THE RACE TO MAKE THE BOMB

The Manhattan Project: Columbia's wartime secret

BY LAURENCE LIPPSETT

In the pre-electronic mail days of 1939, the year Hitler invaded Poland, the Danish physicist Niels Bohr carried important scientific news to the New World aboard a transatlantic steamer. He and only perhaps a half-dozen others in the world knew about the tantalizing but inexplicable results of a recent experiment: Two German scientists had bombarded uranium with subatomic particles called neutrons and, to their surprise, produced barium, an element about half the atomic weight of uranium.

When the word reached Morningside Heights, it sparked a dizzying cascade of events. Within days, Columbia physicists working in Pupin Physics Laboratories demonstrated that neutrons could split uranium atoms, releasing enormous power. Within weeks, they ascertained that the process released enough neutrons to split more uranium atoms and spark a chain reaction. Within months, the scientists contacted skeptical government officials about the potential of their experiments. And within a year, they secured the first federal contract to explore the harnessing of atomic power for energy, or, for bombs—and had built the first atomic pile.

Cloaked in wartime secrecy, attracting almost no attention, Columbia had inaugurated what came to be known as the Manhattan Project—a $2 billion enterprise that involved thousands of scientists and military personnel and eventually spawned the huge military-industrial complex of federal laboratories and weapons plants that exists today. That whole establishment, wrote Spencer R. Weart in his biography of the atomic physicist Leo Szilard, "can be traced back to a few people sitting at laboratory benches discussing the peculiar behavior of one type of atom." Many of those people were at Columbia, where at the time, "a great deal of the world's knowledge of neutron physics was centered," said William W. Havens, then a lecturer and now Professor Emeritus of Physics. The 1945 annual report of Columbia President Nicholas Murray Butler noted that "more than 250 members of the Scientific Staff and more than 1,200 others" were engaged in research that occupied parts of Havemeyer, Pupin, and Schermerhorn Halls, most of a large building at 133d Street and Broadway, and numerous other structures on and around campus.

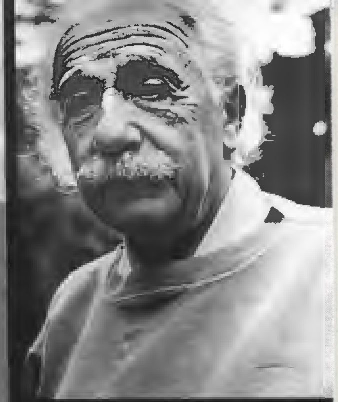
It was with such resources that Columbia launched a feverish project with awesome moral implications, which ushered in an entirely new era of warfare and world politics heralded by the mushroom cloud that burst above Hiroshima 50 years ago.

In the waning days of 1938, the German physicists Otto Hahn and Fritz Strassman found that neutron bombardment of uranium produced barium. Puzzled, they wrote to Lise Meitner, an Austrian physicist who had fled Nazism and moved to Sweden. "Perhaps you can suggest some fantastic explanation," Hahn wrote. "We understand that it really *can't* break up into barium.... So try to think of some other possibility."

Meitner and her nephew Otto Frisch, also a physicist, speculated that barium was created when uranium nuclei split into two smaller nuclei. On January 6, 1939, Frisch disscussed their theory with Bohr, who was scheduled to leave the next morning for the United States to work at the Institute for Advanced Study in Princeton. In the days after Bohr's arrival, two Columbia physicists, Willis Lamb and I. I. Rabi, who both later won the Nobel Prize, happened to be in Princeton, and on January 16 they returned to New York and shared the news with Enrico Fermi, the Nobel Laureate physicist who had fled fascist Italy to teach at Columbia.

