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HAROLD EUGENE EDGERTON
1903–1990

A Biographical Memoir by

J. KIM VANDIVER AND PAGAN KENNEDY

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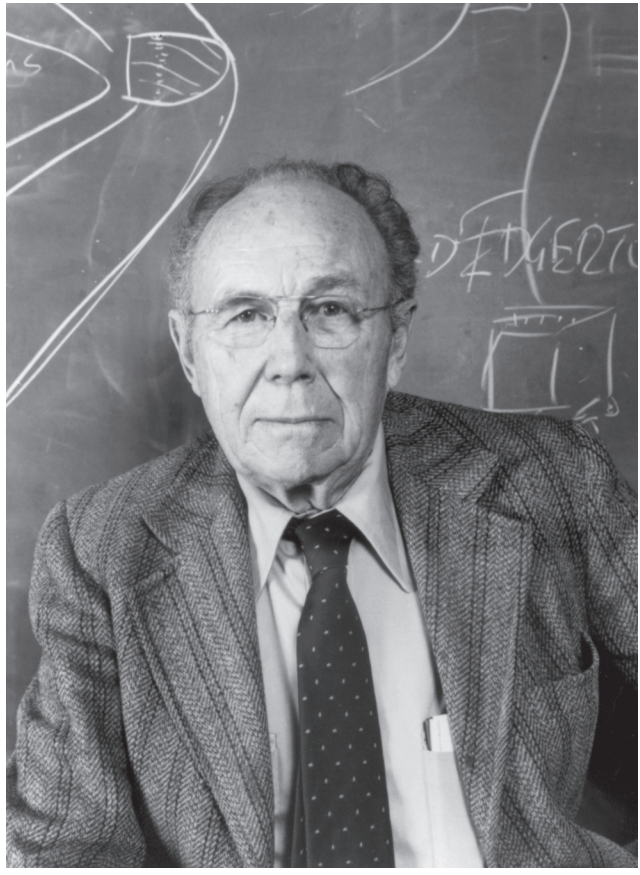

Harold E. Edgerton

HAROLD EUGENE EDGERTON

April 6, 1903–January 4, 1990

BY J. KIM VANDIVER AND PAGAN KENNEDY

HAROLD ("DOC") EDGERTON, born in Fremont, Nebraska, in 1903, transformed the strobe from an obscure technology to a fixture of American life. He made flashing light cheap and portable, and found endless applications for it, from the airport runway to the office copy machine. But despite his importance as an innovator, Edgerton is best known for the photographs he took. His images have become icons of the twentieth century: the drop of milk exploding into a crown, a bullet hovering beside an apple, an atomic blast caught the instant before it mushroomed, a smudge that might have been the flipper of the Loch Ness monster. His strobe photographs illustrated scientific phenomena in a way that was instantly understandable to millions of people. Later in his career he developed sonar tools that revolutionized marine archeology, again using images to explore the unknown.

From the 1930s on, Edgerton was the go-to man for anyone who needed a stroboscopic solution. Niels Bohr, golfer Densmore Shute, Jacques-Yves Cousteau, Colonel George Goddard, and a parade of other notables stopped by his lab at the Massachusetts Institute of Technology. Faced with many requests, Edgerton made key contributions to a variety of fields and garnered dozens of awards: What other

person can boast an Oscar, a Medal of Freedom from the War Department, and an induction into the National Inventors Hall of Fame?

Though Edgerton was celebrated as an innovator and photographer, he considered himself first and foremost a teacher. For decades he presided over some of the most popular classes at MIT. Edgerton kept his door open not just to his own protégées but also to the stray 14-year-old who might wander in with a question about cameras. Soon after his death in 1990, two science centers opened up to honor his memory, one at MIT and one in Aurora, Nebraska. Both Edgerton centers make it their central mission to carry on what he felt to be his most important work: hands-on teaching.

THE STROBE IN A SUITCASE

In the summer of 1933 Harold Edgerton and his wife, Esther, packed up their car and headed to Nebraska to visit family. It had been a momentous few years. In 1931 Esther had given birth to their first child, Mary Louise, and Harold had received his doctorate in electrical engineering from MIT. Now their baby slept in the front of the car and in the back, among the bundles and suitcases, sat the first strobe he'd developed for commercial use. Weighing 60 pounds, equipped with a mercury-filled tube that gave off a bright flash, and housed in a suitcase, the machine would have blended in with their other belongings. Edgerton planned to introduce it to every company he could find on his way from Massachusetts to the Midwest.

