DEAN E. EASTMAN

1940–2018

Elected in 1988

"For early work in photoemission measurements and interpretation, and for subsequent leadership in process and packaging technologies."

BY FRANZ J. HIMPSEL, JOSEPH E. DEMUTH,
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SUBMITTED BY THE NAE HOME SECRETARY

DEAN ERIC EASTMAN'S father emigrated from Sweden during the Great Depression to seek an opportunity in the iron-mining industry of Michigan's Upper Peninsula. Born January 21, 1940, to Eric and Mildred Benson Eastman in Oxford, Wisconsin, Dean spent his youth, with three brothers and a sister, in the small town of Stambaugh, MI, with a population under 2000 and a total high school enrollment of about 300 students. Dean played on the basketball, baseball, and tennis teams.

Dean's academic options shrank after 8th grade, when his father purchased a small farm two miles out of town. The farm was in a different school district, where he had to attend an even smaller school of about 30 students. Fortunately, for his junior and senior years he attended the Stambaugh high school—where the faculty immediately realized they had a special student in their midst. As a junior, Dean took over teaching the physics course from a teacher who recognized that he himself was unqualified to do it properly. Dean was then given an IQ test, which he had missed when transferring schools. The score was not made public, but word got around

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that it was off the charts, and the faculty became intimidated by this transfer student.

Of course, intelligence is no shield from the harsh realities of life. The summer before his senior year, the mine and steel workers went on strike, leaving Dean's father unemployed for a time. Like many of his classmates, Dean joined his father cutting pulpwood in the forest. The backbreaking work paid $5 a day, much-needed income for the families.

Dean (and the rest of America) got a shock of a different sort when the Soviet Union launched Sputnik. The following day, the high school chemistry teacher told students he was glad he was old and would soon die, and that he pitied the students because they would likely spend their lives living under communist rule!

Dean began constructing a rocket for a science club project together with one of the authors (PEK) and another student; PEK recalls the ensuing events as follows: We built a solid-fuel projectile and successfully tested it in a vertical flight in the spring, but we had ambitions to reach the maximum possible flight distance. As science club members and "mature" honor students, we were allowed to work independently on our project in the chemistry lab. But we were running out of time—graduation (in June 1958) was only a week away. Under the circumstances, we decided to simplify logistics by doing our second launch right out of the laboratory window—conveniently assuming that nothing could possibly go wrong!

We set up the launch pipe at a 45° tilt and ignited the fuel. But instead of the anticipated blast-off, the rocket jammed in the unstable tube and the exhaust gases filled the laboratory. It burned for what seemed an eternity, but probably on the order of a minute. We scrambled around the room, opening all the windows and turning on the hood fans. This was not an effective response, and moreover the chemistry teacher caught us red-handed.

That night, the three rocket musketeers held a clandestine meeting to plan our damage-control strategy, but we conceded that in all likelihood we'd be expelled. The next day we were tasked with repairing the lab floor, which had been charred from the hot exhaust gases. But to our surprise, we were not summoned to the principal's office. Every day that week we waited for the call, but nothing! They let us sweat it out right up to the graduation ceremony, in which Dean served, as planned, as valedictorian. The rocket fiasco was apparently forgiven.

So college was still in our future. Dean planned to attend Michigan Tech, with its affordable in-state tuition. His academic horizons broadened, though, when his College Board exam scores landed him a full national merit scholarship and his acing of the Michigan Mathematics Exam resulted in a second scholarship to cover his additional expenses.

Given the distraction of the rocket fiasco, it was only a month after graduation that Dean belatedly applied to MIT. He was accepted, and the national merit scholarship was increased to reflect MIT's greater costs.

He earned his BS in electrical engineering (EE) in 1962. Drawn to a professor who had a much broader view of EE—encompassing, for example, the scientific understanding of materials used in electronic devices—than other faculty, Dean did his senior project on ferrite memory devices and wrote his BS thesis on this topic. He went on to a master's degree (1963), with a thesis on high-speed pulse transmission in strip-line arrays. His theses, together with his high grades and class participation, undoubtedly helped attract the attention of IBM.

