Cosmos Club Occasional Paper Series No. 3

The Fiery Sword of Lafayette Square

by Arthur Herman

Published by the Cosmos Club

January 8, 2013

Cosmos Club Occasional Papers Series

Address of the Cosmos Club:
2121 Massachusetts Avenue, N.W.
Washington, D.C. 20008-2871
Telephone number: 202-387-7783
Facsimile number: 202-234-6817
Website: Cosmoclub.org

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by Arthur Herman

It's pleasant to think that the dining room in the old Cosmos Club on Lafayette Square was the scene of many moments of inspiration over the years, as members gathered to eat and talk and try out new ideas regarding the laws governing the natural world, whether in physics or geology or chemistry. But in December 1941 one such meeting really did lead not only to an explosion of mind, but matter – an explosion that would end a world war and change forever the nature of science and its place in the world.

That chilly Washington morning three of the country's most distinguished scientists sat to consider a proposition so unexpected and so radical, that two of them – Vannevar Bush and James B. Conant – could barely catalogue all their objections. But what was said at that table was the culmination of a process that had begun two years earlier on a steamy summer day on Long Island, when two men drove from New York City to ask the most famous scientist in the world to write a letter to the president of the United States.

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> August 2, 1939
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> Sir,
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> In the course of the last four months it has been made possible – through the work of Joliot in France as well as Fermi and Szilard in America – that it might be possible to set up a nuclear chain reaction.... Now it appears almost certain that this could be achieved in the immediate future.
>
> This new phenomenon would also lead to the construction of bombs....
>
> In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of scientists working on chain reactions in America....

This was the letter Albert Einstein signed at his summer retreat at Peconic on Long Island, at the prompting of Hungarian emigre physicists Leo Szilard and Edward Teller. What inspired all three was the fear that in Germany scientists were working on the same problem and would, if Einstein's own calculations were correct, deliver to their Nazi masters the most destructive weapon ever conceived.

It was the late summer of 1939. Germany and Europe were poised for war; America was not. Indeed, Einstein's letter – and the advice but also implicit warning it contained–sat unread for almost two months. It was not until October 11, 1939 – a month after the fall of Poland to the Nazis – that Alexander Sachs, a Wall Street economist and sometime speech writer, brought the letter to Roosevelt's Oval Office. Even then Sachs showed the president not the complete letter, but a brief summary. FDR, however, grasped the point at once.

"Alex," he said, "what you are after is to see that the Nazis don't blow us up."

"Precisely."

Roosevelt leaned forward. "This requires action."[1] In this case, "action" took the form of the appointment of a board to monitor developments in nuclear research around the country. For almost half a year it did very little, despite the fears of Sachs and others that time was not on America's side.

Roosevelt's attitude changed with Hitler's invasion of France in May 1940. He instructed his atomic board to merge with his new National Defense Research Committee, headed by Vannevar Bush. By now it had been confirmed that the Nazis were indeed working on a bomb, and that by every indication they had a good head start.

With Bush and Harvard's James Conant leading the way, the issue for the NDRC was no longer *if* a bomb was feasible, but how to make it feasible. By 1940 scientists had concluded that the best element from which one could make the continuous nuclear chain reaction necessary for sustaining an atomic bomb, would be uranium. In November the NDRC contracted with Columbia University to begin work on uranium fission, and by the spring of 1941 the NDRC's Uranium Committee under Lyman Briggs began looking for someone who could sort through all the theoretical leads on achieving uranium fission, and decide which ones might really lead to the making of a usable atomic weapon.

The man Briggs and Vannevar Bush chose was an Ohio-born, Princeton-educated physicist named Arthur Holly Compton. Until now Compton's best-known work had been in the study of gamma rays, work that eventually won him a Nobel Prize for the discovery of what is still known as the Compton effect. But Compton had become intrigued by the possibility of nuclear fission from his days working at London's Cavendish Laboratory under the legendary Lord Rutherford. Conversations in 1940 with Ernest Lawrence at the University of California, who was working on developing a cyclotron for producing fissionable uranium isotopes, had fascinated him still further. By then, rumors were flying about the federal government's interest in nuclear fission – even as war had broken out in Europe and threatened in Asia. Lawrence told Compton he was absolutely convinced that a fission explosion of immense size was practical – *if* one could solve the problem of how to get enough uranium to do it.