Early photographs show him as a spindly young man with brilliant blonde hair combed back in waves. Invariably, he wears a three-piece suit, and invariably the tie is askew. Already he had begun to exhibit the pluck that would become his trademark. Instead of booking appointments ahead of

time so that he could demonstrate his strobe, Edgerton drove to Nebraska keeping an eye out for factory buildings. When he spotted one, he'd head to the nearest drug store, shut himself in the phone booth, and call the president of the company; oddly enough, top bosses always seemed to be available to the young man. Edgerton would announce that he had a strobe to show off: Did the company have any motors that whirred or shook when they shouldn't? Then, with the president's invitation, Edgerton would lug his suitcase into the factory and point his strobe at the offending gear or spring, synchronizing the flash with the movement of the motor part. Once he got the timing right, spinning gears appeared to stand still. Edgerton had found a way to photograph speed without the blur, allowing technicians to study the behavior of fast-moving objects.

At the General Motors Research Lab in Detroit he sold a dozen of his suitcase strobes. "It's lucky you were here today," the manager told Edgerton, and then led him into a room where a machine the size of a desk gave off a dim flash. "I was just about to order ten of these built by our people."[1]

As that anecdote illustrates, Edgerton was hardly the first to bring strobe technology into the factory. In the 1920s two French brothers, Laurent and Augustin Seguin, patented in Europe and the United States a "flash-producing apparatus," an unwieldy, expensive machine designed to help troubleshoot motors. Edgerton might have encountered one of these when he worked at General Electric in Schenectady, New York, in the mid-1920s. In the late 1920s as an electrical engineering graduate student at MIT, he worked under Vannevar Bush, using rudimentary computers to predict the behavior of motors: Results could be verified by flashing a strobe at the motor. Edgerton, the consummate tinkerer, was more interested in the strobe itself than in

the theories it was used to test. "Though he was deeply involved in the mathematics of this problem in his masters and doctorate work as a student at MIT, his aptitudes were higher in laboratory work," according to his son, Bob Edgerton.[2] The young engineer had a hunch that the strobe could become a popular technology but only if it were repackaged. So he shrunk it down and gave it a souped-up tube, creating a flash bright enough to make compelling photographs.

SEEING SPEED

At first, Edgerton used his strobe to take pictures of moving motors—and only motors. And then one day in 1932 he aimed the flash at water flowing out of the faucet in his lab. Under a split-second burst of light the water turned motionless, bulbous, hollow in places, like an icicle from another planet (1939, p. 135). From then on, Edgerton would point his flash at the world around him, using photography to discover what the unaided eye couldn't see.

Again, he was not the first to do so. His predecessors had used flash photographs to investigate the motions of a pole-vaulter's body, drops of water, a horse's legs. Edgerton likewise created photographs that could answer scientific questions. But he also labored to make his images concise and compelling, as easy to read as advertisements, so that they would speak to people with no scientific training at all. In his photos of athletes in motion he showed a tennis racquet curving under impact, the toe of a boot embedded deep inside a football, a baseball that melted against the bat, taking viewers on a tour of the secret world of high-speed impact, where hard objects turn to mush (1939, pp. 55-115). In his hummingbird series for *National Geographic* magazine he posed the birds around a ruby-lipped girl in puffy sleeves who could have passed for Tenniel's Alice in

Wonderland; the tiny birds, with their wings stilled, appear to be floating around her. Most famously, Edgerton fussed over his drops of milk for 25 years, plinking and plunking, rejecting misshapen splashes, waiting for the milk to fly up into a near-perfect coronet. In the resulting 1957 photograph Edgerton finds a gorgeous logic even in spilt milk (1987, p. 127).

Though he never billed himself as an artist, the art community—and Hollywood—embraced him. In 1937 his works hung in the Museum of Modern Art's first photography exhibition. In 1940 MGM studios invited him to fly out West and show his stuff; he ended up collaborating on, and starring in, a short film, *Quicker Than A Wink!,* that won an Academy Award.

