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EDWIN HERBERT LAND
1909–1991

A Biographical Memoir by

VICTOR K. McELHENY

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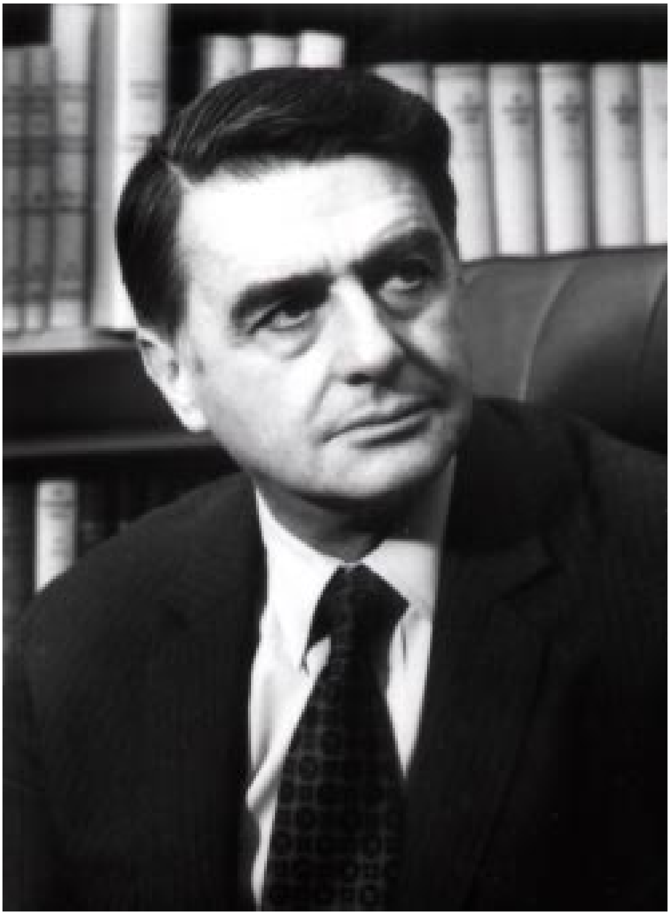

Photo by J. J. Scarpetti

EDWIN HERBERT LAND

May 7, 1909-March 1, 1991

BY VICTOR K. McELHENY

Less than two weeks after Edwin Land's death in 1991, members of the American Academy of Arts and Sciences (and the author) met to plan a day-long memorial conference. Swiftly, they decided on a title, "Light and Life." The agenda, however, was more difficult. Land was not just a scientist-industrialist. Speakers would have to encompass topics ranging from color vision to business innovation, from military intelligence to patronage of architecture. As the group talked about Land's character, Jerome Wiesner exclaimed, "Din never had an ordinary reaction to anything!"

Wiesner was referring to the extraordinary versatility of Land's mind and conversation, which enabled him to concentrate intensely on solutions to problems, and to charm and win over the talented people to tackle them. Until late in his life, he took pleasure in leaping up stairs two at a time. Besides energy, the dominant impressions Land created were artistic sensibility, a sense of drama, delight in experiment, relentless optimism. Less evident was a remarkable ability to keep both work and people in compartments. Less than six feet tall, Land had intense eyes and a shock of black hair that riveted attention on him. Despite a soft voice and frequent use of half-sentences, Land was able to convert interior monologues into dramatic public presentations.

The watchword was: "If anything is worth doing, it's worth doing to excess." This principle applied also to behavior in the laboratory. He told a press interviewer, "My whole life has been spent trying to teach people that intense concentration for hour after hour can bring out in people resources they didn't know they had."

Land's attitudes from boyhood were those of a physicist, but he is best known as the inventor and re-inventor of instant photography from the mid-1940s to the early 1980s. Those innovations had a prehistory: twenty years' work on the first plastic-sheet light polarizers, the great invention of his youth. The polarizers in turn led him into work on the Vectograph process of three-dimensional photography, which found its first important application in reconnaissance during World War II. His desire for autonomy and the challenges of reliably manufacturing his inventions reinforced his determination not to be absorbed by large corporations with large research budgets. But as a pioneer of the science-based company from the early 1930s, he frequently formed alliances with big firms, such as Eastman Kodak, to manufacture components of the systems. He became a vigorous prophet of the efficacy of science-based companies in promoting innovation and providing all their workers a rewarding life on the job.