To Compton, it was easy to see why the students of fission had chosen uranium. Once you split one uranium atom, the nucleus contained many more neutrons than were needed to form the nuclei of two new atoms. "This made it seem likely that when fission occurs new neutrons would be released," Compton wrote later.[2] When those neutrons from one splitting uranium atom hit other uranium atoms, this would cause them to break apart in turn, releasing still more neutrons – a process that could go on infinitely as long as there were enough uranium atoms on hand to feed the chain reaction.

There, however, was the problem. Lawrence's experiments had shown that the best uranium isotope for fission purposes was the volatile and highly unstable uranium 235 – a fragile atomic vessel just waiting to shatter into pieces. The isotope found most abundantly around the world, however, was uranium 238. That extra atomic weight signaled a crucial difference. Uranium 238 was far too stable to break apart on its own, while 235 was so scarce everyone doubted that they would ever find enough to make even a minor chain reaction, let alone a bomb.

The issue confronting the scientists at the NDRC, then, was how to separate out molecules containing uranium 235 from those harboring its more stable cousin, 238. When Compton accepted Bush's and Briggs' request to head their investigating committee, he already knew there were theoretically three ways to do this.

The first involved using a high-speed centrifuge to rotate uranium molecules in a gaseous form, so that the heavier molecules containing the 238 isotope were thrown toward the walls of the centrifuge, while the lighter 235-laden molecules congregated toward the center, where they could be skimmed away from the gas. Physicist Jesse Beams at the University of Virginia had been experimenting with using centrifuges to separate chlorine isotopes, and although the estimated size of the centrifuges needed to do the same thing with uranium seemed to Compton "staggering," it still seemed a method worth pursuing.

The second was the so-called gaseous diffusion method British scientists were working on, as well as Harold Urey at Columbia University. This involved converting uranium into a gas, then passing the gas through a series of porous barriers so that any 235 isotopes could be trapped. Alfred Nier at the University of Minnesota had actually done this early in 1940 using uranium hexafluoride which turned into a gas at 140 degrees Fahrenheit.[3]

The third was the electro-magnetic approach that pulled 235 away from its 238 cousin by running them through a powerful magnetic field. All three methods were still deep in the experimental stage. No one knew which would work best or fastest, since all involved creating enough 235 molecule by molecule to sustain a nuclear explosion – and all would require no less than 140 parts of uranium 238 to draw off one part of uranium 235.*

Scientists had seen the methods work in the laboratory. But, Compton had to ask himself, what if none of them worked under real practical conditions? Or even if they did, what if gathering together enough uranium 235 molecule by molecule proved too complicated or too slow to form the quantities needed to make a bomb? Then months, possibly years of research would have been wasted – while the Nazis were forging ahead with their own bomb-making efforts. The risks were too great to press ahead with uranium enrichment alone, Compton decided. He and the NDRC needed another alternative.

That's what led him to look at plutonium.

At first glance, plutonium seemed an even wilder outside bet than uranium. It was so unstable it didn't even exist in nature; Ernest Lawrence had discovered it almost by accident in his laboratory a few years earlier. But once a chemist colleague of his named Glenn Seaborg had succeeded in isolating the new element, Lawrence had found that plutonium had a cross-section for fast fission ten times greater than uranium 238 – and that like uranium 235 it could be made out of existing quantities of uranium 238.[4] All that was needed, Lawrence had explained to Compton, was to set up a sustained "slow" chain reaction of uranium 238 – something Enrico Fermi and his team of scientists at the University of Chicago were experimenting with using uranium and graphite. In that process some atoms of 238 were bound to take on an extra neutron, becoming uranium 239 which then tends to turn its free neutron into a proton and become an entirely new element, neptunium 239. Neptunium doesn't last long, either. In a day or two, its free neutron becomes a proton, and the end result is plutonium.