Most impressive, Edgerton's images remain familiar today. Charlie Mazel, who worked with Edgerton on marine archeology projects, found that out when he gave a slideshow to a room full of people. "I said, 'How many of you have heard of Doc Edgerton?' Only two hands went up. Then I showed a picture of a bullet going through an apple. Every hand went up. The image outlives the name. A hundred years from now people will still know those pictures."[3]

POPULAR MECHANICS

Right from the beginning Edgerton understood that the strobe could do more than provide data. It could entertain. By the late 1920s he had already hatched the idea of taking his gear to downtown Boston and catching dancers in midleap, to use the flash as a new window onto popular spectacles.[4] However, in those early years his equipment was not equal to the task of lighting cavernous arenas.

But a decade later Edgerton and his partners—his former students Kenneth Germeshausen and Herbert Grier—had tweaked the machine, replacing the mercury gas with argon,

for a brighter flash. In 1938 Gjon Mili began using Edgerton's techniques to produce arresting art photographs in *Life* magazine. Still, commercial success remained elusive. Edgerton complained that engineers at Eastman Kodak Company regarded the strobe as a novelty item rather than a potential blockbuster. Even so, in 1939 Eastman Kodak struck a deal with Edgerton and his partners to develop a strobe for professional photographers, the Kodatron.

The next year, when a newspaper photographer named George Woodruff showed up at the lab, Edgerton hit on the gimmick that proved the commercial appeal of strobe once and for all. The two men hauled equipment to the Boston Garden, a sports arena with a busy schedule of races, rodeos, fights, and circuses. That day, they found a track meet in progress. Edgerton set up some of his largest lights and handed Woodruff the camera. When a pack of runners rounded the corner, Woodruff snapped the shutter and the flashes popped. The photo captured the runners hovering in the air, every fold in the fabric of their shirts delineated, their straining muscles petrified into odd shapes. It was an utterly novel take on news photography, and sports pages around the country ran it.

In the following weeks Edgerton returned to the Garden to photograph whatever happened to be there, including skater Sonja Henie. "All the [news] wires in the country were loaded with these beautiful, well-lighted strobe pictures," he remembered later. "It broke the impasse."[5]

For Edgerton, developing a new technology was only the first step. You had to go out and convince folks that they needed it. This he did, tirelessly. Boy Scout troops, garden clubs, and old-age homes; no group was too small for Edgerton's attentions. "People used to say, 'You're crazy,'" Edgerton wrote, about his willingness to lecture. "But I found that practically every time you go out, say to a Rotary Club

out in Fall River, Massachusetts, you've got a cross section that covers that whole town. . . . There will be one man at the end of the demonstration [who] will up and say, 'Hey, there's a factory down here that needs that real bad.'"[6]

Edgerton gave his lectures with democratic abandon because he knew the strobe would succeed only if he won over thousands of ordinary people. For the same reason, he carried a stack of postcards in his pocket, reproductions of his famous photographs with his phone number on the back. He handed these out to everyone he met, sometimes with an invitation to stop by the lab. The postcards were tickets into the world of Doc. All were invited.

WAR AND PEACE

"The war effort started on a Saturday when an unannounced visitor popped into the laboratory and said his name was Goddard," Edgerton remembered later of the events of 1939.[7] Lt. Colonel George Goddard, the man in charge of the Army's aerial photography effort, had come to Edgerton for help with a problem that bedeviled the military.

The Allies needed to illuminate vast areas during the nighttime, to take aerial photographs of roads and bridges in order to track the movements of the enemy. During World War I, the military had used a system that involved tossing tins of flash powder from the hold of the plane, a method with obvious drawbacks. He hoped Edgerton could come up with a strobe lamp that could safely and reliably illuminate cities from thousands of feet above.

Then Goddard—with a dramatic widow's peak plunging down his forehead, a ramrod military posture, and a promotion to brigadier general in his future—proposed that they go to the circus. That, he revealed, was why he was *really* in town. He wanted to shoot circus photos with

Edgerton. And so the two men packed up strobes and cameras and headed off.

