

BOOKS

Edwin Land: A Life Devoted to Making the Impossible Probable

Insisting on the Impossible: The Life of Edwin Land

Victor K. McElheny
Perseus Books, Reading, Mass.,
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Reviewed by Richard L. Garwin

Edwin H. Land, inventor of the sheet polarizer and of instant photography, was a man who changed the world. Born in 1909 in Bridgeport, Connecticut, Land became an excellent student who devoured first the high school physics text his mother had kept and then R. W. Wood's *Physical Optics*. His goal was clear to him early in life: "As soon as I was old enough to escape from my family, at the age of 17," he was to recall, "I decided that the world needed a synthetic polarizer, an extensive sheet of polarizing material."

Escape he did. As Victor McElheny tells it in his fine biography, *Insisting on the Impossible*, after a few months at Harvard College in 1926, Land left for Chicago to attempt the great American novel; he then returned to rented rooms in Manhattan and to the New York Public Library, where he read avidly the literature on polarizers and began his lifelong commitment to experimentation. Within two years his intense work had paid off with his first sheet polarizer: He aligned the polarizer's tiny crystals of herapathite—an iodine salt of quinine—by stretching the plastic in which they were embedded. His first patent application was filed in April 1929. He soon resumed his studies in the physics department at Harvard, married Terre Maislen, who was to be his lifelong companion, and was given his own laboratory at Harvard by John McCloud, a perceptive physics instructor. In 1932, Land once again left Harvard, and with a

defecting graduate student, George Wheelwright II, formed Land-Wheelwright Laboratories.

Land's patent for the sheet polarizer was issued in 1933, the first of 535 patents he would eventually receive. In 1934–35, he signed his first contracts with Kodak and with American Optical to produce polarizing filters for cameras and lenses for sunglasses. In 1937, he founded Polaroid and bought out holders of competing patents. But his lifetime goal, polarizing screens for automobile headlights and polarizing windshields, so that drivers would be "freed from the terror of blinding lights," was to elude him.

In December 1940, in his annual address to employees about the company's future, Land predicted that the US would be at war within the year; thenceforth Polaroid's only purpose would be "to win this war." McElheny tells well the story of some of the Polaroid innovations in design and manufacturing that stemmed from this effort and later served as part of the basis for the company's activities in instant photography.

Polaroid photography itself was initiated during that time, too: In December 1943, on a family vacation in Santa Fe, Land's three-year-old daughter asked why she couldn't see instantly the picture Land took of her. Within the hour, he had thought through the camera, the film and the physical chemistry that could do the job. Instant photography had been perfected "except those few details that took from 1943 to 1973," as he recalled later. In 1948, sepia instant photography was marketed by Polaroid, in 1950 black and white, in 1963 color and in 1972 the marvelous SX-70 camera, with its integral film system, microelectronic brain and motorized drive.

Land was an inventor; an unconventional scientist and a man of unbounded energy, persistence, and endurance. At Polaroid (as at Land-Wheelwright) he created what he was convinced was a model science-based company and an engine of progress and democracy. Among the many excellent scientists at Polaroid, some had no formal technical education. An outstanding example was Meroë Marston Morse, who joined Polaroid in 1944 straight from Smith College, where she

had taken no courses in physics, chemistry or business administration but focused instead on art history. By the time she died in 1969 at the age of 45, the laboratory she led at Polaroid had contributed immeasurably to the development of black-and-white instant photography—for example, to film that was stable without having to be "coated" after removal from the camera.

In his public speeches to and about young people, Land insisted that a far larger number of them could be "great," if they didn't settle for conventional knowledge and for being only useful and valuable. In his May 1957 speech at MIT, "Generation of Greatness," he urged the university to change its curriculum to one that would involve every undergraduate in research.

Following the Soviet launch of Sputnik on 4 October 1957, Land was appointed to a four-person panel that created for the lay public an *Introduction to Outer Space*, with a foreword by President Eisenhower, who used it to launch NASA. Land was also active at that time in stimulating and reforming science education.

In 1954, Land had headed Project 3 of Eisenhower's Technological Capabilities Panel, which found US intelligence of Soviet capabilities wanting. Project 3 then played a major role in spurring and guiding the development of the U-2 spy plane, which flew eight months after the contract's start. The U-2 overflew Soviet territory at 70 000 feet, tracked by radar but beyond the reach of existing weapons—until it was downed in 1960 by an improved surface-to-air missile. Three months later, the super-secret Corona satellite program returned its first bucket of film from orbit. This was another program initiated by Land's panel in 1958 and, like the U-2, directed by Richard Bissell of the Central Intelligence Agency. These images from space showed that there was no "missile gap" and immensely enhanced world security. Corona flew 145 times by the program's end in 1972 and was the first of several generations of US satellite reconnaissance systems. Detailed histories of the U-2 and Corona have now been published by the CIA, but all other intelligence satellites remain behind the veil of secrecy, as does the full story of Land's leadership in

For more than 10 years, RICHARD L. GARWIN, of the IBM Thomas J. Watson Research Center, in Yorktown Heights, New York, was a member of Edwin Land's panel on overhead reconnaissance, which met in the Old Executive Office Building of the White House or sometimes in the Polaroid boardroom, with an occasional midnight visit to Land's own color-vision laboratory.

the development of these highly successful satellite capabilities. (See "Corona: The First Reconnaissance Satellites," by Albert D. Wheelon; PHYSICS TODAY, February 1997, p. 24)

In 1955, Land noticed what hundreds of others must have also observed—that the redness of an apple in a bowl or a color projection is extraordinarily robust to variations in the spectral composition of the light. Demonstrating this fact ever more clearly and seeking a sound theory to explain it became Land's passion for the next 30 years, at Polaroid and then at the Rowland Institute, founded and endowed in Cambridge, Massachusetts, by Land and his wife.