At the time, IBM was greatly expanding its R&D efforts, having just established the Thomas J. Watson Research Center in 1963. A major part of this expansion was the recruitment of young scientists, recently graduated from top-tier universities, who had been trained to think broadly and who would be willing to tackle problems that eluded solution by standard engineering methods. IBM anticipated that some of these young recruits would join top management later in their careers and help steer the company in the right direction.

Dean was seen as an unusually promising prospect for IBM. The company hired him while he was still a graduate student and supported him until he finished his PhD (1965). His clearly defined research topic—ultrasonic study of magnetoelastic and inelastic properties of yttrium iron garnet—allowed him to finish quickly and start work at IBM, on what became a steep career path.

When he arrived at the Watson Research Center, a solid state theory group had just been formed there. The researchers were using large-scale first-principles calculations to probe and predict the electronic structure of solids, starting with metals. Given Dean's interest in the fundamentals of materials, he was attracted to the emerging technique of photoelectron spectroscopy, which he thought would complement the theoretical work.

He applied photoelectron spectroscopy to a wide range of topics, pioneering the characterization of electrons in a variety of materials. In addition to bulk materials he studied surfaces, using a combination of ultra-high-vacuum technology and ultraviolet photons. Careful control of surfaces enabled him to demonstrate how photoemission could reveal the molecular nature of chemisorbed molecules on a metal surface. Since then, such experiments have been used widely to study chemical reactions at surfaces, such as in catalysis.

He also explored the energy levels at clean surfaces of metals[1] and semiconductors. His work on the efficient emission of electrons from the diamond surface generated continued interest over the years in the search for a chemically stable electron source. He was particularly interested in magnetism, and he managed to resolve the magnetic exchange splitting,[2] which causes a material to become ferromagnetic.

To characterize electrons in solids completely, one needs to measure not only their energy but also their momentum (in all three directions). The ultimate goal is to determine the relationship between energy and momentum (often called the energy band dispersion), and angle-resolved photoelectron spectroscopy is uniquely suited to pursuing that

[1] Eastman DE. 1970. Photoelectric work functions of transition, rare-earth, and noble metals. *Physical Review B* 2(1).

[2] Eastman DE, Himpsel FJ, Knapp JA. 1978. Experimental band structure and temperature-dependent magnetic exchange splitting of nickel using angle-resolved photoemission. *Physical Review Letters* 40(23):1514.

goal. Dean designed a special instrument for this purpose, which he called the ellipsoidal mirror display analyzer.[3] The device not only selected the energy but also displayed two components of the momentum simultaneously. The third momentum component was more difficult to obtain because it required photons with continuously variable energy. Such photons were provided by using synchrotron radiation, the area in which Dean had arguably his largest impact.

Synchrotron radiation was ideal for photoelectron spectroscopy, given that it was tunable, orders of magnitude brighter than traditional UV lamps and X-ray tubes, and could produce polarized photons. These features made it possible to extract the complete information about electrons in solids. Dean became known for his push toward continuously variable photon energy by means of synchrotron radiation. Because this radiation was generated by high-energy accelerators and storage rings, he and other early users had to travel to particle physics centers to get access to it in the so-called "parasitic" mode. Since then, these parasites have become major players at their hosts. Many dedicated synchrotron radiation sources have been built worldwide. Dean's efforts in using synchrotron radiation started with a sabbatical to the MIT Cambridge accelerator in 1974.

Having contributed so much to IBM research's reputation as a center of excellence in science and technology, he was named an IBM fellow—the highest honor that can be bestowed on an IBM technical employee—in 1974. This status, which comes with substantial freedom and funding to pursue new ideas, allowed Dean to expand his operation in photoelectron spectroscopy by establishing his own IBM beamline at the Tantalus electron storage ring of the Synchrotron Radiation Center (SRC) near Madison, Wisconsin.