Edgerton had begun by thinking small, miniaturizing the strobe so that it could become a useful consumer item. During the war, he thought big: lamps the size of tympani drums that were capable of casting beams through a mile of darkness. Edgerton flew with crews in Italy, Britain, France—at one point taking a turn on a machine gun that poked out of the side of a B-24. The result: He and his team produced bright-as-day shots of the terrain. General George Patton depended on these photos to plan his route into Germany. Edgerton's aerial strobe photographs gave the Allies a crucial edge over the enemy.

After the war, he decided to treat his family to a cross-country trip. Edgerton's vacations were usually ambitious—and productive—affairs, and this one was no exception. Since the 1930s, he had been aiming his strobe at birds and bats, freezing them in the air to study the secrets of their flight. Now, because "he wanted to do something in the summertime with the family," according to Bob Edgerton, he organized an expedition around the country to photograph hummingbirds. He'd bought a 1941 Ford Woody (the station wagon that came to be identified with surfers) and into this he packed himself, Esther, three children, and two strobes. They spent weeks camping in Army-surplus tents.[8]

When the war ended, war work did not. The Atomic Energy Commission approached Edgerton and the two partners, Germeshausen and Grier, and requested that they form a corporation. The three men had been working together since the 1930s, and many of Edgerton's designs (including the original strobe) had been put together in collaboration with one or both of his partners. They had sealed deals with handshakes; Esther had been their bookkeeper. But,

in 1947 with government contracts coming in, they made their arrangement official.

The new corporation, Edgerton, Germeshausen, and Grier (later EG&G), took over the job of photographing nuclear tests from the Army Air Corps. The task required a camera shutter that captured exposures of 1/1,000,000th of a second, too fast for moving parts. EG&G came up with a novel solution. Instead of a conventional shutter, two polarizing filters kept the film in the dark until the filters were exposed to a magnetic field. For an instant, as the plane of polarization rotated, light was able to hit the film. Thus EG&G obtained its infinitesimally small exposure times.

The resulting photographs revealed the atomic blast as a bubble of light hovering over the desert, pocked and malevolent. Edgerton, who watched the fireball through a piece of glass from miles away, marveled at the silence in which it unfolded. The sound took half a minute to travel over the desert, roaring only as the cloud itself began to decay.[9]

In time EG&G would grow into a Fortune 500 company, one of the top providers of technical services to the U.S. government and industry. Edgerton, ever focused on practical concerns, regarded the EG&G offices as an adjunct to his lab, a place to scrounge up secretarial help and machine parts. "It would be Sunday morning and he'd realize he needed some stuff and he knew where it was over at EG&G," according to Sam Raymond, who worked for the company and then went on to found Benthos Corp., a maker of oceanographic equipment. Edgerton, dressed in his usual technician's outfit of rumpled khaki shirt and khaki pants, would use wire cutters to force his way into the stock room. When security guards stopped him, he told them that it was OK. He was one of the owners.[10]

UNDER WATER

Like so many of his other ventures, Edgerton's foray into sonar and underwater photography began with a visitor in his lab. In the 1930s Newton Harvey, one of the world's leading experts in bioluminescence, dropped by to ask for tips on taking pictures of deep-sea fish. Harvey had tried to protect his cameras in watertight, pressure-proof casings, with no luck. "Harvey's casing design was a square box, as I recall, which distorted badly, causing cracks that leaked," Edgerton wrote. "I became interested in the problem. Why not a spherical design or even a cylindrical one? Soon, I was sketching all sorts of designs."[11]

So Edgerton was prepared when Jacques-Yves Cousteau made the pilgrimage to MIT in 1952. Cousteau hoped to find an alternative to the dangerous rigs that divers were then using to take underwater photos. Edgerton had never heard of the French explorer, but the two men immediately hit it off. Within a few hours of his arrival, Cousteau had found his way to the MIT pool, where he tested out Edgerton's equipment. The men planned an expedition to the southern coast of France, to study clouds of living organisms in the ocean, called the deep scattering layer.

In the summer of 1953 teenaged Bob Edgerton and his father flew to Marseille, where they squeezed into Cousteau's crowded ship; Bob slept in a 6-foot-long drawer in the boat's workshop. The pair, dubbed Papa Flash and Petit Flash by Cousteau, joined evening jam sessions with the crew, improvising on pots and pans. During that trip, as well as the Cousteau expeditions that followed, Edgerton lowered his cameras and flash units off the side of the boat, to catch glimpses of the ocean at a variety of depths.