Research on color vision, which he described in lectures at the National Academy of Sciences in 1958 and 1983, brought him into conflict with many in psychology—but eventually led to collaborations with neurophysiologists. The crisis of the 1950s, when thermonuclear weapons were succeeding nuclear ones and an open United States confronted a closed Soviet Union, brought Land into a crucial role of energizing and supervising high-altitude airplane and satellite surveillance from the mid-1950s to the late 1970s. Such surveillance, by giving incontrovertible physical evidence of the size of opposing forces, helped limit U.S. spending on weapons systems and later provided a principal factual basis for a succession of arms limitation treaties. Land thought constantly about education and research and sought new institutional forms. In 1957, he challenged the Massachusetts Institute of Technology to provide direct experience of research to undergraduates, thus helping to spur MIT's eventual adoption of such a system. In the late 1960s, he helped formulate and advocate the program of federal assistance to public television. He endowed the new house of the American Academy of Arts and Sciences in Cambridge, Massachusetts, and founded the Rowland Institute for Science in the same city.

PERSONAL HISTORY

As refugees from the ever-tightening persecution of Jews during the reign of Russian Tsar Alexander III (1881-94), Land's grandfather Avram Salomonovitch, his grandmother Ella, Land's father Harry, and uncles Sam and Louis, sailed from Odessa and landed at Castle Garden in New York City. In an incident typical for immigrants to America, they acquired the name of Land and Avram's name was Americanized to Abraham. Once in America, Abraham and Ella Land had two more sons and three daughters. Abraham started a scrap metal business. Many of Abraham and Ella's children settled in Brooklyn, where two sons became lawyers and a third entered the secondhand machinery business. The three daughters married, respectively, a lawyer, an architect, and a retailer. Later in life, Land had few contacts with relatives, including eighteen first cousins. After his father's death, in 1965, Land told a nephew, "My work is my life." Harry Land's scrap metal business took him to Bridgeport, Connecticut, and then to Norwich, Connecticut. There he handled most of the scrap from Electric Boat, a major manufacturer of submarines, shrewdly evaluating the content and worth of the metal he was recycling. Harry and his wife Matha Goldfaden had a daughter Helen, and in 1909 (when Harry was twenty-six) a son, who was named Edwin Herbert Land. Helen found the name hard to pronounce, and called her little brother "Din," a nickname that stuck.

In 1929, Land married Helen (Terre) Maislen of Hartford, Connecticut. His wife and he had two daughters, Jennifer Land Dubois and Valerie Land Smallwood. Mrs. Land and they survived him at his death in Cambridge, Massachusetts, on March 1, 1991. He was elected to the National Academy of Sciences in 1953, during his service as president of the American Academy of Arts and Sciences.

POLARIZER

As a boy, Land acquired a fascination with the kaleidoscopes and stereopticons so notably studied in the nineteenth century by the English optical scientist David Brewster. He also came across the textbook *Physical Optics* written by Robert W. Wood of Johns Hopkins University. The first edition of Wood's book (1905) had become well enough known to be cited in the 1911 *Encyclopedia Britannica* article on polarized light. Wood's teacher had been Henry Rowland, who in turn had studied with Hermann Helmholtz. Land was fascinated and read Wood's second edition (1915), he said, like the Bible. At the age of thirteen, at a boys' camp not far from Norwich, Land's fascination with polarization deepened when the camp's leader used a piece of Iceland spar to extinguish glare from a table top. Also at the camp, a near-collision in a car at night with a farmer's wagon underlined the perils of nighttime driving. Headlights should be stronger, but how could they be prevented from blinding the drivers of oncoming cars? The boys discussed how glare might be controlled by polarization. In 1926, the year his sister Helen graduated from Wellesley College, Land entered Harvard College. In a hurry to do actual research on optics, particularly polarization, Land left a few months later and went to New York, where he spent long hours in the great reading room of the New York Public Library. His idealism was roused, as he often recounted, when he walked down a major avenue in New York. The procession of headlights on the line of approaching cars embodied for him the primary reason for developing a thin and cheap polarizer.

