Science at General Electric

Research underwent profound changes in scale and style during the Second World War; that this transformation also stirred industry is illustrated by the changes at one large laboratory in the postwar era.

George Wise

The decade after 1945 saw substantial changes at the General Electric Research Laboratory in Schenectady both in the way in which research was done and in the people doing the research. The passing of the generations at a research laboratory in a small city in Upstate New York reflected a broader change undergone after World War II by all of American science. Science and technology had helped win the war. Scientists and engineers now appeared to be the bulwarks of national defense and the preservers of national prosperity. In the heady postwar climate, no one worried much about where science ended and where technology began. There was enough for both. Inventions and innovations launched before or during the war—televisions, plastics, atomic energy, electronics, computers—now loomed as huge and expanding opportunities. A person who had embarked on a career in science now had a wide choice of well-paying jobs in government or industry.

To the young scientist in 1946, the prospect of employment at General Electric was indeed an attractive one. Some of the scientists at the laboratory, such as Saul Dushman, Albert Hull, William D. Coolidge and Irving Langmuir, were widely known by reputation. Dushman had written a widely used book about the theory and practice of vacuum techniques. Hull had invented several important electronic devices, and had recently completed a term as president of the American Physical Society. Coolidge had been GE's research director from 1932 until 1945, and had earlier improved filaments and x-ray tubes used around the world. Langmuir was probably the first Nobel laureate the job candidate had ever met.

If he got offered a job by GE, the young recruit would not be asked to work with these giants. He would be asked to help replace them. GE's long-running experiment in industrial research was changing its guard.

The candidate for employment at General Electric may have come east from Berkeley, Chicago or Los Alamos, north from Oak Ridge, or west from Cambridge to explore opportunities in industry. His trip to the banks of New York State's Mohawk River took him back in time as well: from the scientific revolution of the mid-20th century to a revolution in electrical technology that had begun more than half a century earlier. In 1886, Thomas Edison had moved his machinery works to Schenectady. In 1946, its row on row of red and brown brick buildings still suggested more of Edison than of Einstein. Factory workers poured castings, handcrafted precision fittings, shaped turbine buckets, assembled motors, and

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Volney C. Wilson developed high-power vacuum tubes for the study of the direct conversion of heat into electricity. (General Electric photo.)

Katharine B. Blodgett, the first woman PhD physicist in American industry, demonstrates experiments in surface chemistry at the opening of General Electric's new Research Laboratory building at the Knolls site in 1950.

turned out the heavy apparatus that was the major product of the world's largest electrical company. Near the main gate of the works stood buildings 5 and 37, the home of the GE Research Laboratory.

The laboratory had been born half a mile and half a century away from its 1946 site. On the banks of the Erie Canal in December 1900, GE's chief consulting engineer, Charles Proteus Steinmetz, had led out of his boarding house and into a barn in the backyard of his house an instructor in chemistry from MIT named Willis R. Whitney. The barn became GE's first laboratory, and Steinmetz installed Whitney there as GE's first director of research. Physics soon came to play a major role alongside chemistry. The laboratory's most important achievement in the prewar era was the invention by Coolidge, a physicist, of a process for turning the brittle metal tungsten into flexible wire suitable for use as light bulb filament. Coolidge succeeded Whitney in 1932 as the laboratory's director. By 1945, the laboratory had 630 employees, of whom 160 were trained scientists or engineers. About half of them worked on physics and its applications, about 30% on chemistry, 15% on metallurgy and 5% on mechanical investigations.[1]

The laboratory marked a milestone for the world of science and technology, as well as for GE. "The interdisciplinary research laboratory has been the most significant institution for modern technological development," historian Edwin Layton has stated.[2] He added: 'The rise of interdisciplinary research is sometimes associated with the founding of the General Electric Research Laboratory."

Another historian, Kendall Birr, concluded[3] in a history of the laboratory's first half century, "One characteristic of the laboratory stands out above all others: its success." He attributed that success to four causes. First, from the beginning GE's top officers granted the lab substantial independence and solid financial backing. Second, the lab recruited outstanding researchers. Third, it did not insist on exclusive dedication to research but carried out development work, troubleshooting, and testing, and put results before research. And, fourth, the lab had the good fortune to be associated with one of the financially strongest and most technically diverse companies in the world.

In describing the conditions that had produced these successes, Birr also noted that those conditions were changing. When the Research Laboratory had been created in 1900, General Electric had recently been centralized into a single company ruled from corporate headquarters. In the postwar period, GE was decentralizing into a collection of largely independent operating units. The company had concerned itself exclusively with electricity in 1900. In the 1940s, it was diversifying. Many businesses of the old GE, such as incandescent lamps, x-ray tubes and electronics, rested on strong patents. In the postwar period, some new technologies, such as plastics, would lend themselves to that kind of protection. But other big-growth areas—solid state devices, computers, jet engines, atomic power—would be much less influenced by patents. And, finally, in 1900 GE had been a pioneer in industrial research. By 1950, many rivals in government and universities as well as industry competed for bright young scientists.