Edgerton did not confine his innovations to the camera work; he also came up with ways to improve the ship itself.

"In the mid-1950s, he realized that the heavy cables used to hang the camera and to anchor the ship could be replaced with nylon ropes" that would be nearly weightless in the seawater, according to Bob Edgerton.[12]

In the beginning of his undersea career Edgerton struggled to get the best photographic images he could, but he soon discovered that photography was not well suited to the murky conditions near the bottom of the ocean. Increasingly he came to rely on sonar as an alternative to photography. At first, he'd used a sonar "pinger" to find the ocean floor, so he knew where to position his photographic equipment. Later he dispensed with the cameras entirely, turned the pinger sideways, and dragged it along behind the boat. By taking continual side-looking soundings he could track the contours of the ocean floor, creating an image out of sound. This side-scan sonar, which had previously been available only to the military and academic communities, was perfected as a commercial tool by a team led by Marty Klein at EG&G. The new tool revolutionized the field of marine archeology and many other areas of ocean exploration. Where divers feared to go, it could explore.

From the 1960s on, shipwreck hunters and archeologists alike called Edgerton with endless invitations to join their expeditions: the Civil War ship *Monitor*, King Henry VIII's flagship *Mary Rose*, the HMS *Britannic,* and even a site rumored to be Atlantis. Edgerton almost always said yes. "Doc would just literally get on the next plane. Whereas maybe somebody else might stew about [an expedition] and plan it for months, he'd be on the next plane with all his stuff," remembers Marty Klein, a former student who later founded Klein Associates, a manufacturer of side-scan sonar equipment.[13]

In the 1970s Klein collaborated with Edgerton on creating equipment that could probe the depths of a Scottish lake,

to turn up evidence of the Loch Ness monster or whatever else might be hidden in the peat-clouded water. The search attracted worldwide attention and became a staple of TV documentaries, so much so that cartoonist Garry Trudeau saw fit to poke fun in *Doonesbury.* Edgerton appears in pen and ink as a rumpled techie in a Cousteau-style watch cap. "It's a good thing," he says as he contemplates a sheet of Loch Ness data, "I've got tenure."[14]

Although the fabled monster was never found, Klein and the late Charles Finkelstein, another Edgerton student, did discover a World War II Wellington bomber, possible caves in the walls, as well as submerged stone circles in Loch Ness.

DOC

For Edgerton it was more than a casual honorific—everyone called him Doc. His son, Bob Edgerton, suggests why the nickname fit so well: "He was a Midwestern homespun guy. Someone who you have respect for, but he's friendly—like a country doctor."[15] The name brought together his two identities: MIT whiz and Nebraska burgher.

His family moved around during his childhood, but by the time Harold Edgerton was in junior high school, they'd settled in Aurora, Nebraska, a farming community with a power plant at its center. Edgerton spent his undergraduate years at the University of Nebraska, but got his real education at the power company, where he worked as a grunt and as a lineman. "I was climbing poles and working with 2,300 volts hot during storms when I was still in high school. . . . You learn, first of all, that the time clock doesn't matter and the real value is to get that power on."[16]

The nickname, "Doc," fit in another way, too: It announced his dedication to teaching, not just as a job but also as a way of life. Many of his students, as well as strangers

who wandered into his lab, remember his avuncular warmth. He was willing to spend hours helping a young person to develop a thesis topic or solve a technical problem.

"As president of MIT [from 1971 to 1980], I was not above putting Doc's involving nature to use myself," recounts Professor Paul Gray. "Once a freshman came into my office to protest how inappropriate it was for us to have missiles on campus. He said he had found one in tall grass behind the swimming pool. I told him I'd look on my way home that night, and sure enough, lying on a wooden sled was a 16-inch naval shell. It was disarmed, of course, and I knew right away whose it was. Doc modified such shells and added plumbing to make pressure chambers for testing undersea cameras. After I wrote the young student an explanation, I suggested he drop by Doc's lab and get acquainted. Like many freshmen, he didn't yet appear to have his moorings and I thought the exposure to Strobe Alley couldn't hurt."[17]

