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SQUIDs Past, Present, and Future

A Symposium in Honor of James E. Zimmerman

R.L. Kautz, Editor

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R.L. Kautz, Editor
Electromagnetic Technology Division
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Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology

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Raymond G. Kammer, Director

Preface

The symposium on "SQUIDs Past, Present, and Future" was held at the National Institute of Standards and Technology in Boulder, Colorado on November 15, 1997 to celebrate the career of James E. Zimmerman. As a member of a team at the Ford Scientific Laboratory more than thirty years ago, Jim Zimmerman became coinventor of the radio-frequency Superconducting QUantum Interference Device and coined the name "SQUID." A highly sensitive detector of magnetic fields, the SQUID is limited only by fundamental quantum uncertainties, and its potential was immediately recognized. Later, at the National Bureau of Standards (now NIST), Zimmerman pioneered many applications of the SQUID, from measurement science to geomagnetism and magnetoencephalography. As a tribute to Zimmerman's long and productive career, the symposium presented talks by prominent researchers reviewing the SQUID's origin and the present state of the art.

In the tradition of a "festschrift," this symposium booklet gathers documents providing a glimpse into the life and science of Jim Zimmerman. The documents include a biographical sketch that gives the particulars of Jim's career, a banquet address in which Jim pays tribute to his mentor Immanuel Estermann, and letters from colleagues remembering Jim's lust for life.

Jim Zimmerman will celebrate his 75th birthday next February, and we might have used the event as a pretext for our symposium. The truth is that we were motivated by a less happy circumstance. Jim was diagnosed with lung cancer in June of 1996 and has been fighting for his life ever since. A series of chemotherapy treatments, ending in May of this year, were at least partially successful, and over the following months Jim regained his strength to the extent that no one would have suspected his ailment at the time of the symposium. However, Jim's cancer is by no means cured and he expects to continue chemotherapy in the near future.*

Arranging a symposium on short notice is not a simple task, and I would like to thank the many people who helped make the event a success. In particular, I thank the speakers for agreeing immediately and for following through with excellent presentations. In addition, I thank Sandy McCarthy who served as symposium secretary, Don and Alice McDonald who handled the finances, Jack Burden who video taped the symposium and banquet presentations, and Clark Hamilton and Don Sullivan who helped with refreshments. However, I surely speak for all when I say that it was a pleasure to arrange a proper tribute to Jim Zimmerman.

R.L. Kautz
November 1997

* Editor's note: Zimmerman died in Boulder on August 4, 1999, after battling cancer for three years.

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3:20	—	"Magnetoencephalography with SQUIDs" Martin Reite, University of Colorado Health Sciences Center
4:00	—	End

Attendees

George Alers	NIST, Boulder, CO
Vincent Arp	Cryodata, Boulder, CO
Samuel Benz	NIST, Boulder, CO
Antonio Bruno	Catholic University of Rio de Janeiro, Brazil
Jack Burden	NIST, Boulder, CO
Blas Cabrera	Stanford University, Stanford, CA
Wallace Campbell	National Oceanic and Atmospheric Administration, Boulder, CO
Robin Cantor	Conductus, Sunnyvale, CA
James Chervenak	NIST, Boulder, CO
Alan Clark	NIST, Gaithersburg, MD
John Clarke	University of California, Berkeley, CA
Mark Covington	NIST, Boulder, CO
Gene Dantsker	TRW, Redondo Beach, CA
Bascom Deaver	University of Virginia, Charlottesville, VA
Mark DiIorio	Magnesensors, San Diego, CA
Edgar Edelsack	Office of Naval Research, Washington, DC
Ali Eichenberger	NIST, Boulder, CO
John Ekin	NIST, Boulder, CO
Randolph Elmquist	NIST, Gaithersburg, MD
Fred Fickett	NIST, Boulder, CO
Patricia Giarratano	NIST, Boulder, CO
Ronald Goldfarb	NIST, Boulder, CO
Linda Greco–Sanders	University of Colorado Health Sciences Center, Denver, CO
Erich Grossman	NIST, Boulder, CO
Clark Hamilton	NIST, Boulder, CO
Richard Harris	NIST, Boulder, CO
Christoph Heiden	University of Giessen, Germany
Andrew Hibbs	Quantum Magnetics, San Diego, CA
Gene Hilton	NIST, Boulder, CO
Martin Huber	University of Colorado, Denver, CO
Kent Irwin	NIST, Boulder, CO
Jenh-Yih Juang	NIST, Boulder, CO
Robert Kamper	NIST, Boulder, CO
Richard Kautz	NIST, Boulder, CO
Mark Keller	NIST, Boulder, CO
Creston King	Loyola University, New Orleans, LA
Jonathan Koch	NIST, Boulder, CO
Roger Koch	IBM, Yorktown Heights, NY
Robert Kraus	Los Alamos National Laboratory, Los Alamos, NM
Jason Lee	University of Colorado, Boulder, CO

Hanqing Li	NIST, Boulder, CO
James Lukens	State University of New York, Stony Brook, NY
Ming Luo	Stanford University, Stanford, CA
John Martinis	NIST, Boulder, CO
Sandra McCarthy	NIST, Boulder, CO
Donald McDonald	Boulder Metric, Boulder, CO
John Moreland	NIST, Boulder, CO
Barry Muhlfelder	Stanford University, Stanford, CA
Martin Nisenoff	Naval Research Laboratory, Washington, DC
Ronald Ono	NIST, Boulder, CO
Ray Radebaugh	NIST, Boulder, CO
Martin Reite	University of Colorado Health Sciences Center, Denver, CO
Nicholas Rizzo	NIST, Boulder, CO
Don Rojas	University of Colorado Health Sciences Center, Denver, CO
John Rowell	Conductus, Sunnyvale, CA
David Rudman	NIST, Boulder, CO
Hiroshi Sato	Purdue University, West Lafayette, IN
Ulrich Scheven	Schlumberger–Doll Research, Ridgefield, CT
Raymond Schramm	NIST, Boulder, CO
James Siegwarth	NIST, Boulder, CO
Arnold Silver	TRW, Redondo Beach, CA
Michael Simmonds	Quantum Design, San Diego, CA
Andrew Smith	TRW, Redondo Beach, CA
Robert Soulen	Naval Research Laboratory, Washington, DC
Andrew Steinbach	NIST, Boulder, CO
Donald Sullivan	NIST, Boulder, CO
Peter Teale	University of Colorado Health Sciences Center, Denver, CO
Susanne Thomasson	University of Southern California, Los Angelos, CA
Paul Vichot	Johns Hopkins University Applied Physics Laboratory, Laurel, MD
John Wikswo	Vanderbilt University, Nashville, TN
David Wollman	NIST, Boulder, CO
Jia Hua Xiao	NIST, Boulder, CO
Yizi Xu	NIST, Boulder, CO
James Zimmerman	NIST, Boulder, CO

Sunday Camera

November 16, 1997

SQUIDish tales abound of former NIST physicist

By KATY HUMAN
Camera Staff Writer

Everyone seems to have a story to tell about Jim Zimmerman, a physicist who retired from Boulder's National Institute for Standards and Technology in 1985 and was honored Saturday for his contributions to the field of physics.

Dick Kautz, who worked with him at NIST for years, illustrates Zimmerman's creative and practical spirit with the hilarious story of a hiking trip during which Zimmerman ended up with socks on his hands and undershorts on his head.

Then there was New Year's Eve 1969, when Zimmerman stripped down to his shorts and put a SQUID near his heart.

It wasn't the slimy marine animal, however.

It was a novel instrument called a superconducting quantum interference device, or SQUID, that Zimmerman helped invent when he worked with a team of scientists at Ford Motor Co. in Dearborn, Mich., 30 years ago. Since then, SQUIDs have become an essential part of physics research and medical practices.

Saturday, researchers from around the country gathered in Boulder to recognize the achievements of the retired SQUID physicist, who has liver and lung cancer, with a not-so-optimistic prognosis.

"It's going to be a strain," said a soft spoken Zimmerman, worrying aloud about the emotional and physical burden of attending.

Zimmerman and his colleagues at Ford discovered the value of SQUIDs in the 1960s almost accidentally. "They actually became very excited about this before they realized how they worked," said Kautz, who organized Saturday's symposium and banquet.

While the team was working with small loops of superconducting metal, someone accidentally moved a steel chair that was across the room. The movement momentarily interrupted the smooth conduction of electricity along the loop.

"They said 'This is amazing! We can't believe we have something so sensitive to magnetic fields that it would detect the movement of a steel chair on the other side of the room moving,'" Kautz said.

Within a few years, the physicists began to understand the breadth of potential applications for their magnetic-field sensing device, and New Year's Eve 1969 soon rolled around.

"That's when we did the first demonstration of using the phenomenon to measure biomagnetic fields," Zimmerman said.

Kautz's story is a bit more elaborate.

Zimmerman was then a guest at the Massachusetts Institute of Technology. A colleague there, David Cohen, was in

(See FORMER, Page 3B)

Jim Zimmerman, a physicist who retired from the National Institute of Standards and Technology in the mid-1980s, sets up a SQUID designed for geophysical research.

Photo courtesy of NIST

Former NIST scientist honored for his contribution to physics

(From Page 1B)

terested in measuring the magnetic field generated by the heart. "He had built a room to shield out external magnetic fields," Kautz said, "and wanted to see the magnetic field outside the body that comes from the heart beat."

Zimmerman realized a SQUID would be the perfect measuring device. And he made himself the guinea pig. Stripping off all clothing with metal fasteners, he sat under the instrument.

By measuring the strength and pattern of the interruption of electrical conduction by the SQUID, the researchers could visualize the magnetic field produced by a beating heart.

"They created the first magnetocardiogram using a SQUID," Kautz said.

For heart research, electrocardiograms — pictures of the electrical signals from the organ measured using probes stuck to a patient's chest — however, eventually proved more practical in the diagnosis of problems.

But for studying the brain, magnetic signals work elegantly. Soon after the heart experiment, Zimmerman said, his group tested SQUIDs on the brain. Like the heart, the brain uses electricity to conduct signals. Neurons communicate with each other using minute pulses of electricity that generate extremely weak magnetic fields on the outside of the skull.

To be detected outside the skull, electricity must travel through the microscopic holes in the bone. "With electric fields, you see the signal but you don't know where it's happening," Kautz said. "But the skull is transparent to the magnetic field. It tells you where the action is in the brain. You can actually localize the response to an auditory signal ... to a few millimeters."

Marty Reite, a professor at the University of Colorado School of Medicine, worked with Zimmerman at NIST for several years developing instruments to record magnetic fields from the brain. He's using SQUIDs to figure out the differences between people with and without major mental illnesses such as schizophrenia, bipolar disorder and autism.

People with schizophrenia, for example, often have auditory hallucinations, so Reite is using SQUIDs to peer into the temporal lobe of the brain, where auditory information is processed. "We've found evidence of abnormalities in the localization of where auditory processes takes place in the brain in schizophrenic males."

He's also discovered some interesting differences between women and men with schizophrenia.

His discoveries eventually could be helpful in setting up an appropriate environment for people genetically at risk of schizophrenia "before the illness develops," he said.

The uses of SQUIDs go on and on.

Blas Cabrera, a physicist at Stanford University in California, is using them to try to detect "exotic elementary particles," particles such as magnetic monopoles and WIMPS (weakly interacting massive particles) that have never been seen but are predicted to exist by theory.

Researchers at NIST are using them as thermometers. "You use the SQUID to sense the noise in a resistor," Kautz said. "When it's hot it's noisy, when it's cold it's less so ... that's a very accurate way to get temperature."

At Saturday's symposia, people raved about Zimmerman's contributions to the field. "He's always thinking about different ways to make things simpler, easier, cheaper."

"I remember once hiking with Jim. We were up at 13,000 feet, we were crossing a ridge. It was August and it should have been warm and sunny, but it was freezing ... we were starting to get a little snow or sleet.

"Jim had just come with the bare essentials, his lunch and nothing else. At one point I said 'Where's Jim?' I looked back and he was catching up. He had his socks on his hands

"A little later, again, I looked around and said 'Where's Jim?' I looked back, and he was catching up again, and he had his undershorts on his head," Kautz said, laughing. "He's always thinking."

Added Reite: "I think he's one of the world's greatest physicists."

Reite finds Zimmerman's cancer tragic. "He of anybody shouldn't get it ... he was one of the healthiest people. He was an outdoorsman ... I never saw him smoke."

Jim Zimmerman

James Edward Zimmerman was born on February 19, 1923 at Lantry, South Dakota. His father was a farmer and sheep rancher, keeping about 300 head on land that was part of the Cheyenne River Indian Reservation. Jim grew up with two brothers and two sisters on the desolate wind-swept prairie, and spent much of his childhood keeping the coyotes away from the sheep. Jim hated grade school and high school with a passion, but during high school he became interested in radio and read everything he could find about electronics. He built receivers and transmitters using parts scavenged from broken radios and studied circuit theory until he understood how radios worked, from antenna to output amplifier.

After Zimmerman graduated from Dupree High School in 1939, he moved on to the South Dakota School of Mines and Technology in Rapid City and began to study electrical engineering in earnest. Given his familiarity with radio, the curriculum at the School of Mines was not difficult, and Jim received his bachelor of science degree "With Highest Honors" in February of 1943. He graduated a few months early owing to an accelerated schedule implemented during World War II.

Soon after graduation, Zimmerman became part of the war effort when he joined the Westinghouse Research Laboratory in East Pittsburgh to work on microwave radar. During 1943, Jim helped design transmit/receive switches and other components for 1 and 3 cm radar. In 1944, he was selected to be the Westinghouse representative to an Australian radar group being formed at the MIT Radiation Laboratory in Cambridge, Massachusetts. This group, which also included a representative from Western Electric and five from MIT, first assembled at the Radiation Laboratory, and Jim remembers briefly using the desk of Hans Bethe, while Bethe was out of town. Early in 1944, the group traveled to Australia to execute its assigned task of assisting the Australian radar effort. Although civilians, members of the group were given a simulated military rank in case of capture by the Japanese, and Jim was made a lieutenant. He worked at the Radio Physics Division of the Counsel for Scientific and Industrial Research (CSIR), in a laboratory located on the campus of the University of Sydney. While in Sydney, Zimmerman designed a bolometer for measuring microwave power and a transmit/receive switch for the 10 cm band. Also in Sydney, Jim met and married Jean McLeod, an Australian.