Land began with experiments on reflection polarizers, but went on to repeat William B. Herapath's nineteenth century attempts at making giant thin crystals of iodosulphate of quinine in the hope of making simple polarizers for microscopes. Land had no more success than Herapath. Faced with this impasse, Land reversed course and envisaged a plastic material to be coated on sheets of film that would contain billions of tiny needle-like crystals in each square centimeter (in one dimension smaller than the wavelength of visible light). At first by electric or magnetic fields or later by stretching, the microcrystals were aligned to act as a polarizer. In 1929, with the invention perfected and the first patent applied for, Land returned to Harvard for three more years of study. His work on polarizers so intrigued Theodore Lyman, head of Harvard's physics laboratory, that undergraduate Land was given a separate lab.

In 1932, Land gave the first and so far the only Harvard physics department seminar by an undergraduate, "A New Polarizer for Light in the Form of an Extensive Synthetic Sheet." Instead of remaining to get a degree, however, Land pushed ahead with manufacture and commercialization of the polarizer, founding his own company in partnership with George Wheelwright III, a Harvard physics instructor. Because of the potential uses in controlling headlight glare—and in viewing three-dimensional movies—Land's invention received attention at the research laboratories of General Motors, General Electric, and Eastman Kodak. In 1934, Kodak became the first customer, buying polarizer sheet for camera filters. The next year, American Optical began buying polarizer-laminated sunglass lenses, opening the way to reorganization of Land's enterprise as Polaroid Corporation in 1937.

Polarizing spectacles, made of cardboard and plastic for viewing 3-D movies, were tried dramatically at the 1939-40 New York World's Fair. There, 5 million visitors to the Chrysler pavilion saw a 10-minute time-lapse 3-D film by John Norling, which showed the parts of a Plymouth car assembling themselves. But commercialization only occurred during the short-lived 3-D movie craze of the early 1950s, a boom in polarizers followed quickly by a bust. In the headlight field, where Land was seeking universal adoption by all car makers, the technological barrier went ever higher as the illuminating power of lamps rose and generated more heat, and the car industry demanded lamination of the polarizers on the outside of the lamps. To cope with wear from sun, dust, rain, and wind, as well as the higher temperatures, Land invented a new class of polarizers using dyes instead of microcrystals. At the same time, he worked along with Czech refugee Joseph Mahler on a new technology for 3-D still photos, which were named Vectographs.

INSTANT PHOTOGRAPHY

In World War II, the American military used Vectographs for aerial surveys of such major battlefields as Guadalcanal and Normandy. Land converted Polaroid Corporation entirely to war work in such fields as glare-controlling goggles, tank telescopes, gunsights, flight training machines, and heat-seeking bombs. In 1943, with the end of the war in sight, and uncertain about the commercial prospects for the polarizers, Land turned his thoughts to photography as a field ripe for innovation. His invention of instant photography, putting the chemistry of the darkroom between two sheets of film and producing a finished print in 60 seconds, was spurred during a vacation in Santa Fe by a question from his three-year-old elder daughter. Why couldn't she see right away the picture he had just taken of her? Setting off at once on a walk, "stimulated by the dangerously invigorating plateau air of Santa Fe," Land visualized the elements of an on-the-spot print system—in an hour. By chance, his patent attorney also was visiting Santa Fe, and Land could begin at once documenting his concept. Later, Land recalled, "You always start with a fantasy. Part of the fantasy technique is to visualize something as perfect. Then with the experiments you work back from the fantasy to reality, hacking away at the components." On another occasion, he said, "If you sense a deep human need, then you go back to all the basic science. If there is some missing, then you try to do more basic science and applied science until you get it. So you make the system to fulfill that need, rather than starting the other way around, where you have something and wonder what to do with it."

