Memories of James D. Meindl

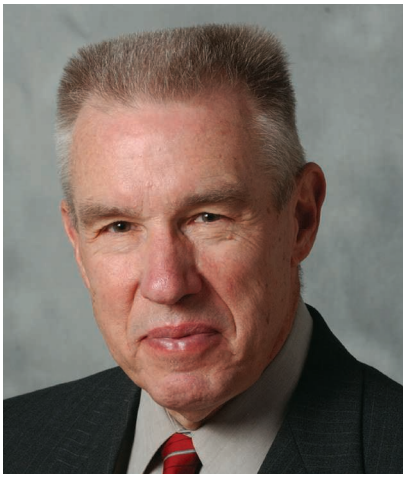
A Tribute

James D. Meindl, our treasured friend, colleague, and mentor, passed away peacefully on 7 June 2020 at his home in Greensboro, Georgia, after a long illness. He was 87 years old. Meindl was a pioneer and a giant in the world of semiconductors, a gentleman, and a leader of the highest magnitude who has made a remarkable impact and left an unforgettable legacy for generations to come.

The authors of this article are several of Prof. Meindl's many students, colleagues, friends, and family members. They are sharing their personal experiences with Jim and the impact he made on so many of us.

I worked and interacted directly with Jim Meindl for more than four decades—initially at Stanford University, as his Ph.D. student, and then as his colleague and associate director of the Stanford Electronics Labs. Later, when I was CEO of Zoran Corporation, the company I cofounded out of Stanford, Jim served on our board of directors for 26 years.

As many other contributors here share, I learned so much from Jim as a research advisor, colleague, mentor, and person. He instilled in me the concept and value of "learn and teach" from every interaction with others and the idea that innovations can be triggered and proactively occur with the right focus and urgency: Meindl's "Go invent" principle. I have used this principle successfully throughout my academic, research, and business careers.



James D. Meindl (1933–2020).

Another concept we learned from Jim was the powerful value of integrating disciplines at all levels and areas—from basic research to applications as well as from device physics and fabrication to complete system design, integration, and use. One example occurred in the 1970s: a new and revolutionary ultrasound 2D medical imaging system and a noninvasive quantitative blood flow measurement solution that several groups in the IC Lab and across the Electrical Engineering Department at

Prof. Meindl and his wife, Freddie, with several of his former Ph.D. students, attending the ceremony during which Meindl received the 2006 IEEE Medal of Honor. (From left) Bottom row: Sharbel Noujaim, James Meindl, Freddie Meindl, Nicky Lu, and Jim Plummer; middle row: John Shott, Steve Combs, Fred Shapiro, and Levy Gerzberg; top row: Ernie Wood and Rafael Reif. (Photo courtesy of Levy Gerzberg; used with permission.)

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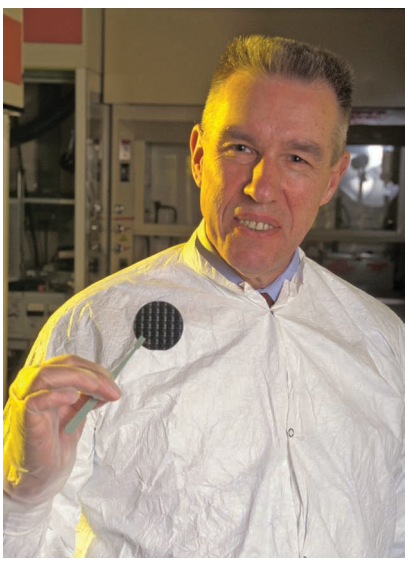
Meindl with colleagues and other luminaries during a 1984 visit by French President Francois Mitterand to Stanford University's Center for Integrated Systems. (From left) venture capitalist David Morgenthaler; mainframe pioneer Gene Amdahl; Stanford professor John Linvill; Intel cofounder Robert Noyce; President Mitterand; Stanford vice-provost Gerald Lieberman; Prof. Meindl; Apple founder Steve Jobs; Nobel laureate and Stanford professor Paul Berg; Genentech chair Thomas Perkins; Hewlett Packard president John Young; Stanford professor Edward Feigenbaum; and venture capitalist Burton McMurtry. (Photo by Chris Painter, Stanford News Service; used with permission.)

Jim also taught us how to work in teams and produce both individual and group achievements that have not always been common in academia.

Stanford worked on in collaboration with the Stanford Medical School and Hospital. The results of this remarkable project are still embedded today in many clinical systems worldwide.

Jim also taught us how to work in teams and produce both individual and group achievements that have not always been common in academia. At Zoran, Jim Meindl was a valuable board member who added unique perspectives on interdisciplinary-based solutions to enhance our competitive edge and business performance.



Meindl in his lab at the Georgia Tech Institute for Electronics and Nanotechnology. (Photo courtesy of Georgia Tech; used with permission.)

Jim was a visionary, always challenging and inspiring his students and associates toward higher achievements and discoveries. He was a man of principles and integrity, and he cared deeply for others—a remarkable person, friend, and family member whom we will greatly miss.

—Levy Gerzberg

About the Author

Levy Gerzberg received his Ph.D. degree in electrical engineering from Stanford University. In 1981, he cofounded Zoran Corp. and served as its president, CEO, and director until its acquisition in 2011 by CSR, now part of Qualcomm. He pioneered and led several major consumer electronics markets.

Dreamer of the Art of the Possible

The year was 1966, and I had just arrived from the Massachusetts Institute of Technology to enroll in the Medical School at Stanford, with a goal of pursuing both an M.D. and a Ph.D. degree in electrical engineering (EE). The Stanford campus was literally ablaze in some not-so-peaceful antiwar demonstrations, making attending classes somewhat difficult.

In 1968, having passed the EE Ph.D. degree qualifying exams, I was searching for a thesis project in an area that would now be considered bioengineering, but the field didn't exist at the time. Through one of the medical school faculty members, I was introduced to Jim Meindl, who had arrived at Stanford the previous year and recently received a National Institutes of Health grant to construct implantable IC to relay information from Doppler ultrasonic flowmeters placed in research animals that had undergone heart transplantation.

When I first met Prof. Meindl, I was shocked—Jim stood ramrod straight with a flat-top haircut, popularized in the 1950s, which was his signature identifier throughout his career. In the 1960s and early 1970s, sporting a flat-top haircut was like waving red flag in front of an antiwar demonstrator! I wondered how Jim would survive the increasingly dangerous demonstrations that were just getting underway at Stanford, including ones that ultimately forced Stanford to close the classified research being conducted in the engineering research labs in the heart of the EE Department where Jim's office was located.