In May of 1945, with the end of the war in sight, Jim was recalled to the U.S., and he temporarily parted with Jean. Jim left Westinghouse when the war ended in the fall of 1945 and enrolled as a graduate student in physics at the Carnegie Institute of Technology (later Carnegie–Mellon University). His wife joined him in Pittsburgh after his first semester in graduate school. However, because they were short of money and Jean was unhappy in America, Jim dropped out of school, and they returned to Sydney early in 1946.

In Australia, Zimmerman joined the Heat Division of CSIR and became head of the photometry section, with three employees under his direction. Jim's lab was located at other end of the same building at the University of Sydney in which he had worked during the war. The photometry section was charged with routine tasks such as the calibration of standard lamps, but the group also worked on a photometer for testing blood by measuring its absorption spectrum. Jim remembers that they all donated many drops of blood to the cause. A daughter, Janet, was born to Jim and Jean in March of 1947.

Still wanting to complete his doctorate, Zimmerman returned to the U.S. in the spring of 1948 and enrolled again at Carnegie Tech. Jean followed Jim back to Pittsburgh somewhat later but was again unhappy in the U.S. and returned to Australia shortly after she arrived. Jim and Jean eventually parted ways, and Jean raised their daughter on her own in Australia.

At Carnegie Tech, Zimmerman worked under Immanuel Estermann, an outstanding teacher and experimentalist in a variety of fields. Under Estermann, Jim began to learn cryogenics, the science and technology of low temperatures. He held the Gerard Swope Fellowship during the 1950 academic year and completed his doctoral thesis in 1951 on the topic of "Heat Conduction in Alloys and Semi-Conductors at Low Temperatures." This work was later published in the *Journal of Applied Physics*.[1]

Zimmerman stayed on at Carnegie Tech as a research associate for two years after receiving his doctorate. During this time, he set up one of the first Collins helium liquefiers and operated nitrogen and hydrogen liquefiers as well, in support of the cryogenics program at Carnegie. Jim also continued to do research, measuring specific heats of metals with Howling and Mendoza[2] and demonstrating the existence of a predicted component of the lattice heat conduction that is linear in temperature, observed in high-resistivity alloys. In 1953, Jim married Ida Caporali, who became his constant companion from that time onward.

Later in 1953, Zimmerman accepted a position with the Smithsonian Institution and moved to California to become an assistant at the Table Mountain Observatory in the San Gabriel Mountains north of San Bernadino. This observatory was part of a program, begun around the turn of the century by Smithsonian director C.G. Abbott, to routinely measure the "solar constant," the energy flux of the sun corrected for atmospheric absorption. After nine months learning the ropes at Table Mountain, Jim was reassigned to the Montezuma Observatory in the Atacama Desert of northern Chile, one of the driest places on earth. Jim was the observatory director in Chile and, together with an assistant, was responsible for daily measurements of the solar constant, weather permitting. While in Chile, Jim owned a motorcycle, which he used for trips into the mountains to escape the barren landscape of the observatory. In 1955, however, after Jim had been in Chile for fifteen months, Fred Whipple of Harvard was appointed director of astronomy at the Smithsonian, and the solar-constant program was terminated.

Soon after returning to the U.S., Zimmerman received a letter from Jack Goldman, a former collaborator of Estermann, offering him a position with the low-temperature group at the Scientific Laboratory of the Ford Motor Company in Dearborn, Michigan. While he might have elected to stay on at the Harvard Smithsonian Observatory, Jim accepted

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[1] I. Estermann and J.E. Zimmerman, "Heat conduction in alloys at low temperatures," *J. Appl. Phys.* **23**, 578–588, May 1952.

[2] D.H. Howling, E. Mendoza, and J.E. Zimmerman, "Preliminary experiments on the temperature-wave method of measuring specific heats of metals at low temperatures," *Proc. Roy. Soc. A* **229**, 86–109, Apr 1955.

Goldman's offer and switched from astronomy back to cryogenics, a discipline that would be central to his career.

Beginning in 1955 and for the next eight years, Zimmerman's work at Ford was reminiscent of his doctoral thesis. He measured the thermal, electrical, and magnetic properties of a variety of metals and alloys at low temperatures. During this time, Zimmerman also published several papers on cryogenic techniques and apparatus, from a liquid-helium level indicator to a cyclic magnetic refrigerator that reached 0.2 K using a superconducting solenoid.[3]

Jim's work at Ford suddenly changed direction in the early 1960's, when he became involved in experiments related to quantum effects in superconductors and began work that would eventually make him a coinventor of the rf SQUID, or radio-frequency biased superconducting quantum interference device. The initial impetus for this work was an experiment carried out at Ford by John Lambe in late 1962 or early 1963. During experiments on nuclear magnetic resonance at frequencies around 10 GHz, Lambe noticed that the rf impedance of a fragment of indium used in an electrical contact varied periodically as a function of an applied magnetic field. The periodicity of the effect was one or two nanotesla, indicating that the device was extremely sensitive to magnetic fields. Indeed, Lambe's experiment easily detected the change in field resulting when a steel chair was moved anywhere within the room. As Zimmerman has written,[4] "This exciting observation was so puzzling that at one time I was consulted for suggestions as to the fundamental nature of the phenomenon and how to investigate it experimentally. I was able to shed not the faintest light on the subject."

The Ford group understood that the wonderful sensitivity of Lambe's experiment probably resulted from effects related to the quantization of magnetic flux, observed experimentally for the first time in 1961,[5] and possibly to superconductive tunneling effects predicted by Josephson in 1962.[6] In fact, Lambe had probably created by accident a device that was essentially an rf SQUID. While the indium-contact experiment was not well understood and could not be published, the Ford group knew that they had discovered something important and began looking for simpler ways to realize the effect.

The first practical realization of a SQUID occurred at Ford about a year after Lambe's initial experiment and was inspired by the work of John Rowell at Bell Telephone Laboratories. In September of 1963, Rowell published a paper describing the observation of a "diffraction pattern" that resulted when a Josephson tunnel junction was subjected to a

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[3] J.E. Zimmerman, J.D. McNutt, and H.V. Bohm, "A magnetic refrigerator employing superconducting solenoids," *Cryogenics* **2**, 153–159, Mar 1962.

[4] J.E. Zimmerman, "Evolution of the SQUID and its use in biomagnetic research," in *Advances in Biomagnetism*, edited by S.J. Williamson, M. Hoke, G. Stroink, and Makoto Kotani (Plenum Press, New York, 1989) p 67–72.

[5] B.S. Deaver and W.M. Fairbank, "Experimental evidence for quantized flux in superconducting cylinders," *Phys. Rev. Lett.* **7**, 43–46, Jul 1961; R. Doll and M. Näbauer, "Experimental proof of magnetic flux quantization in a superconducting ring," *Phys. Rev. Lett.* **7**, 51–52, Jul 1961.

[6] B.D. Josephson, "Possible new effects in superconductive tunneling," *Phys. Lett.* **1**, 251–253, Jul 1962.

magnetic field.[7] When the Ford group saw the paper, they realized that Rowell's result was analogous to single-slit diffraction and that much greater sensitivity to magnetic fields would be obtained if two junctions were connected in parallel by a superconducting loop, to create the analog of a two-slit interference pattern. Robert Jaklevic had already been making tunnel junctions at Ford, and, thinking that Bell Labs would pursue the same idea, worked quickly to fabricate the required structure. As it turned out, the competition from Rowell was only imagined, and Jaklevic, Lambe, Arnold Silver, and James Mercereau at Ford had the honor of inventing and demonstrating the first two-junction, dc-biased SQUID.[8]

Up to this point, Zimmerman was merely an interested observer of the work on quantum interference at Ford. However, shortly after Jaklevic *et al.* demonstrated the dc SQUID, Jim suggested a new approach to making the required junctions. At the time, Jim was working on a control mechanism for power steering in automobiles that used pressure-sensitive resistive contacts. He thus knew that the resistance of a contact between two pieces of metal is roughly $R = \rho/D$, where ρ is the resistivity of the metal and D is the diameter of the contact. This led to the suggestion that superconducting weak links of suitable resistance might be formed by small-area pressure contacts. Working with Silver, Zimmerman was able to make a dc SQUID simply by placing a bent niobium wire across a niobium ribbon, so that the wire contacted the ribbon on each edge. This simple arrangement revealed the same kind of interference pattern as the earlier thin-film devices and ushered in an era of Josephson junctions made with point contacts.[9] The wire and ribbon SQUID was also the first to use a hard, type II material and the first to allow adjustment of the junction critical current. In this case, the tension on threads tied to each end of the niobium wire provided a crude adjustment, rather like the cat's whisker of an early crystal radio.

The niobium wire experiments, which revealed a remarkably simple approach to SQUIDs, were completed in just a few days and began a highly productive collaboration between Zimmerman and Silver that would continue for the next five years. These experiments are also typical of Zimmerman's approach to science. Reducing a complex situation to its essentials, Jim often arrived at a simple approach, requiring a minimum of apparatus, that provided as much insight as the elaborate and sophisticated experiments of others. Very quickly, the experiments with wires led Zimmerman to point contacts consisting of 000–120 niobium screws that allowed a more reproducible adjustment of the junction's critical current and permitted fabrication of a variety of practical SQUIDs.[10]

The next step on the road to the rf SQUID was taken in early 1964 by Lambe, Silver, Mercereau, and Jaklevic, who investigated the behavior of a thin-film, two-junction

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[7] J.M. Rowell "Magnetic field dependence of the Josephson tunnel current," *Phys. Rev. Lett.* **11**, 200–202, Sep 1963.

[8] R.C. Jaklevic, J. Lambe, A. H. Silver, and J.E. Mercereau, "Quantum interference effects in Josephson tunneling," *Phys. Rev. Lett.* **12**, 159–160, Feb 1964.

[9] J.E. Zimmerman and A.H. Silver, "Quantum effects in type II superconductors," *Phys. Lett.* **10**, 47-48, May 1964.

[10] J.E. Zimmerman and A.H. Silver, "Macroscopic quantum interference effects through superconducting point contacts," *Phys. Rev.* **141**, 367–375, Jan 1966.

SQUID in a 9.4 GHz microwave field.[11] As in the earlier indium-contact experiments, the microwave impedance of the two-junction device was found to vary periodically with applied magnetic field, but a full understanding of the mechanism was still lacking.

The two-junction device was certainly a kind of rf SQUID, but it was unnecessarily complicated. Sometime after this work, Silver suggested to Zimmerman that an rf field could be used to modulate the flux passing through a superconducting loop with just one junction. At that point there was some confusion about whether inductive coupling would modulate the flux in the loop in the absence of a direct connection. However, Jim's electrical engineering experience immediately told him that a coil placed inside the superconducting loop would modulate flux in the loop and that the rf losses would depend on the applied field, because it determines whether or not the junction's critical current is exceeded and flux is allowed to shuttle in and out of the loop. With this insight, Jim realized that the rf SQUID was functionally similar to a class C amplifier, a circuit he had studied during his high-school radio days. Thus, the essential idea of the rf SQUID was understood only after the basic effect was observed accidentally in an indium contact and under more controlled but still complex circumstances in a two-junction device. Silver and Zimmerman published their first paper on the canonical single-junction rf SQUID in December of 1965.[12]

The term "SQUID" was not used in the early papers on interference devices, although the phrase "superconducting quantum interference magnetometer" appeared in a 1966 paper.[13] Zimmerman remembers that they began using the abbreviation "QID" for "Quantum Interference Device" but that he and Silver discussed the matter one day and agreed on "SQUID" as an appropriate acronym for "Superconducting QUantum Interference Device." After that, they used "SQUID" so routinely in conversations that the term was picked up by other groups, and it was first used in print by Forgacs and Warnick, also of Ford, later in 1966.[14]

In 1967, the SQUID group at Ford began to break up due to internal dissension. In particular, Zimmerman felt that Mercereau had gained more than his fair share of credit by giving a series of lectures around the U.S., almost one per week over the span of a year, while contributing very little in the lab.[15] The impression given to people outside of Ford led Philip Anderson of Bell Labs to suggest that superconducting quantum interference be called the "Mercereau effect."[16] In November of 1967, spurred by such difficulties,

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[11] J. Lambe, A.H. Silver, J.E. Mercereau, and R.C. Jaklevic, "Microwave observation of quantum interference effects in superconductors," *Phys. Lett.* **11**, 16–17, Jul 1964.

[12] A.H. Silver and J.E. Zimmerman, "Quantum transitions and loss in multiply connected superconductors," *Phys. Rev. Lett.* **15**, 888–891, Dec 1965.

[13] J.E. Zimmerman and A.H. Silver, "Flux entry in macroscopic superconducting rings," *Solid State Commun.* **4**, 133–136, Mar 1966.

[14] R.L. Forgacs and A. Warnick, "Lock-on magnetometer utilizing a superconducting sensor," *Trans. Instrum. Meas.* **IM-15**, 113–120, Sep 1966.

[15] J.E. Zimmerman, recorded interview, Oct. 1997

[16] P.W. Anderson, "The Josephson effect and quantum coherence in measurements in superconductors and superfluids," in *Progress in Low Temperature Physics*, Vol. V, edited by C.J. Gorter (North-Holland, Amsterdam, 1967), p 1–43.

Zimmerman left Dearborn for a position at the Aeronutronics Division of Philco–Ford in Newport Beach, California.

At Aeronutronics, Zimmerman became manager of the cryoelectronics section and continued to work on SQUIDs. During his two years in California, Jim made important progress by gaining a more complete understanding of the mechanism of the rf SQUID. In particular, he realized that its properties could be fully understood simply by using the Josephson equations (Stewart-McCumber model) to represent the weak link. The resulting publication[17] has received more citations than any of his other papers. The realization that the SQUID is well described using the Stewart-McCumber junction model also led Jim to begin thinking in terms of a mechanical analog, in which the dynamics of a junction is represented by that of a pendulum. This analogy was pointed out by Anderson[18] as early as 1963 but had been largely ignored. Later, Zimmerman and Donald Sullivan made this insight accessible to a wide audience by building pendulum models and demonstrating equivalent behaviors important in Josephson phenomena.[19]

In 1969, while still at Aeronutronics, Jim joined with John Wheatley, Olli Lounasmaa, and Jeremy Good to start a company called SHE (Superconducting Helium Electronics). John Wheatley was the organizer, but each of the founders contributed $5000 in initial capital. The idea of SHE was to manufacture both SQUIDs and helium-3 refrigerators. Zimmerman designed the first SQUID system sold by SHE, based on the published niobium-screw point-contact devices he had introduced at Ford. This device and its successors became the first commercially successful SQUIDs, and SHE (later renamed BTI, Biomagnetic Technologies Incorporated, when biomagnetic sensors became its primary product) has remained a leader in the field of superconducting electronics. However, Zimmerman dissolved his relation with SHE about two years after it was founded, due to a possible a conflict of interest with a job he had taken at the National Bureau of Standards (NBS).