Experiments began at once, by Land and a small group of collaborators. The aim was a system for simultaneous development of the negative and positive. After exposure to light, the unexposed silver halides in the negative that developers had not reduced to metal were transferred to the positive, where special structures allowed the molecules to be anchored and then developed. The highly alkaline chemicals to set the process going were encased in metal-lined "pods," which were burst by the camera's rollers, thus spreading the processing fluid between positive and negative when the two were brought together after the exposure. To avoid interference, precise timing of many operations was required to achieve “the careful balancing of the simultaneous growth of the negative and positive.” Equally vital was chemical stability before, during, and after the picture was made and the positive peeled apart from the negative. Land worked with relentless optimism: “An essential aspect of creativity is not being afraid to fail. Scientists made a great invention by calling their activities hypotheses and experiments. They made it permissible to fail repeatedly until in the end they got the results they wanted. In politics or government, if you made a hypothesis and it didn’t work out, you had your head cut off.” A colleague, the chemist Myron Simon, praised “the spirit, the joy, the excitement of working with Land. . . . He was a charismatic leader. . . . He [could] choose and train people to do the work just the way he wanted it done, [and could] select people to fill in the voids in his own scientific background.”

After three years’ work, Land demonstrated the film publicly at a meeting of the Optical Society of America in New York in February 1947. A commercial film and camera went on sale in November 1948. The first film produced sepia images, but in 1950 Polaroid began selling a black-and-white restatement of the technologies. A fading problem forced prompt redesign, including the use of a plastic coating, invented by Howard Haas, that had not been required with sepia. During the 1950s, Land and such collaborators as Meroë Morse developed faster versions of black-and-white films, positive-negative and high-contrast films for professional use, and transparencies.

Meanwhile, Land’s co-worker Howard Rogers, began fifteen years’ research on color instant pictures. Rogers’s key invention was a molecule of dye for each of three colors—yellow, magenta, and cyan—linked to developer. The dye developers could be distributed in separate layers that adjoined silver halide layers sensitive to blue, green, or red.

Just before the color film went on sale in 1963, Land led a crash effort to avoid a coating step, by creating a self-washing system. This involved a spacer and a layer of acid polymer that would trap alkali processing molecules and release water. As with sepia and black-and-white, Eastman Kodak produced the color negative, while Polaroid made the innovative positive and assembled the film.

In the 1960s, sales of instant color cameras and film soared even more steeply than the larger Eastman Kodak color business, which was driven chiefly by small Instamatics. Competition from Kodak seemed ever more likely. The mounting Polaroid sales around the world allowed the company to retain more and more earnings to finance the next stage of instant photography, including taking over the manufacture of negative. For this multi-hundred-million dollar effort, costing a large fraction of one year's sales, Land mobilized a larger array of research teams than before and made arrangements with a web of outside suppliers. He regarded the new system as removing many years of compromises with his goal of a highly immediate, intuitive mass photography. He said that "one of my main purposes was to have a camera that's part of you, that's always with you." He wanted most amateurs "to get as good as professionals because it would enlarge their horizons." Doing this, millions of photographers would gain "a feeling of personal identification with the world in the way that photography has always hoped to do."

The compact, motorized, electronically controlled, single-lens reflex SX-70 camera and its new film were introduced in 1972 and nationally marketed a year and a half later. For the camera, numerous inventions were made on demand, such as a compact, four-element lens designed by James Baker, a viewing light path involving several aspheric surfaces designed by William Plummer and colleagues, and a flat four-cell LeClanché battery concealed at the bottom of each 10-picture film pack.