Despite first appearances, I was delighted when Jim agreed to take me on as one of his early Stanford Ph.D. students, starting a long-term relationship of more than 35 years as a mentor, colleague, and friend. Despite his rigid appearance, in reality, Jim was exceedingly warm, kind, and flexible. The parties that Jim and his wife, Freddie, held at their home provided lots of good food and, more importantly, warm support to his students.

While I thought my project might involve working on IC technology, it became clear very early in the project that these Doppler ultrasonic flowmeters didn't function reliably, making them unsuitable for chronic monitoring of blood flow. Some people tried to redesign the monitors, but the performance paradoxically got worse.

Prof. Meindl asked me to take on an initial project to determine why these devices provided unreliable estimates of blood flow and how to design the optimal flowmeters. This first "project" morphed into my dissertation—the development of the theory of measuring blood flow using ultrasound. Over the next two years, it became obvious that this was a problem more related to radar and statistical communication theory than IC technology.

Jim enlisted another faculty member, Prof. Joseph Goodman, an expert in advanced optics, to be my second reader. Eventually, we developed algorithms for the optimal estimation of blood flow with ultrasound that provided substantial performance improvements. As the field of medical ultrasonic imaging was just beginning, these algorithms ultimately became the basis for the commercial systems providing colorized Doppler maps that are now incorporated into virtually all medical ultrasonic imaging machines.

Jim was incredibly well organized, supervising a stable of students working in the IC laboratory, many of whom went on to become professors, inventors, and/or CEOs of successful start-up companies. I would characterize Jim as a "dreamer of the art of the possible," with incredible focus to work on the baby steps that would eventually lead to big breakthroughs. No problem was too difficult to undertake. With respect to ultrasound, Jim and his students developed many of the applications of ultrasound for medical imaging (and blood flow estimation) years in advance of when the IC technology was sophisticated enough to bring these ideas to routine use in hospitals and clinics.

—William R. Brody

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About the Author

William R. Brody became a professor of radiology and electrical engineering (by courtesy) at Stanford, followed by the position of radiologist-in-chief at the Johns Hopkins Hospital. From 1996 to 2009 he served as president of Johns Hopkins University and from 2009 to 2016 as president of the Salk Institute.

Child-Like Curiosity and Enthusiasm

Jim Meindl was an academic who wanted to be sure his innovations became practical and useful for others. I was new on the faculty of the Stanford School of Medicine, across the street from the Meindl Lab. We were some of the first in the United States to use ultrasound as a noninvasive sensor for the motion of heart walls and valves. The recording was done on a strip chart, with the distance of the multiple reflected signals plotted against time—essentially, "squiggles" on paper that had to be interpreted.

Jim learned of the possibility of making actual 2D images of the cardiac anatomy and thought he could use his technology innovations to improve what we were doing in the Medical Center. He and his group went on to measure blood flow noninvasively as well. I was completely impressed by his enthusiasm to go on beyond the publication of academic papers and make imaging systems that could improve the recognition of cardiac disease and improve patient care. He immersed himself in understanding the challenges of noninvasive imaging inside the body. "Echocardiography" was new, and he had an almost child-like curiosity and enthusiasm to learn about what I was doing.

Jim was one of the first people I met who understood the value of multidisciplinary collaboration to solve important problems. He found what was needed in other disciplines, like medicine, and applied his wide-ranging knowledge to find solutions to those needs. Jim was a famous professor, but he treated this very young assistant professor as an equal. Like many others, I am very fortunate to have known him.

—Richard L. Popp

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About the Author

Richard L. Popp is a professor of medicine (emeritus) at Stanford University and teaches in the Stanford Biodesign Program. His research has focused on developing all forms of ultrasound. Dr. Popp was president of the American College of Cardiology, the American Society of Echocardiography, and the Association of University Cardiologists and chair of the American Board of Internal Medicine's Cardiovascular Diseases Subspecialty Board.

Three Outstanding Merits of Meindl's Career: A Personal View

As Prof. Meindl's Ph.D. student (1978–1981) in the Stanford IC Lab, which he established as the world's top academic research center in ICs/semiconductors, I have always been so proud that he was my advisor, cultivating in me essential skills in research and leadership for my 40+ year career. He was a unique leader and educator in shaping our industry of microelectronics and micro-power biomedical devices for the benefit of humanity.

1) He is the only technical leader who has had the honor of delivering multiple plenary speeches at the IEEE International Solid-State Circuits Conference (ISSCC). Our industry enthusiastically looked forward to hearing his pioneering views on major subjects: where semiconductor technologies are going, how much ICs can be miniaturized, and how many functions can provide outperformance beyond what human beings can expect. He also received the highest number of Best Paper awards from the ISSCC.
2) In 1975, I received earlier training at National Taiwan University under Prof. Simon Sze and then traveled thousands of miles to Stanford to pursue my research with Prof. Meindl. Now, 45 years later, Taiwan has established itself as a major region for producing ICs. However, in 1978, Prof. Meindl showed me some pictures from the 1960s of him with the president of the Republic of China on his trip to Taiwan—not only to share his experiences of establishing the IC Division in the U.S. Army Electronics Lab but also to advise that ICs and microelectronics should be Taiwan's focus for growing a prosperous economy. He told me that was one of the reasons that he took me as his Ph.D. student, expecting that one day I may be contributing to Taiwan, from where I came. Ever since, I have always been grateful and admired Prof. Meindl for his global perspective of selecting and educating his close Ph.D. students from not only the United States but other geographies to share his own findings and contributions with the world. His breadth of mind and spirit is truly admirable.
3) After graduating, I constantly received great advice from him; e.g., he gave me his way of shaping one's career: write down explicitly and crisply, with fewer than 50 words, what one expects to achieve in the next few years so as to lay a clear road map for the most worthwhile career development. In 2016, he contacted me in Taiwan and inspired me on how to make contributions to science, technology, engineering, and mathematics education. I recorded my views in an educational video for public broadcasting, and he praised me for making contributions toward that direction. He was a rare leader in our field who could easily have had goals that prioritized making money, but, instead, he dedicated his most valuable wisdom, resources, and entire professional life to education and was awarded an IEEE Medal of Honor.

Prof. Meindl was truly a remarkable and unforgettable figure in the civilization of human beings. I am very proud and honored to write this article to tell the world about such a giant as J.D.M. as well as his true partner, Mrs. Freddie Meindl!

—Nicky Lu

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About the Author

Nicky Lu is an inventor of several key IC designs/technologies and serial founder of several companies, from start-ups to publicly listed ones. He has dedicated his career to worldwide IC design and the semiconductor industry.