The offer of a job at the NBS laboratory in Boulder, Colorado came late in 1969. Before joining NBS, however, Jim made an important detour, taking him to the National Magnet Laboratory at MIT. The trip resulted when Edgar Edelsack of the Office of Naval Research, who was funding Jim's research at Aeronutronics, suggested a collaboration with David Cohen, another recipient of ONR funds, who was attempting to measure the magnetic field of the human heart. At the end of 1969, Zimmerman and Edelsack joined Cohen at MIT to try an experiment. On the way to Cambridge, Jim stopped in Boulder long enough to assemble a SQUID, then carried his apparatus to Boston on the plane. After two days of scrambling to find a suitable Dewar and set it up in Cohen's newly completed shielded room, they were ready to make a measurement. Jim stripped down to his shorts to avoid stray magnetic fields from metallic fasteners, sat next to the magnetometer, and

[17] J.E. Zimmerman, P. Thiene, and J.T. Harding, "Design and operation of stable rf-biased superconducting point-contact quantum devices, and a note on the properties of perfectly clean metal contacts," *J. Appl. Phys.* **41**, 1572–1580, Mar 1970.

[18] P.W. Anderson, in *Lectures on the Many-Body Problem*, Vol. 2, edited by E.R. Caianello (Academic, New York, 1964) p 115.

[19] D.B. Sullivan and J.E. Zimmerman, "Mechanical analogs of time dependent Josephson phenomena," *Am. J. Phys.* **39**, 1504–1517, Dec 1971.

became the first subject of a SQUID based measurement of the magnetic field of the human heart. This was on New Year's eve, December 31, 1969. The results, published in April of 1970,[20] marked the beginning of what would become a long and fruitful association between SQUIDs and biomagnetism.

After joining NBS in January of 1970, Zimmerman became an advocate of SQUIDs for a variety of applications, including metrology, geomagnetism, and biomagnetism. Later, he would focus his attention on the development of low-power, closed-cycle refrigerators, often called cyrocoolers, tailored to cooling SQUIDs. During his fifteen years at NBS, the bulk of Jim's work was funded by contracts from the Office of Naval Research, through Edgar Edelsack.

Early on at NBS, Jim had two original ideas for improving SQUID magnetometers. First, he conceived of using the SQUID with a flux transformer having two oppositely oriented coils to measure the gradient of the magnetic field. Because a gradiometer is insensitive to uniform fields, it responds primarily to nearby sources and effectively filters out distant sources of noise. Using a gradiometer, Zimmerman and Frederick were able to record a magnetocardiogram in the absence of magnetic shielding.[21] Second, Jim had an idea for making a SQUID with enhanced sensitivity that he called a fractional-turn SQUID.[22] In general, the response of a SQUID scales as the magnetic energy Φ_0^2/L, where Φ_0 is the flux quantum and L is the inductance of the SQUID loop, and avoiding thermal noise requires $\Phi_0^2/L \gg k_BT$. Thus, a good signal-to-noise ratio results when L is small, but coupling external fields to a small inductor is difficult. Jim's solution to this problem was a SQUID loop consisting of several large inductors connected in parallel to provide ample coupling area while keeping the net inductance small. This elegant method of enhancing sensitivity has since been reinvented by several other workers.

One of the first applications of the fractional-turn SQUID magnetometer was to geomagnetic measurements, and on two occasions Zimmerman collaborated with Wallace Campbell of the U.S. Geological Survey. In June of 1973, they traveled to Chad in Africa to measure the earth's magnetic field during a solar eclipse. The idea was that an eclipse would perturb a normal ionospheric current, called the equatorial electrojet, which flows along the magnetic equator. This current should be diminished during an eclipse because the shadow cast by the moon will reduce the local ionization. However, the measurements made in 1973 at the Fort Lamy (now Ndjamena) airport were taken during a peak in the sun-spot cycle, and there was too much background noise to distinguish the small effect of the eclipse.[23]

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[20] D. Cohen, E.A. Edelsack, and J.E. Zimmerman, "Magnetocardiograms taken inside a shielded room with a superconducting point-contact magnetometer," *Appl. Phys. Lett.* **16**, 278–280, Apr 1970.

[21] J.E. Zimmerman and N.V. Frederick, "Miniature ultrasensitive superconducting magnetic gradiometer and its use in cardiography and other applications," *Appl. Phys. Lett.* **19**, 16–19, Jul 1971.

[22] J.E. Zimmerman, "Sensitivity enhancement of superconducting quantum interference devices through the use of fractional-turn loops," *J. Appl. Phys.* **42**, 4483–4487, Oct 1971.

[23] J.E. Zimmerman and W.H. Campbell, "Tests of cryogenic SQUID for geomagnetic field measurements," *Geophysics* **40**, 269–284, Apr 1975.

On another occasion, in August of 1978, Jim traveled to Alaska with Campbell in order to measure currents in the Alaskan oil pipeline induced by the polar electrojet, the effects of which are usually observed as the northern lights. They set up a SQUID gradiometer a few feet from the pipeline at a section near Fairbanks where the pipeline is above ground, hoping to see fluctuations in pipeline current correlated with the aurora. In this instance, there was not enough sun-spot activity to observe either the aurora or the desired effect.[24]

In 1975 Jim began a collaboration with Martin Reite of the University of Colorado Health Sciences Center in Denver to measure the magnetic field of the brain. Magnetoencephalography (MEG) with SQUIDs was in its infancy at the time, but Cohen had performed the first such experiment in his magnetically shielded room at MIT in 1972.[25] Jim decided that it wasn't necessary to build an expensive magnetic shield of the kind used by Cohen. Because the signals of interest are at a few hertz, it is sufficient to screen out fields in this frequency range, something that could be done using the eddy-current shielding from a 2-inch thickness of aluminum, according to Jim's back-of-the-envelope calculation. Zimmerman built a suitable room at NBS, and by 1976 Riete, Zimmerman, Jochen Edrich, and John Zimmerman had observed correlations between their MEG measurements and conventional electroencephalography (EEG).[26] Two years later, this group observed for the first time an evoked auditory response by MEG and determined that the response was from the part of the brain known to be associated with the sense of hearing.[27] For many years after this initial collaboration, Zimmerman continued to act as a consultant to Reite's research group.

In the mid 1970's, Zimmerman began to think about closed-cycle refrigeration as a means of making SQUIDs more useful outside the laboratory environment. He quickly learned that commercially available refrigerators were poorly suited to the job. Because SQUIDs dissipate very little power, Jim realized that they can be cooled with a much smaller refrigerator than is required for other applications. In addition, if the SQUID is to be used as a magnetometer, the refrigerator must be made of non-magnetic materials, a feat that had not previously been attempted. Jim guessed that a refrigerator about the size of a bicycle pump would be sufficient to cool a SQUID, and calculations confirmed his intuition. Thus, Zimmerman set about building a low-power, Stirling-cycle refrigerator made largely of plastic. In 1977, working with Ray Radebaugh, Jim demonstrated a refrigerator with a four-stage nylon displacer that achieved a temperature of 8.5 K, just low enough to operate a niobium SQUID.[28] This low-power refrigerator, often called a

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[24] W.H. Campbell and J.E. Zimmerman, "Induced electric currents in the Alaska oil pipeline measured by gradient fluxgate and SQUID magnetometers," *IEEE Trans. Geosci. Remote Sensing* **GE-18**, 244–250, Jul 1980.

[25] D. Cohen, "Magnetoencephalography: Detection of the brain's electrical activity with a superconducting magnetometer," *Science*, **175**, 664–666, Feb 1972.

[26] M. Reite, J.E. Zimmerman, J. Edrich, and J.T. Zimmerman, "The human magnetoencephalogram: Some EEG and related correlations," *Electroencephalogr. Clin. Neurophysiol.* **40**, 59–66, Jan 1976.

[27] M. Reite, J. Edrich, J.T. Zimmerman, and J.E. Zimmerman, "Human magnetic auditory evoked fields," *Electroencephalogr. Clin. Neurophysiol.* **45**, 114–117, Jul 1978.

[28] J.E. Zimmerman and R. Radebaugh, "Operation of a SQUID in a very low-power cryocooler,"

cryocooler, looked remarkably like a bicycle pump.

Zimmerman continued to work on Stirling-cycle cryocoolers for several years, but the goal of achieving reliable operation in a device suitable for cooling SQUIDs remained elusive. However, Jim's initial success prompted many others to enter the field, and the cryocooler conferences that he sponsored at NBS in 1977 and 1980 initiated a series of meetings that have grown to become the International Cryocooler Conference, a regular biennial event.

In November of 1985, at the age of 62, Zimmerman chose to retire. Jim accomplished many things of outstanding significance during his fifteen years at NBS and received a number of awards for his work. In 1975, he was awarded a Department of Commerce Gold Medal for "innovative contributions to practical precise measurements using superconducting quantum interference devices." In 1978, his work on cryocoolers was recognized with a NBS Special Achievement Award, and in 1979 he received the Samuel Wesley Stratton Award, the highest award for scientific achievement conferred by NBS, for "pioneering developments of superconducting quantum interference devices and refrigeration support systems for them, and for energetic application of superconducting magnetic sensors in diverse fields." Finally, in 1983 Zimmerman was made an NBS Fellow.

Zimmerman's career in cryogenics did not end with retirement however. Just before Jim left NBS, he began working with Ray Radebaugh on an exciting new idea for low-temperature refrigeration. In reading the paper of a Russian group headed by Mikulin,[29] Radebaugh realized that pulse-tube refrigerators, which are intrinsically reliable because they do not require moving parts at cryogenic temperatures, could be pushed to much lower temperatures than had previously been attained. Thus, Jim participated in the construction of the first pulse-tube refrigerator to achieve a temperature of 60 K, and returned to continue this work on contract after he retired. The group's initial work on pulse-tube devices[30] was sufficiently innovative that it received the Russel B. Scott Outstanding Paper Award at the 1987 International Cryogenic Engineering Conference.

In 1987, Zimmerman was induced to reconsider the SQUID when superconductivity was reinvigorated by the discovery of ceramic materials with transition temperatures exceeding the boiling point of liquid nitrogen. Returning to NBS as an unpaid guest worker, Jim began to work with pressed pellets of yttrium barium copper oxide (YBCO) fabricated by James Beall and Ronald Ono. The situation must have reminded Jim of his early work with niobium-wire SQUIDs at Ford, and he took a similar simple and direct approach. Gluing a round pellet into an aluminum frame to support the easily fractured material, Jim found that he could drill a hole through the center and then break the pellet along a ra-

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in *Applications of Closed-Cycle Cryocoolers to Small Superconducting Devices*, edited by J.E. Zimmerman and T.M. Flynn, NBS Special Publication 508 (Nat. Bur. Stand. (U.S.), 1978) p 59–65.

[29] I.A. Mikulin, A.A. Tarasov, and M.P. Shkrebyonock, "Low-temperature expansion pulse tubes," in *Advances in Cryogenic Engineering*, Vol. 29, edited by R.W. Fast (Plenum Press, New York, 1984) p 629–637.

[30] R. Radebaugh, J. Zimmerman, D.R. Smith, and B. Louie, "A comparison of three types of pulse tube refrigerators: New methods for reaching 60 K," in *Advances in Cryogenic Engineering*, Vol. 31, edited by R.W. Fast (Plenum Press, New York, 1986) p 779–789.

dius to form a loop with a single weak link. Ono remembers that Jim suddenly announced that they had an rf SQUID when he noticed that the oscilloscope trace was sensitive to the position of his chair, echoing events at Ford more than twenty years earlier. Although published accounts of dc SQUIDs made from YBCO had just appeared, the NBS group was able to claim the first rf SQUID operating at the temperature of liquid nitrogen.[31]

The advent of high-temperature superconductivity (HTS) also brought the need for a simple way of achieving variable temperatures in a range extending from 4 to 100 K or more, suitable for testing HTS materials and devices. Working with Arnold Silver again after more than twenty years, Jim suggested using a liquid helium cryostat with a valve at the top to control the rate at which helium is allowed to leak in at the bottom.[32] With feedback control, this system can achieve temperature regulation to about 1 mK, more than adequate for routine testing of HTS devices. Jim and his grandson Jason Lee, then a student of electrical engineering at the University of Colorado, made the first half dozen such cryostats in Jim's home, under contract with TRW. Later produced commercially in larger quantities, the Z-cryostat ("Z" for Zimmerman) is now a standard apparatus in HTS laboratories.

An important part of Jim's career has been the cultivation of long-term friendships with colleagues in other countries. In particular, Jim has maintained a friendship with Olli Lounasmaa of Finland since meeting him during the early days of SQUIDs. At Lounasmaa's invitation, Zimmerman visited Helsinki Technical University for extended periods on several occasions to consult and present lectures. Jim particularly remembers a visit during January and February of 1979 when he learned many of the fine points of cross-country skiing. During these visits, Jim also formed a lasting friendship with Toivo Katila, who leads an active biomagnetism group in Helsinki. Similarly, Zimmerman has been a close friend of Paulo Costa Ribeiro of the Catholic University of Rio de Janeiro since 1970 and has returned to Brazil to serve as a visiting professor for extended periods on many occasions, totaling more than two years, principally in Rio but also at branches of the University of São Paulo in São Carlos and Ribeirão Preto. More recently, in 1987, Zimmerman was the guest of Christoph Heiden for six months at the University of Giessen in Germany, under the sponsorship of an Alexander von Humboldt Senior Fellowship, and this also led to a lasting friendship.

Over his long and distinguished career in superconductivity and cryogenics, Zimmerman has proven himself many times over to be the consummate experimentalist. Using his keen understanding of both electromagnetism and thermodynamics, he has often gained quick insight into a physical problem, reduced it to essentials, and proposed a clever solution. In the laboratory, Zimmerman has a reputation for working with minimal materials, dental floss and rubber bands being essential supplies. Whatever the problem, however, you can be assured of finding a solution that is simple, efficient, and elegant if it is from the hand of Jim Zimmerman.