The choice before GE was either to stand pat on the tradition that had made it a successful model of industrial research or to change with the times. General Electric chose to change.

A new guard

By 1946, Coolidge had joined Whitney in retirement; and Langmuir, Dushman and Hull were soon to follow.

Francis P. Bundy, one of the inventors of a method for making diamonds, examines the die that forms the heart of the high-pressure and high-temperature system used for this purpose. The photo was taken in 1971.

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To replace them, a generation hired in the 1930s should have been coming of age. But few researchers had been hired during the depression decade. GE had to fill the gap left by this lost generation with a new guard. The job fell to one of the last scientists hired in the prosperous 1920s, the man who had become the laboratory's director in 1945, C. Guy Suits.

Suits was a short, trim, balding physicist with a straightforward manner; a pharmacist's son from Wisconsin whose interests leaned more to the shop and the outdoors than to mathematics or philosophy. As an undergraduate student in physics at Wisconsin University, and later, as a PhD candidate at the Swiss Federal Technical Institute, Suits had never seen an industrial scientist and had never talked to a professor who recommended an industrial career. But he had read of the work of Langmuir, Coolidge and Hull. He had little interest in teaching, and his versatility would have been difficult to confine within the classroom. He had played the clarinet professionally to earn his way through college and would later prove just as proficient at turning out furniture in his home workshop, making dresses for his wife, piloting a plane, designing boomerangs, and stalking game in the wilds of Alaska.[4]

He joined the Research Lab in 1929 and immediately began earning a solid reputation for his work in physics and electronics. He conceived an original and effective method for studying the characteristics of electric arcs and designed nonlinear circuit elements, whose uses included the switches for the blinking gigantic GE monogram that identified the Schenectady Works. His superiors, Hull and Coolidge, were impressed with his organization, self-direction and independence. Although he had never managed more than a handful of people, he was chosen in 1940 to become the lab's assistant director and Coolidge's heir apparent.

Before he could move up further, the war broke out and so offered him a new management opportunity. As director of the National Defense Research Council's Division 15, he led some 1000 scientists and engineers in developing countermeasures to enemy radar.[5] The success of the effort catapulted him into the position of a promising junior member of the nation's science establishment.

He also met some of the nation's outstanding young scientists and kept their names in mind. After the war he could supplement his memory with a document compiled and distributed by the Office of Naval Research, listing 2000 young scientists in the war effort. Late in 1945 he sent Research Laboratory executive engineer Dudley Chambers and physicists Albert Hull and Kenneth Kingdon out to recruit—to Los Alamos, to the Metallurgical Laboratory at the University of Chicago, to the Radiation Laboratory at MIT, and to the Underwater Sound Laboratory at Harvard. By March 1946 he could announce that 60 scientists had joined the Research Lab's staff since the end of the war, including 20 from the Manhattan District atom bomb project.

GE's research was on the verge of a major change in both scale and nature. Ground had been broken for the construction of a new laboratory—not a squat, brown-brick office building in the midst of an industrial plant like the current home, but a structure specially designed for laboratory use, and placed on the landscaped grounds of what had formerly been the estate of a patent-medicine king.

Already, at the existing lab, the nature of the work was changing. Small-scale work by small teams was giving way to large-scale projects. And many of these projects ranged much further beyond GE's immediate needs than would have seemed possible or desirable before the war.

Combustion and gas dynamics laboratory in the late 1950s. In this facility research was conducted on combustion processes and phenomena occurring at flight speeds of Mach 5.

For example, in the years before the war, Irving Langmuir and his colleagues Vincent Schaefer (whom Langmuir had brought from the machine shop to the laboratory and who had developed into a scientist) and Katharine Blodgett (the first woman PhD to work in an industrial research laboratory) did research using simple tools in the classic tradition of string and sealing wax. Some of their major discoveries grew out of industrial needs. One of their effects led to the discovery of the monomolecular liquid-on-liquid layers, now known as Langmuir—Blodgett films. This discovery had been partly inspired by a request for a better lubricant for meter bearings.[6]

In the fall of 1946, Schaefer followed up on some of his wartime work on precipitation static in airplanes and discovered how to turn simulated supercooled clouds (actually water vapor in a food freezer) into a simulated snowstorm. A few weeks later, he repeated the same experiment in the actual atmosphere, dropping dry ice from an airplane to create the first manmade snowstorm. Within two more years, Langmuir and Schaefer became the leaders of a government-sponsored program on weather-modification experiments, the Project Cirrus. Cirrus involved dozens of people, years of field tests, nearly 300 aircraft flights over cloudy sites from the Adirondacks to Florida, and from New Mexico to Puerto Rico.[7] The little science of Langmuir's prewar laboratory had become big science, indeed, after the war.