Edgerton's hospitality didn't stop at the lab: He invited his students home to sample Esther's cooking and sing backup on "You Are My Sunshine," which he twanged on the banjo. An assignment sheet from a 1946 class reads as follows: "Appear at 205 School Street, Belmont, about 6:30 p.m. equipped with appetite. No textbooks, slide rules or class notes will be allowed. . . . Try to memorize words of these Tech songs. Penalty for nonperfection may be an opportunity to help with the dishes!"[18]

I (J.K.V.) was lucky enough to receive a good deal of Edgerton's attention when I worked as a teaching assistant in his Strobe Lab in the fall of 1972. He assigned me a project of my own, a tremendous kindness, considering that professors often expect nothing more from their teaching assistants than a stack of graded papers. He suggested I find a way to produce schlieren photographs in color. Schlieren photography—the name comes from the German

word for "streak"—records variation in the densities of gasses. It is a way to make phenomena that are usually invisible to us, like shock waves and vapors and heat, into something we can see on film. A candle, for instance, appears to be surrounded by billowing veils and ghostly bubbles. When Edgerton suggested schlieren to me, no one had figured out how to create a sharp, full-color image using the effect. The results promised to be stunning.

After some library research, I built a system with 10-inch mirrors and brought some slides in to Edgerton in about October 1972. He pulled his 10-power magnifier from his pocket and held one of my slides up to the light for inspection. "Van," he said, "It looks out of focus to me." So I tried again a few weeks later with another technique. "Van," he said, "I don't like the color."

I was stumped until I came across an article in *Scientific American*; a graduate student named Gary Settles had found a new way to produce four-color schlieren photographs. I combined Settles's technique with a high-speed flash, capturing the shockwave of a bullet in blue on a red background. This time when I came to Edgerton with the slides in January 1973, he said, "Van, I think you've got it."

In August of 1974 *Scientific American* ran the schlieren photographs: a heady turn of events for a graduate student. That same summer Edgerton wrote to the organizers of the Eleventh International Congress on High-Speed Photography and arranged for the pictures to be displayed in a gallery during the conference. The editor of the journal *Nature* saw them and decided to run one of the images on the November 1974 cover. When the photographs appeared in these high-profile magazines, Edgerton insisted that my name be first in the credits, even though I'd relied on him for equipment, lab space, expertise, and his counsel. I am at MIT today because of the boost he gave me at the beginning.

He supported generations of grad students like me; some of them he literally supported by paying them out of his own salary. "He 'invented' a summer job for me at EG&G when we were expecting our second child," according to Gray. "But that was nothing compared to what he quietly did for others when need arose."[19]

THE FACE OF MIT

The hallway echoed with the report of gunshots. Flashes jumped across the walls. Boxes spilled wires, capacitors, barnacled wood. By contrast, other wings of MIT seemed downright sterile. Strobe Alley, the hallway that cut a line between Edgerton's labs, sucked visitors in and invited them to become part of the action. To make his lair even more inviting Edgerton hung displays all along the hall: photographs, framed bits of equipment, buttons to push. Klein, who wandered into Strobe Alley as an undergraduate in 1961, loved the tantalizing smell of the place. It reminded him of the junk shops in lower Manhattan, the perfume of "connectors and coils and motors—sometimes motors that have burned out."[20]

The MIT campus tour would invariably take prospective freshman through this wonderland, where Edgerton, the reigning spirit, would emerge to shake hands and pass out postcards. He had become a star attraction at MIT, a living advertisement for the institute and for a certain spirit of inquiry. "If you don't wake up at three in the morning and want to do something, you're wasting your time," he famously said.

In 1964 he was elected to the National Academy of Sciences. Four years later he retired from his duties at MIT, but only on paper. He went right on teaching and stayed put in Strobe Alley. Only in the late 1970s did he begin to slow down.

"In 1980, I had the opportunity to work with a French group in Mauritania in West Africa," remembers Mazel. He asked Edgerton for some equipment, and was dismayed when the 77-year-old, who'd just had a stroke, insisted on joining the expedition. "I wasn't comfortable with saying, 'Doc, you can't do that.' But I was getting phone calls from Esther in the background saying, 'Make sure he doesn't go.' He didn't go."[21]

In the 1980s he ignored the stroke, dizziness, a blood clot, and heart problems, reporting to his lab as usual, and even taking up new interests. It was his heart that finally got him. He died in the MIT faculty dining hall on January 4, 1990. He was 86.

