Left: Andrew Lange, Frances Arnold, and their sons, James, William, and Joseph, on vacation during a five-day camel trek in the Sinai Desert in 2004.

Below: If the universe is closed, then parallel lines converge and features on the CMB will look magnified (bottom left). If the cosmos is saddle-shaped, parallel lines diverge and the patterns will appear smaller (bottom right). BOOMERanG showed that the universe is almost completely flat.

ANDREW LANGE

1957-2010

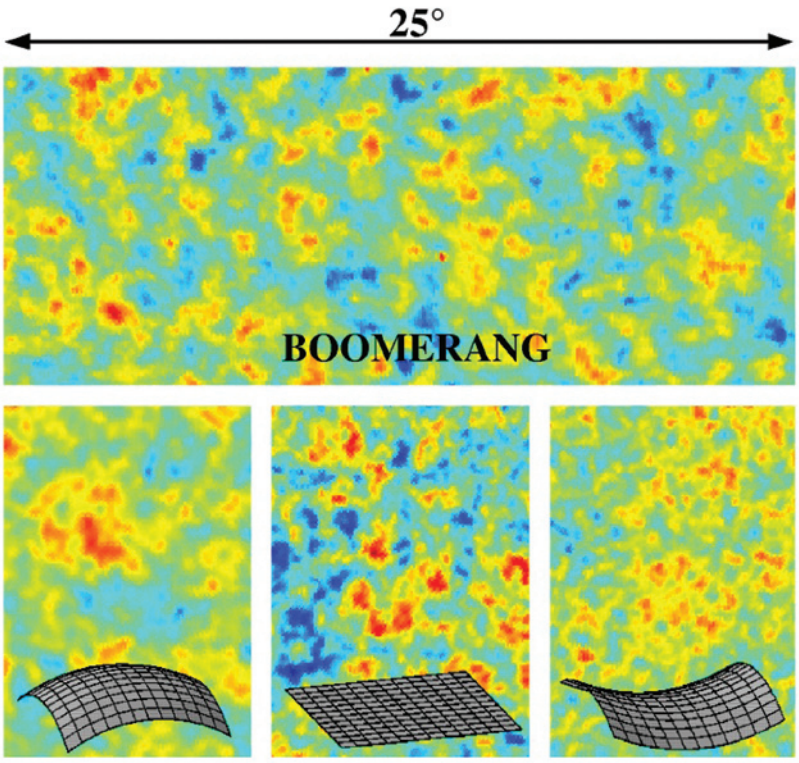
Noted cosmologist Andrew Lange, the Goldberger Professor of Physics at Caltech and a senior research scientist at the Jet Propulsion Laboratory, took his own life on January 22, 2010, shortly after stepping down as chair of the division of physics, math and astronomy. At a packed memorial service in Beckman Auditorium on May 7, friends and colleagues—interchangeable terms, in Lange's case—paid tribute to the prolific instrument builder and consummate experimentalist whose balloon-borne BOOMERanG instrument, on a 10-day circumpolar flight around Antarctica, provided the first evidence that the "inflationary theory" was correct and that the universe was flat. The experiment also independently showed that the cosmos was mostly made up not only of dark matter but something even weirder called dark energy. (For the full story of the BOOMERanG experiment, see Lange's "An Ultrasound Portrait of the Embryonic Universe," in *E&S* 2000, No. 3.)

The BOOMERanG results were announced on April 26, 2000, which Michael Turner (BS '71) of the University of Chicago called "the day cosmology changed." He noted that "BOOMERanG appeared on the front page of the *New York Times* twice," and that the second occasion "was a first for science—the first time that a spherical harmonic power spectrum has ever appeared above the fold." (This second article also included results from Chicago's own experiment, DASI, which had a number of Caltech and JPL collaborators.)

A "flat" universe—meaning that parallel lines really *are* parallel out to infinity—was the biggest prediction, and therefore easiest to prove wrong. The prediction arose from "this crazy idea theorists had that the universe underwent inflation" after the Big Bang, Turner said, "expanding in a jiffy—a jiffy, for those of you who are not familiar with the term, is 10^{-35} seconds." In that instant, the universe grew more than it has ever since, from perhaps one ten-billionth the size of a proton to about the diameter of a grapefruit at speeds well in excess of the speed of light.