Similar changes in scale occurred in other fields. In solid-state physics, GE had made only the smallest and most tentative explorations before the war. Wartime research brought GE researchers into the field permanently. Postwar advances, especially the invention of the transistor at Bell Laboratories, led GE to launch major efforts in semiconductor science and technology. Before the war, the Research Laboratory's efforts in high-energy physics had been concentrated almost entirely on x-ray apparatus, an important GE business. But by 1945 the lab possessed one of the world's highest-energy electron accelerators, a 100-meV betatron, and was making it available to scientists studying elementary particles. Then, using a 70-meV synchrotron completed at the lab in 1947, GE researchers Herbert Pollock, Robert Langmuir and Frank Elder made the first observation of synchrotron radiation.[8] But no field of GE's research showed more clearly the change from prewar to postwar attitudes than nuclear physics.

The peaceful atom

In 1939, Irving Langmuir had come back excited from a meeting of The American Physical Society. Speakers there had told of recent experiments in Germany that had breathed life into the 40-year-old dream of extracting power from the atom. Uranium atoms, it appeared, could split into fragments, releasing enormous amounts of energy. Langmuir's enthusiasm convinced lab director Coolidge to assign two scientists to the problem. Early in 1940, Kingdon and Pollock extracted from a sample of uranium chloride a few micrograms each of uranium's two isotopes, U^{235} and U^{238}. Scientists at Columbia University waited eagerly to test whether the rarer of the isotopes, U^{235}, would split when bombarded by neutrons, giving off both energy and more neutrons, which, in turn, would split other U^{235} nuclei.

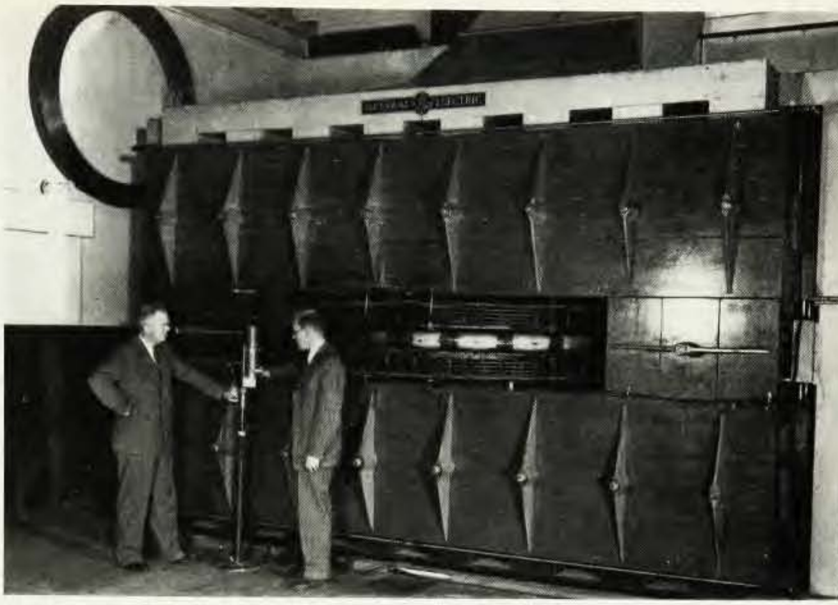
But the urgency of the question was not enough to override totally the spirit of economy that still gripped the lab in the aftermath of the great depression. "Get the excursion fare to New York," Kingdon instructed. So Pollock rode in the low-cost early-morning coach, carrying with him a substantial fraction of the world's supply of separated uranium isotopes.[9]

In Kingdon and Pollock's prewar laboratory, the sensitive equipment for the separation of uranium isotopes had to be shut down by day for fear that transient voltages from nearby trolley-car lines would upset it. By 1946, the nation's atomic energy effort commanded areas of specially designed equipment, running day and night behind a wall of secrecy and high priority, with the energy of the Tennessee Valley and the Columbia River and the skills of some of America's strongest technology-based corporations at its command.

By the end of the war, General Electric had established a Nuclear Investigations Group, consisting of a dozen scientists and engineers at its Research Laboratory. By April 1946, the company had agreed to take over responsibility for the nation's plutonium-producing plant at Hanford, Washington. Within a few more months, the government had agreed to fund a $36-million laboratory located near Schenectady and run by GE, dedicated to the peaceful use of nuclear power. Its staff, which reached 650 in 1947 and 1000 in 1950, quickly filled the available space in the Research Laboratory's downtown headquarters, and expanded into an abandoned tank plant in Schenectady and a demobilized radar test station in a rural area north of the city.[10]

It included veterans of the GE Research Laboratory and new faces, too. Theorist George Placzek arrived to head the theory group and was known

Betatron. Ernest Charlton (left) and Willem Westendorp in 1950 with the 100-MeV betatron they helped design in the early 1940s.