The “integral” film of SX-70 posed new stabilization problems because it permanently held both positive and negative. Lloyd Taylor developed temperature-independent timing layers for the negative and polymeric interlayers for the positive. Land had specified a camera that could be carried in a pocket. Hence, the thin mylar-encased film units could not be processed inside the camera. The mechanized rollers ejected each picture into orders of magnitude more light than had been used to expose it. The required opacification system, developed under the leadership of Land’s co-worker Stanley Bloom, combined a pair of phenolphthaleine dyes found by Myron Simon’s team with titanium dioxide particles, which formed much of the mass of the SX-70 processing fluid. The dyes, developed by a team under Land’s co-worker Stanley Bloom, were required to be completely opaque in the highly alkaline conditions of the first few seconds of processing and then to decolorize promptly to allow the photographer to judge the SX-70 image against the white backdrop of titania which sealed off the negative. The metallized-dye image, approximately 3 inches by 3 inches, “emerged” over several minutes, and a new acid polymer system regulated development and maintained stability thereafter.

Making the negative called for a large new factory, which drew on a new specialty chemical plant. Yet another new factory assembled the black-backed negative, the transparent positive, and pod of processing chemicals into integral film units, which were placed in 10-picture black plastic “packs.” Now controlling all the key parts of film manufacture, Polaroid could and did introduce running changes, such as more brilliant colors, an anti-glare coating, and faster processing times. The films adapted easily to smaller and cheaper cameras. Under Land's continuing control, the SX-70 dyes were retrofitted to peel-apart color films, such as those used to make full-scale replicas of paintings with the help of yet another Baker lens.

Throughout, Land emphasized the need to identify basic needs and imagine a system to meet them: "There's a tremendous popular fallacy which holds that significant research can be carried out by trying things. Actually it is easy to show that in general no significant problem can be solved empirically, except for accidents so rare as to be statistically unimportant. One of my jests is to say that we work empirically—we use bull's eye empiricism. We try everything, but we try the *right* thing first!"

When he said this to employees and shareholders, Land was stepping down after forty-three years as chief executive of Polaroid, in part because of the commercial failure of an additive-color instant movie system, introduced in 1977 as Polavision. Minute stripes of color were deposited on one side of the film, which was kept within a cassette. A very thin black-and-white negative was exposed to light in a camera similar to many used for home movies. As the exposed film was rewound for viewing on a television-like player, processing fluid covered the film to develop it, and bring metallic silver over into a positive layer. Instantly projected, the silver images were viewed through the color stripes.

A major factor in the failure of Polavision was the meteoric rise of electronic amateur photography with camcorders. Land was skeptical about the move from photographic to digital image making. The photographic emulsion, he said in 1982, was "that wonderful material, the first solid state recorder, done intuitively" in the 1850s through the 1870s. Although the light-sensitive silver halide grains are put on at random, the emulsion "records the whole image at once, just as your eye and brain record the whole image at once.

It records it in graduated detail. It records it with just a few photons of light. Twenty photons on a grain. And then it is converted with the snap of a finger from . . . the recording medium to . . . the final image." He said that he was not the first to wonder "how far you could go if you knew how to put [the grains] down in orderly arrays."

SCIENCE-BASED COMPANY

The enterprise Land led for half a century was less a business than an institution focused on making significant inventions. In 1975, he told a press interviewer, "Every significant invention has several characteristics. By definition it must be startling, unexpected, and must come into a world that is *not* prepared for it. If the world *were* prepared for it, it would not be much of an invention."

Land argued that "neither the intuition of the sales manager nor even the first reaction of the public is a reliable measure of the value of a product to the consumer. Very often the best way to find out whether something is worth making is to make it, distribute it, and then to see, after the product has been around a few years, whether it was worth the trouble."

The world, Land understood, was not necessarily friendly to a scientist who wished to operate this way. "Most large industrial concerns," he lamented in 1945, "are limited by policy to special directions of expansion within the well-established field of the company. On the other hand, most small companies do not have the resources or the facilities to support 'scientific prospecting.' Thus the young man leaving the university with a proposal for a new kind of activity is frequently not able to find a matrix for the development of his ideas in any established industrial organization."

Land prophesied that "the small company of the future will be as much a research organization as it is a manufacturing company, and that this new company is the frontier for the next generation." In the "next and best phase of the Industrial Revolution," Land expected businesses to be "scientific, social, and economic" units on the periphery of big cities and in the countryside, which will be "vigorously creative in pure science" with contributions comparable to those of universities. The career of the pure scientist, he expected, would be "as much in the corporation laboratory as in the university." He said this at a forum on the future of industrial research in 1944, just four years after he had been named, with Irving Langmuir, Edwin Armstrong, and others, as one of the most significant innovators of the previous twenty-five years. He was already working on instant photography.