Testing this prediction meant mapping temperature fluctuations in the Cosmic Microwave Background (CMB), the afterglow of the Big Bang, over the entire sky in unprecedented detail. BOOMERanG achieved a thermal sensitivity of one hundred-millionth of a kelvin and a spatial resolution of about one-third of the size of the full moon, thanks to a kind of heat detector called a spiderweb bolometer, invented at UC Berkeley while Lange was on the faculty there. In fact, one of his grad students, Jamie Bock, designed and built the first ones.

Lange earned his BA in physics from Princeton in 1980 and then spent 14 years at Berkeley—half his academic career, from grad student through postdoc to professor—before coming to Caltech in 1994. Paul Richards, his thesis advisor and, later, faculty colleague, recalled that Lange was fond of telling how, on a road trip in the summer of '79, "he stopped in cold at the Berkeley as-



A youthful-looking Lange in his dorm room on the upper floor of Witherspoon Hall at Princeton University during his junior year (1977-1978).

tronomy department and asked about research. The secretary took one look at him, decided he was a high school student, and brushed him off with the statement that only the most brilliant scholars should even consider applying to the Berkeley astronomy department. So Andrew wandered over to the physics department, where he got a better reception, and he left with a handful of graduate-school application papers." After Lange was admitted, Richards continued, his undergraduate advisor, David Wilkinson, "wrote to me to say that Andrew had written the best senior thesis that he had seen in 15 years, and that I should get him into the laboratory as quickly as possible. The Andrew Lange who walked into my office, or maybe rode his motorbike into my office, exhibited great enthusiasm, great confidence and remarkable people skills. It would obviously be fun to work with him. He wanted to work on the most difficult and most important project that I could offer, with the idea that this way, he could learn the most."

Lange had a thing for fast cars and motorcycles.

That first year as a graduate student set Lange's future course. He learned to make bolometers, working on a balloon-borne infrared mapping experiment with Steve McBride. "And by the time the balloon was ready to fly," said Richards, "Andrew had not only completed his coursework, but he had learned a tremendous amount about ballooning, about bolometers, and quite a bit about what happens to you if you pull too many all-nighters before a balloon flight."

Lange's own thesis project flew on a series of Japanese sounding rockets. On the first flight, the experiment's cover didn't open, and he had to settle for a description of the instrument for his PhD thesis, which he earned in 1987. He had better luck on the next attempt, publishing a major paper the following year describing an unexpected hump in the CMB spectrum that became known as the "submillimeter excess"—an exciting result that might have marked the birth of the very first stars, had it not later turned out to be spurious. "It was a difficult experiment," says Richards. Yet, "somehow, no matter how tough things got, he had people smiling."

In 1992, Richards and his protégé Lange entered into a collaboration with Francisco Melchiorri of the University of Rome and *his* protégé, Paolo de Bernardis, for a new series of balloon experiments. The Italians would be in charge of the telescopes, the cryogenics, and the gondolas the instruments rode in, and the Americans were responsible for the bolometers and the electronics. This evolved into MAXIMA, led by Richards, and BOOMERanG, led by Lange and de Bernardis. MAXIMA, which had the better cryogenics and higher sensitivity, was designed for relatively short flights from NASA's National Scientific Balloon Facilities (NSBFs) in the United States.; the less-sensitive BOOMERanG would compensate by staying aloft longer, operating from the NSBF at McMurdo Station, Antarctica.

Recalled de Bernardis, "After one year of detailed instrument design, we presented our parallel proposals in Italy and in the U.S. And they were both rejected. But, as Andrew stated, 'a new experiment of this kind is like falling in love. There's no way anybody can stop it.'" They tried again the following year, and the funding gods smiled. Meanwhile, Lange and his grad student Jamie Bock were in the process of moving to Caltech and JPL, respectively, where the spider-web bolometers would be perfected.