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to work out equations with lipstick on the mirror of his new Schenectady home. Henry Hurwitz, one of the most promising young Los Alamos theorists, joined him, as did Harvey Brooks, already recognized[11] by his colleagues as "a brilliant mathematician and a very dynamic fellow." Later, Brooks became one of America's leading science policymakers. The new staff underwent a crash course in nuclear power taught by some of the world's leading experts. Hans Bethe of Cornell, Ernest Lawrence of Berkeley and Eugene Wigner of Princeton—all of whom were already, or were soon to become, Nobel laureates—came to Schenectady as consultants.

Not all the hopes for the laboratory were realized. It had been created to develop a civilian nuclear reactor for power production. In the cold war climate of the late 1940s, and at the urging of Hyman Rickover of the Navy, it was redirected into the national effort to develop nuclear propulsion systems for submarines. Its researchers made notable innovations in nuclear power, proposing the use of uranium oxide fuel and zircalloy cladding in nuclear fuel elements. They designed the sodium-cooled nuclear reactor for the second US nuclear submarine, the Seawolf, and in this the laboratory served as a graduate school in nuclear engineering for a Navy lieutenant named Jimmy Carter. Soon the laboratory near Schenectady grew into one of the nation's two laboratories dedicated to the development of nuclear reactors for the propulsion of naval vessels.

It may not have become what General Electric had initially intended it to be: an arm of its Research Laboratory aimed at fundamental research that would give the company a grip on an emerging commerical use of atomic power. But the experience had not caused GE's management to become disillusioned with the shift its Research Laboratory was making into larger-scale, more exploratory research efforts. GE would proceed to undertake basic research programs in a remarkably wide range of areas—experimental high-energy physics, thermonuclear fusion, superconductivity, polymers, solid-state physics, information theory, fundamentals of metallurgy and ceramics, and more. In the postwar period, it would stand alongside Bell Laboratories as one of the world's preeminent industrial performers of fundamental research.

Funding research

GE's redirected laboratory would pay for its work in a new way. Before the war, the lab had raised about three-fourths of its annual budget from the company's operations, with the rest coming from corporate headquarters. To raise the money, the laboratory's principal goodwill ambassador, executive engineer Laurence Hawkins, would visit the company's different operations. Trained as an engineer and a patent attorney, Hawkins hid behind the cowlick and guileless face of an aging Huck Finn, a salty vocabulary, a mastery of bargaining and an unmatched familiarity with General Electric.[12]

Hawkins would annually ask each GE department to allocate a certain amount of money to the Research Lab. Some departments, such as Lighting or X-ray, had gained so much benefit from the lab's past work that they usually agreed to the request with no strings attached. Others agreed only to fund specific projects. Still others refused to pay anything. However, if the lab had not obtained research money up front, and if it then proceeded to invent something a department could use, it had the right to sell that invention to the department. The selling price would be set to recover the costs that had gone into the research and development. But checking up on those costs was impossible for the outsider. So the lab often succumbed to temptation and padded the cost with what it called "dead horses"—the carcasses of past projects that had not yet been written off.

This practice created an atmosphere of suspicion between the lab and some of the other operations, and could seriously delay the innovation process. The case of the mercury switch illustrates the problem.[13]

In the 1930s, an ingenious engineer at the Reseach Lab, John Payne, had conceived of a way to make a silent electric wall switch for homes by using as the electric contact a tilting vial of mercury. The help he got from his scientist colleagues—for example, from Suits he learned the characteristics of the electric arc; and from ceramist Louis Navias he obtained a ceramic container—enabled him to reduce it to practice. Payne even designed a machine to make the switches. But when Hawkins presented the package and its accompanying bill to the manager of GE's Small Apparatus Department, that manager thought the price was too high and turned it down. Then he called in one of his own engineers and asked him to reinvent the product and process. That engineer failed. A couple of years later, Small Apparatus had to admit defeat, call Hawkins back in, and sign on the dotted line. In other words, GE had lost valuable lead time in the marketplace and years of engineering effort due to a family squabble about internal bookkeeping. Lab direc-