In the small company Land had in mind "an industrial group of about fifty scientists," studying intensely the recent advances in "newly available polyamide molecules, the cyclotron, radar technics," color photography, and enzymology. If the industrial scientists were "inspired by curiosity" about such fields and determined "to make something new and useful," they could "invent and develop an important new field in about two years."

A small science-based enterprise depends vitally on patents, and Land eloquently defended the temporary monopolies created by the patent system from the charge, made particularly sharply during the New Deal, that it stifled innovation. Land asked, "Who can object to such monopolies? Who can object to a monopoly when there are several thousands of them? Who can object to a monopoly when every few years the company enjoying the monopoly revises, alters, perhaps even discards its product, in order to supply a superior one to the public? Who can object to a monopoly when any new company, if it is built around a scientific nucleus, can create a new monopoly of its own by creating a wholly new field?" Eventually, Land was awarded more than 500 patents, and other Polaroid researchers hundreds more. During 1976-85, Land and co-workers successfully defended a number of SX-70 patents. A federal court required Eastman Kodak to cease making and selling products involving infringements.

A corollary for such an enterprise, Land said, was a work force ready for constant reinvention of products and jobs. Polaroid workers, or "members," were protected by a growing array of benefits. He told employees, "You cannot rely on what you have been taught. All you have learned from history is old ways of making mistakes. There is nothing that history can tell you about what we must do tomorrow. Only what we must not do." To a remarkable extent, Polaroid operated in the fashion Land specified, and grew to nearly 20,000 employees by the time he left in the 1980s.

COLOR VISION RESEARCH

In 1951, years before a laboratory accident launched him on thirty years of study of color vision, Land described it as the "very beginning of vision in the human." He exclaimed, "How nebulous, how preliminary, our knowledge of the mechanism of vision is!"

In 1955, amid the difficult quest for a workable instant color system, Land decided to repeat Maxwell's experiments of a century earlier, which used projectors, one for each of the primary colors of blue, green, and red. Identical images taken through filters of those colors were projected onto the screen. To simulate the blue-poor light of sunrise, Land and his colleague, Meroë Morse, were experimenting with the red and green projectors only. Somehow, the green filter was removed, flooding the screen with white light. Morse noted that she still saw colors, although Land dismissed it as adaptation. Troubled by this glib explanation, Land later returned to the laboratory to repeat the experiment, this time with the intensity of the green projector turned down. With red light from one projector and white light from the other, the screen was filled with a gamut of colors.

In many years of research, Land found that such sensations would occur even if the eye had been exposed to the images for a millisecond, vastly shortening any interval for adaptation. He also found that the colors of objects reported by human subjects bore no relationship to the flux of light in particular wave bands from those objects. An apple was perceived as red early in the morning, and at noontime, even though the mixture of light frequencies was very different at the two times.

The beginning of the work was reported in 1955 to the Society of Photographic Scientists and Engineers and in 1957 and 1958 to the National Academy of Sciences in New York and Washington. Land developed what he called the retinex theory, which held that color sensation was the product of calculations, either in the retina of the eye or in brain structures, or both, in which lightnesses, not flux, in each of the three major wavebands were compared.

Psychologists tended to dismiss Land's color vision research as either trivial or not new. Neurophysiologists such as David Hubel of Harvard University and Semir Zeki of University College, London, however, conducted experiments on regions of monkey brains they had found to contain color-sensitive cells. They also collaborated with Land. Observations with a human patient, whose corpus callosum had been cut to moderate the number and intensity of epileptic seizures, demonstrated that color perception was located in the visual cortex and not the retina of the eye.