The move to Caltech coincided with Lange's marriage to Frances Arnold, now the Dickinson Professor of Chemical Engineering, Bioengineering, and Biochemistry, in March 1994. (The pair had met in Monterey, California, in 1992, when both were Packard Fellows. They separated in 2007.) The universe around us may have no center, but the blended family's three sons, James, William, and Joseph, were the center of Lange's universe. "Andrew was a very private person," de Bernardis said. "He loved his family immensely, and used any opportunity to spend more time with his sons. He carefully avoided mixing personal life and work. I treasured the rare occasions when we spoke about our lives and our expectations for the

Although the CMB variations are faint, they are quite large. Here, in a more suitably Antarctic color scheme, the CMB has been inserted to scale behind BOOMERanG's launch preparations.

future of our sons."

Lange had taken a sabbatical from Berkeley as a visiting associate at Caltech in 1993. Recalls JPL Director Charles Elachi (MS '69, PhD '71), "At that time I was in charge of space science and instruments, and I got this call from campus saying, 'There's this young researcher that we're trying to attract—do you mind spending some time with him?' So he shows up in his usual way with a big smile—very charming—and I was so taken by his vision, by his enthusiasm, that in half an hour he got a promise out of me that if he comes to Caltech, I'll fund his research. And then he left, and I said, 'How in the heck am I going to come up with all that money?' I called Virendra Sarohia [MS '71, PhD '75] at the microdevices lab, and I said, 'I have good news and bad news. The good news is I met this great scientist, the most inspiring I've ever had a discussion with, and we really need to bring him to Caltech. The bad news is, you have to figure out how to come up with $400 K.'"

BOOMERanG's maiden flight in the summer of 1997 at the NSBF in Palestine, Texas, went even worse than Lange's first rocket adventure. The flight was aborted just after launch, recalled de Bernardis, and "[we] found our payload, lying on its side, in the middle of a muddy pond used to water cattle near Waco [more than 90 miles from the launch site]. I still have the rubber boots." After several hours of recovery work in cow-scented muck, "the cryostat was still cold, and five bolometers out of the six were still alive. So we decided that we wanted to fly it again as soon as possible, and Andrew used all of his charisma" to convince the NSBF to give them a second chance. But with the balloon campaign ending in two weeks, "the following ten days were a nightmare. We had to open all the electronic and mechanical systems, clean out mud, frogs, and unidentified filth, dry them and test everything extensively. We made it, and ten days later, BOOMERanG was flown. We had our first data set, and we qualified for the 1998 Antarctic campaign."

Lange's managerial style on the project brought out the best in people, de Bernardis said. "I appreciated his capacity to listen, and to take every important decision in open meetings or teleconferences, where everybody could just say what they thought. And he was really able to instill enthusiasm in the younger collaborators."

In the process, Lange raised the bar for Caltech-JPL collaborations. "He saw how to bring the science of Caltech and the technology of JPL together better than anybody else I have known," Elachi said. "He always used to stop at JPL as he was driving from his home in La Cañada down to Caltech. We have a grassy mall with a coffee stand right in front of the administration building, so I used to regularly see him sitting there, sipping his coffee." (As Lange remarked in a video clip of a JPL presentation from 2009 that was shown at the memorial, "My usual office hours are right out by the fountain early on Wednesday and Friday mornings.") "And then half hour later, I would see a group of students and JPL people sitting around him, discussing the research they were doing. He had this very casual, very pleasant, magic way of bringing the two institutions together to do great things."

Many of Lange's grad students and postdocs would become JPL employees, and several JPL staff members came down to Caltech to get their PhDs with him. Lange mentored some 20 grad students, one of whom was William Jones (PhD '05), now a professor of physics at Princeton. Jones recalled making a trip to California to shop for grad schools, and meeting Lange "in his nearly windowless office in the crumbling basement of West Bridge. That meeting was electric. It was warm. And it was inspiring. If you're familiar with the basement of West Bridge, you'll know that these words do not at all describe the place. But it was my first experience with the extraordinary charisma of the man, and like many others who came before and after me, it left little doubt in my mind where I wanted to spend the rest of my graduate career.

"Andrew himself was driven by success and he expected as much of his students," Jones continued. "When you were able to bring an interesting result to Andrew, or evidence of progress that truly excited him, his enthusiasm was infectious. It came with a sense of validation that kept us striving to come back with more. When his expectations were not met, the contrast was stark. Andrew had little patience when he felt that you weren't realizing your full potential. And he did let you know it. In that regard, the relationship between Andrew and his students was parental." This aspect of the relationship extended beyond work. "When Andrew would ask you how you were doing, he meant it. He wanted to know how *you* were doing."