A Model of Leadership, Kindness, and Humility

Jim was my Ph.D. advisor at Stanford, so I had many opportunities to learn from him and also study him—not just bask in his obvious brilliance but understand how he thought. In one of Jim's lectures, I was chatting with a classmate seated next to me, when I abruptly paused the conversation and said, "Wait, Jim is going to ask me a question"—and then Jim asked me a question! My classmate was startled, but to me it was not at all surprising. I had spent so much time observing, admiring, and trying to emulate Jim that I had internalized how he thought and made mental associations. From the start, I could sense that having the opportunity to learn how Jim's mind worked was a rare gift.

Of course, there is no substitute for the real thing, so I continued to reach out to Jim for his perspective, especially during my days as a junior faculty member. Even after that, I just kept calling him, and he, graciously, kept taking my calls. I will deeply miss having the chance to seek his advice, talk through a thorny decision, or work through a challenging problem.

A while back, I learned an impressive statistic: 90 graduate students that Jim shepherded toward their Ph.D. degrees have found success in their chosen professions, from research to industry to administration. However, he set us on a path to something more important than just professional achievement. Jim modeled for us how to be leaders and show kindness and humility—not just how to *think*, but how to *be*. I am enormously and endlessly grateful that he taught me and so many others so well. He represented the gold standard of what a teacher and mentor can be, and it is no exaggeration to say that I benefit from his wisdom every single day.

—L. Rafael Reif

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About the Author

L. Rafael Reif has served as the 17th president of the Massachusetts Institute of Technology (MIT) since July 2012, where he has championed basic research, pioneered the future of education, and led the redevelopment of MIT's neighboring innovation district. On the MIT faculty since 1980, he received his Ph.D. degree in electrical engineering from Stanford University.

"Impossible" Problems, Unexpected and Powerful Outcomes

I first met Jim Meindl not long after I came to Stanford as a graduate student. At the time, he was a relatively new electrical engineering faculty member whom Stanford had hired to build a program in ICs. That was a topic I knew very little about, but Jim had a vision for how tiny silicon chips could literally change the world. His excitement about this possibility was contagious, and I ended up being one of his first Ph.D. students.

What was particularly compelling about Jim's research was that he and his students didn't just work on building silicon chips. They worked on creating chips that solved important problems. Chips that enabled the Optacon, a reading aid for the blind. Chips that transmitted and received ultrasound for medical imaging systems. Chips that operated at low enough power that they could be implanted and operate on small batteries for long periods of time. Jim and his students prototyped systems that later started companies and became commercial products. I was truly fortunate to be in the middle of all of that.

Throughout my career, Jim Meindl has been a role model, mentor, friend, and someone whose advice I have sought countless times. He taught me that working on important problems brought great satisfaction. He also showed me that working with great people and treating them with respect were crucial to being successful. He helped me understand that challenging people with "impossible" problems often leads to unexpected and powerful outcomes.

Jim Meindl had an amazing ability to see opportunities before others did. Throughout his career, he always seemed to be working on things that others would recognize as truly important only many years later—low-power circuits, medical applications of ICs, interconnects on chips, and the fundamental limits of silicon technology, to name just a few.

Jim was fond of saying that "one of the reasons I became an engineer is because I believe engineering is a profession that allows you to predict the future." By this, he meant that engineers create the future by building systems that solve important problems. This is exactly what he did, and he leaves a remarkable legacy. He was an innovator, an inspiration to many, and, most importantly, a friend. Along with many others, I miss him.

—Jim Plummer

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About the Author

Jim Plummer joined the Stanford University faculty in 1978. He is currently a professor of electrical engineering and was dean of Stanford's Engineering School from 1999 to 2014.

A Visionary and Nurturer

Prof. Jim Meindl was a visionary. He could see the importance of future technology well before others as if he had a crystal ball.

Jim saw the potential of research on ICs in academia by establishing Stanford's IC Lab in 1967, well before other universities followed his footsteps. He fostered research not just on mainline electronics but in diverse fields, such as medical electronics and manufacturing science. He was also an early proponent of the university–industry partnership model, cofounding the Stanford Center for Integrated Systems in 1983 and helping forge lasting relationships between Stanford and notable semiconductor companies.

While he was a giant tree with a huge shadow, Jim nurtured small plants to grow and blossom. He was instrumental in shaping me not just as an academician and a scientist but as a better human being. He heavily influenced my career, not just during my Ph.D. degree studies under him from 1971 to 1974, but as a member of his research team from 1975 to 1982 and, finally, as a colleague upon becoming a faculty member in 1983.

In the 1970s, when the rest of the world was focusing on transistors, Jim encouraged me to work on interconnects. That early research was instrumental in shaping my career. Decades later, when he joined Georgia Tech in 1993, he founded the Interconnect Focus Center and led a team of more than 60 researchers from leading U.S. universities to continue advancing Moore's law. I was fortunate enough to lead the effort of the Stanford team.

In addition to his invaluable contributions to technology, Jim left an everlasting impression on academia and industry through the more than 90 doctoral students he graduated who have become leaders in their fields. Prof. Jim Meindl left an incredible legacy that will be transmitted through his research and students for generations to come.

—Krishna Saraswat

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About the Author

Krishna Saraswat is the Rickey/Nielsen Professor of Electrical Engineering at Stanford University. His research involves materials, structures, and process technology of semiconductor devices and interconnects for nanoelectronics as well as high-efficiency and low-cost solar cells.

A Shining Beacon

Jim Meindl joined the Electrical Engineering (EE) Department at Stanford University in September 1967. I had the great pleasure of working with Jim from the day he arrived until the day he left to become provost at Rensselaer Polytechnic Institute (RPI) in 1986.

Jim's goal at Stanford was clear from the beginning: to create the first and best academic center in the world focused on the physics, technology, and application of ICs. He understood instinctively how to do that. He collected a group of dedicated graduate students who could share his enthusiasm for ICs and their applications. He found funding to create a lab on campus where they could work, and he imparted his own conviction that the problems most worthy of their attention were problems that would change people's lives. It was a worthy goal, one that would have a long-term impact on our EE Department, our Medical School, and well beyond.

However, the design of IC-based systems took a sharp turn in 1971 with the invention of the microprocessor. Now, the software that controlled the microprocessor became a critical part of system design, as did application-specific sensors. Jim saw in this a new opportunity for Stanford, one that would require new facilities and a new model for interaction between Stanford and its industrial partners. That opportunity led to the creation of the Center for Integrated Systems, where Jim was responsible for designing the new fabrication facility that was critical to the Center's success.