Land's studies of color vision led him to reject the notion of human beings as "advanced out of and away from the structure of the exterior world in which we have evolved, as if a separate product had been packaged, wrapped up, and delivered from a production line." In a 1977 address, he denied that the human spirit was condemned to "tragic separation and isolation" from the world. "Of what meaning is the world without mind? The question cannot exist." In a symphony, "the opening theme asks a question and the closing theme states that the question is itself the answer." Through science, the mind seemed to have been schooling itself in "reverence, insight, and appreciation of itself," so that it could pursue understanding "with all the techniques of thoughtfulness that the mind has used for investigations away from itself."

OVERHEAD RECONNAISSANCE

Many members of the National Academy of Sciences have made contributions to American defense programs over many years. Land was no exception. His field of concentration was national means of reconnaissance of the size and location of an adversary's military forces. Cameras for reconnaissance developed rapidly during and after World War II, and Land's work in optics, including Vectographs, brought him close to designers of new equipment at Boston University and elsewhere.

In the early 1950s, he took part in the succession of MIT summer studies that helped to spur the formation of Lincoln Laboratory for air defense and to focus attention on the need for direct overhead surveys of the Soviet Union in a time of intense confrontation. The United States needed precise and sustained observations to help plan the pace and cost of its own armaments programs to keep them from growing too fast or too slowly. Land was on the steering committee of the Technological Capabilities Panel of 1954, led by James R. Killian of the Massachusetts Institute of

Technology. The panel produced a timetable for U.S. development of intercontinental and intermediate-range missiles.

Land headed the TCP project on intelligence. In the summer and fall of 1954, Land worked with James Baker and others on the design of cameras for overhead photography of the Soviet Union, and was brought into contact with Lockheed Aircraft engineers who had developed the very-high-flying glider-like craft known as the U-2. The plane was designed with a bay behind the pilot to carry the cameras Land worked on or other packages for electronic monitoring. Land played an important role in two assignments to the Central Intelligence Agency: development of the U-2 by the CIA instead of the U.S. Air Force and firm control of the interpretation of its photographs. The program involved cooperation of Itek and many other firms. One of these, Eastman Kodak, provided a thin film for the U-2 cameras that allowed more pictures per flight, or more "bits per pound." The planes began flying over the Soviet Union in 1956 and soon discovered the limited size of both the Soviet bomber fleet and its intercontinental missile stock.

Because it was understood that it was only a matter of time before the secret of the U-2 was broken, development of U.S. spy satellites began soon after, going into high gear in 1958. The first successful Corona satellite returned pictures in a re-entry capsule in August 1960, less than four months after a U-2 was shot down over Sverdlovsk. Land headed a succession of panels supervising development of both spy planes to succeed U-2 and spy satellites. The panels gave particular attention to understanding the advancing art and helping designers and operational people clear away technical obstacles.

EDUCATION AND PHILANTHROPY

Education was the focus of many of Land's gifts from a fortune that reached $500 million in the late 1960s. His own experience made him impatient with the usual student's life. His chief complaints were lack of access, not only to first-rate minds but also to direct experience of research. The anonymous gift of $12.5 million in 1968 for a science center at Harvard was designed to give undergraduate science greater weight in a research-oriented university and to promote interaction among disciplines. His public gift in the 1970s of building funds and endowment for the new house of the American Academy of Arts and Sciences was also designed to intensify communication among scientists and humanists. Heading the building committee, Land sought what the architect called "a house of beautiful ideas . . . a large, comfortable house which would be a refuge from the unstructured intensity of the surrounding world." At the groundbreaking in 1979, Land noted that to add to knowledge individuals had to "limit themselves by excluding many other areas." To make sure that ideas moved from one field to another, the academy must provide "intimacy, informality, and friendliness, because the transfer is usually not a conscious process. Models for physics may come from music, for chemistry from physics, for art from cosmology." The speech is displayed on a wooden panel at the academy, not far from the often-used fireplace of a large public hall.