Lange attributed his mentoring principles to David Wilkinson, his faculty advisor at Princeton, Jones

said, and codified them as "Dave's Rules" for a memorial for Wilkinson, who died in 2002:

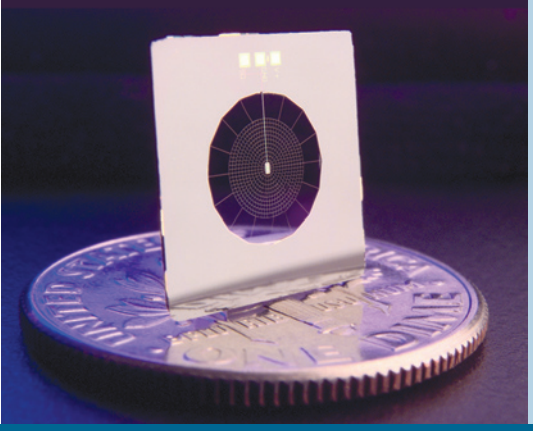
- Work on important problems—better to "fail" at something important than "succeed" at something unimportant.
- Make it look fun and easy—the students won't know any better until it's too late to turn back.
- Give the students lots of room—all of the survivors will be great.
- Keep an eye out for new technology—an important problem + great people + new technology = success.
- Keep it simple—you'll be able to move on to the next attempt more quickly.
- Be gracious—nurture everyone's potential.

In following Dave's Rules, Jones said, "Andrew encouraged his students to bite off a lot. But not more than they could chew, although perhaps sometimes they thought it was more than they could handle. The esprit de corps in the group, forged in the flames of the intense activity, was something he cared deeply about, and the enduring friendships among so many of his students are a testament to his success in this regard. Andrew, I think wisely, was not at all a micromanager. He set priorities and expectations, provided advice and resources, and then enjoyed watching his students flourish. Much of his genius, I think, was centered on identifying good people and good problems and getting them together. He nurtured everyone's potential. And that's *everyone*, from the students to the building staff. Andrew took an interest in every individual that participated in the life of the lab. Supportive, inspiring, and driven, I can say for myself and for his former students that we all owe Andrew a deep debt of gratitude."

Abigail Crites (BS '06), now a graduate student in astronomy and astrophysics at the University of Chicago, worked in Lange's lab from the beginning of her prefrosh summer. She said, "Andrew had this way of seeing something in a person, and taking a risk to give them an opportunity to flourish because of what he saw. When I came to him that summer asking for a job, I merely had the idea that physics was cool. It turned into four years of undergraduate research, and that's what really turned me into a scientist." Lange thought hard about the projects he assigned her, Crites said, picking tasks commensurate with her developing abilities and taking every opportunity to use her results to teach her new physics. "I did things as simple as peeling old aluminum tape off the BOOMERanG cryostat with Brendan [Crill, a JPL scientist], to as complicated as doing my senior thesis on testing sapphire for half-wave plate development."

Crites also commented on Lange's involvement with students beyond the lab. A rocky freshman year academically had her on the verge of leaving Caltech, but Lange "reassured me that I was just having a typical Caltech experience. So I decided to stay, but I still had my parents to tackle. They wanted me to move. Andrew made a personal phone call to my lovingly overprotective father and told him that he really believed that this was the best place for me, and the best place

Lange at McMurdo Station in Anarctica working on BOOMERanG in December 1998.



A spiderweb bolometer, with a dime for scale. The freestanding mesh is etched from the silicon nitride film deposited on the silicon wafer that supports it, and is then coated with thin gold film. The CMB photons are absorbed by the metal, and a highly sensitive thermometer, sitting like a spider in the middle of the web, registers the infinitesimal temperature rise. The web design catches nearly all the CMB radiation while using as little material as possible—the mesh only covers about 5 percent of the interior area—to avoid collecting cosmic rays and to minimize heat capacity. The spiderweb was originally designed for BOOMERanG to use in Antarctica, where the high incidence of cosmic-ray collisions was a concern.

for my career as a scientist. He went out on a limb for me, after only knowing me nine months, telling my father that he was going to be there to support me. And he really was. He was there to support me for the rest of my time at Caltech. If I ever had a hero, it was Andrew. Even four years into my time at Caltech, I approached each of our meetings with this nervous excitement. It just never wore off."