On January 25, Fermi dropped by the office of John R. Dunning, the physicist and later dean of the School of Engineering and Applied Science. Over lunch at the (then) Men's Faculty Club, they discussed an experiment that Dunning carried out later that night with other Columbia scientists in the basement of Pupin. They bombarded a thin plate covered with uranium oxide with neutrons and watched as green lines leaped upward on an oscilloscope screen. In his laboratory notebook, Dunning called them "enormous kicks," each indicating a large amount of energy being generated. By midnight, the theory of nuclear fission was fact. The next day, Dunning wrote in his notebook: "Believe we have observed a new phenomenon of far-reaching consequence." (Unknown to any American, Frisch had conducted a similar experiment 10 days earlier.)

Enrico Fermi *fled Mussolini's Italy to teach at Columbia, where he helped build the first atomic pile.*
PHOTO: ARGONNE NATIONAL LABORATORY

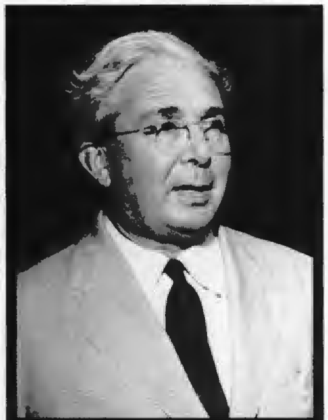


Einstein *told FDR of the vast potential of atomic power.*
PHOTO: UPI/BETTMANN NEWSPHOTOS

Man and machine: *John R. Dunning, the first person in this hemisphere to split the atom, at the Columbia cyclotron with which he performed the experiment.*
PHOTO: COLUMBIANA COLLECTION

"This requires action," *said President Roosevelt, setting the project in motion.*
PHOTO: UPI BETTMANN NEWSPHOTOS

Alamogordo: *The Trinity test of July 16, 1945—the first explosion of an atomic bomb.*
LOS ALAMOS NATIONAL LAB/AIP
EMILIO SEGRÈ VISUAL ARCHIVES



Columbia physicist Leo Szilard urged that atomic experiments be shielded in secrecy.
PHOTO: AIP EMILIO SEGRÈ VISUAL ARCHIVES

Physicists immediately realized the Promethean ramifications of the discovery. In his Pulitzer Prize-winning book *The Making of the Atomic Bomb,* Richard Rhodes described a scene witnessed a few days later by the Columbia physicist George Uhlenbeck, who shared an office in Pupin with Fermi: "Fermi was standing at his panoramic office window high in the physics tower looking down the gray winter length of Manhattan Island, its streets alive as always with vendors and taxis and crowds. He cupped his hands as if he were holding a ball. 'A little bomb like that,' he said simply… 'and it would all disappear.' "

"It's hard to re-create the attitude at the time," Professor Havens said recently. "The Germans had a lot of brilliant people who had been working on atomic energy and we didn't know how far along they were on a bomb. We had every incentive to get a bomb first, and we had no idea if one ever could be constructed. Until you got done with one experiment, you didn't know what to do next. We tried to do as much as we could simultaneously and we worked very hard. We would run the cyclotron all night and then I'd teach classes at 8 a.m. and then go home and take a nap."

The discovery that individual uranium atoms could fission fueled only atomic potential, not an atomic bomb. To produce one, millions of atoms would have to be split in a millionth of a second. That would happen only if fission liberated neutrons from nuclei, which split other uranium nuclei in a chain reaction—a process that clearly did not occur naturally in an ordinary lump of uranium.

Bohr quickly came up with a theoretical explanation. Uranium came in at least two isotopes, U-238 and U-235. The latter, with its odd atomic mass, fissioned easily. U-238 did not, and in fact absorbed neutrons. Since uranium contained 139 times more U-238 than U-235, neutrons liberated by fission would much more likely be absorbed by U-238 or by other impurities, or shoot aimlessly into space, rather than hit another atom of U-235.

So the question became: Could fission produce sufficient neutrons to overcome these hurdles, hit more U-235's and produce a self-sustaining chain reaction? In a speech Fermi gave at McMillin Theatre a few months before he died in 1954, he said the solution was "a matter of numbers": If fission released enough neutrons, a chain reaction was nearly unstoppable; too few and it was unstartable.