R.L. Kautz

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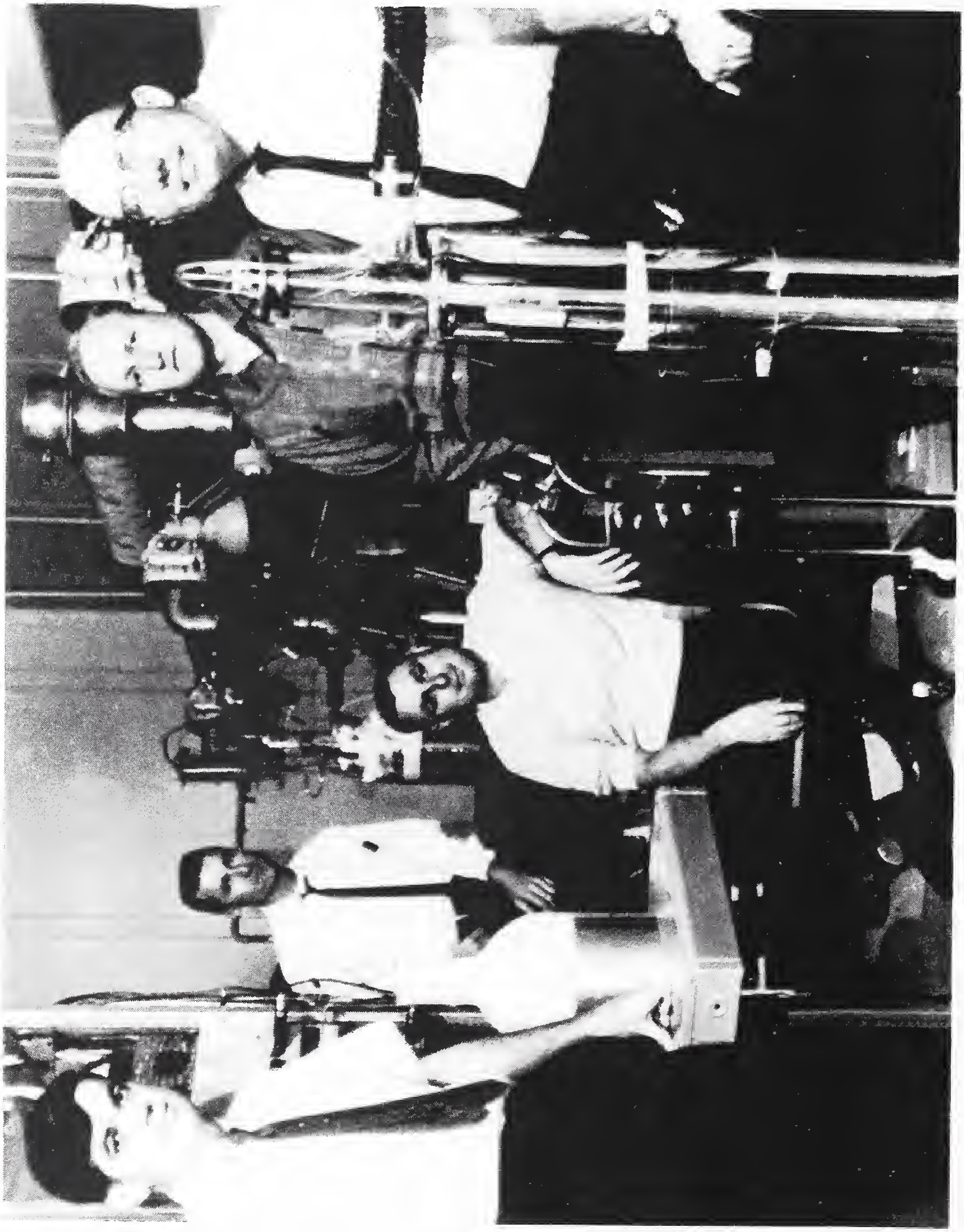
[31] J.E. Zimmerman, J.A. Beall, M.W. Cromar, and R.H. Ono, "Operation of a Y–Ba–Cu–O rf SQUID at 81 K," *Appl. Phys. Lett.* **51**, 617–618, Aug 1987.

[32] A.H. Silver and J.E. Zimmerman, "Controlling the temperature in a cryogenic vessel," U.S. Patent 5417072, May 23, 1995.

Photographs

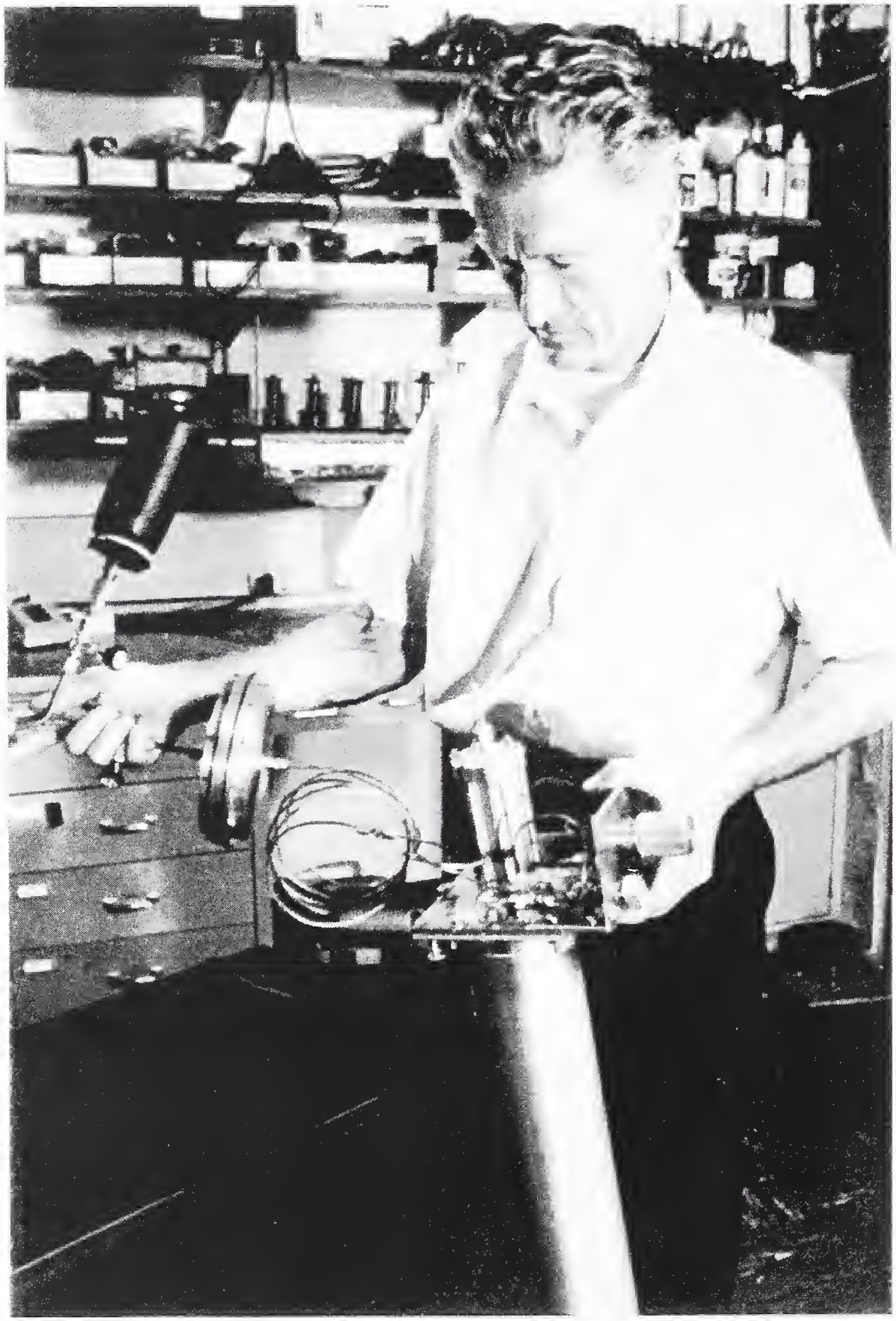


John Lambe, James Zimmerman, Arnold Silver, Robert Jaklevic, and James Mercereau at the Ford Scientific Laboratory in Dearborn, Michigan, 1964.

Edgar Edelsack, David Cohen, and James Zimmerman with the magnetically shielded room at the National Magnet Laboratory at MIT in Cambridge, Massachusetts, *ca.* 1970.

James Zimmerman at Boulder, Colorado with a fractional-turn rf SQUID. The pin vise holds a 000-120 niobium screw that forms the point contact.

James Zimmerman with a SQUID magnetometer at the National Bureau of Standards in Boulder, Colorado.



James Zimmerman with a Stirling-cycle cryocooler at the National Bureau of Standards in Boulder, Colorado.

Immanuel Estermann

"Where Credit is Due"

I hardly know what to say on an occasion like this, but what I can do is to pay belated tribute to the man who was responsible, more than any other single individual, for my being here in this particular context.

At the end of World War II, I was accepted as a teaching assistant and graduate student at Carnegie Institute of Technology, in Pittsburgh, Pennsylvania, with a stipend of $1500 per year. At that time Frederick Seitz had been made head of the Physics Department and had brought with him a number of young professors to augment the "old guard" who had been there since before the war. Seitz was a recognized authority on the modern theory of solids.

I was soon taken on by one of the young professors who was in the process of setting up a diffraction grating for high-resolution spectrometry, perhaps on color centers in alkali halides, a subject on which Seitz had done theoretical work. I was not there very long. It was a time of serious personal difficulties for me, and after a year I had to quit and get a job. I was away for two years, and then, in 1948, I made a long-distance call from Los Angeles and asked if I could come back and take up where I left off. So I showed up in Pittsburgh and had an interview with Fred Seitz. Fortunately, the young professor I had previously been connected with was no longer there, and in reviewing the options Seitz told me of an older professor, Immanuel Estermann, who was looking for a student to take over a project which had been started by another student who had gone off to work on the design of the Carnegie Tech synchro-cyclotron. Seitz gave Estermann high praise, but there was a warning. He was variously described by Seitz and others as irascible, crusty, hard to get along with, or words to that effect.

Estermann had been at Carnegie Tech since 1933. He was born in Berlin in the year 1900, making him four years younger than my father, and so he was 48 when I returned to Carnegie Tech in 1948. He had received a Ph.D. in 1922 from the University of Hamburg, and was appointed Privatdozent of physical chemistry in 1929. A Privatdozent is a lecturer without pay who is permitted to use the university facilities and support himself on whatever his students are willing to pay. This of course was at the height of the Great Depression, and in Germany during those times things were bad beyond belief.

Except for a year or two in Rostock as a post-doc, and a year at Berkeley on an International Fellowship in 1930–31, Estermann remained at Hamburg until 1933. He then accepted a position at Carnegie Tech, and was made full professor in 1938. From 1950 to '55, he held the position of Division Director at the Office of Naval Research in Washington, D.C. From '55 to '64, he was in the London office of ONR, where he was made Scientific Director in '59. In 1964, he emigrated to Israel and was Professor of Solid State Physics at the Technion in Haifa.

Much of the information I have about Estermann is from material that he himself has written, although not necessarily about himself. One article is a short biography of Otto

Stern in the Dictionary of Scientific Biographies. Another article is essentially the first part of a three-part book on The History of Molecular Beam Research which he began writing in the early 70's and which was interrupted by his death in 1973, at the age of 73.

Beginning in 1921, Estermann published a series of papers on thin metal films, low-temperature and high-vacuum techniques, molecular beams, electric dipole moments of organic molecules, and other topics. He also taught a course in nuclear physics at a time when there was barely enough known for a one semester course. Until the early 30's, most of these papers were under his name alone, indicating that his grasp of fundamental principles and talent for new experimental methods in physics began at an early age. Clearly the most influential of his collaborators in these times and later was Otto Stern.

Otto Stern was a theoretical physicist who spent the years from 1912 until August 1914 as a post doctoral associate of Albert Einstein. To quote Estermann, Stern "was less attracted to Einstein because of his spectacular achievement in formulating the theory of relativity than by his work in molecular theory, particularly [on] the explanation of ... the temperature behavior of the specific heat of crystalline bodies .... But what Stern really learned from Einstein was the evaluation of the importance of current physical problems, which questions to ask, and what experiments should be undertaken .... Stern's work during the years 1912–1918 was concerned with various problems in statistical thermodynamics."

That phrase "Stern's work during the years 1912–18" is interesting, because from beginning to end of WWI, Stern was a private and later noncom in the German army. One of his papers during the war was published in 1916 under the "dateline Lomsha, Russian Poland, probably the only scientific paper that ever originated in this small town. Stern was stationed there ... as a weather observer .... To escape boredom he tackled the tedious problem of calculating the energy of a system of coupled mass points—doing all the computations in longhand." In 1920, in Frankfurt, Stern enlisted the aid of Walther Gerlach to do the molecular-beam experiment which proved the reality of space quantization. In 1921, Stern, at age 33, received his first academic appointment at the University of Rostock, where he was joined by Estermann, who had just received his degree from Hamburg . In 1923, Stern was offered a position at Hamburg to build and direct an Institute of Experimental Physics. Estermann went with him, although it is not clear that he was offered any financial support, since he only became a Privatdozent in 1929.

Estermann writes that "The period 1923–33 marks the peak of Stern's contributions to physics .... He set out to organize a laboratory ... for molecular beam research and to devise a program for conducting this research, which was executed, to a large degree, with remarkable success. The first part of the program was concerned with ... developing new and improved techniques; the second, with demonstrating the wave nature of particles; and the third, with measuring the magnetic moment of the proton and deuteron." Estermann played a major role in all three parts of Stern's program.

The wave nature of heavy composite particles, namely atoms and molecules, was demonstrated by Estermann and Stern in 1930, proving that the wave-particle duality, already demonstrated for electrons by Davisson and Germer in 1927, was valid for matter in all its forms. In 1931, Estermann, Frisch, and Stern used a velocity-selected beam of He atoms diffracted from a LiF crystal to confirm the de Broglie formula for wavelength as a function of velocity with an accuracy of about 1%. For the non-technical I might explain that the wavelengths associated with moving atoms and molecules are analogous to the wavelengths associated with the spectrum of the colors of the rainbow. The spectrum of iridescent colors that are reflected from the feathers of many birds (swallows, humming birds, ducks, even magpies) when seen from certain angles in bright sunlight, are analogous to the wavelength spectrum inferred from the diffraction of those He atoms scattered by the LiF crystal.