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*The Germans, meanwhile, were working on a still another form of uranium extraction, called thermal diffusion. Eventually the engineers and scientists working on the Manhattan Project would turn their attention to this method, as well, and in 1943-4 managed to build a thermal diffusion plant at Oak Ridge that began processing fissionable uranium with amazing speed – even as the German effort fizzled, despite their multi-year head start.

Unlike its predecessors in the chain reaction, however, plutonium has staying power: its half life is just over 24,000 years. That's certainly long enough to separate it out from the remaining uranium using various chemical processes. Seaborg believed those amounts of plutonium would necessarily be minute, and the chemical processes would have to be elaborate – the plutonium would be radioactive and dangerous as well as hard to find. But Seaborg believed once the process was complete, "it would only be a matter of weeks" before they'd be able to extract enough pure plutonium to make a bomb.

Compton was convinced. Now he had to convince his colleagues, including Bush and Conant. It was now the late fall of 1941. German armies were besieging Moscow; Japan's new prime minister was the militant General Hideyoshi Tojo; and a German U-boat had just sunk the American destroyer USS *Reuben James*.

"The Nazis had begun their intensive study of the releasing the atom's power two years before," Compton remembered later in his memoir, *Atomic Quest*. "With our rivals' big head start, nothing that we could do to speed our work would be too much. We must not let the Nazis win."[5]

On December 6, Compton was staying at the Cosmos Club to attend the organizational meeting of the committee that would oversee every aspect of getting the American uranium fission project off the ground. Vannevar Bush, now also head of the president's Office of Scientific Research and Development, handed out the various assignments. Harold Urey, physics professor at Columbia University and Compton's fellow Cosmos Club member, would head the gaseous diffusion program. Ernest Lawrence would take over the magnetic separation program from his laboratory in California. Eger V. Murphree, head of Standard Oil's research division, would see what could be done with the centrifuge approach to enriching uranium.[*]

As for Compton, Bush wanted him to oversee the design of the bomb itself.

Compton agreed, and then set off with Bush and James Conant to the Cosmos Club for lunch.

When the trio were seated, Compton made his opening remarks about reconsidering plutonium as an alternative to extracting uranium 235. Even though establishing a controlled nuclear reaction would be difficult, he pleaded, didn't the advantage of chemical extraction of plutonium make the process a worthy competitor to the isotope extraction of uranium?

Bush was astounded. He pointed out the uncertainties of trying to re-create a process on a large industrial scale something that had yet to be proven in the laboratory.

Then Conant chimed in. "Even if we could produce the plutonium," he said, "we know almost nothing about its chemistry. It could take years to get the chemical extraction process in operation." Compton understood that Conant, an experienced chemist, knew what he was talking about. But he plunged on.

"Glenn Seaborg," he said, "tells me that from six months from the time the plutonium is formed he can have it available for use in the bomb."

Conant smiled. "Glenn Seaborg is a very competent chemist," he said gently, "but he isn't that good."[6]

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[*] The answer was, not much. After some initial trials, the centrifuge method was dropped in 1944, for fear it would never be ready in time to make enough uranium. After the war, however, the Soviets turned to centrifuges for their atomic bomb program, and since then it's become one of the accepted methods for enriching uranium – most recently, by the country of Iran.

Still, Conant and Bush decided to let Compton have a try *if* he would take over the job of producing the plutonium – the job that, on that quiet Saturday afternoon, seemed as remote as landing a man on the moon. But Compton eagerly agreed and as they finished lunch, plutonium had become the fourth option for making an atomic bomb.

Compton went straight from the dining room to his room. There he sat down and sketched out a preliminary plan and budget. He then headed for the office of Conant and Briggs at the National Academy and got preliminary approval of a $300,000 budget for the first half of 1942 (roughly $3 million today). "That figure seemed big to me," Compton recalled, "accustomed as I was to work on research that needed not much more than a few thousand dollars per year."[7]

The estimate was realistic, because even before they figured out how to extract the plutonium, they'd have to create the nuclear reaction necessary to make it. Back in his room Compton placed a call to Chicago and Enrico Fermi. Fermi was delighted; he would press ahead with his uranium and graphite experiments at once. Compton placed another call to Columbia University and George Pegram, the chairman of the physics department. They arranged to meet the next day in New York to discuss where and how to set up the plutonium production process.