On March 3, 1939, two Columbia physicists, Leo Szilard and Walter Zinn, performed an historic experiment on the seventh floor of Pupin to measure the amount of neutrons emitted from fissioning uranium.

"After two days of preparation everything was ready and all we had to do was to turn a switch, lean back and watch the screen of a television tube," Szilard later recalled. "If flashes of light appeared on the screen, that would mean that neutrons were emitted in the fission process of uranium, and this, in turn, would mean that the large-scale liberation of atomic energy was just around the corner. We turned the switch and we saw the flashes. We watched them for a little while and then we switched everything off and went home. That night there was little doubt in my mind the world was headed for grief."

Working independently in Pupin, Fermi and a graduate student, Herbert Anderson, used a different apparatus to confirm almost simultaneously that each fission produced an average of two neutrons, making a chain reaction theoretically possible. At this juncture, the scientists began to promulgate a self-imposed and unprecedented code of silence. In his 1954 speech, Fermi related how Szilard startled the scientific community by proposing that with war in the air, and given "the danger that atomic energy and possibly atomic weapons could become the chief tool for the Nazis to enslave the world, it was the duty of the physicists to depart from what had been the tradition of publishing significant results" as soon as possible. Instead, Szilard urged his compatriots to "keep back some results until it was clear whether these results were potentially dangerous or potentially helpful to our side."

But there was one audience these scientists did want to inform: the U.S. government. On March 16, 1939, the day Hitler annexed Czechoslovakia, Columbia's Dean of Graduate Faculties, George B. Pegram, called Admiral Stanford C. Hooper in the Office of the Chief of Naval Operations, who agreed to see Fermi. The scientist carried a letter from Pegram that spoke of experiments at Columbia which indicated "that uranium might be used as an explosive that would liberate a million times as much energy per pound as any known explosive."

The Navy showed little interest.

Determined to convince the government, Szilard conspired with two fellow Hungarian-born physicists who had fled Nazism: Edward Teller, who was then teaching at Columbia, and Eugene Wigner of Princeton. They persuaded the world's best-known and respected physicist, Albert Einstein, to write a letter to President Roosevelt, alerting him to the potential, good and bad, of atomic energy.

Szilard met with Alexander Sachs '12, who had helped write speeches for Roosevelt and served as an economist for three years in FDR's National Recovery Administration. Sachs agreed to carry Einstein's letter personally to the President. On October 11, 1939, Sachs visited FDR, and in his own words told him of the recent research in nuclear physics and its potential for energy and destruction. FDR reportedly declared, "This requires action." Ten days later, the first meeting of the newly created Advisory Committee on Uranium convened. When asked how much money would

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Szilard when he saw the first flashes of

be needed to launch research, Teller responded with a first-year figure of $6,000. Later he reminisced: "My friends blamed me because the great enterprise of nuclear energy was to start with such a pittance."

The $6,000 bought Fermi and Szilard lots of graphite, the greasy black stuff in pencils, which acted as a medium to slow down neutrons so they would not be absorbed by U-238 atoms and could remain free to hit U-235 atoms ("Physicists on the seventh floor of Pupin Laboratories started looking like coal miners," Fermi said). The resulting graphite mound, interspersed with uranium, eventually rose to the height of Pupin's ceilings and by July 1941 weighed about seven tons.

"We went to Dean Pegram, who was then the man who could carry magic around the University, and we explained to him that we needed a big room," Fermi said. "And when we say 'big,' we mean a really big room. Perhaps he made a crack about a church not being the most suited place for a physics laboratory, but I think a church would have been just precisely what we wanted. Well, he scouted around the campus and we went with him to dark corridors and under various heating pipes and so on to visit possible sites for this experiment and eventually a big room, not a church, but something that might have compared in size with a church, was discovered in Schermerhorn."