Lange had a hand in 22 different CMB projects, according to a list compiled by Turner, who said "I was astonished to find out that Andrew had his name on 300 papers. Now for a theorist, that's not uncommon, because we just make stuff up. But he actually *built* things and measured things."

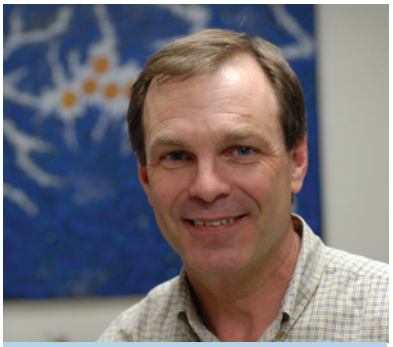
Lange's culminating contribution to cosmology is 52 bolometers, designed and developed at JPL. They are now flying in the High Frequency Instrument on Planck, a European Space Agency mission launched in May 2009. Planck will look for the so-called "B mode" polarization of the CMB that is supposed to be produced by Einstein's long-sought, but as yet undiscovered, gravity waves. "To good approximation, JPL got to do the most fun, sexy parts of this mission," Lange said in that same JPL video clip. "Now that the detectors are alive on orbit, they are officially obsolete, and we've moved on to the next technology. There's a very interesting tension: at any given time in this business, what you can do on an orbital mission and what you can do with a small experiment put together by six graduate students at the south pole has been pretty comparable. And the reason is the graduate students have technology that's ten years younger."

And there will be new technology to come. At Lange's instigation, JPL has embarked on a major initiative under Bock to build very-large-format superconducting arrays that will represent as big a jump over the spiderwebs as they did over preceding designs. Says Elachi, "[Lange's] vision was to fly these arrays on a future mission to measure the polarization. With his enthusiasm, I didn't need to be convinced. I knew that when Andy is enthusiastic about something, he's going to make some major new discoveries. That will be the legacy he has left for us at JPL."

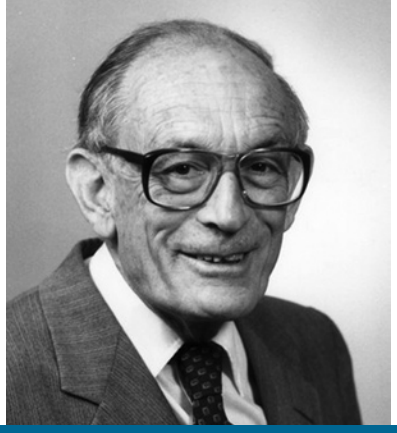
Caltech's president, Jean-Lou Chameau, announced at the memorial that Lange had been posthumously awarded NASA's Exceptional Public Service Medal—its highest award for nongovernment employees—for his leadership in JPL's contribution to the French-built High Frequency Instrument, and for the development of its detector technology. (Earlier notable awards include the 2009 Dan David Prize, which he shared with de Bernardis and Richards, and the 2006 Balzan Prize, which he shared with de Bernardis.)

Chameau called Lange's death "a personal tragedy for Andrew's fans, his family, and his colleagues here at Caltech and in the world," and "a universal tragedy, because Andrew will not be able to continue his vital work—universal both in the field of study of our universe, and in the scope of potential achievements that may now be lost," adding that "It must inspire us to recommit, as a community, to do whatever we can to help people suffering from depression. The entire Caltech community was shocked by Andrew's death and we will all truly miss his presence on campus, and the feeling he engendered that anything was possible."