Some discoveries and inventions at GE

1882	General Electric Company is formed by combination of Edison General Electric and Thomson-Houston Company.
1900	GE Research Laboratory is established under Willis R. Whitney.
1908	William D. Coolidge renders tungsten ductile, thus paving the way for modern electric illumination.
	Coolidge demonstrates first practical and safe x-ray tube.
1915	Saul Dushman develops first high-voltage vacuum rectifier.
1917	Albert W. Hull invents the magnetron (later used for radar transmission in World War II).
	Development of portable x-ray tube made possible by self-rectifying Coolidge tube.
1928	First public demonstration of radio transmission of photographs.
1941	Research Laboratory in cooperation with University of Illinois builds a 20-MeV betatron electron accelerator and begins work on a 100-MeV betatron.
1946	Vincent Schaefer performs the first successful cloud-seeding experiment, resulting in the first manmade precipitation.
1947	Herbert C. Pollock, Frank R. Elder and Robert V. Langmuir discover synchrotron radiation.
1950	Robert N. Hall invents the "p–i–n" structure, a method of alloying the metal indium with the semiconductor germanium to make a p–n junction, the basic element in power rectifiers and some transistors.
1952	Robert N. Hall proposes the theory of electron–hole recombination in semiconductors, a theory later elaborated by Shockley and Read of Bell Laboratories and since known as the Hall–Shockley–Read theory.
1954	Francis P. Bundy, H. Tracy Hall, Herbert M. Strong and Robert H. Wentorf Jr., invent the first reproducible process for making diamond.
1957	Robert H. Wentorf Jr invents borazon, cubic boron nitride, a manmade material second only to diamond in hardness.
1957–62	William C. Dash and Arthur W. Tweet invent a method for growing dislocation-free crystals of silicon.
1960	Ivar Giaever discovers superconductive tunneling, both a scientific phenomenon of major importance and the basis for the invention of new types of high-speed electronic switches. For this discovery he shares the 1973 Nobel prize for physics.
1962	Robert N. Hall and colleagues invent the semiconductor laser, which produces coherent light by the combination of electrons and holes at the junction of p-type and n-type semiconductor material.

tor Suits believed that this incident—on top of many similar but less pronounced ones—should signal the end of the old funding system.

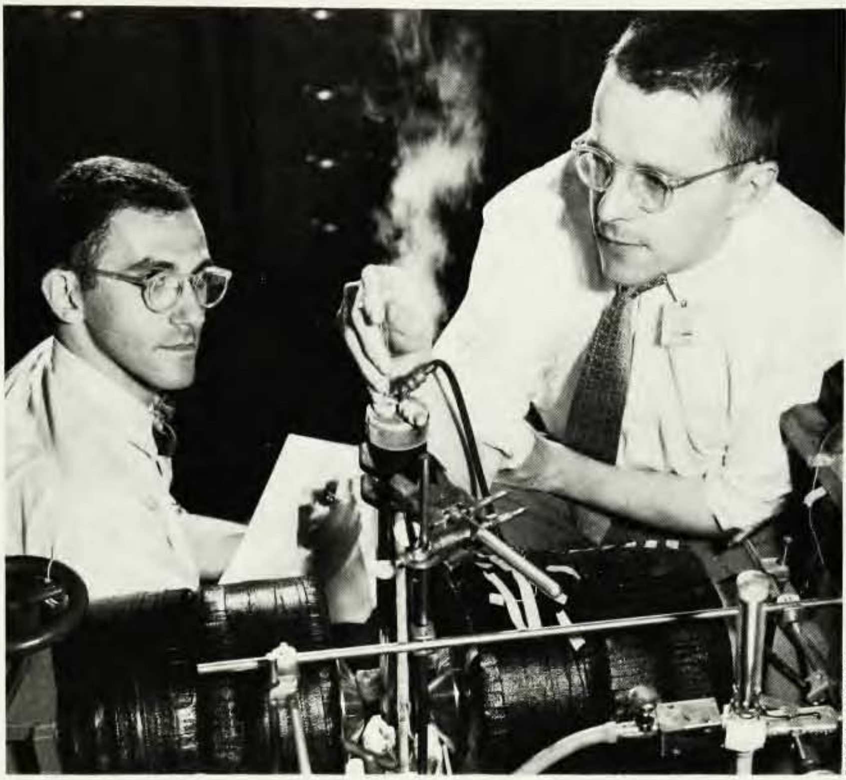
In 1946, Suits and GE president Charles E. Wilson devised a new funding method. Business operations would no longer have the choice of whether or not to pay for the Research Laboratory's work. Instead, the corporate office would levy an assessment on each GE business, a sort of technology tax consisting of a fraction of a percent of sales. The exact fraction was initially set at a uniform level. But within a few years, the businesses less dependent on technology complained and subsequently convinced the corporate office to assign a different percentage to each business, based on a formula that took technology intensiveness into account. These "assessed funds" came to cover about two-thirds of the lab's expenditures. The rest came from additional contracts with the businesses or with external agencies, mainly in the Federal government.