In a famous speech at MIT in 1957, "Generation of Greatness," Land said college education was destroying the dream each student had of "greatness," that is an original contribution. Group research and "community progress" must not take over. In a democracy, one must cooperate, but democracy's "peculiar gift is to develop each individual into everything he might be." If the dream of personal greatness died, he said, "democracy loses the real source of its future strength." He wanted arriving students to be assigned an "usher," an experienced researcher, and to be launched at once on research. Drawing from his life, Land said that education must produce people who, no matter how tightly they conformed to the innumerable commands of society, would find one domain where they would make a revolution. Students should go as rapidly as possible through all the intellectual accumulations of the past, to reach quickly the domain where they would have their own work to do. Lectures must be streamlined. Why not use movies to "can" a professor's best lectures "with the vitamins in"? The professors would be captured "at the moment when they are most excited about a new way of saying something or at the moment when they have just found something new." They would waste less time redoing their lectures. With the movies, students could view the lectures as many times as they needed. The proposal looked visionary in the 1950s, but Land soon launched his colleague Stewart Wilson on interactive lectures using such films, a process that appears more attainable in an era of ubiquitous networked computer keyboards and screens. Land's ideas on student research helped inspire MIT's undergraduate research program, created in the late 1960s. He also financed the start of Harvard's freshman seminars.

A concern with popular education made him an effective advocate in Congress for the 1967 recommendation of the Carnegie Commission on public television that federal support be increased sharply. He told a U.S. Senate committee that funds were needed for public television to aim at smaller audiences than the networks, to search for "ways to tell young people what we know as we grow older—the permanent and wonderful things about life." He added, "We are losing this generation. We all know that. We need a way to get them back."

Land was not satisfied with a university research system in which scientists were swamped with committee work and the endless search for grants. As a demonstration of another way to proceed, he endowed and led the Rowland Institute for Science in Cambridge in the 1980s. A small group of scientists continues to work at the Rowland Institute on many topics related to light and matter, and light and life.

THE AUTHOR, A SCIENCE journalist since the 1950s, first met Edwin Land in the White House in 1968, when Land accepted the National Medal of Science. In 1972, he spent a year at Polaroid Corporation as a consultant on the description of the SX-70 film and camera system. At the *New York Times* between 1973 and 1978, he covered developments in the photographic industry. During 1982-91, while directing the Knight Science Journalism Fellowships at the Massachusetts Institute of Technology, he was a part-time public information consultant at the Rowland Institute for Science. This work brought McElheny into frequent contact with Land and his associates. His full-length biography of Land, *Insisting on the Impossible* (Perseus Books, 1998) contains a bibliography and footnotes. The book is based on more than twenty years of interviews and notes by the author, numerous unpublished sources in the archives of Polaroid Corporation, press reports over more than fifty years, and Land's published papers, including those listed below.

HONORS AND DISTINCTIONS

Cresson Medal, Franklin Institute, 1937
National Modern Pioneer Award, National Association of Manufacturers, 1940
American Academy of Arts and Sciences, 1943; president 1951-53
Rumford Medal, American Academy of Arts and Sciences, 1945
Holley Medal, American Society of Mechanical Engineers, 1948
Duddell Medal, Physical Society of Great Britain, 1949
National Academy of Sciences, 1953
Potts Medal, Franklin Institute, 1956
American Philosophical Society, 1957
Society of Photographic Scientists and Engineers, 1957
Doctor of science degree, Harvard University, 1957
Member, President's Science Advisory Committee, 1957-59; consultant-at-large 1960-73.
Member, President's Foreign Intelligence Advisory Board, 1961-77
Royal Photographic Society of Great Britain, Honorary Fellow, 1958
Presidential Medal of Freedom, 1963
National Academy of Engineering, 1965
Albert A. Michelson Award, 1966
William James Lecturer on Psychology, Harvard University, 1966-67
Frederic Ives Medal, Optical Society of America, 1967
National Medal of Science, 1967
Founders Medal, National Academy of Engineering, 1972
Optical Society of America, Honorary Member, 1972
The Royal Institution of Great Britain, 1975
National Inventors Hall of Fame, 1977
The Institute of Electrical and Electronics Engineers, Honorary Member, 1980
The Royal Society, foreign member, 1986
William O. Baker Medal of Achievement, Security Affairs Support Association, 1988
National Medal of Technology, 1988

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