Jim's ability to lead at the highest levels made him a much sought-after candidate for jobs at many other laboratories and universities. He turned down many of these but finally left Stanford to become provost at RPI, where he served with distinction for seven years, after which he accepted an appointment at Georgia Tech as the J.M. Pettit Professor of Electrical Engineering and director of the J.M. Pettit Microelectronics Center.

Jim was amply rewarded for this extended effort, receiving a number of very distinguished awards, among them, election to the National Academy of Engineering in 1978, the IEEE Education Medal in 1990, and the IEEE Medal of Honor in 2006. The citations for these awards offer an accurate, if only partial, reflection of Jim's extraordinary leadership. His 90 Ph.D. students offer another measure, one of which Jim was especially proud. His beacon still shines for all of us at Stanford, at RPI, and at Georgia Tech.

—Jim Gibbons

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About the Author

Jim Gibbons joined Stanford University's electrical engineering faculty as an assistant professor in 1957, was appointed professor of electrical engineering in 1964, and served as dean of the School of Engineering from 1984 to 1996. He built Stanford's first semiconductor processing laboratory (1958) and was instrumental in creating Stanford's Center for Integrated Systems (1980).

"The Chief" of Silicon Valley

Prof. Jim Meindl became my dissertation advisor in 1970, when Intel was only two years old. That changed my life. I had never heard the term *Silicon Valley* until my first day at the Stanford IC Lab, an amazing place in which Prof. Meindl's students talked of changing a world in which personal computers and even calculators were not available. The IC Lab gave us the opportunity to make transistors and ICs with our own hands.

Many of Prof. Meindl's students called him "The Chief" or "J.D.M." because of his prowess at raising the significant funding needed to support all of us and the IC Lab. He never mentioned the enormity of this task, which I did not fully appreciate for another decade, when I had to raise money for my own company.

Jim also supported us on a personal level. During the last quarter of my undergraduate education as a physics and chemistry major at Dartmouth College, I took a single electrical engineering (EE) course—and fell in love with EE to the extent that I abandoned my graduate school position in applied physics at Stanford. After arriving at Stanford, I scrambled to find a paying job in the EE department. In our first meeting, I asked Jim how a metal–oxide semiconductor transistor worked. He explained it to me carefully and lent me one of his books. Despite my naivete, Jim hired me to run an epitaxial reactor in the IC Lab. He said that with my chemistry background, I could support his other students—and that was enough to cover my tuition.

Later that fall, he overheard me say that I could not afford to fly home for Thanksgiving—my favorite holiday—and invited me to his home for Thanksgiving dinner. Prof. Jim Meindl was a kind man who enhanced the lives of many in Silicon Valley.

—T.J. Rodgers

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About the Author

Thurman John "T.J." Rodgers is a Silicon Valley entrepreneur. He was a founder of Cypress Semiconductor Corporation and served 34 years as the company's CEO. Rodgers received 20 U.S. patents and has been inducted into the Silicon Valley Hall of Fame. He serves on the board of several high-technology companies in the areas of high-performance residential solar systems and utility-scale solar power plants, gallium nitride power transistors, and advanced lithium-ion batteries.

An Amazing Legacy and Inspiration

Prof. Jim Meindl had a huge, long-lasting, and positive impact on me, as he did with so many others he touched. He was very supportive of his students, deeply engaged in our work, and yet very forgiving of our shortcomings. When I later joined the Stanford University faculty, I endeavored to follow his example of what a professor should be.

With the development of the Stanford IC Lab and, later, the Center for Integrated Systems (CIS), he helped put Stanford on the microelectronics world map. The CIS became a mecca in the 1970s for those who wanted to pursue microelectronics technology. It was a very stimulating place to be, learn, and grow.

Being immersed with his students was a life-changing and seminal experience for me. We formed a tight-knit community that explored IC technology with gusto and excitement—all made possible through his leadership and the facilities he helped create. The time at Stanford working with Jim Meindl and his students will remain among my fondest memories. I am doubly grateful for those world-class capabilities because the solar cell technology underlying SunPower Corporation was developed there.

Jim helped make Silicon Valley the amazing fount of technology it has become. What a superb legacy and inspiration to all who followed him.

—Richard M. Swanson

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About the Author

Richard M. Swanson received his Ph.D. degree from Stanford University in 1974, after which he joined the electrical engineering faculty at Stanford. In 1991, he resigned from his faculty position to devote his full time to SunPower Corporation, which he founded.

Georgia Tech Years

Jim Meindl's Impact and Legacy at Georgia Tech

James D. Meindl, our treasured friend and colleague in the School of Electrical and Computer Engineering (ECE) at Georgia Tech, was a giant in the world of semiconductors and a gentleman of the highest magnitude. Meindl's arrival at Georgia Tech in 2013 brought immediate and significant visibility to the Institute, and his leadership was immediately and positively felt in the development of microelectronics research and education. His record of leadership in microelectronics and nanotechnology is simply unmatched.

During his 20-year career at Georgia Tech, Meindl graduated more than 30 Ph.D. students and established several national research and educational programs in microelectronics and nanotechnology. Meindl was the founding director of the Nanotechnology Research Center, which eventually became what is now known as the Institute for Electronics and Nanotechnology.

While Meindl's influence on his own Ph.D. students is unquestionable, he made a significant and lasting impact on the Georgia Tech ECE faculty, enriching their lives and those of his many colleagues and friends elsewhere at Georgia Tech as well as throughout the United States and the world.

—Jackie Nemeth

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About the Author

Jackie Nemeth is a communications manager in the School of Electrical and Computer Engineering (ECE) at Georgia Tech; she has worked in communications and administrative roles for ECE since 1992. Prior to joining ECE, she worked with the Georgia Tech News Bureau.

Contagious and Empowering Enthusiasm

Being around his students was a true source of joy for Prof. Meindl. Nothing made him happier than seeing his students become successful. He never spoke of the many professional awards he received. However, when a student received a paper award or a recognition, he celebrated it with the greatest excitement and enthusiasm and highlighted it throughout the student's Ph.D. studies. Being humble was one of his many gentlemanly qualities, but perhaps one of his greatest gifts was inspiring the people around him—instilling confidence through kind words and actions, especially in technical meetings with his students.

No matter how difficult the research seemed, Prof. Meindl's enthusiasm about his students' ideas and work were contagious and empowering. I believe this is a key reason for the virtually unmatched success of his research group. Following his retirement, I often walked by his portrait in the Marcus Nanotechnology Building and smiled back at Prof. Meindl; his memory is our treasure, and his wisdom and kindness will always be with us.