The third part of Stern's program at Hamburg, carried out during 1932 and part of 1933, was the measurement of the magnetic moments of the proton and the deuteron, and later also of the neutron. To quote Estermann, "[this] part of Stern's program had a completely different outcome. Dirac had promulgated a theory according to which the ratio of the magnetic moment of the proton to that of the electron should have been the same as the inverse ratio of their masses. This theory was believed so generally that [we] were told more than once that [we] were wasting [our] time .... As [Wolfgang] Pauli remarked, 'It is very laudable that you are making such an effort .... Don't you think that is really superfluous, since we know perfectly well what the result will be?'"

The experimental and theoretical difficulties involved in these measurements would take hours to describe. Sometime in 1932, they threw both theory and their experimental setup out the window. When they succeeded in improving their experimental techniques in 1933, the results of their measurements were wildly at variance with theoretical expectations. The magnetic moment of the proton was nearly three times the value that Pauli knew "perfectly well" and the neutron also exhibited a magnetic moment, contrary to expectations. What is interesting about these difficult measurements, done in about a year and a half, is the increasing pressure and uncertainty under which they were carried out. As Estermann has written, "In June, 1933, I was notified, together with other Jewish faculty members, that my tenure would be terminated as of 30 September 1933, and Stern, who, having served on active military duty during WWI, was as yet exempt from the Nürnberg Laws,* tendered his resignation .... This is the end of the story ... in the Hamburg laboratory .... The center of effort on nuclear magnetic moments moved to Columbia University in New York where I. I. Rabi, who had spent a postdoctoral year in Hamburg in 1929, introduced new and powerful molecular beam methods and founded a school which was able to achieve spectacular results in the coming years."

Estermann and Stern accepted faculty positions at Carnegie Institute of Technology "where they began to build a molecular-beam laboratory ... but the means put at [their] disposal during the depression years were rather meager. The momentum of the Hamburg laboratory was never regained, although a number of significant papers originated at Carnegie." Stern received the Nobel Prize in 1943 for his work developing the molecular beam method, with specific mention of the measurement of the magnetic moment of the

* Writing in the early 70's, nearly 40 years after the fact, Estermann was mistaken regarding the Nürnberg Laws, which were passed in 1935, revoking Jewish citizenship and prohibiting marriage between Jews and non-Jews. In 1933, the strategy was to deny Jewish academics and other professionals the means to make a living and force them to leave the country, clearly a case of a country shooting itself in the head. As a footnote to this footnote, in 1956 Estermann was appointed Professor Emeritus at Hamburg where he had been thrown out 23 years earlier.

proton. He retired from Carnegie Tech in 1945 or '46 and died in 1969 at the age of 81. Estermann published many significant papers on a variety of subjects while at Carnegie Tech, especially in the post-war period with the influx of graduate students and support from the Office of Naval Research and other agencies.

I joined Prof. Estermann as a graduate student in mid 1948, and began building a liquid-helium cryostat which he had designed and for which most of the constituent parts had already been machined. It was a fairly complicated apparatus comprising a high-pressure helium container and an attached low-pressure reservoir for liquid hydrogen enclosed in a metal vacuum chamber, all immersed in a bath of liquid nitrogen inside a glass vacuum vessel about a meter long. There were a number of stainless-steel tubes the size of hypodermic needles up to a half-inch or so in diameter, and innumerable silver-brazed and soft-soldered joints, plus a Wood's-metal joint to seal the experimental chamber to the liquid-helium reservoir. I assembled the cryostat within a few weeks and was on the way to carrying out my thesis project, which was a study of the mechanisms of heat conduction in metals and semi-conductors at low temperatures. Mine was the first research to be done at Carnegie Tech at liquid-helium temperatures.

Within a year it was deja vu all over again. I told Estermann that I would have to leave and get a job. I felt that I had no alternative, but he saw it differently. Without a murmur he hired me as a research assistant at a salary of $3600 a year. It turned out that my financial woes became inoperative within a few months, and I told him that I no longer needed the money and that I could go back to graduate student status with the stipend of $1500 for ten months. Again, Estermann saw it differently, and so I remained on salary during my remaining time at Carnegie.

In fact from the beginning I performed a number of services unrelated to my own project. It was my responsibility to maintain and operate an army surplus nitrogen liquefier and also a small hydrogen liquefier about once a week, both for my own purposes and in support of several other graduate students who had projects involving measurements at low temperatures. At one point I was given the job of sorting and distributing a wholesale order of thin-walled low-conductivity metal tubing to about ten different universities which, like Carnegie Tech, were getting into experimental research in low-temperature physics. Later, when we bought the first commercially made helium liquifier, that too was mine to maintain and operate. And, when one of Estermann's graduate students gave up his molecular-beam project, I tried to carry on with it.

Nothing much came of the latter, partly because of my lack of time, but mainly because Estermann himself left Carnegie Tech in 1950 and joined the Office of Naval Research. He made frequent visits to see us, his graduate students, through our oral exams and our Ph.D. awards in 1951.

Regarding Seitz's warning about Estermann, during our two years of almost daily contact and his subsequent visits after 1950, I experienced not one single instance of his legendary irascibility, although he must have noticed that quality in me once or twice. I think we were united by common or at least compatible purposes, and I was awed by his experimental expertise, his profound understanding of modern physics and his lectures on Atomic Structure and Spectra, Statistical Mechanics, and Thermodynamics, and his precise and grammatical use of the English language. In my opinion he was not given the recognition and support he deserved at Carnegie Tech, and two or three times he expressed to me his bitterness at having lost out in a competition for space with the newcomers of the Seitz era.

Immanuel Estermann was surely the primary influence in setting me up for a highly rewarding career in cryogenics and solid state physics. It was not long afterward that I began a long-term, scientific collaboration and friendship with Arnold Silver and his family during the last 40 years, with Edgar Edelsack of ONR since 1968, and with Don Sullivan of NBS since 1970, and with Marty Reite of the University of Colorado Medical Center since about 1973. I appreciate my friends Hiroshi and Kyoko Sato being here. Hiroshi and I worked together for some time back around 1960.

It was Edgar Edelsack who brought me and David Cohen together for one of the shortest collaborations on record, mostly on New Year's Eve of 1969, when the three of us demonstrated the use of the SQUID magnetometer for biomagnetic measurements. This demonstration opened up the biomagnetic community from a total of three people, worldwide, to the hundreds or perhaps thousands who are currently engaged in studies of the brain, the heart, and other biological sources of magnetic fields.

One of the great rewards of having lived through the golden age of physics is the privilege of working with people in various parts of the world. These include my colleagues Toivo Katila and Olli Lounasmaa in Finland where I was invited for extended visits on several occasions. Chris Heiden of the University of Giessen sponsored me for a Humboldt Fellowship several years ago. The Humboldt Foundation must be the greatest organization on earth for promoting a worldwide fellowship of scientists in a wide variety of disciplines. One of the closest of all my long-term colleagues and friends is Paulo Costa Ribeiro of the Catholic University of Rio de Janeiro. Since 1970 I have spent a total of two years or more in Brazil. Paulo could not be here, but one of his most outstanding students Antonio Carlos Bruno is here. Antonio Carlos and I have worked together intermittently for ten years or so, and he is now on the faculty at the Catholic University. And there are many others. I thank all of them, and I thank all of you for being here.

J.E. Zimmerman

Letters

Universidade de São Paulo
Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto
"Campus"de Ribeirão Preto

Ribeirão Preto, October 21, 1997

Dear Colleagues:

I am very pleased to write some memories about our friend Jim Zimmerman. I met Jim for the first time in 1988 when I was starting my activities in biomagnetism. Jim was already a frequent traveler to Brazil collaborating with Prof. Paulo Costa Ribeiro and his group to perform research activities in biomagnetism in the city of Rio de Janeiro. This time Jim was there participating in the *Latin American Conference on High Temperature Superconductivity*, held in Rio de Janeiro from 4 to 6 of August 1988, and trying to put to work his newest idea on how to build a SQUID made out of newly discovered high critical temperature material. Because of the look of these materials he used would refer to them as "cinder materials" and as a consequence we were doing some sort of Cinderella work ! This was just a little sample of his always fine sense of humor. During this week we were rushing from the Conference in Superconductivity and the laboratory, located at the Federal University some 30 miles away, to work on this project. I was a low level beginner in this game and very curious about how he would test his ideas. I remember also that most of the questions I asked were never answered in a straight way. I was kind of annoyed after some time, but as I met Jim other times in the future I started to appreciate his way of answering questions with other questions that always led us to a deeper understanding of the underlying physics rather than just a quick, well wrapped answer by the expert.

Then, in 1990 during one of his visits to Rio de Janeiro he came to Ribeirão Preto to spend a few weeks helping our group in many aspects. We needed to put our single channel SQUID system to work, ambient noise was very high, and many other problems were plaguing the laboratory. Jim's presence was a blessing ! In a very short time, and with hard work (he even gave up long hours of tennis playing with his brother to stay at the laboratory !), he was able to help us in many aspects and when he left we were acquiring data and the students were confident of their work.

After this our friendship strengthened, he visited our home several other times, we were always corresponding through this wonderful e-mail and meeting in Congresses and Conferences. Then, I got to know other aspects of his character, his concern for human kind and his "joye de vivre". He is truly a humanist person. Through our exchange of ideas I must confess that I learned many things about how the world is being shaped. Every moment in his company was rewarding. In one of his visits my family and I went hiking in a small canyon near our place and Jim at the peak of his age surpassed everyone. He was very happy to be in the country in contact with nature and exercising.

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14040-901 - Ribeirão Preto - SP
Brasil

By all the qualities I know of Jim, including these small reminiscences, I believe that this Symposium is an excellent opportunity to honor a great scientist that contributed so much to make measurements of low intensity magnetic fields an easy thing !

With all the best wishes,

Oswaldo Baffa, Professor
Departamento de Fisica e Matematica
Universidade de Sao Paulo
Ribeirao Preto, Brazil

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To:

Dr. R. L. Kautz
NIST Boulder
Boulder, CO 80302
USA

3rd November, 1997

Dear Dick,

we became aware only a few days ago of the Symposium "SQUIDs Past, Present, and Future" organized for the coming November 15th in honor of Jim Zimmerman.
Due to the little time left before that date, we regret it will not be possible for any of us to join the meeting. This is a great pity as we are very fond of Jim for reasons that go beyond his legendary scientific accomplishments. Jim represents a nowadays rare figure of scientist capable of transmitting love and interest toward science by the strength of intelligence, creativity and intellectual curiosity. The interaction with him was one of the most enjoyable notes of our stays at NIST Boulder. We all benefited from his ideas, intuitions and exceptional qualities as an experimental physicist.
Please, forward our warmest greetings to the other scientists attending the Symposium and the note below to Jim Zimmerman.

Ciao Jim,
un saluto caloroso e tanta riconoscenza da noi e dagli altri colleghi Italiani che ti conoscono.
Un abbraccio alla cara Ida.

Sandro Barbanera
Pasqualino Carelli
Matteo Cirillo

Sandro Barbanera, Pasqualino Carelli, Matteo Cirillo

James Zimmerman's First Carnival in Rio and the US$ 1.00 SQUID

Dear Colleagues,

For a Brazilian there are some events and commemorations that have to be respected as if they were Holy Days, or even more than that, days that even the Creator should once more stop and rest, just like Sunday: the final of the Soccer World Cup, one's birthday and ... yes! Carnival. Four days that the country literally stops. No work, no commitments but having fun or resting. But the Carnival of 1978 was not like that. As God was duly resting in those days, someone apparently more persistent than Him managed to convince a few Brazilians working at the Department of Physics of the Catholic (!!!) University of Rio de Janeiro to go back to the lab during those four days. The person behind this miracle was Jim Zimmerman.

At that time we were starting to study the literature on biomagnetism and one paper called our attention: this paper had some key words that already belonged to the sphere of activities in the lab: SQUIDs, Dewars and magnetic fields. We decided to repeat the experiment. The challenges were many: the Dewars we had were all metal and to measure external magnetic fields they would need one made with glass or fiberglass; the distance between the inner Dewar and the outer one should be the minimum possible in order to detect the signal coming from one's chest; no shielding at the coils could be used to prevent noise, and above all, nobody had ever in that lab had the slightest idea of how to face this obstacles! Only one person could help them: the author of the article, Jim. His brother was by then working at the University of São Paulo and after a contact, to both the lab team's happiness and distress, he informed that Jim would be coming soon to Brazil ... and could only visit Rio during Carnival!!!

Everybody rushed to start the new program: build a nonmetallic Dewar according to the minimum specifications that could be gathered from the paper, build the detecting niobium coils and have everything ready by Carnival. Friday before Carnival everything was ready for the first Helium transfer which was to happen on Sunday or Monday (Carnival Holiday is from Saturday until the next Wednesday) when Jim would arrive. Everybody was curious and anxious. Curious to see the results, anxious fearing a disaster in the presence of a scientist that by then was pretty recognized as a successful one in his field. Jim arrives and he, like a simple drop of water on clay, dissolves our fears. The secret? His humbleness, his dedication and friendship towards all. He opened wide his 'book of inner knowledge' and offered it to all. No secrets, no reason to hide anything.

The first step was given. Since then, Jim made about 10 trips to Rio, lasting from a few weeks to a couple of months, in all times of the year, but Christmas. He helped us to build Dewars, cryocoolers, magnetic shields, all with very little technology but lots of Physics. Last but not least, he taught us to build SQUIDs in a design that even the simplest machine shop would be able to do it. Yes, the old two-hole symmetric SQUID still works in our lab for cardiomagnetic measurements and for nondestructive testing of metallic structures. The performance – comparable with the commercial RF SQUIDs; the reliability – total, since if anything goes wrong with the junction we have just to make a new one; the cost – about US$ 1.00.