The businesses now paid for their research in advance, so they had added incentive to see how much they could get out of the lab. And the laboratory had increased its autonomy in the choice of how to put this large amount of no-strings-attached corporate funds to work.

Trying industrial research

New fields of research and new sources of money would have meant little if GE could not have attracted

Israel Jacobs and Charles P. Bean studying the magnetization of small iron particles at low temperatures in studies of superferromagnetism in the 1950s.



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good scientists to do the work. Why would a postwar job candidate have given industrial research a try? A look at some people who did make that choice suggests some possible answers. Consider, for example, three physicists who had been graduate students together at Ohio State back in 1935. For Francis Bundy, Volney Wilson and Herbert Strong, studying physics had offered a temporary haven from the Depression. Each of them had come to science through boyhood hobbies and curiosity rather than through a clear sense of career. But as they acquired degrees and raised families, careers became necessary.

"I'll teach for four or five years," Francis Bundy remembers[14] thinking when he got his doctorate. He was off to Athens, Ohio, for an instructor's job in the physics department of Ohio University on a salary of $1800 a year. Teaching shunted research into his spare time, and meager equipment kept his personal studies simple. He analyzed the way broken-off chimneys fall and spent summers studying cylinder wear in diesel engines.

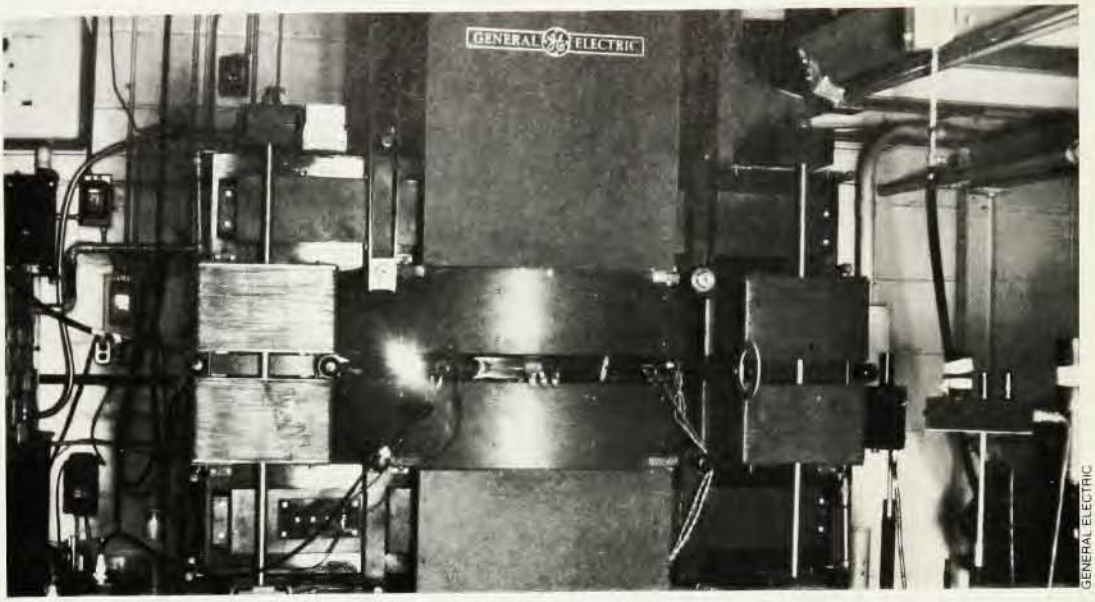
Then came the war and an "out-of-the-blue" invitation from Frederick V. Hunt of Harvard for Bundy to come to Cambridge and join the Underwater Sound Laboratory. This implied an education in electronics and acoustics, contact with industrial firms such as General Electric and, above all, participation in the "biggest and best scientific melting pot that ever occurred." The war ended and, in 1946, the recruiters descended on Harvard, Dudley Chambers of GE among them. The trip to Schenectady that followed included a drive out to the new laboratory site on the Mohawk and lunch with Langmuir. ("He had been my guiding star since high school," Bundy recalls. "I had to pinch myself to see if it was real.") He went home to consider offers from Harvard, Texas and International Nickel. But he looked back on his four years of mission-oriented interdisciplinary work with outstanding people and decided that the GE Research Lab might offer more of the same. "The experience of working with these guys had been such an education," he decided, "that I really ought to go over to the GE lab for a couple of years."

Volney Wilson had left Ohio State University in 1937 for the University of Chicago to study cosmic rays with Nobel laureate Arthur Compton. The war swept him into Chicago's Metallurgical Laboratory, a part of the atomic bomb effort. When the world's first controlled chain reaction went critical on the squash court under the stands of Chicago's Stagg Field, he was there as head of the instrument group. He did more work on instruments at Los Alamos.[15]

After the war, Arthur Compton gave Wilson some advice: Why not look over the GE lab, where Compton was a consultant? Wilson arranged an interview and was impressed, especially with the old guard. "I think it was Coolidge and Hull," he says. He got an offer, and accepted.