There they constructed a new pile of graphite bricks and cans of uranium oxide. "Well," Fermi continued, "we were reasonably strong, but I mean we were, after all, thinkers. So Dean Pegram looked around and said, 'Well that seems to be a job a little bit beyond your feeble strength, but there is a football squad at Columbia that contains a dozen or so very husky boys who take jobs by the hour just to carry them through college. Why don't you hire them?'

"And it was a marvelous idea; it was really a pleasure for us to direct the work of these husky boys, canning uranium—just shoving it in—handling packs of 50 or 100 pounds with the same ease as another person would have handled three or four pounds."

While all this was going on, Dunning and a Columbia team that included the Nobel laureate chemist Harold Urey was pursuing a completely different track. If Bohr was correct about U-235, a pure batch of the material would be easy to ignite. In the spring of 1939, Dunning wrote to Alfred Nier of the University of Minnesota and proposed a kind of shotgun wedding: Nier had one of the world's few mass spectrometers, a device that could separate microscopic quantities of isotopes, and Columbia had one of the first cyclotrons, which could produce a continuous source of neutrons. "If you could separate effectively even tiny amounts of the two main (uranium) isotopes, there is a good chance that Booth and I could demonstrate, by bombarding them with the cyclotron, which isotope is responsible [for fission]," Dunning wrote. "If we could all cooperate and you aid us by separating some samples, then we could by combining forces, settle the whole matter."

Dunning sent uranium samples to Nier. "The first separation of U-235 and U-238 was actually accomplished on February 28 and 29, 1940," Nier recalled. "On Friday afternoon, February 29, I posted the little samples (collected on nickel foil) on the margin of a handwritten letter and delivered them to the Minneapolis Post Office at about six o'clock. The letter was sent by airmail special delivery and arrived at Columbia University on Saturday. I was aroused early Sunday morning by a long-distance telephone call from John Dunning (who had worked through the night bombarding the samples with neutrons from the Columbia cyclotron). The Columbia test of the samples clearly showed that U-235 was responsible for the slow neutron fission of uranium."

Dean George Pegram situated the atomic pile in Pupin and enlisted the football team to cart uranium there.
PHOTO: COLUMBIANA COLLECTION

But no one seemed able to separate enough U-235 quickly enough. It would have taken 27,000 years, for example, for Nier's mass spectrometer to produce one gram of U-235. Scientists all over the country tried hundreds of methods. "At that time," Fermi said, "isotopes were considered almost magically inseparable" and "it was not very clear that the job of separating large amounts of uranium-235 was one that could be taken seriously." At one point, Havens recalled, Urey had set up a column of chemistry apparatus in the open space in the stairwell of Havemeyer. Braced to the ceiling and banisters, it rose several flights and was passed daily by anyone using the stairs.

Finally, the Columbia team hit upon a process called gaseous diffusion. It involved pumping uranium gas against a porous barrier of sheet metal with millions of submicroscopic openings per square inch, allowing the lighter molecules containing U-235 to pass through more rapidly than the heavier U-238 molecules. "These sheets were formed into tubes which were enclosed in an airtight vessel, the diffuser," wrote Gen. Leslie R. Groves, director of the Manhattan Project, in his postwar memoir. "As the gas, uranium hexafluoride, was pumped through a long series, or cascade, of these tubes it tended to separate, the enriched gas moving up the cascade while the depleted move down." But with so little difference in mass between the hexafluoride of U-238 and U-235, a single diffusion step yielded little separation. Several thousand successive stages were thus required.

By late 1942, Columbia had a gas diffusion pilot plant in Pupin that spilled over into a former Nash automobile plant on 133rd Street and Broadway. The program, which was designated with the purposefully uninteresting name of Special Alloyed Materials (SAM) Laboratory, employed more than 1,000 people at its peak and devised a workable barrier late in 1943.