—Muhannad Bakir

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About the Author

Muhannad Bakir is the Dan Fielder Professor in the School of Electrical and Computer Engineering at Georgia Tech. His research interests include heterogeneous and 3D integration technologies.

Constructive Feedback, Positive Influence

My Ph.D. research focused on the limits of power consumption and parameter variations at the circuit level. As an example of a Prof. Meindl teaching moment, I recall giving my first presentation at the weekly graduate students group meeting, where one student gives a talk on his or her research. I worked hard to prepare and felt confident about the presentation. As a young member of the group, I wanted to impress Prof. Meindl. During the presentation, he and the more experienced graduate students identified multiple issues with my research that I clearly needed to address. From my perspective, the presentation was a disaster!

I learned later that Prof. Meindl was excited and upbeat about how well the meeting went. Although I was shocked to hear this at the time, I later learned to appreciate Prof. Meindl's perspective with his vast experience of mentoring graduate students before and after me. He viewed this meeting as a valuable growth opportunity for me. He knew the constructive feedback from this meeting would positively influence my future research, and he was right. His encouragement, guidance, and problem-solving skills enlightened my thinking about microelectronics research topics and beyond. He encouraged me toward the physical insights and key tradeoffs.

—Keith A. Bowman

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About the Author

Keith A. Bowman received his B.S. degree from North Carolina State University and his M.S. and Ph.D. degrees from Georgia Tech, all in electrical engineering. He is a principal engineer and manager at Qualcomm in Raleigh, North Carolina, USA.

An Unconventional and Thoughtful Problem Solver

I was always in awe of the creative and carefully crafted way Prof. Meindl chose to represent ideas. For example, I remember, when I first started to study with him, he wanted me to illustrate the relationship between on-chip interconnect time delay and interconnect length. I came to my meeting with him with a plot of time delay versus interconnect length to illustrate this relationship, which I thought was an obvious choice; however, Prof. Meindl's thoughts were much more creative and insightful. He wanted to plot the reciprocal length squared versus time delay so that the diagonals in a log–log plot were loci of constant resistance per unit length and capacitance per unit length product.

This is just a small example of my first experience with the completely unconventional and thoughtful way Prof. Meindl approached problems. He had such intellectual gravitas that students listened attentively, and, with this hyperattention in hand, he kindly and respectfully helped them see a much deeper world of knowledge and way of thinking. I appreciate his helpfulness and willingness to meet with his students often. I know that his mindset and ethos will live on through the many people he has impacted.

—Jeffrey A. Davis

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About the Author

Jeffrey A. Davis is an associate professor in the School of Electrical and Computer Engineering at Georgia Tech, Atlanta, Georgia, USA. He is currently the faculty director for the Grand Challenges Living Learning Community, where he uses his passion for undergraduate education to train students to be entrepreneurial problem solvers to improve the human condition.

Brilliant, Kind, Gentle, and Generous

I was simply fortunate to have Prof. Meindl as my Ph.D. thesis advisor and, later, professional guardian, role model, and mentor throughout my career. I have never met any person so brilliant and yet so kind, gentle, and generous to one and all. He had a way of inspiring those around him to strive for excellence and enjoy the journey with him. He instilled in me a work ethic and sense of integrity as well as the courage of conviction simply by living these rare values in everything he did every day—throughout his life. My wife Dipta and I will miss him dearly.

—Vivek De

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About the Author

Vivek De is an Intel fellow and director of circuit technology research at Intel Labs. He is responsible for providing strategic technical directions for long-term research in future circuit technologies and leading energy efficiency research across the hardware stack.

"Do the Simple Case First"

While always kind and courteous, Prof. Meindl did not spoil the child (or graduate student). In my first meeting with him, he gave me a recently published article to read and requested I come back next week prepared to discuss. I quickly realized the following week, as the heat seemingly increased in his office, that I had inadequately prepared.

For all future meetings, I had a written report with supporting material; that strongly encouraged habit has served me well throughout my career. Finally, the concepts we researched were complicated, full of advanced math and many variables, and had gotten to the point where most researchers would run sophisticated software modeling. However, one could quickly overcomplicate things to the point where insights and conclusions were lost in the immense amount of data and experiments. Prof. Meindl always preached, "Do the simple case first," understand it fully, and derive the baseline trends and insights; then, add the layers of accuracy/complexity necessary to refine results.

—John C. Eble

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About the Author

John C. Eble received his B.Cmp.E. degree in 1993, M.S.E.E. degree in 1994, and Ph.D. degree in electrical engineering in 1999 from Georgia Tech. He is currently vice president of product marketing for Rambus Inc.'s memory interconnect chip business unit.

"Don't Complicate, Simplicate!"

I still remember many of Prof. Meindl's questions and pieces of advice and share them with my students. When thinking about picking a research topic or a task, he would ask, "What is your unfair advantage?" When coming up with a new design or proposal, he quoted one of his "wise friends": "Don't complicate, simplicate!" Meetings with Dr. Meindl always ended with an emotional fulfillment—a sense of surprise, accomplishment, and wonder. Put simply, meetings with him were a "gift," and what a gift he was to all of us who knew him and those of us who were touched by his wisdom and kindness. He will be so deeply missed, but his legacy will live on.

—Azad Naeemi

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About the Author

Azad Naeemi is a professor in the School of Electrical and Computer Engineering at Georgia Tech. His research crosses the boundaries of materials, devices, circuits, and systems, investigating ICs based on conventional and emerging nanoscale devices and interconnects.

Remembering Our 1,000 1-Min Conversations

I miss my office in the Georgia Tech Microelectronics Research Center (MiRC). It is where I first heard Jim Meindl speak in 1992. I instantly liked his talk and approach to science and technology. His presentation was army crisp, direct, and impactful.

I came to work with Jim in several capacities over the next 25 years after our first meeting. My MiRC office was halfway between Jim's director's office and the faculty office in the two opposite corners of the MiRC. One of my memories is the 1,000 1-min conversations we had as he walked from one office to the other past my office. Jim would walk in and settle down in a chair, and one of us would say the first thing on our mind. The other would then give a concise, honest response. The topics included technology, people, history, and the issue of the day. After the response, we would smile, and he was off to his office. We would not say goodbye because the conversation was not over, just paused. I noticed that sometimes he would return the way he came, and he wasn't just passing by.