For Herb Strong, the path was longer. By the time he completed his dissertation in 1936, he already had a full-time job developing new surgical dressings for the Kendall Company. He moved on to a textile plant in Rhode Island. "It bothered me a lot that I was getting away from physics," he recalls.[16] "The work didn't have enough challenge—there wasn't room for a physicist." Visiting Bundy, he admitted to some envy about his friend's GE opportunity. Bundy put in a word, and Strong soon got a message to contact the GE recruiter at the next American Physical Society meeting. By the end of 1946, the three contemporaries at Ohio State were back together again at General Electric.

Other members of the new guard were equally attracted by the opportunities to do some real science and remain in the type of climate they had found attractive during the war. The bait Suits dangled before Los Alamos nuclear physicist Henry Hurwitz was the chance to do pure research. "Shockley at Bell labs made no bones about it that their job was to support the communications industry," he remembers.[17] "I was hired [by GE] to do high-energy physics." Jim Lawson of MIT's Radiation Laboratory got to know Suits during the war when both were working on radar problems. Many conversations and a couple of visits gradually warmed him toward GE, until he decided that "I might try it for a couple of years." Metallurgist Joe Burke went first from Los Alamos to



Manmade synchrotron radiation was observed for the first time in the 70-Mev synchrotron at the GE Research Laboratory in 1947. The radiation is visible as a bright spot on the left side of the "doughnut."

the University of Chicago, but he found the pay too low and the city constricting, and found a new job at GE.

A look at a sample of 33 scientists with PhDs who joined the research staff of the GE Research Lab in 1946 shows typical members of the new guard as about 30 years old, married, and just starting families.[18] All of the new researchers hired in 1946 were men (though in 1945, the lab had doubled its number of female researchers by hiring Edith Boldebuck, who held a PhD in chemistry from the University of Chicago). Almost all of the newly appointed researchers had gone to the best American graduate schools—Harvard, Princeton, Berkeley, Chicago, Caltech, Michigan, Wisconsin, Johns Hopkins, and Rochester, for example. About half were physicists; the rest were chemists or metallurgists. Most of them had worked in a government-sponsored research and development program during the war, with Los Alamos and the MIT Radiation Lab most strongly represented.

The move into industry did not always go smoothly. Volney Wilson went to GE in the hope of turning atomic energy into a benefit to humanity.[11] "I sort of felt it to be one way to justify my working on the bomb, if I could also make a peaceful application," he remembers thinking. But within two years, he was being shifted back into military work: "I was quite a pacifist still, and so this irritated me, and so I quit." Wilson continued:

> I wrote a big, long nasty letter to Suits and then Suits called me to come and see him. I was going to resign from the company and, as I walked into the office, he was talking to someone on the phone and just said 'yes, yes.' And I'm quite sure it was Albert Hull, and I think it was Hull who persuaded Suits to treat me gently. And so, I did stay, and Suits was extremely generous; he told me to spend all the time I wanted to read and decide what I'd like to do.

Not all of Wilson's colleagues made the adjustment. Of the 1946 sample of 33 recruits, 12 had left GE within five years. Not all should be assumed to have left disillusioned. It was a seller's market for scientists, and some simply got a better offer.