Antonio C. Bruno
Paulo Costa Ribeiro
Iradj Eghrari

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November 10, 1997

Dr. James Zimmerman
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80303

Dear Jim,

It is a great pleasure for me to attend the *Symposium SQUIDs Past, Present, and Future* in your honor this Saturday, November 15, 1997. I was first introduced to your work on SQUIDs while I was a senior at the University of Virginia working in Bascom Deaver's laboratory. I was immediately fascinated by the macroscopic quantum phenomena exhibited by SQUIDs as described in Richard Feynman's third volume of *Lectures on Physics*. Bascom convinced me that going to Stanford and working in Bill Fairbank's group was the right thing to do. For my thesis research, I set out to improve the measurement of h/m_e using a rotating superconducting ring. The first such measurement had been made by yourself and Jim Mercereau in 1965 by rotating a SQUID. An elegant demonstration of the London moment accurate to a few percent. Bill Parker and Mike Simmonds improved on your measurement at the 10^{-4} level in 1970. As an Assistant Professor at Stanford, my group, Janet Tate, Sue Felch, John Anderson and myself, finally completed our own h/m_e at the 10^{-5} level in 1987. Our measurement showed a deviation from the free electron mass for the first time. I hope to return to these measurements to better understand the significance of the Cooper pair mass in different superconductors.

Over the years, I continued to be impressed with your contributions to SQUIDs, with your multiple hole SQUID in analogy to a multi-slit interference pattern for increasing the sensitivity. In addition, your contributions to refrigeration have been very important. Simple refrigerators continue to be the important enabling technology for SQUID applications. Most impressive was your return from retirement to build the first SQUID with a high transition temperature superconductor. Again an elegant mechanical design proved successful in demonstrating that the physics of SQUIDs was directly applicable to these new exotic high temperature superconductors.

I wish you well in your retirement, although I fully expect you back in the laboratory the next time you can make an important contribution. Thanks for the memories.

Sincerely,

Blas

Blas Cabrera
Professor of Physics
and Chair of Physics

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO | SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF PHYSICS
John Clarke
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BERKELEY, CALIFORNIA 94720

November 13, 1997

To: Symposium in Honor of James E. Zimmerman

Dear Colleagues

When I first became a graduate student in the Cavendish Laboratory in the Autumn of 1964, my thesis advisor – Brian Pippard – gave me a project requiring me to detect voltages much smaller than any that had previously been measured. He said "there's been some very interesting work in the last year or two with this new idea of 'Josephson tunneling' and why don't you go and read all the literature." Well at the time, the literature ran to something like six papers! I started off reading the famous 2-page Physics Letter by Brian Josephson, which I did not understand at all. I then turned to the experimental papers, starting with those by John Rowell. These were much more straightforward, and I thought that the results were quite beautiful. However, John's work relied on thin films, for which at the time the Cavendish had no capability. But then I moved on to papers by Zimmerman and Silver, who used bits of niobium wire and bulk niobium, which I felt that we could deal with. I begged a foot of niobium wire and in the space of a week or two repeated several of the configurations suggested in the Zimmerman and Silver paper. However, I wanted to try something a bit different. One day over tea, a fellow graduate student, Paul Wraight, suggested I try freezing a blob of solder on a piece of niobium wire, on the grounds that the natural oxide layer of the wire should act as a tunneling barrier. To cut a long story short, it worked like a bandit! Fortunately, the experiment actually worked the very first time I tried it, because I am sure I would have never tried such a crazy idea a second time! This led to the development of the SLUG, and it enabled me to measure the then unprecedentedly small voltage of 10 fV $Hz^{-1/2}$.

Well, Jim and Arnie – you introduced me to this whole field, and it has given me immense satisfaction for the last one third of a century. You got me started because you did such beautiful experiments with such simple implements.

There is also a personal recollection of Jim that I would like to mention. I think it was around 1975 that I attended a workshop at NBS (as it was then) in Boulder, together with a postdoc, Gil Hawkins. I had called Jim a couple of weeks before coming out to Boulder and he said "Why don't you take an extra day and I'll take you cross-country skiing." This sounded like a great idea, and after the workshop, Gil and I duly rented some skis and Jim took us off to the mountains. I have to say that I felt I was pretty fit, but Jim skied both of us off our feet. He was, however, very polite about it! The thing I recall most vividly was his teaching me how to do a Telemark turn – this is a long sweeping curve that one usually does across a downward slope and it's very elegant when someone like Jim does it. I won't say I exactly mastered the turn but at least I learned the idea.

By the end of the day, Gil and I had fallen so many times that we were soaked to the skin, but as I recall Jim didn't fall once. Jim took us back to his home where Ida had a roaring fire going and plied us with hot chocolate until we had thawed out. Many years later, I showed my daughter how to do a Telemark turn, but I told her that really I always think of it as the Zimmerman turn.

Jim – thank you for all that you have taught me.

Yours sincerely,

John

John Clarke

Francis Bitter
National Magnet Laboratory
Massachusetts Institute of Technology
Building NW14-
Cambridge, Massachusetts 02139
Telephone 617-253- 5544

November 13, 1997

TO THE SYMPOSIUM FOR JIM ZIMMERMAN:

Dear colleagues:

I regret not being able to attend this fine occasion, but I want to share some personal experiences of the years 1969-70.

I am talking about the period when Jim brought one of his early SQUIDs to MIT, and we set it up inside my new shielded room. The idea was to see if this was an improvement over my previous way to measure magnetic fields from the human body, using copper coils. It all worked beautifully, of course, and modern Biomagnetism was launched, in December of 1969. Then Jim came back four or five times during 1970 to service his SQUID.

As I think about those days, many memories crowd in. I recall Jim's aversion to hotels. He would rather sleep in my lab, on an old sofa, instead of checking into one of the many Cambridge hotels. When I sleepily went home late at night, he was still working away, and when I arrived early the next morning, he was again working away, tuning his point-contact SQUID. I also recall his boredom with Cambridge parties. Being a bachelor, I was on the Cambridge party circuit, and occasionally dragged Jim along. He is a handsome devil, and women turned on for him, but this guy simply was not interested. Believe it or not, he was supremely loyal to his wife. And this was at the high time of romantic freedom!

But this was part of his virtue generally. He never showed anger or negative feelings toward anyone, at a younger time in our lives when it was easy to be hot-blooded and lose one's cool. Truth and decency were indeed important to him. My best wishes to this fine person and gifted scientist.

David Cohen

David Cohen

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October 28, 1997

SQUID Symposium
NIST
325 Broadway
Boulder, CO 890303

Dear Colleagues:

It is a great personal pleasure for me to participate in the symposium, "SQUIDs Past, Present and Future" being held to honor Jim Zimmerman. Like so many others, I have enjoyed immensely Jim's intuitive understanding and insightful explanations of the physics of weakly linked superconductors, and he is certainly one of the most creative experimenters I know. For many years my graduate students and I have turned for guidance to the remarkable series of papers he and his colleagues at the Ford lab published during 1964-1967. Now SQUID is so ubiquitous that it is hard to remember just when the word gained its new meaning in the English language.

My perspective on SQUIDs is one that now seems like ancient history. It begins in 1959 with William Fairbank at Stanford where I was his first graduate student there. He showed me Fritz London's monograph published in 1951 in which he describes his concept of superconductivity as a macroscopic quantum phenomenon exhibiting long range coherence, and predicts that a quantity he called the fluxoid should be quantized. Bill had conceived an experiment to test this prediction, and I asked to work on it. In May 1961 we succeeded in observing that the magnetic flux trapped in a hollow superconducting cylinder is quantized, as implied by London's prediction, but in units of h/2e, half the value anticipated by London, who, of course, did not know about electron pairs of the BCS theory, which emerged in 1957. These experiments and those of Doll and Näbauer, which were also published that summer, gave substantial support to London's concept of superconductivity as a macroscopic quantum state and was direct evidence for the existence of electron pairs. An immediate question was how to make transitions between quantized fluxoid states without heating the superconductor through its transition temperature.

Josephson's famous Physical Review Letter in 1962 led to a flurry of experiments that confirmed his predictions and led to many profound results, including a deeper understanding of the macroscopic quantum nature of the superconducting state. From early 1964 through 1967 there was the incredibly beautiful series of experiments on weakly linked superconductors reported by Jacklevic, Lambe, Mercereau, Silver and Zimmerman from the Ford Research Laboratories in which they explored quantum interference effects and created dc and rf SQUIDs. The remarkable paper by Silver and Zimmerman on "Quantum States and Transitions in Weakly

Connected Superconducting Rings" answered definitively the questions about transitions between quantized fluxoid states. The rf SQUID and ideas Silver and Zimmerman presented in this paper became the basis for a number of experiments we carried out at the University of Virginia, where I joined the faculty in 1965.

For years following our initial measurements on quantized flux in superconducting cylinders we had been working to develop magnetometers with sufficient sensitivity to repeat the measurements more accurately. The rf SQUID gave us that capability. At UVa William Goodman and Ashley Vincent worked for many months on various SQUID configurations. With one of them, Goodman was able to measure quantized trapped flux values with an accuracy of better than one percent. However, just as in the data that Fairbank and I had obtained, the average flux in the cylinder also had values between quantized values. Using a tiny pickup loop with an rf SQUID and a technique that Jim Zimmerman had used some time before, Goodman was able to map the flux along the slender cylinder and show a distribution of bands in states differing by one flux quantum. Subsequently others in the lab used rf SQUID configurations to measure the temperature dependence of trapped flux and show that it agrees with the quantized fluxoid condition, and to measure the current phase relations of thin film microbridges.

It has been very exciting to me to see the evolution of superconducting electronics from those early days. Edgar Edelsack had the vision to foresee the enormous potential of superconducting devices. He provided ONR support and was instrumental in organizing the Symposium on the Physics of Superconducting Devices held at the University of Virginia in Charlottesville in 1967. Many of you were there and discussed new ideas for devices that have now progressed so far. The SQUID is probably the most remarkable of all.

I am very pleased to be included among those here to honor Jim Zimmerman and to learn into what new realms SQUIDs may be taking us in the future.

Best regards,

Bascom

Bascom S. Deaver, Jr.
Professor of Physics

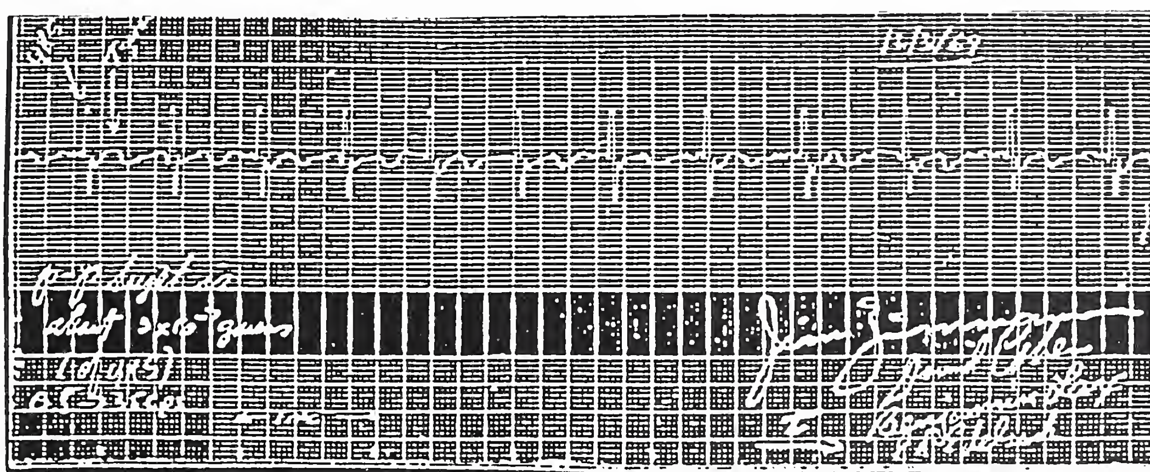
Edgar A. Edelsack
3530 W Place, NW
Washington, D.C. 20007

October 16, 1997

Dear SQUID Symposium Colleagues,

In 1967 I first met Jim Zimmerman at Philco-Ford Corporation in California. He had been awarded an Office of Naval Research contract to study the properties of SQUID magnetometers. The justification given for support of his research was that ultrasensitive magnetic sensors would revolutionize antisubmarine warfare, making magnetic detection of enemy submarines a relatively easy task. Years later, when I found out his views of the military , I was glad I never told him of this overly exuberant justification. Had I told him, I suspect he might have declined to accept the Navy contract.

The following year I introduced Jim to David Cohen who was trying to measure the magnetic field from the human heart using room temperature pick-up coils in a magnetically shielded chamber at the MIT National Magnetic Laboratory. Jim and David decided to collaborate. However there was the problem of transporting Jim's SQUID system, dewar and electronics from NBS Boulder to Boston. Typical of Jim, he readily agreed to carry it all on the plane with him. After setting up the equipment at the Magnetic Lab. Jim undressed down to his shorts crawled in the shielded chamber and on New Year's eve, December 31, 1969 he made the first SQUID measurements of a human heart--his heart.



The last time I saw Jim was in 1989 at a meeting in New York City which included the celebration of the 20th anniversary of his research in SQUID biomagnetism. I look forward to the pleasure of attending the 30th anniversary of Jim's pioneering research in this field in 1999.

Ed Edelsack
Ed Edelsack

Bavarian „Schnaderhüpfl" (mountain songs)

(for the symposium in honor of Jim Zimmerman, entitled "SQUIDs Past, Present and Future," on Nov. 15, 97 at the NIST Laboratory in Boulder, Colorado)

2. After Ji-im taught us pointing SQUIDS,
and also ba-lance coils,
we-e did advance in gi-ant steps,
even found the ear's response.

3. Whe-en dewars cracked with lea-eaks,
our gang then climbed the peaks.
We-e skied Mt. Elbert's to-op
almost dying in the drop

4. The-en Jim moved closer in with shrinks,
and Schizo-Phre-ni-acs.
Even now he still maintains some links
with certain ma-ni-acs

5. Ji-im built his SQUID concoctions
with many rubber bands.
These are now slick constructions
in almost all the lands

6. We-e hope our team will be so smart,
and never break apart.
We-e wish you all from our heart:
God Bless and Happiness!

With greetings from Jochen Edrich
in Ulm, Germany. November 11, 1997

(perhaps somebody could accompany Marty in these little Bavarian songs. However, Jim will definitely hear the authentic version when he comes to visit our new SQUID facilities in Ulm)

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Institut für Angewandte Physik

Prof. C. Heiden

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Some recollections on the occasion of Jim Zimmerman's 75th birthday

Dear colleagues,

looking back on my acquaintance with Jim, it occurs to me that my first direct contact with him was 25 years ago at the Int'l Conference on Low Temperature Physics LT 13, which was held in summer 1972 in Boulder. I was very intrigued by his work at the NBS, and my visit at his labs turned out to be the starting point of the efforts in my group at the Univ. of Muenster on RF-SQUIDs. It was Horst Rogalla, who got the task to build a microwave biased RF-SQUID system, which then led to his Ph.D. He now has a leading impact on superconducting electronics, not only in the Nederlands.