The IBM beamline, together with beamlines from Bell Labs and collaborations between universities and national labs,

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[3] Eastman DE, Donelon JJ, Hien NC, Himpsel FJ. 1980. An ellipsoidal mirror display analyzer system for electron energy and angular measurements. *Nuclear Instruments and Methods* 172:327.

attracted researchers from all over the world. Many of them went on to careers in synchrotron radiation, sometimes as leaders of their own synchrotron light sources. The Tantalus storage ring is now a Historic Site of the American Physical Society.[4]

Dean's pioneering experiments made him famous at a young age. He was a sought-after speaker at international conferences, impressing audiences with his magisterial style of presentation and his insights into future research avenues.

In 1980 he received the Oliver E. Buckley Prize, the highest honor in solid state physics, awarded by the American Physical Society. He shared it with Bill Spicer, his long-time competitor. The two were cited for "their effective development and application of photoelectron spectroscopy as an indispensable tool for study of bulk and surface electronic structure of solids."

In 1981 Dean decided to switch from research to technology development—a more direct way, he thought, of contributing to IBM's business successes. He moved up rapidly in management, simultaneously leading R&D in compound semiconductor devices, lithography, and "packaging" (the sophisticated manufacturing processes for the assembly of semiconductor chips to build complete computing systems). In 1986 he became vice president for logic, memory, and packaging and vice president and director of product development.

Eventually, he moved from the IBM Watson Research Lab to IBM headquarters in Armonk, NY, where he led the Department of Hardware Development and Reengineering.

As a leader in technology development, Dean took on the enormous challenges facing IBM at the time. And because he pushed farther and harder toward solutions than anyone else, in the end he either won big or lost big.

One such challenge was the development of X-ray lithography for semiconductor manufacturing. The project addressed

[4] The Synchrotron Radiation Center (SRC) in Wisconsin: A historic site of the APS. 2018. Online at https://www.aps.org/programs/honors/history/historicsites/synchrotron.cfm.

a perceived obstacle to the continued miniaturization of digital electronics: the inability of optical lithography to pattern devices with critical dimensions smaller than 1 micrometer. To replace the established optical lithographic tools and processes and deliver the necessary manufacturing throughput, a very bright X-ray source would be necessary.

Dean and his team favored X-ray contact lithography. Under his informed technical leadership and confident direction, they assembled, tested, and largely demonstrated a compact synchrotron source at IBM's East Fishkill (NY) manufacturing site. However, a series of innovations, some unforeseen, extended the established optical lithographic processes far beyond 1 micrometer to today's critical dimensions measured in tens of nanometers. While X-ray contact lithography had some important niche applications, it never much contributed to the development of digital electronics or to IBM's business.

By contrast, Dean's forceful advancement of another exploratory project had great positive impact for IBM. The enterprise began when one of the authors (TNT) briefed Dean on test results indicating that in the scientific and technical computing arena, IBM's new engineering workstations based on the emerging RISC (reduced instruction set computing) architecture could deliver some 60 percent of the performance of IBM's mainframes at about 5 percent of the cost. Within days, Dean had assembled a small team of semiconductor packaging experts, led by Janusz Wilczynski (NAE 1987), to prototype a high-performance scientific computer based on harnessing many RISC processors in a modularly expandable system.

Thinking Machines, a noted company at the time, was already selling scientific supercomputers that harnessed multiple processors, but these were based on expensive proprietary processor designs. The IBM team used workstation processors that were manufactured in high volume and thus had a low per-unit cost.

With Dean's encouragement and support, a prototype piece of hardware was very quickly built, and this helped to kick-start a larger effort in the IBM Research Division.

Selling the concept to the product divisions as well as potential customers, however, was an uphill battle involving many people over several years, but the inexpensive modular architecture gradually prevailed. The company's ultimate influence in this arena may be seen by the racks of interchangeable computers that now fill every modern server center. The crash execution of the kick-start project and its contribution to a greater success set a precedent for other IBM researchers confronting the company's looming financial crisis of the early 1990s. Their attitude was: Be bold, and you can make a difference!

Years before, Dean had foreseen some of the company's problems and voiced his conviction that extraordinary measures would be necessary to address them. In particular, he understood that the exponentially compounding miniaturization of semiconductor electronic devices would greatly reduce the part count for even the most complex and powerful computing systems. He predicted that this development would reduce the value of IBM's lead in chip-packaging technology and render much of the associated manufacturing capacity extraneous. When Dean was appointed director of hardware development and reengineering in 1994, his job was to identify and develop plans to address this new direction and other structural problems that plagued the company. Where other executives hesitated, Dean usually prescribed action, and he was very effective in this role.