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world was headed for grief," said Leo
of light on a screen in Pupin Hall.

THE PRESIDENT'S BOX

Our goals are in sight

BY MARTIN S. KAPLAN '61

PRESIDENT, COLUMBIA COLLEGE ALUMNI ASSOCIATION

We continue to make tremendous progress toward the goals set forth in the *Report on the Future of Columbia College*. In addition to continuing the core curriculum's 75th anniversary with the most successful Dean's Day ever, there is other great news to report:

1) Furnald Hall will be completely refurbished by September 1996. When it reopens, it will become the sixth dormitory to join our formal house system, which will then include 85 percent of the student body. Each house has offices for deans and advisors to serve student needs, and three houses have faculty-in-residence.

2) The Career Services Office has been transferred from the University to the College, reporting to the Dean of Students, with the goal of providing better service. The house deans will be directly involved with Career Services in order to improve that function.

3) The Dean of Students' Office is also working with the Alumni Association to assist students in finding summer jobs, and in providing career advice and guidance. You will hear more about this program as we develop it, first in the New York area, and then in other locations with significant groups of alumni.

4) We now have over 3,000 alumni working with the Alumni Representative Committee, which helps recruit and interview prospective students. Our applications are now at an all-time high, with 8,712 applicants for the Class of '99. As the reputation of the College continues to rise (as it did this year in the *U.S. News & World Report* survey), we will need to involve more alumni in this important process.

5) Final plans for the new student center and the new College Library have been presented to the Alumni Association board and the Board of Visitors. Meanwhile, the University and College are busily engaged in planning for two new dormitories and improved athletic facilities.

6) Finally, our celebration of the 75th anniversary of the Core was highlighted at Dean's Day by a powerful, eloquent and important address by Judge José Cabranes '61 which emphasized the value of a core curriculum for all students, regardless of gender, race or ethnicity. The speech is reprinted in the forthcoming issue of *Columbia Magazine*. I urge all of you to read it.

The Manhattan Project

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By that time, the mind-boggling engineering required to make all those materials, tubes, pumps, seals and barriers work efficiently on a mass scale had caused Columbia's atomic research to expand exponentially. Because of space limitations on Morningside Heights, as well as for political and security reasons (some officials feared German U-boats coming up the Hudson River), every piece of portable atomic research equipment used in Fermi's atomic pile research, from a can opener to 18 tons of graphite, had been moved in the summer of 1942 from Columbia to the University of Chicago, where the first self-sustaining chain reaction was performed in a squash court under Stagg Field on December 2, 1942.

Most wartime Columbia students graduated without knowing what had been going on just outside their dorm rooms. Fermi's and Urey's research programs were governed by a newly formed district of the U.S. Army Corps of Engineers, with no territorial limits, which was created to oversee atomic energy research. Headquartered in Manhattan, it became known as the Manhattan District, and the research program became known as the Manhattan District Project. The military purposely used a nondescript bureaucratic name to arouse less attention and curiosity.

"We asked the government whether [the atomic pile] should be guarded," Pegram later wrote, "and we were told that less attention would be attracted to it if no special precautions appeared to be taken. As it happened no one showed any interest in what a few scientists were doing in the basement of Schermerhorn. In fact, no one seemed particularly curious at any time, not even when the lack of space for the gaseous diffusion work of Dr. Dunning forced us to take over garages and finally apartment houses on Morningside Heights."

On August 6, 1945, the world suddenly took notice. That morning, Havens was in the basement of Pupin when the telephone rang.

"It was someone from an international news service," he recalled. "He said, "President Truman has just announced the dropping of a bomb equivalent to 12,500 tons of TNT. We don't understand how it works. Can you explain it to us?'

"I said, 'I never heard of it' and hung up," Havens said. He was slightly more forthcoming when his wife asked him what he had been working on for the past five years at Columbia. "I said, 'Listen to the radio.'"

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