This however was not the only influence Jim's work had on us. The need for adequate cooling was soon recognized, and again it was Jim's pioneering work on plastic Stirling cryocoolers that triggered corresponding efforts at our place at the beginning of the 80ths, then already at the Univ. of Giessen. Of great help in this regard was the fact that we could have Jim for some time in our institute as an awardee of the A. v. Humboldt-Foundation. Our cryocooler group has been working since then on several cooling techniques for operating superconducting devices with some temporary slowing down caused by my task at the Research Center Juelich from 1988 to 1993. It gained full strength again after my return to Giessen and resulted recently in pulse tube refrigerators with attractive properties for device cooling down to temperatures in the liquid helium range.

Let me conclude by mentioning a gift, Jim presented me on one of his visits to our place: He knew about my interest in tools and gave me the "Leatherman Tool", a collection of different tools like a Suisse pocket knife, but in their selection quite different. Who else would think of such a gift if he did`nt use it himself? For me this was a symbol of one of his attitudes towards life: To achieve goals with a minimum amount of means. I have been carrying leatherman tool during most of my trips. So far it served above all two purposes: a) as a test for the safety screening of the airlines during check-in procedure (did they discover it or not?) and b) as a repair tool for deficiencies in hotel equipment, mostly concerning bathrooms in countries of the former Soviet Union.

Jim, as you can realize, had quite an impact on my life. I am very grateful indeed that I was able to meet him.

Christoph Heiden

Ford Motor Company

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Dearborn, Michigan 48121-2053
Mailing Address:
P.O. Box 2053
Dearborn, Michigan 48121-2053

November 1, 1997

Symposium on SQUIDs Past, Present and Future

Dear Colleagues:

It is a pleasure to send my greetings and congratulations to Jim Zimmerman on the occasion of this symposium when his many colleagues and friends acknowledge his long association with SQUID research and his lifelong dedication and contributions to experimental physics. I am sorry that I cannot be there in person.

My work with Jim occurred during the early 1960's at the Ford Scientific Laboratories in Dearborn, Michigan. It was a unique time when support for basic research in industry was strong and exciting new discoveries were being made in many fields of physics. My laboratory was across the hall from Jim's and, since my background was in surface science and ultra-high vacuum, Jim and his assistant Dick Root became an important resource for me to learn the techniques of cryogenics. During the period when the dcSQUID work at Dearborn was done, 1963-64, Jim began what was to be a thirty year interest in SQUIDs and built a point-contact version very early on. He and I did an experiment using the widest SQUID possible (About 10 cm because that was the largest substrate and mask that would fit in my vacuum system). We wanted to see if we would get interference fringes thus proving that the superconducting wave function extended over at least that distance. This fact seems obvious now, but then it seemed impossible that conduction electrons could have a wave function that large. We called it the broad jump experiment. (Today it would be called the long jump experiment.)

I came to Ford in 1961 primarily because of the quality of the people and the unequaled opportunity to interact with them. I especially remember Jim asking the most pointed questions about the details of my thesis research. After that I became accustomed to talking to him about current research and greatly valued his comments and advice. As many of you probably know, Jim is a repository of many unique ways of doing things in the laboratory, usually simple, direct and inexpensive. Such things applied not only to laboratory experiments, but also to how to build a kayak from scratch or an igloo with nothing but a hacksaw. I never got to build either one but hope to build a conoe this winter.

I have visited with Jim only a few times since he went west. I recall a visit to the Bureau of Standards in Boulder somewhere around 1970. Jim took me out to the foothills around Boulder and introduced me to cross country skiing. Somewhere I have pictures of that expedition and this winter sport has been a lifelong activity for me.

Over the years my wife Mary and I have kept in touch with Ida and Jim. We both want to wish Jim the very best and know we will all continue to benefit from his contributions to physics and his friendship for a long time to come.

Best wishes Jim!

Sincerely,

Bob Jaklevic

Bob Jaklevic
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248-488-0221
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UNIVERSITY OF
STRATHCLYDE

To the Participants, **"SQUIDs Past, Present and Future"**
NIST
Boulder, Co. 80303
USA

Dear Colleagues

I am happy to respond to the invitation of Dr Dick Kautz to contribute this short letter recalling my memories of your honoured Guest, **Dr JIM ZIMMERMAN.**

I first remember Jim when he visited the Australian Josephson Volt team at CSIRO Sydney, of which I was a junior member, in the early 1970s. His immediate experience in cryogenics and rf SQUID technology provided much inspiration to our effort at that time, and helped establish the CSIRO group as significant players in the field, a position which has been maintained through the high T_c revolution in the late 1980's and '90's. I recall too, enjoyable bush walks and barbecues with Jim and Ida in the Blue Mountains outside Sydney.

I also met Jim when I first visited NBS Boulder in October 1971, and on that occasion too, his love of outdoor pursuits (this time of course in the Rocky Mountains) was evident. Another vivid memory from that time was the weekend pastime of hunting down derelict steam engines, (which I imagine was a relevant step towards Jim's later work on Stirling-cycle coolers!).

I am at present back in Scotland, the land of my ancestors, but still working on SQUIDs and noise thermometry. So I feel I owe much to Jim's early encouragement and innovative personality. I send him my very best wishes on this happy occasion.

Sincerely

John Macfarlane

28 October 1997

(J.C. Macfarlane, Senior Research Fellow).

A PLACE OF USEFUL LEARNING SINCE 1796

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THE QUEEN'S ANNIVERSARY PRIZES 1996

Pontifícia Universidade Católica
do Rio de Janeiro

Dear Colleagues,

I would like to share some personal memories about such a special friend, Jim, who is really a living legend.

Beyond his coexisting very known professional brightness and great simplicity on his relationship with everyone, he revealed to be one of the rare tools, spread in the world, that contribute for the planet transformation, for the process of man's humanization.

During his comings to Brazil, he often visited some very poor communities, where he could get in touch with a very crude reality, that is an example of what happens in many places in the world as a fruit of the inequalities and injustices of the economy. In general these people is forgotten by everyone who is in the privileged situation. In fact, people in these slums still ask a lot about him, they liked him too much. On his personal interest to these people, many times Jim asked, by e-mail, about the health of some specific persons who he assisted to have some health problems in the slum.

His love to the nature is revealed by his simplicity in dealing with all kind of situations, without the masks or fantasies of the appearance, discussing always the human fundamental problems. He exhibits a special interest on subjects like: poverty, demographic questions, women's rights, problems concerning the distribution of world resources, etc. But he is not only just concerned, he act against the injustice. His love to the nature is also revealed by his admiration to the naturally beautiful places. He is a special company for any kind of adventure.

His power of diving into the poor people culture is impressive. It is not possible unless there is a profound respect to these people. His clearness of thinking permits him to focus only the really important subjects in the life. It is being a great opportunity to share some moments with Jim. I learned and go on learning enormously with him!!

Elisabeth Costa Monteiro

Rio de Janeiro, 13/11/1997

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
[formerly National Bureau of Standards]
325 Broadway
Boulder, Colorado 80303-3328

Reply to the attention of:

November 12, 1997

Symposium on SQUIDs Past, Present, and Future
%Dick Kautz
NIST
325 Broadway
Boulder, CO 80303

Dear Colleagues,

It is a great pleasure for me to share with you some of the experiences I have had in my interactions with Jim Zimmerman. In addition to his pivotal role in the development of SQUIDs and cryocoolers, he has also significantly influenced my career. As coinventor of the SQUID, Jim naturally understood the physics behind the operation of this device like the back of his hand. He knew its potential for useful applications, as well as the difficulties in dealing with noise when using such a sensitive device. Jim was not content in dealing only with the physics of the device. Instead, he had a vision of how such devices could be used for the benefit of mankind, and he had the strong desire to bring about such applications. He was not afraid to roll up his sleeves, get his hands dirty, and get down in the trenches and do whatever work was necessary to make SQUID devices more useful to a wide range of potential users. I was always impressed by his knack in finding the simple, yet creative, approach to solving these problems. This emphasis in Jim's research to continue a project well into the application stage had a significant impact on me, and has inspired me to achieve similar goals in my work.

Jim was particularly interested in the biomedical applications of SQUID magnetometers, such as magnetocardiography and magnetoencephalography. After arriving at NIST in 1970, he soon began experimenting with the SQUID magnetometer for these applications. He initially used small dewars filled with liquid helium to provide the necessary cooling of the SQUID magnetometers. As a low temperature physicist, Jim had no problem in dealing with liquid helium. However, he was able to put himself in the shoes of someone not so familiar with the handling of liquid helium, and he realized that the use of liquid helium for the cooling of SQUIDs would prevent them from ever being used in any significant way in practical applications. This potential roadblock became a challenge that Jim sought to overcome. By the mid 1970s Jim began to look into the possible use of commercial cryocoolers for cooling SQUIDs, but he soon realized that there were no existing commercial cryocoolers that would do the job.

He then began his research in the area of cryocoolers that could be used for cooling SQUIDS. After a few short years had discovered how to design and build cold heads for Stirling refrigerators out of fiberglass-epoxy and nylon in order to achieve temperatures around 4 K with a remarkably low power input of only 15 W. He used completely different design approaches than had been used previously for commercial cryocoolers. Jim had recognized that for cooling a SQUID he need only design a cryocooler that would cool itself down to 4 K. Many expert engineers in the field of cryocoolers had initial doubts about the possibility of success with Jim's approach to 4 K Stirling refrigerators. After Jim's success, the doubts of others quickly turned to amazement. I was impressed with how Jim would get involved with making many of the critical parts himself and how he would find very simple and inexpensive ways for doing the job. He is noted for creative uses for dental floss and rubber bands. I am happy to have had the chance to work with Jim in these early years on the development of the 4 K Stirling refrigerator. It was this work that really stimulated my interest in the field of cryocoolers.

Jim interacted very well with so many people in a wide variety of fields because he always had much respect for the ideas of others. In order to be able to hear about the ideas of others in the area of cryocoolers, he soon began to organize a conference for people working in this area. Thus, because of Jim's efforts in organizing this first conference in 1977, along with support from the Navy, the series of conferences that would later become to be known as the International Cryocooler Conference was born. These conferences now attract about 300 participants every two years from around the world.

Shortly before Jim's retirement from NIST in November of 1985 he was eager to work with me and others in our group in Building 2 on the development of a very new concept in pulse tube refrigerators, which we referred to as the orifice pulse tube refrigerator. I have very pleasant memories of the time Jim came to me to announce that our pulse tube refrigerator had achieved 60 K. His contribution to the paper for the Cryogenic Engineering Conference in 1985 describing this work was instrumental in our team receiving the Russell Scott Best Paper Award for that year. That work also helped propel a worldwide effort in the research and development of pulse tube refrigerators.

Even after Jim retired from NIST he was eager to work with us on contract (with only a nominal amount of money) to help us develop cryocoolers. His many creative ideas helped us in many ways over the next several years. I always enjoyed having discussions with Jim in the area of cryocoolers, and also in other areas from time to time. I like his way of thinking about a problem, how he goes about solving the problem, and how he likes to understand the mysteries involved with the problem.

I am greatly honored to have had the opportunity to work side by side with Jim over a period of several years. His has been an inspiration to me, and I have learned much from him.

Sincerely,

Ray Radebaugh

Ray Radebaugh
Leader, Cryogenic Technologies Group
Physical and Chemical Properties Division

University of Colorado Health Sciences Center

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University Hospitals
School of Medicine

School of Nursing
School of Dentistry

School of Pharmacy
Graduate School

October 31, 1997

Dear Colleagues:

Were it not for Jim Zimmerman, the entire Denver-Boulder MEG effort would likely have come to naught. As I recall, our first (unsuccessful) effort to record human MEG in Denver was in the early 1970s. It involved an instrument Jochen Edrich had borrowed from, I believe, SHE Inc. We set up in a large empty field in south Denver behind an Albertson's supermarket, with a long extension cord running across the street to Edrich's house to power the electronics. I don't remember what, if anything, we saw on the oscilloscope.

It was shortly after that time that Jim offered both his lab and instruments at the National Bureau of Standards in Boulder to continue these efforts. For a period of some years thereafter we made a regular weekly trek from Denver to Boulder to spend an afternoon in Jim's lab, using a variety of instruments Jim had constructed to record the first human MEG-EEG comparison in 1976, and not long thereafter the first human auditory evoked field in 1978. Jim then arranged for us to occupy a separate, then largely empty, metal sided building further up the mountain from his main lab, and hopefully therefore magnetically quieter, that could be largely devoted to the MEG effort, and we began recording in an aluminum shielded room that Jim had designed and had built.

These early efforts used both axial first order coil sets with point contact SQUIDs, all of which Jim built, as well as a novel double-D design which he had machined from a block of niobium. Jim's early instrument always worked amazingly well, considering that a major component of their construction usually included a generous component of rubber bands and dental floss. Balancing these early instruments meant traipsing up the hillside behind the NBS to an area that was hopefully relatively quiet, and then tinkering with the tab settings until Jim was satisfied with the performance. These weekly treks to Boulder also usually included a lunch with Jim, where he would spend time sketching out on the blackboard what might possibly be generating the fields we were measuring, and how these generators might best be conceptualized.

Albeit primitive in retrospect, a number of early publications on the human MEG resulted from these efforts, which were sufficient to interest the Office of Naval Research in purchasing for us our first commercial instrument, a single channel Bti system with rf SQUID, which with Jim's help, we managed to install in the basement of the Colorado

Psychiatric Hospital on the campus of the University of Colorado Health Sciences Center in Denver. We thought this location would provide improved patient access, which it did, and therefore facilitate clinical studies. Jim again helped design the novel shielded room, which Peter Teale constructed from 6.3cm thick seam welded aluminum panels.

Early recordings with this simple single channel instrument found evidence of interesting differences in auditory processing in the left hemisphere of individuals with schizophrenia. This in turn was sufficient to interest the NIMH in providing us with a larger 7 channel instrument to continue the work in the major mental illnesses.

Thus our efforts continue and the work progresses, but clearly had it not been for Jim's early involvement and support of the effort, it would never have gotten off the ground in the first place. He has continued to keep a hand on the tiller of this research effort, and has attempted to keep us on path over the years. It wouldn't have happened without him.

With best regards,

Marty

Martin Reite, M.D.
Professor of Psychiatry

John Rowell Inc.