John Mather, who shared the Physics Nobel in 1996 for his CMB work on the COBE satellite, and who had known Lange since the latter had taken a year off from Princeton to work in his lab at NASA's Goddard Space Flight Center, was unable to attend the memorial but sent a letter that concluded: "I remember Andy as a very young, extraordinarily bright, extremely imaginative, and thoughtful scientist. I also knew him as a person with exceptional empathy for others, who could make an instantaneous connection on an emotional level. . . . I think he would want us all to take good care of our own selves, and perhaps have a little more faith that things would work out fine in the end. I only wish he had been able to have that faith for himself. He was much loved." —*DS* E&S



Reminiscences and pictures of Lange can be found on this public Facebook page: http://www.facebook.com/group.php?gid=297676654852&v=wall Or, you can search for "Andrew Lange" on Facebook.



HANS W. LIEPMANN

1914-2009

Hans Wolfgang Liepmann was known for his wit and infectious enthusiasm that inspired generations of students. As a leading researcher in fluid mechanics, Liepmann was the Theodore von Kármán Professor of Aeronautics, Emeritus, and was the third director of Caltech's Graduate Aeronautical Laboratories (GALCIT) from 1972 to 1985. He died on June 24, 2009, at the age of 94.

"When all is said and done, his greatest contribution to Caltech and to the scientific area was the enthusiasm he brought to his work, the confidence he gave younger folks convincing them how important they were and what their work meant in the context of the aeronautical world," said Frank Marble, the Hayman Professor of Mechanical Engineering and Professor of Jet Propulsion, Emeritus, in his oral history. At Liepmann's memorial, held on January 23, 2010, John Cummings (BS '69, MS '70, PhD '73) recalled his experience as a sophomore in a thermodynamics course taught by Liepmann: "Hans gave us a test and none of us did very well. And instead of coming back and being frustrated with us, Hans said, 'I haven't taught you well. Let's try again.' I just can't imagine another Caltech professor ever saying something like that." When it came to publishing, Liepmann didn't care to have his name attached to every paper, Cummings said. "Hans didn't have a big ego," he recounted. "He wouldn't allow me to list him as a coauthor on two publications from my thesis work . . . It was, as he said, my work, not his—very different from many professors."

In his own oral history, Liepmann explained why he always emphasized teaching. "I consider teaching more important," he said. "That's really our main goal in life, if we take the professorship seriously. And also, I think, it has the more lasting influence. Whether you like it or not, most of your startling papers are going to be footnotes in handbooks in the not-too-distant future, and that goes for everybody. . . . But the teaching, the passing on of a certain style and approach to science, and also to knowledge, in a sense; that is, in my opinion, a more challenging and also more rewarding business."

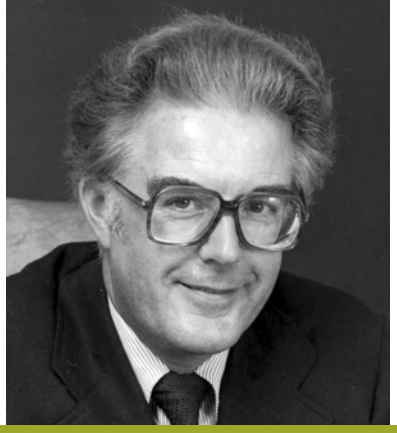
Liepmann genuinely cared for his students, always taking the time to talk to each of them and entertain everyone when he threw parties at his big white house overlooking the Rose Bowl. "If there was one thing I remembered about Hans besides being a great teacher, it was his ability to host a party," Cummings said. Years later, after Cummings graduated from Caltech, he would return with his wife and spend time with Liepmann, who always welcomed them with coffee and snacks.

He was always an advocate for the students, and they invited him to be Caltech's commencement speaker in 1982. "I think the undergraduates are really mistreated here," he said in his oral history. "I'm amazed that they don't make more noise, because they are overloaded. . . . They are always behind, always overworked, and then you get this famous burn-out; they suddenly want to take a leave. I do not think we should cater only to the best-prepared and brightest guys, but take into account the possibly deeper, but certainly slower-moving ones."

Born in 1914 in Berlin, Liepmann grew up during World War I. His father was a physician and his grandfather was a professor of surgery, and because of family tradition, he was put into a classical school, where he was forced to study Greek and Latin—even though he had decided early on that he wanted to study science. "I had a terribly tough time in school," he said. "I only kept going because I always thought, 'Boy, when I get out of here! I have to get out, I have to go to the university, and then I will do physics.'"

