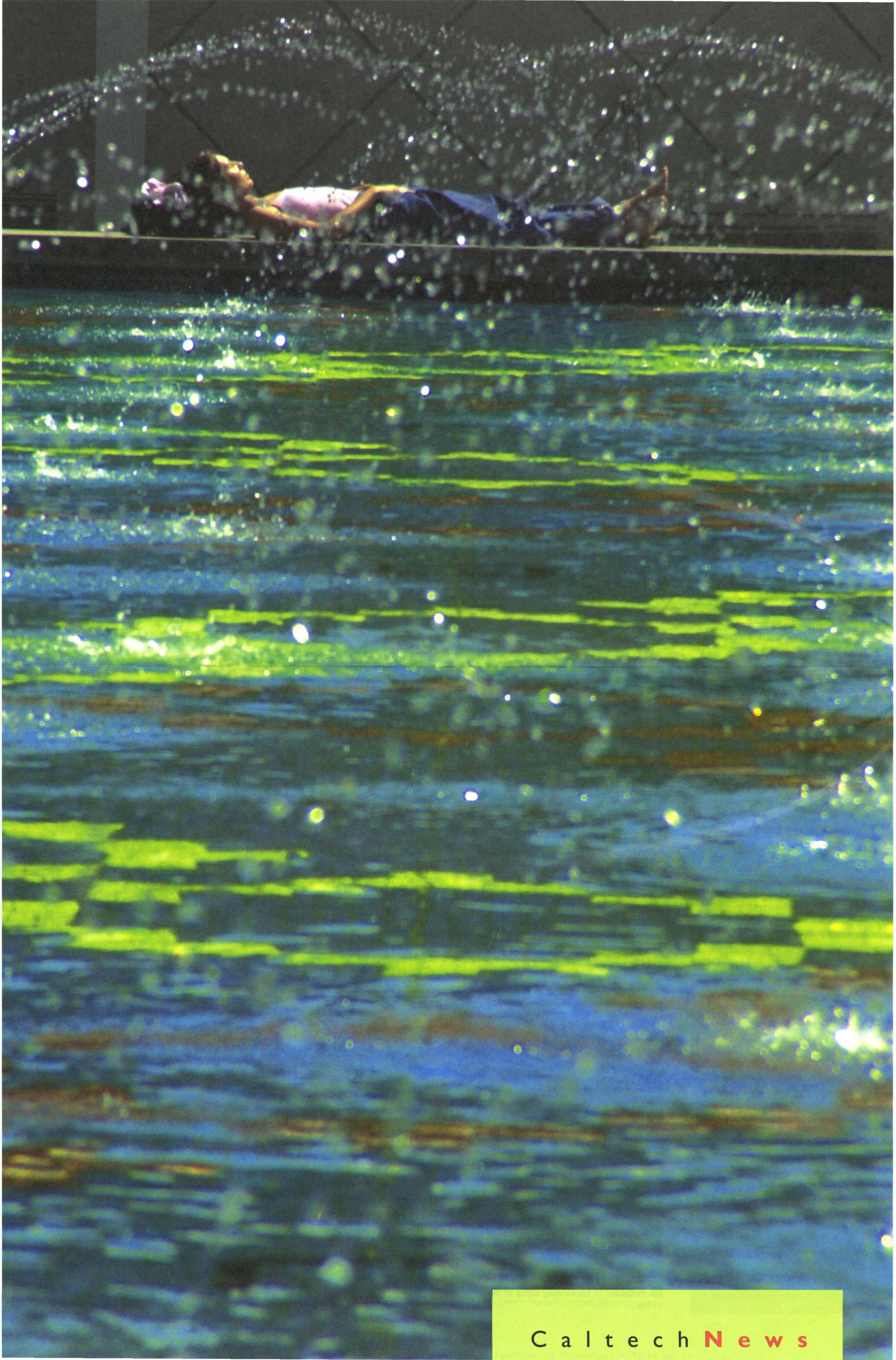
In a 1973 issue of *Engineering and Science*, McCaldin and his coauthor, James Mayer, discussed the ways in which crystal growth was revolutionizing the electronics industry, noting that the structures giving rise to metal-semiconductor contacts were smaller than anticipated—in some cases a few hundred Angstroms in thickness. "With improvements in instrumentation and fabrication skills, it may soon be possible to reduce this thickness to, perhaps, atomic dimensions," they wrote.

McCaldin was editor of the journal *Progress in Solid State Chemistry* from 1969 to 1976, and invented several patented technologies. He was a member of the American Physical Society, a former chairman of the Southern California section of the American Institute of Mining, Metallurgical, and Petroleum Engineers, and a former secretary of the Southern California and Nevada section of the Electrochemical Society.

He is survived by a brother, Roy McCaldin, of Tucson.

California dreamin'

The "gene pool" that extends from Beckman Institute toward Beckman Auditorium is a good place to soak up entrepreneurial inspiration as one considers the creative work that has sprung from these environs. The back-page poster sets the scene.



Caltech News