In 1996 Dean was tapped by the US Department of Energy to lead the Argonne National Laboratory. He left in 1998 to start a second career as professor of physics at the James Franck Institute of the University of Chicago. In a return to his past, he initiated a synchrotron radiation experiment at the SRC with one of the authors (FJH), at the Aladdin storage ring. Dean impressed the local staff with his attention to the details of the experiment, making valuable suggestions to improve the setup.

Dean further shared his expertise through service on committees of the National Research Council. In the early 1980s he cochaired, with Frederick Seitz (NAS 1951), a committee that outlined the future of major facilities for materials research.[5] The committee's recommendations led to the construction of the Advanced Photon Source and Advanced Light Source, which respectively became the premier X-ray and UV light sources in the United States. He also chaired the Condensed Matter and Materials Research Committee (1976–83) and served on the Board on Physics and Astronomy (1983–86) and Commission on Physical Sciences, Mathematics, and Resources/Applications (1986–92).

For his contributions in applied physical sciences and engineering, Dean was elected to the National Academy of Sciences in 1982 and the National Academy of Engineering in 1988. He was also a member of the American Academy of Arts and Sciences.

In 2000 Dean took up a new challenge: renovation of Frank Lloyd Wright's Coonley House in Riverside, a suburb of Chicago. He liked designing things, particularly buildings. During his life he moved into a variety of houses in need of repair and completely redid them, waxing especially proud when he managed to improve on a contractor's design. He oversaw building projects at homes in New York, Maine, and Chicago. The Coonley House was his ultimate challenge.

Dean and his wife Ella Mae purchased the "public wing" of the sprawling former Coonley estate in 2000 and restored it with exquisite attention to detail, chasing down old photographs of the original design, doing an analysis of the original paint, and dealing with the onerous constraints encountered and permits required for renovating a building listed in the National Register of Historic Places. He was on the site daily in order to monitor progress and be available for quick decisions.

His restoration earned him the admiration and praise of preservationists, the 2004 Wright Spirit Award from the Frank Lloyd Wright Building Conservancy, and recognition as an honorary member of the American Institute of Architects. In

[5] Major Materials Facilities Committee of the Commission on Physical Sciences, Mathematics, and Resources. 1984. *Major Facilities for Materials Research and Related Disciplines*. Washington: National Academy Press.

a kind of victory lap, but primarily to reveal the secrets of his success for the benefit of other such projects, he wrote a book about his restoration efforts: *Frank Lloyd Wright's Coonley House Estate: An Unabridged Documentary* (self-published, 2014).

Dean also really liked cars. After he moved to a house with a three-car garage, he started collecting them—first a truck, then a big white Cadillac convertible with a huge engine, a Camaro (with a comparable engine), a BMW, and a classic Corvette. There was also a newer Corvette model, which he purchased because it was a deal he couldn't pass up (he was always keenly conscious of value and a lover of bargains).

Riding on the highway with Dean in his BMW could be a rather hair-raising experience. He kept a radar detector on the dashboard, and while cruising at high speed would quickly brake at the slightest alert. His passengers would worry about getting rear-ended, but this was not an issue because he was going so fast. He also had the unsettling habit of facing his passengers when talking to them—even those in the rear seats.

Colleagues and students enjoyed the annual Christmas party hosted by Dean and Ella Mae. As Dean became a wine connoisseur, he offered excellent wines at the event.

Dean was a lighthearted and jovial person, but would focus intensely on a technical problem or managerial issue. He could be a demanding manager, but also took time to provide detailed suggestions on how to accomplish a task. He appreciated smart people who worked hard and helped their careers in various ways. "Picking smart people's brains" was his efficient way of becoming familiar with the gist of a new topic. He quickly grasped the heart of a problem and was articulate in stating it. He also was an excellent writer and speaker, expressing things clearly and with uncanny insight.

He died March 4, 2018, at the age of 78. He is survived by his wife of 38 years, Ella Mae (née Staley).