Just a month after Hitler came to power, his family left Germany in 1933 for Istanbul. There, Liepmann got his wish and studied physics, mathematics, astronomy, and mechanics. After graduate studies at the University of Zürich, he came to Caltech in 1939 to work with Theodore von Kármán, who recruited him after he, having downed a few too many beers at his PhD party, inexplicably blurted out that he wanted to study "hydrodynamics." Up until that party, he never drank, he said.

Liepmann hardly spoke English when he first came to the United States, which he initially tried to avoid because of its reputation as a country filled with "very rich people, very poor people, and gangsters." Of course, he discovered that "it was pure nonsense," and he soon mastered the language, although his distinctive accent stuck, becoming an endearing quality to those around him. "They loved his very strong Berlin accent," said Donald Cohen, Powell Professor of



Applied Mathematics, Emeritus. "They loved it so much that they mimicked it. Hans knew it, but he didn't mind."

Friends and colleagues fondly remembered his endless string of anecdotes and his wit. Colleague Robert Liebeck told one story that took place at the cafeteria, where Bill Se–ars (PhD '38) turned a blind corner and almost bumped into Liepmann, who was carrying a tray. "My God, I almost hit you," Sears said. Without missing a beat, Liepmann answered, "I told you not to call me that in public." According to Von Kármán Professor of Aeronautics, Emeritus, Anatol Roshko (MS '47, PhD '52), he was also known for his penchant for "the friendly insult, of which he was a master."

Roshko added that he was never politically correct. "He disliked bombast and self-importance, and here his agility with a polite insult often came in handy."

Liepmann inspired and encouraged generations of students, but his message to the class of 1982 is applicable to us all: "Remember that there is an outside world to see and enjoy. Add a fourth dimension: to know, to understand, to do—and to dream." —*MW* E&S

R. DAVID MIDDLEBROOK

1929-2010

R. David Middlebrook, emeritus professor of electrical engineering, died on April 16. He was 80.

Middlebrook passed away at his home with family by his side. Born in 1929, he was raised in Newcastle, England, and came to the United States in 1952 on the Queen Mary.

Middlebrook wrote a pioneering transistor textbook that included mathematical models to help engineers use transistors in their circuit designs; a later book focused on differential amplifiers. In 1970, he founded the Caltech Power Electronics Group, which graduated 36 PhD students, many of whom are now leaders in the power electronics field.

A distinguished international lecturer, Middlebrook was particularly noted for presenting complex material in a simple, interesting, effective, and entertaining manner. He was especially interested in design-oriented circuit analysis and measurement techniques, and his Structured Analog Design course was attended by design engineers and managers from the United States, Canada, and Europe.

Middlebrook also taught in-house analog-design courses for more than 20 years, working with companies such as AT&T, Boeing, Ericsson, Hewlett Packard, Hughes Aircraft, IBM, Motorola, Philips, Tektronix, TRW, and many others.

He is well known for his Extra Element Theorem, which describes the effects of adding a single element to a circuit. This theorem and its variations are widely used in circuit design and measurements.

Middlebrook received his BA and MA degrees from the University of Cambridge, and his MS and PhD degrees from Stanford University. He joined Caltech as an assistant professor in 1955; he was named associate professor in 1958, and professor in 1965. He became emeritus in 1998.

In 1996, the Caltech student body recognized him as an outstanding educator with its Feynman Prize for Excellence in Teaching.

"For more than 40 years, Dr. Middlebrook taught his students a way of thinking, not just a body of knowledge," the award's citation noted. "[H]e demonstrated to thousands of delighted students how to simplify complex subjects and how to marry theory and experiment. He also taught them a lesson in scientific modesty, as he constantly adopted the best solutions generated by his students."

Middlebrook was a Life Fellow of the IEEE and a Fellow of the IEE (UK). In addition to the Feynman Prize, he was the recipient of the Franklin Institute's Edward Longstreth Medal, the IEEE's Millennium and Centennial medals and its William E. Newell Power Electronics Award, and the Award for Excellence in Teaching, presented by the Board of Directors of the Associated Students of the California Institute of Technology.

He leaves behind a wife, Val, sons John Garrison and Joe Middler, daughter Trudy Wolsky, and grandchildren Chad and Teagan.—*JW* E&S