Those of us who'd been close to him—who had been changed by him—wanted to make sure that Edgerton would live on at MIT. His attorney, Marty Kaplan, brought a group of museum experts to campus in order to discuss how best to conserve the trove of photographic prints scattered around the lab. "Find out what Doc meant at MIT," Kaplan instructed them. The museum people interviewed Edgerton's friends, including myself (J.K.V.). We agreed that what we wanted most to preserve was the spirit of Strobe Alley itself, a place where anyone could walk in and push buttons, study photographs, smell the burning machines, and find help with a project.

So that's how the Edgerton Center came to open its doors in 1992. Housed in the Strobe Alley and its surrounding rooms, the center strives to follow Edgerton's magnificent example of hands-on teaching and generous mentorship. Any MIT student who needs help with a project will find the Edgerton Center stocked with lab benches, testing equipment, photography resources, and staff. In addition, the center hosts a hands-on educational outreach program for local teachers and their classes. It serves as a link between

MIT and the larger community, much as Edgerton himself once did.

Just after Edgerton's death in 1990, his admirers in Aurora, Nebraska, also began to discuss what they could do to preserve his legacy, and they came to the same conclusion we did at MIT. The Aurora planners realized that "for all Edgerton's fame as a photographer and an engineer, he'd always viewed himself as a teacher. So we conceived the notion of a center that would carry on the tradition of hands-on learning that he believed in," according to Phil Nelson, president of the Edgerton Education Foundation.[22] The Edgerton Explorit Center, which opened in 1995, now serves about 100,000 people a year with science exhibits and teaching programs, traveling demonstrations, workshops, and lectures. It has become Nebraska's premiere science education center.

What did Doc Edgerton give the world? Unforgettable photographs, 47 patents, and a new way of looking at objects in motion. Perhaps more important, he doled out thousands of kindnesses to students and friends, dispensing favors as eagerly as the postcards he kept in his pocket. It is this legacy—his habit of generosity—that we especially hope to preserve at MIT.

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NOTES

1. Harold Edgerton, interview by Marc Miller, transcript of tape recording, Cambridge, Mass., August 26, 1975, pp. 37-39. Collection MC 132, MIT Institute Archives and Special Collections, Cambridge, Mass.

2. Bob Edgerton, interview by Pagan Kennedy, tape recording, Somerville, Mass., December 30, 2003.

3. Charles Mazel, interview by Pagan Kennedy, tape recording, Cambridge, Mass., December 19, 2003.

4. Ken Beardsley, letter on occasion of Edgerton's retirement, undated, Collection MC 25, MIT Institute Archives and Special Collections, Cambridge, Mass.

5. Harold Edgerton interview, pp. 85-86.

6. Ibid, p. 58.

7. Ibid, p. 103.

8. Bob Edgerton interview.

9. Harold Edgerton interview, pp. 116-117.

10. Marty Klein and Sam Raymond, interview by Claire Calcagno, transcript of tape recording, Rockport, Mass., December 20, 2002.

11. Harold Edgerton, "Underwater Photography," January 28, 1985, and September 18, 1985, p. 2. Collection MC 25, MIT Institute Archives and Special Collections, Cambridge, Mass.

12. Bob Edgerton interview.

13. Marty Klein and Sam Raymond interview.

14. Garry Trudeau, *Doonsbury* cartoon, 1976.

15. Bob Edgerton interview.

16. Harold Edgerton interview, pp. 1-2.

17. Paul Gray, "Unforgettable 'Papa Flash,'" August 1, 1990, p. 5. Collection MC 25 MIT Institute Archives and Special Collections, Cambridge, Mass.

18. Harold Edgerton, "Fundamentals of Electrical Engineering," assignment sheet for May 3, 1946, Collection MC 25, MIT Institute Archives and Special Collections, Cambridge, Mass.

19. Paul Gray, p. 12.

20. Marty Klein and Sam Raymond interview.

21. Charles Mazel interview.

22. Phil Nelson, interview by Pagan Kennedy, tape recording, Somerville, Mass., January 5, 2004.

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