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11/8/97

Dear SQUID Enthusiasts,

For the record, roughly 35 years later, let me recall when I first heard of a SQUID, although not by that name.

In the summer of 1963, or maybe it was 1964, a conference on superconductivity was held at Colgate University in New York State. I remember two things from this meeting. The first was standing behind Kurt Mendelssohn in the breakfast cafeteria line, when he tried to teach the college student serving coffee and tea, how a cup of tea had to be made with boiling water, if she indeed had to make it with a tea bag.

The second memory is of questions asked after I gave a talk on the work Phil Anderson and I had done on both the observation of the Josephson Effect and also on tunneling spectroscopy. I showed the diffraction pattern of a single Pb - I - Pb junction, with the current scale in logarithmic units, to show how close to zero the minimum values really were. Brian Pippard got up to comment that this must imply a remarkable uniformity of the oxide barrier, in fact I think he might have even estimated a value for it. Either in the same question period, or it could have been at a rump session later in the week, someone asked if it would be possible to do the same experiment with two junctions, to see "two slit optical interference". I remember the question clearly, but I do not remember with certainty who the questioner was, but it might have been Brian Pippard again. I also remember my answer, that we were having difficulty making even single junctions, so did not see how to make two. I did not think, then or later, of simply painting a line of insulator down the middle of one junction, as the Ford group did. My only excuse for not following up the suggestion was that I was actually much more interested in developing tunneling spectroscopy than in the Josephson Effect, hard as that might be to believe for the attendees at this symposium.

So, to my knowledge, the first public description of interference between two junctions, which later became known as the DC SQUID, was made by someone, who might have been Brian Pippard, at the Colgate conference. Of course, it needed Jim Zimmerman and his colleagues at Ford to turn that question into reality.

Best Wishes to Jim, and to all those who have nurtured SQUIDS for 35 years.

John Rowell

John M. Rowell

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
[formerly National Bureau of Standards]
325 Broadway
Boulder, Colorado 80303-3328

November 6, 1997

Reply to the attention of:

Dear Jim,

About the only project I worked on with you was your effort to develop miniature refrigerators. I especially recall the staff meeting concerning that project. In that meeting, Kropschot and Strobridge argued passionately that working on miniature refrigerators should not be done by anyone in the Cryogenics Division no way no how. As I recall, you didn't say much during the meeting if anything at all. You were apparently unfazed by their admonishments. After the meeting, you walked out and continued your development of miniature refrigerators. I don't recall any further efforts on the part of management to discourage your refrigeration work.

Though we didn't spend much time working on projects, we made up for that by the amount of time we spent over the years wandering the hills and mountains. I still remember our first trip. We went on the Colorado Mountain Club climbing class trip up Mount Toll in the spring of 1970. We left at 4 AM and skied in to join the climbing group at the CMC cabin at 7 AM. The trip was fine going up but our modest skills at that time plus the mixture of icy then mushy snow made the trip back down the mountain a struggle. That was the trip on which I broke my backpack frame in two.

Then came our igloo trips. You had already tried a few before you talked me in to trying one. On my first trip with you, we went to Crater Lakes. I wore cotton jeans and darn near froze to death. I did learn to avoid wearing cotton but it was several years before we developed the wisdom to spend winter nights at home. The night are definitely shorter at home.

We have whiled away many a day on yo-yo skis but even more days on cross country skis over the last 27 years. Their were some real adventures on these trips, especially high up on the divide on the crossing route by the Iceberg Lakes that we pioneered.

But we didn't frolic about the mountains just in winter. We started our summer activities in August 1971 when we went on the Gore range backpack trip, you, me, Dave Millhiser and "Shoeless" Don Sullivan. This was the first trip of what was to become our annual backpacking tradition. Some if not all of us have gone on it every year since for 26 years now.

Our activities weren't just limited to running around in the mountains. In the early 70's we came upon the 7 by 10 horizontal steam engine while hiking in Columbine Gulch. I commented that the engine was still in good shape, someone ought to haul it out and restore it. You said, "Let's do it!" So we did. Sullivan used to haul pieces of old stoves out of the woods when he found a part he liked. We went him several tons better. We spent a weekend cabling the 7 by 10 out of Columbine Gulch, loading it onto Nolan Frederick's trailer and hauling it home. That was just a start. Before we finished our steam equipment collection, we bagged yet another engine and a boiler.

We have had many adventures over the last 27 years. We will have more.

Sincerely,

Jim

Jim Siegwarth

TRW

TRW Space & Electronics Group
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November 6, 1997

SQUIDs Past, Present, and Future
NIST Boulder Laboratory
325 Broadway
Boulder, CO 80303

Attn. Dr. Richard Kautz

Dear Colleagues

I want to share a few of the fond memories and recollections that I have of Jim Zimmerman. We collaborated closely for approximately 5 years in the 1960's (that surely was a long time ago) at the Ford Motor Co. Scientific Laboratory, and on all too infrequent occasions afterward. Jim and I and our families formed a friendship which has endured over the years.

We were office-mates when I first went to Ford from graduate school. He was the low temperature physics guru and I was trying to start a magnetic resonance research program. So, we went our separate ways in terms of our daily work, but formed a friendship nevertheless. Jim was the individualist and outdoorsman. Once, he broke his leg skiing and came to work in a cast. He soon decided that wearing a cast 24 hours a day was uncomfortable. So he made a string saw which he snaked inside the cast and sawed it in half lengthwise so he could take it off at night. He reassembled it every day by wrapping it with tygon tubing. That was typical of his research style: rubber bands, dental floss, pliobond, whatever was available, design on the fly and fix it later. Not to say he wasn't thoughtful, just extremely clever and resourceful.

We finally got a chance to work together in the early days of SQUIDs at Ford. Jack Lambe, Bob Jaklevic, and I had been struggling with thin film tunnel junctions on one hand and thin film microbridges on the other. The first thing Jim did was to cross two Nb ribbon wires with small weights and fasten them with epoxy. These were the first "point contact" SQUIDs. Not too much later, he fashioned 000-120 screws from Nb wire, tapped 000-120 holes in Nb parts, and made the venerable point contact SQUIDs which were the staple for at least 10 years. Jim's technique enabled us to make and measure many different devices in a short time span and enabled our development and understanding of the RF and DC SQUIDs. We used the long name "quantum interference devices" and Jim was responsible for coining the acronym *SQUID*.

I clearly remember the many stimulating, frustrating, and illuminating discussions we had while trying to solve the puzzles of how SQUIDs worked. These arguments were critical to whatever successes we achieved. Jim was as adept as anyone I have ever known at finding simple solutions and overcoming technical barriers. He was and still is a truly "hands-on" physicist. He introduced and brought into general practice many innovations, some of which were eventually rediscovered by others, such as the fractional-turn SQUIDs. He took the first SQUID magneto-cardiogram, built the first small Stirling cryocooler for SQUIDs, and worked with Radebaugh to demonstrate the first "pulse tube" cooler.

I had a few chances to work with Jim after we each left Ford in 1969, but I always looked forward to when we could get together to discuss or work on some problem, or just socially. Jim did some consulting for me at Aerospace and TRW. And whenever he came out to Los Angeles to consult, he stayed at my house and we spent many hours in conversation (myself, my wife and my daughter) discussing the problems of the world about which he felt so deeply. He invented and developed a unique variable temperature flow cryostat, which we named the Z-cryostat. It has been instrumental in our measurement systems. Jim manufactured the first half dozen or so for us.

But through all of this, Jim has always maintained his unique dignity and individuality, even as he is facing his life's greatest challenge.

Sincerely,

Arnold Silver

Arnold H. Silver

DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
4555 OVERLOOK AVE SW
WASHINGTON DC 20375-5320

IN REPLY REFER TO

6340/157
19 November 1997

Dr. Richard Kautz,
Chairman of the Zimmerman Symposium
NIST
325 Broadway
Boulder, CO 80303

Dear Richard

I enjoyed attending the Zimmerman SQUID Symposium and congratulate you for organizing such a full and productive day. I was particularly touched by the evening ceremony and am motivated to submit the following poem which I hope captures the quintessence of this very notable scientist and humanist.

Roses are red
Violets are blue
Jim showed that one junction
is better than two

Sincerely,

Robert J. Soulen, Jr, Head
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UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
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Reply to the attention of:

November 12, 1997

Comments on the Occasion of a Symposium Honoring James E. Zimmerman

Not only have I had the pleasure of working with and learning from Jim Zimmerman in the laboratory, but I have also enjoyed sharing numerous summer and winter outdoor experiences and debating local and world problems with him. As a direct result of my association with him, I have expanded my knowledge of science and have been exposed to a terrific philosophy of life that has had an impact on the directions of my own life. I was indeed fortunate that Jim joined the NIST Cryoelectronics Group 28 years ago. Other letters in this collection will certainly outline Jim's substantial technical accomplishments, so I will bypass these and focus my comments on some of my other experiences with him.

Jim is the consummate experimental scientist. He has never been prone to do extensive calculations when faced with a question. It is not that he lacks the skills to do the analysis, but that he seems to find he can get to an answer more quickly through a simple experiment. And simplicity always marks his experiments. It was obvious to all of us in the group that, while others were spinning the dials on their latest electronic instrumentation, Jim was finishing his experiment, which often involved a grid-dip meter, rubber bands, dental floss, and other detritus. When his experiment demanded machine work, it was always done in a most utilitarian fashion. His experiments never looked beautiful, and I enjoyed poking fun at all of them. But they almost always produced the answer to a carefully considered question.

This approach to problem solving seems to have seeped into many other aspects of Jim's life. I have seen him experiment with his garden, his car, his house, and his recreational gear. His experiments seem to flow from an extraordinary degree of curiosity about the world around him. It is clear to me that he revels in attacking almost any problem using sound scientific methods. While this surely involves his natural curiosity, I imagine that his style of doing things has been influenced by his early life on a South Dakota farm. This appears to have left him with a self-sufficient, Spartan style. I can't just make such general observations without relating a few specific examples.

For a number of years several of us (including Jim) would lash on our cross-country skis and packs and trek into the nearby mountains to build an igloo and then spend the night in it. In the course of these adventures, I watched Jim develop a light-weight snow saw for cutting blocks for the igloo, long underwear that could be donned without taking off his pants, and a homemade pack that unfolded to become his bedroll or a sort of cocoon that he would wrap around himself if the weather was foul at lunchtime. At one point, as I was snuggling into my bedroll trying to get warm, I watched Jim make temperature measurements in different parts of the igloo. He was simply curious about the temperature profile in our temporary home. Jim was the first to determine that it was best to place a porous fabric under his sleeping bag and that, things being so still in the closed igloo, he could cook his meal using only a candle.

Much of Jim's outdoor gear is homemade. He seems to prefer homemade over store-bought equipment for two reasons. First, he is convinced that he can come up with a better (not prettier) design. And second, he has always been determined to minimize his consumption of goods. This is part of his deep social consciousness, not his interest in saving money.

Jim's home is a museum of many successful (and a few failed) experiments. There is no doubt but that his wife Ida has sometimes become exasperated with his experimentation. Jim has experimented with moving heat from his south-facing greenhouse to other parts of the house. The pump systems and plumbing that he has designed for his home and water wells are a sight to behold. He has experimented with starting his garden as seedlings in the greenhouse and with determining just how early he could plant his corn. He even took metal shears to his VW Karman Ghia to reduce its weight so that it would be more energy efficient.

These examples might appear humorous, but to my way of thinking they reflect a life style to be admired. Jim's highly principled approach to life reflects a deep concern about major societal problems. While still working at NIST, Jim (with a little help from a few of us) organized a lunchtime discussion group on the topic of nuclear arms. His letters on the subject started appearing regularly in the paper, and following his retirement, he spent the major portion of his waking hours working on peace issues. He has also educated himself on population growth, women's issues and other global issues, and has expanded his activism into these areas.

I hope I have conveyed my perceptions of Jim as, not just an excellent low-temperature physicist, but a successful experimentalist in every-day living, a committed social activist, a good outdoorsman, a mentor, and a friend. He has exerted a major influence on my life and my career.

Donald B. Sullivan, Chief
Time and Frequency Division

VANDERBILT UNIVERSITY
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John P. Wikswo
A.B. Learned Professor of Living State Physics
Professor of Physics
Department of Physics and Astronomy
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November 5, 1997

Dear Colleagues -

It is a pleasure to acknowledge the contributions that Jim Zimmerman has made to my research over the past thirty years. The thread begins with my first car -- while Jim was inventing the Ford RF SQUID, I was learning to drive a Ford Falcon. Later, his invention allowed me to make my Ph.D. measurements on cardiac magnetic fields with RF SQUIDs, and I have been using SQUIDs ever since. As a result, I have had the fun of chasing ground loops, RF interference, microphonics, elevators, magnetic dirt, and passing cars and trucks that only SQUIDs can show us.

I often benefit from Jim's keen insights into problems and his simple solutions. I use SQUIDs to measure biomagnetic fields just as Jim first did for the first time in 1970. Several of the SQUID systems that have served me well are based upon Jim's asymmetric gradiometers to optimize both spatial resolution and sensitivity. His straightforward approach of welding thick aluminum plates into room-sized magnetic shields has left large unmoveable objects in a number of labs, including ours, and provides a cost-effective way to reduce power-line fields and claim lab space. He provided an intuitively simple approach to estimating the magnetic Johnson noise in such a shield, and this also helped me when we first imaged Johnson noise with our SQUIDs. When I measure a magnetization for non-destructive tests of some object, I fondly remember his comment about placing art objects on a swing beneath a SQUID for detecting remnant magnetization without reducing the object to smaller pieces. Two years ago I was asked to provide the closing summary at a cryocooler workshop, and reviewed the literature to see how insightful Jim's 1970's papers were on the subject -- his comments on cooling SQUIDs with cryocoolers can be readily appreciated in light of today's need to cool cryoelectronics. All I need now is for Jim to complete the design for the liquid-nitrogen powered engine for my bicycle!

Unfortunately, I have never worked closely with Jim; I envy those who have. I hold him in the very highest esteem, and appreciate deeply both his friendship and his scientific contributions.

Sincerely,

John P. Wikswo

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New York University
A private university in the public service

Samuel J. Williamson, Sc.D.
University Professor

Neuromagnetism Laboratory
Departments of Physics and Psychology
and Center for Neural Science

Congratulations, Jim, for making SQUIDs possible! (Even if nature beat you to it!)

Wow, what you're thinking!

Sam

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