The next morning Compton caught a cab to Union Station and boarded the train for New York. At Wilmington, an ashen-faced passenger entered Compton's car.

The radio had just announced the Japanese had attacked Pearl Harbor.

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The coming of war not only speeded up the atomic bomb program; it also expanded the size and value of the resources available for the scientists involved, including Compton, Fermi, and the plutonium team. What had been a controversial idea around a dining table, moved steadily toward reality.

By September 1942 the United States Army was on board in the rotund form of General Leslie Grove of the Corps of Engineers, who would draw up plans for turning what were still only laboratory experiments into full-scale industrial processes. In December with Compton present, Enrico Fermi established what was the very first nuclear reaction in history, under the stands of Stagg Stadium at the University of Chicago, and by the spring of 1943 General Groves had acquired the land around Oak Ridge, Tennessee, where the series of uranium extraction processes would be built and get underway.

Arthur Compton remained at the heart of the bomb design project, as well as the plutonium extraction program, which got underway in late 1943 in Hanford, Washington, at a facility designed and built by the DuPont company. Once the Hanford piles were up and running, Compton and Fermi began to see the first traces of plutonium ready for extraction. Glenn Seaborg had predicted it would take six months to have the plutonium ready for making a bomb. In fact, thanks to DuPont's diligent efforts, it took less than two. That spring of 1945 Arthur Compton was able to hold in his hands a tiny ball of history's first industrially produced plutonium – a tiny ball with the power to shatter worlds.

There remained only one more obstacle. There was no need to test to see if uranium 235 would set off a chain reaction big enough to trigger an explosion; there was for plutonium. And so on July 16, 1945, Robert Oppenheimer and his team at Los Alamos made the first nuclear test over the desert at Almagordo, New Mexico, on July 16, using Compton's plutonium. Arthur Compton was not there, but back in Chicago he read the newspaper accounts of the blast. They carried the official story – an explosion of a munitions dump in New Mexico with what were described as "remarkable light effects." A few days later a Monsanto Company engineer working at Los Alamos named Charlie Thomas gave Compton the full story of what his plutonium had done at the blast site, code-named Trinity.

He explained how the light had been many times brighter than the sun, with the mountains framed as clear as daylight. Thomas told him how an immense ball of flame soared into the sky followed by a dark mushroom-shaped cloud of dust, and how the desert sand around the blast site had been turned into a sea of molten glass.[8]

Three weeks later a similar mushroom cloud appeared over Hiroshima in Japan. The single 13-megaton uranium bomb dropped from a B-29 incinerated 50,000 people almost instantly. Two days later another B-29, *Bock's Car*, dropped the Hiroshima bomb's plutonium cousin on Nagasaki, killing another 36,000. The Japanese government, fearful that there might be more such superweapons, surrendered on August 15.

For hundreds of thousands of American soldiers, and almost certainly millions of Japanese, the bomb meant being spared death in a prolonged invasion and land campaign to take the islands. But for the rest of the world, a force had been unleashed which, if mishandled, could destroy modern industrial civilization itself.

This did not particularly bother Arthur Compton. Compton was a Christian as well as a physicist, and the dropping of the bomb made him think of the expulsion from the Garden of Eden, and how an angel with a fiery sword blocked Adam and Eve's return to the paradise they had abandoned.

"If we long to return to a pre-Atomic Age," he wrote after the war, "the same angel with the fiery sword blocks our path. Atomic power is ours, and who can deny that it was God's will that we should have it? As we struggle with the task of using this new power for the good of man, inevitably there must result a growth of the human spirit."[9]

Where others saw an imminent threat to humanity, Compton saw another step in its progressive ennoblement.

Before he died in 1965, Compton gave a speech entitled "Science and the Supernatural." In it he said, "Beyond the nature taught by science is the spirit that gives meaning to life." It was that spirit that Arthur Compton had sought to defend against the threat of tyranny; and the same spirit that he believed was embodied in science's most important discoveries, including the discovery of atomic energy.

Perhaps it was the spirit that revealed itself the day before Pearl Harbor at lunch at the Cosmos Club.

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