When Jim stepped down as director of the Interconnect Focus Center, I quoted the legendary Lou Holtz in describing Jim. Lou's rule number three for life is "Show people you care." Jim was known for his caring. I recall one day when my wife Betsy came to pick me up at the MiRC. She was 20 min early, so she brought a book to read in the MiRC lobby outside of Jim's office. Jim saw her sitting by herself and brought her a cup of coffee. He sat with her so that she would not be alone. When I arrived, we just smiled and parted. In truth, I don't really miss my MiRC office. I miss Jim Meindl.

—Paul Kohl

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About the Author

Paul Kohl is a Regents' Professor and Thomas L. Gossage Chair Professor in the School of Chemical and Biomolecular Engineering at Georgia Tech.

Commitment to Developing Early-Career Individuals

I first met Jim Meindl in 1974, soon after I joined Bruce Deal's group at Fairchild Semiconductor and after I completed grad school. Bruce and Jim initiated a program to generate the necessary experimental data, develop fundamental understanding, and ultimately formulate models for various processing steps in IC manufacture (e.g., silicon oxidation and dopant diffusion). Bruce and I met with Jim's group every two to four weeks; through that program, I got to know some of Jim's graduate students: Jim Plummer, Krishna Saraswat, and Rafael Reif.

In addition to Jim's amazing insight and perspective on devices and circuits, he was relentless in his commitment to developing early- (and later-) career individuals. For instance, approximately one year after we began the meetings, Bruce had to be out of town during our scheduled session, so I was the only person there from Fairchild. Jim approached me after the meeting and said that he was grateful that Bruce was involved in this work but that he especially appreciated having the next generation of scientists and engineers involved since they could offer new perspectives and directions—he thanked me for my participation and contributions. This attitude pervaded Jim's entire career; certainly, his time at Georgia Tech followed this pattern in that he always offered encouragement and mentoring to everyone around him.

Jim and I spoke on a regular basis after I joined Georgia Tech; I also served on a number of his Ph.D. students' thesis committees. A major advantage to these interactions was that Jim made it clear that he was always open to new ideas and ways of looking at situations and problems. For example, in 2006, I became interested in etching copper films using hydrogen-based plasmas at room temperature or below. Since this was a radical idea at the time, I did not have the funds to investigate this possibility and obtain preliminary data for a proposal. After a brief discussion, Jim allowed my students two days in the clean room to try out the idea. The results initiated a new approach to patterning copper layers, and government and industrial funds and efforts followed.

—Dennis Hess

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About the Author

Dennis Hess is a professor emeritus in the School of Chemical and Biomolecular Engineering at Georgia Tech.

The Ultimate Gentleman

Jim was a mentor, and he and his wife, Freddie, were friends. I have many fond memories of our interactions and the fulfillment and appreciation I always felt when spending time with Jim. He was the ultimate gentleman. Everything he did was done with grace, respect, and care for others.

One of the gentleman's many qualities was that he was always extremely well prepared. The "selling" of what became the Marcus Nanotechnology Building is a good example. Jim had discussed the concept with Roger Webb and me on a number of occasions, and we encouraged him to pursue it. At some point, I felt it was time to present it to a larger segment of the Georgia Tech leadership, including the president, Wayne Clough.

I organized such a meeting and have a great memory of Jim going through his presentation (words, not PowerPoint slides!) that lasted no more than 10–15 min: it was so limpid and compelling that, at the end of it, there was basically no question to be asked! Because of the many and expensive initiatives Georgia Tech was already engaged in at that time, I had expected some tough discussions and came prepared to support Jim. Help was not needed; basically, the answer was "Let's figure out the way to do it." Jim had, in his remarkable, compelling, and respectful way, exemplified one more time what it is to be an institutional builder and showed the path forward.

—Jean-Lou A. Chameau

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About the Author

Jean-Lou A. Chameau is the former provost of Georgia Tech, president emeritus of the California Institute of Technology, and president emeritus of King Abdullah University of Science and Technology. Prior to serving as provost at Georgia Tech, he was dean of the College of Engineering and director of the School of Civil and Environmental Engineering.

A Tremendous Impact on Microelectronics and Nanotechnology Research at Georgia Tech

Jim Meindl's impact on microelectronics and nanotechnology research at Georgia Tech is hard to overstate. I think it is fair to say that, without Jim's vision and leadership, we would not have the Marcus Nanotechnology Building at Georgia Tech, nor would we be a site of the National Science Foundation (NSF)-funded National Nanotechnology Coordinated Infrastructure (NNCI), let alone the coordinating office for the whole NNCI network.

The NSF-funded NNCI (2015–2025) and its predecessor, the National Nanotechnology Infrastructure Network (NNIN) (2004–2015), provide researchers from academia, large and small businesses, and government with access to leading-edge fabrication and characterization tools, instrumentation, and expertise across all disciplines of nanoscale science, engineering, and technology. Prof. Meindl served as director of the Georgia Tech site and the southeastern hub of NNIN from 2004 until his retirement in 2013. This decade included the opening of Georgia Tech's Marcus Nanotechnology Building in 2009, which still features one of the largest academic cleanrooms in the country as well as a state-of-the-art materials characterization facility.

Prof. Meindl's leadership and the resulting Georgia Tech participation in NNIN and, now, NNCI led to significant investment in the nanotechnology faculty and research infrastructure. Today, the Georgia Tech nanotechnology core facilities offer access to more than 200 nanofabrication and characterization tools and support in excess of 1,000 annual users, representing greater than 200 faculty groups across the campus as well as more than 160 external users from academia, industry, and government labs. Comparing this to the 250 annual users that the Georgia Tech site had in 2004 (the first year of NNIN) highlights the tremendous impact Jim Meindl had on microelectronics and nanotechnology research at Georgia Tech.

—Oliver Brand

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About the Author

Oliver Brand is a professor in the School of Electrical and Computer Engineering and the executive director of the Institute for Electronics and Nanotechnology at Georgia Tech.

Providing Georgia Tech an "Unfair Advantage"

When we were in the planning stage of the Marcus Nanotechnology Building, Jim stated that we needed to create a facility that would provide Georgia Tech an "unfair advantage"—that is, a facility that would enable Georgia Tech to continue to recruit the caliber of faculty and graduate students that would provide the advantage. It is precisely that "field of dreams" argument that President Wayne Clough utilized in securing the initial funding for the Marcus facility from the state. The argument is not without precedent. Absent the Pettit Microelectronics Building, it is highly unlikely that Jim Meindl would have elected to finish his remarkable academic career providing Georgia Tech a unique and widely recognized "unfair advantage."

—Roger Webb

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About the Author

Roger Webb is a professor emeritus and the former Steve W. Chaddick School Chair of the School of Electrical and Computer Engineering (ECE) at Georgia Tech. His association with Georgia Tech and the ECE has spanned more than 60 years.