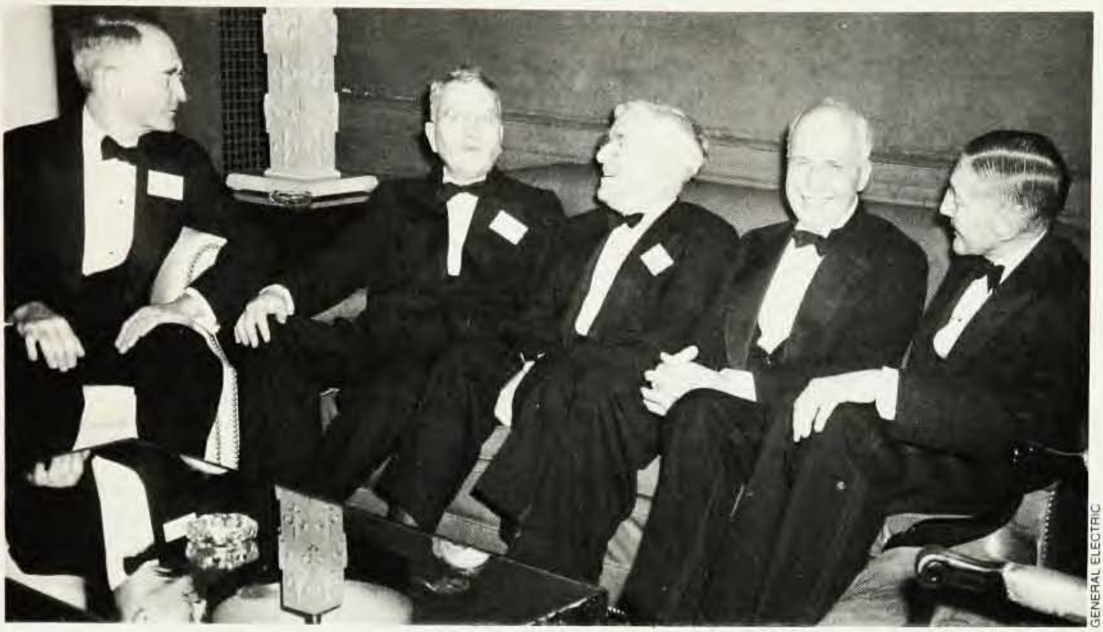
But the majority stayed. Francis Bundy and Herb Strong, for example, moved directly into the lab's Mechanical Investigations Section, an interdisciplinary group tackling varied problems in the development and testing of machinery and propulsion systems. They began with some fairly straightforward tasks: analyzing the vibrations of a misbehaving turbine generator; using spectroscopy to measure the speed of rocket exhausts; or designing a new refrigerator insulation. But within five years they were embarked on what would be one of the most interesting exploratory efforts in industrial research: the production of diamond in the laboratory.

The new guard that they exemplified, and that the recruit of 1946 was being asked to join, was part of a new generation of American scientists. It was the first to be educated by US research universities on a par with those of Europe. This group had experienced the Depression of the 1930s, and appreciated the security of a good job. Many members had no burning desire to teach, and no unbreakable attachment to the amenities of a university. Most had experienced during the war the challenges and rewards of mission-oriented work. They were used to the idea that a scientific project might have a useful output. And, above all, they saw GE as a way station, not necessarily a final destination.

The nation had helped to bring them there. A war had sold science to the public. And that same war had gathered thousands of America's brightest young scientists and engineers into a small number of temporary laboratories. The demobilization of these laboratories gave industry an unprecedented opportunity to harvest bumper crops of talented researchers. At GE this new guard dominated its laboratory until the 1960s, when the faith in research was tested and found wanting. The outcome was a re-emphasis on results—though by no means simply a return to the old strategy. Instead, a new generation of leaders interpreted the relationship of science and technology differently, and took different practical actions. But that is another story.

GE's historical role

General Electric, a pioneer in prewar research, changed the scope and style of its Research Laboratory in 1945 as part of the national trend toward big and visible science. Between 1945 and 1950, it put a new emphasis on projects carried out by large teams in important areas of research such as atomic power and rainmaking. To support that thrust, its total staff grew from 630



Nobel laureates Percy W. Bridgman, Harold Urey, and Irving Langmuir (from left) at the opening of the General Electric Research Laboratory at the Knolls site in 1950.

people (160 of them scientists or engineers) in 1945 to 950 (225 of them scientists or engineers) by 1951. It spun off a new atomic power laboratory with a staff of more than 1000 people. It adopted a new method of funding research that made it more independent of the whims of GE business operations than ever before. Under its old name, and without publicly renouncing the policies that had led to past success, it became essentially a new laboratory.

How might understanding GE's postwar experience help reshape interpretations of the history of modern American science? First, it cautions us against speaking of "the" industrial research laboratory—the embodiment of industry's perception of the relationship between research and results. The laboratory run by Whitney and the one run by Suits were two very different organizations, in both purpose and practice. Research by Margaret Graham indicates that similar changes occurred at RCA.[19] Did they happen at AT&T, Eastman Kodak, Du Pont or the other technology-based giants?

Second, the change at GE highlights an important but rarely commented-on effort by government to established industries resulting from World War II research. When the war ended, demobilization freed many scientists who had participated in an intense and often inspiring experience in the type of interdisciplinary, goal-oriented work in which industry specialized. The new research orientation of industrial laboratories offered an inviting blend of the emphasis on science that the recruit had experienced in a university, and the teamwork and sense of purpose characteristic of the wartime laboratories.

And, third, General Electric's new outlook in research helped amplify the new national view of research. That view proved no more permanent than the ones that preceded it. But while it held sway, it supported work in industry that led to major technological advances ranging from new applications of semiconductors in electronics to the synthesis of diamond and new ways of making plastics. And on the national scale, that new view led to the creation of institutions (such as the National Science Foundation) and practices (like the large-scale sponsorship of research by the military) that continue to shape the support of research in America.

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