Land's ability to achieve the (near) impossible and persuade the public to buy it failed with Polavision—instant film movies—in 1978. A three-minute cartridge, without sound, signaled the conquest of the impossible, but it bombed in a market that was soon to see video cameras and players. In 1982, Land was forced out of Polaroid, and by 1985 he and his family had sold all their stock in the company he had created. He died in 1991 after several years of infirmity.

McElheny has written a fascinating account of the work of Edwin Land, who, for all his showmanship, speeches, patents, and publications, was a private person whose personal papers were shredded during the months after his death. Although they were cordial to McElheny, Land and his family provided no material for the book; the author has thus emphasized the technical and not speculated to fill in the personal gaps. The book makes a major contribution to the reader's understanding of the chemistry and physics of polarizers and instant photography as well as to an appreciation of the accomplishments of one individual and the contagion of his competence and achievement. An accomplished journalist, McElheny covered science and technology over a 40-year span (including stints at *The New York Times* and *Science Magazine*) and was founder of The Knight Science Journalism Fellows program at MIT, which he led from 1982 to 1998. The book is factual and well written.

Ecological Numeracy: Quantitative Analysis of Environmental Issues

Robert A. Herendeen

Wiley, New York, 1998. 331 pp.
\$44.95 pb ISBN 0-471-18309-1

More than most fields of research, environmental science uses and benefits from estimation and approximation. Physics and chemistry can be precise

and are generally approached in a precise way. Engineering can be precise as well, but the "engineering estimate" has a long history as a starting point. In environmental science, the parameters are often poorly understood, or there are unquantified but important variables, or a prediction depends partly on human behavior. As a result, there are often no correct answers, but an estimate or reasoned projection can be of great value. In his book *Ecological Numeracy*, physicist Robert Herendeen has produced a guide to the straightforward, often simple mathematics that has the potential to guide much ecological thinking.

The book is largely based on four equations: one that analyzes components of charge, a second that treats exponential growth, a third used for resource budgeting analysis and a fourth that examines the calculation of indirect environmental effects. A chapter is devoted to each, and three other chapters treat applications. Exercises are liberally provided, with the level of difficulty indicated. Along the way, students will face calculations designed to estimate the number of piano tuners in Chicago, the supply of coal in Illinois and the alteration of global carbon cycles.

Herendeen is at his best when the topic being treated is clearly defined and susceptible to straightforward mathematical treatment, as in the solid chapter on end-use analysis and the excellent one on dynamics, stocks and flows. The student working through these topics will get a good sense of the benefits to be gained by ecological numeracy in these areas.

I share fully Herendeen's notion of the value of simple mathematics in addressing environmental issues and in putting those issues into perspective. His book can be used as a teaching tool in several different ways and at several different levels, and the level of writing and extensive problem sets make it quite appropriate for advanced undergraduates with a modest mathematical background.

Herendeen is not an environmental scientist, and he tends fairly uncritically to climb aboard a few environmental bandwagons. One example is the "ecological footprint," proposed by Matthias Wackernagel and William Rees as a measure of the "load" imposed on nature by a given population. This is an interesting concept, but its quantification is contentious, and Herendeen does not explore its numeracy. Similar treatment is afforded the natural step conditions intended to provide basic principles for sustainability, in which Herendeen repeats the misdefinition of the geological term "lithosphere." An entire chapter is devoted

to ecological economics, an area not yet either well defined or numerated, and Herendeen adds nothing of particular value. The chapter on limits is short and contains little of value, notwithstanding the importance of the subject. Particularly unfortunate is the confusion of stressors and impacts in the classic IPAT (impact = population $\times$ affluence $\times$ technology) identity, an extremely useful conceptual idea, but one that incorporates a logical error now almost three decades old.

Herendeen's style is breezy, often as if he were in casual conversation with friends. This approach offsets the sometimes intricate discussions, and overall the book is quite accessible. I discovered only two errors in printing—a misspelling and an editor's provisional page heading that managed to survive the proofreading process.

A book on this topic immediately brings to mind John Harte's *Consider a Spherical Cow* (University Science Books, 1988), which Herendeen characterizes as "deeper and narrower" than his own book. I think this is a reasonably accurate description, and I would use Harte's book with students actively engaged in research. For a more general introduction to the use of estimation and semiquantitation in environmental studies, however, Herendeen's book has much to offer and deserves serious consideration as a component of modern science and engineering curricula.

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Explorations in Quantum Computing

Colin P. Williams
and Scott H. Clearwater
TELOS (Springer-Verlag), New York, 1998. 307 pp. \$59.95 hc
ISBN 0-387-94768-X.
Includes CD-ROM

Colin P. Williams and Scott H. Clearwater aptly describe their book *Explorations in Quantum Computing* as "the first book on quantum computing" and a "whirlwind tour." It undertakes, with mixed results, the ambitious task of explaining this new field in a self-contained manner, presuming no prior knowledge of quantum physics or theoretical computer science. The book does cover most of the important parts of the field in a readable fashion, but it lacks the accuracy, thoroughness and consistency of exposition one expects of a good textbook.

Explorations in Quantum Computing is likely to be most rewarding to