A Quarterback's Passion and Desire to Win

I first met Jim Meindl when we were fellow graduate students at Carnegie Tech (now Carnegie Mellon University) in Pittsburgh in 1956. My best early memories about Jim start at the time he organized an intramural touch football team at Carnegie Tech. I played on his team from the Electrical Engineering (EE) Department as a pass receiver. Jim was the quarterback for our team, which was named the Static Charges.

The most impressive member of our team by far was Ed Karcher. He was then a grad student in our EE class, but, the previous year, he was a star 180-lb guard on the Tech varsity team called the Tartans. When the football was snapped to Jim, I saw Ed's amazing speed. He kept the other team's players far away so Jim could throw his passes.

I don't remember much more about the game except for a play where I ran far down the field to receive a pass from Jim. The football was sailing pretty far over my head, so I stopped running. Jim yelled at me to keep running until the play was over. It was a good demonstration of Jim's passion and his desire to win, which were evident throughout his career.

While my work at IBM on scaling was underway, I visited Jim's group at Stanford University frequently in the summer to talk to him, Jim Plummer, and their graduate students. I gave lectures on my scaling papers, acknowledging a very important 1972 paper by Swanson and Meindl, that models metal–oxide semiconductor transistor operation in the weak inversion region near turn-on. I also did some recruiting and was happy to hire Nicky Lu to work with me on high-speed DRAM. He went on to found his own company, Etron, and should be counted as one of Meindl's many very successful students.

Jim Meindl was a very dear friend of mine and will be greatly missed. I join you all in honoring his outstanding career.

—Robert H. Dennard

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About the Author

Robert H. Dennard is an IBM Fellow Emeritus at the IBM Thomas J. Watson Research Center, Yorktown Heights, New York, where he was involved in microelectronics research and development from its early days. In 1967, he invented the single-transistor dynamic memory cell (DRAM) used in most computers today and, with coworkers, developed the concept of MOSFET scaling in 1972. He is a Life Fellow of IEEE and received the IEEE Medal of Honor in 2009.

One of the World's Premier Semiconductor Experts

In 1988, having separated from his first start-up, Wafer Scale Integration, Eli Harari told me that he had some ideas on how to create very dense flash memory cells, which, in addition to the benefits of microelectronics, over time could possibly approach the cost per megabyte of rotating storage. Although the prospect of financing a memory company was daunting, I encouraged Eli to take residence in our offices, Concord Partners, the venture capital arm of Dillon Read and Co., and develop his concept. He accepted the offer and went to work.

After a few months, he had come up with some simulations and emulations and was at a point where he required funds for both patent applications and, because he was receiving no compensation, groceries. I figured that if we were going to seed a memory company, with its attendant long gestation time and ultimate dedicated manufacturing requirement, we had better be pretty sure that we had something special.

I had met Jim Meindl several months before. As a Stanford University professor, head of the school's microelectronics lab, and one of the premier semiconductor experts in the country, if not the globe, he spoke often to various student and industry groups. I had attended one of his tutorials, and, although the science challenged my understanding, his enthusiasm and imagery enabled me to visualize all of those little electrons running around their tiny silicon platform. For a nontechnologist, the ability to mentally construct microelectronic devices in dumbed-down form made all the difference. Jim so obviously loved to teach; he had developed his own methodologies that made the science decipherable, even by the unwashed. We spent some time together and became acquainted.

In the meantime, my partners and I listened to Eli's pitch, and we decided to seed the start-up with US$250,000, dependent on whether Jim Meindl would tell us that Eli's inventions had serious technical and manufacturable viability. I called Jim and asked him to do me a big favor: listen to Eli for an hour or two, look at his data, and tell me: Is this real?

Jim had a lot on his plate at the time, but, graciously (graciousness was one of his most compelling attributes) and despite his skepticism that the claimed device attributes could be achieved, he agreed to spend an hour or so with Eli. Well, anyone who has consorted with technologists knows that when a couple of them get together and start gnawing on a bone, clocks have no place. Eli and Jim spent most of the day together, after which Jim told me that Eli really had something, that this could not be a socket flash (it required an external controller), and that it would take time to commercialize because it had to create dedicated sockets, but that the design, capacities, performance, and manufacturability were indeed possible.

I had almost hoped that Jim would have killed the idea because the notion of starting a memory company from scratch was almost crazy. I said, "Jim, if you are so positive about this, will you agree to become chairman of the company's technology committee?"

Without asking for compensation of any kind, he said yes. Concord invested US$250,000, and SunDisk (which, a few years later, at Sun Microsytems's urging, became SanDisk) was born. Jim did indeed chair the company's technology committee and served on its board of directors for two decades. About 25 years after Jim said yes, SanDisk was acquired by Western Digital Corporation for a bit more than US$19 billion.

—Irwin Federman

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About the Author

Irwin Federman is a senior advisor with and, from 1990 until 2015, was a general partner of U.S. Venture Partners (USVP), a 35-year-old Silicon Valley early-stage technology and health-care venture capital partnership. Prior to joining USVP, he was a managing director of Dillon Read & Co., a 100+-year-old investment banking firm, and was a partner in Dillon Read's venture capital arm, Concord Partners.

A True Leader

True leadership can be an elusive quality. I witnessed it during my employment by James D. Meindl at Georgia Tech. I was inspired each day by his zeal and determination in his highly effective leadership among colleagues in academia, government, and industry. I nicknamed him the "Wizard of the Nanotechnology Research Center" because he easily spun the same caring, collaborative web within our staff from 2002 to 2012.

In triple roles as educator, business director, and personal assistant, I watched the Wizard greet everyone with a smile and a calm, pleasant demeanor and then listen intently during each conversation. He enthusiastically led weekly staff meetings where roundtable sharing of successes was encouraged. I recorded, as researchers shared and listened to other engineers, technical and administrative staff, and students equally. The tone of sincere respect uplifted us all. We actively celebrated special events, such as birthdays, weddings, and baby showers as well as costume and pie-baking contests. Professors vied for positions as honored judges. One most special occasion was a retirement celebration for 30-year custodial staff member, Joyce. The Wizard surprised her with a dozen red roses.

From 2012 to 2016, the Wizard and I developed a special cadre of Science, Technology, Engineering, and Mathematics (STEM) Outreach Ambassadors. With leadership communication training, graduate students created and shared an experiment that explained their research. Each ambassador actively volunteered in local K–12 STEM Outreach events. This program reached more than 2,500 young learners each year. Videos of each ambassador explaining his or her research extended our project, adding value to their future opportunities.

The Wizard's guidance molded the next exciting stage of my life, when I created a business website, https://be4steminc.com/, that highlights more than 60 YouTube videos plus early elementary STEM offerings. His inspiration continues in my recently authored series of uplifting future STEM career lessons at https://www.teacherspayteachers.com/Store/Be4steminc. My inspiration, along with that of scores of others, is the legacy of this true leader.

—Diana Palma

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About the Author

Diana Palma is a retired educator, business director, author, and owner of Be4STEMinc, specializing in Pre–K–2 science, technology, engineering, and mathematics (STEM) education materials. She served as the personal assistant to James Meindl, Georgia Tech professor emeritus, from 2012 to 2016, establishing the Volunteer STEM Outreach Ambassador program, and, since 2016, she has continued to produce STEM Outreach materials for early elementary teachers and parents.

A Perceptive, Optimistic, and Always Encouraging Mentor

Prof. Jim Meindl's academic career was almost perfectly synchronized with the rise of the microelectronics industry over the second half of the 20th century. Jim's Ph.D. degree in electrical engineering in 1958 came the same year as the invention of the integrated circuit by Bob Noyce and Jack Kilby and just 11 years after the invention of the transistor at Bell Labs in 1947. At Stanford University, Jim was a giant hands-on contributor to the rise of Silicon Valley, as Stanford and Berkeley universities had a huge impact on the technology, physics, and entrepreneurship that made the Valley world famous.

I first got to know Jim closely when Irwin Federman, our lead investor in SunDisk, my start-up company, asked me to go meet Jim at the Rensselaer Polytechnic Institute for a 1-h interview to get his up or down opinion of our new flash memory technology—would it even work? Jim and I got into a deep discussion in his office that lasted the full day, with drawings on the board and getting deep into the quantum physics of electronic tunneling. At the end of the day, Jim agreed to join our board of directors as technical advisor, which position he held until his retirement.

For the following two decades, Jim was an amazing mentor, always encouraging and optimistic, even when we were deep in the hole, and always perceptive of the most important challenges that we faced. Despite his technological and educational achievements and influence in the technology community, Jim was genuinely humble and soft spoken, bringing his natural warmth and friendly smile. He was much loved and respected by his students and colleagues.

I consider myself lucky and privileged to have known Jim Meindl for the past 30 years. May he rest in peace.

—Eli Harari

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About the Author

Eli Harari founded SanDisk Corp., a pioneer in flash technology, in 1988 and served as its CEO from its founding until his retirement in 2010. His awards include the IEEE Robert N. Noyce Medal (2009) and the U.S. National Medal of Technology and Innovation (2012).

A True Renaissance Man

I first met Jim Meindl when we were both serving on the board of directors of Zoran. A genuinely nice guy, soft-spoken, and appearing almost shy but always directly on point, he also seemed like the perfect person to do an assessment of the technical feasibility of a semiconductor idea that Eli Harari had introduced to Irwin Federman and me as prospective venture capital investors.

Eli's idea was that he believed he had a fundamental design approach to a problem that many had tried for years to solve but had never succeeded: a fast, nonvolatile, rewriteable memory chip. I had just read the *Scientific American* cover story that Jim had authored on the history and future of semiconductor technology, so he seemed, indeed, like the perfect person to assess Eli's idea, although it would involve his getting really down in the quantum mechanical weeds to see if the concept would actually work.

I asked Jim to take a look at it for us (what turned out to be "flash" memory). Jim was initially skeptical but spent a full day with Eli and reported back, in his typical humble and understated way, that the physics and other technical concepts were indeed sound.

We invested, and we asked Jim to join both the board of what became SanDisk, where he served for years offering sage advice at the highest of strategic levels as well as on detailed technical issues, and a new technical advisory board that we were forming at U.S. Venture Partners (USVP). This USVP advisory board was intended as a small working group of four or five senior technologists from various disciplines who would meet once a quarter to educate us on IT-related and biomedical technologies that were still just over the horizon but that would have important implications longer term.

The advisory board included the head of IBM Research, an Internet pioneer and guru at Harvard, the CEO of Amgen, the former chairman of the Santa Fe Institute, and Jim. The idea was that one member of the board would come up with the topic once a year and introduce us to a prominent person in that area to make a presentation and then discuss how and when that new development would be important.

Jim showed us all, over the 10 or so years he served, that he was a true Renaissance man, quiet and thoughtful, with insights in so many different disciplines, from quantum computing to biological processes to thorny personnel and corporate strategic issues. He was disarmingly modest and a real "regular guy"—if you ran into him on the golf course or at the bar, you would never suspect that he was such an accomplished mental giant. I feel fortunate to have known and worked with him. He was a gem.

—Phil Young

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About the Author

Phil Young received his B.M.E. degree in mechanical and nuclear engineering from Cornell University, his M.S. degree in engineering physics from George Washington University, and his M.B.A. degree from Harvard University. He served as a managing partner at U.S. Venture Partners for 20 years, raising US$2.5 billion for early-stage ventures, and he continues as a senior advisor.

Family

Much-Loved Husband and Father

It is with heavy hearts that we said goodbye to a much-loved husband and father (Figure S1). He was a kind and gentle soul and yet determined to forge his way. None of us could have imagined the life that he embraced, which centered around his gifted and talented students and his rewarding research. His students became our extended family and brought him endless joy and pride, and we thank you.

His work ethic, laser-focused questions, moral fiber, and love were as evident and memorable to us as his trademark haircut, briefcase, and jacket/tie. It is so heartwarming to know that the same motivation and thoughtful guidance he gave his family at home was also appreciated by his students and colleagues.

We extend our sincere appreciation for the efforts put forth in Jim's memory. We are truly humbled.

—Frederica Meindl and family

About the Authors

Frederica Meindl, Jim's wife of 59 years, met him when she was the secretary for his commanding officer at the Fort Monmouth Army Electronics Labs. Jim's son, Peter Meindl, received his B.S., B.A., M.S., and Ph.D. degrees from Stanford University and his M.B.A. degree from Northwestern University; he is a founding member of the Kepos Capital hedge fund team. He and his wife, Sarah, have twin sons, Jamie and Eric, who are studying at the Massachusetts Institute of Technology and Washington University, respectively. Jim's daughter, Candace Fleming, received her B.S. and B.A. degrees from Stanford University and her M.B.A. degree from Harvard University; she is COO of Monti Kids. She and her husband, Lee, have a daughter, Piper, in high school and son, Grady, in middle school.

FIGURE S1: Jim and Frederica Meindl with their children and grandchildren.

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