LA-UR -92-53

LA-UR--92-53

DE92 007720

TITLE THE UNIVERSITY OF CALIFORNIA AND THE MOBILIZATION OF SCIENCE FOR NATIONAL DEFENSE

AUTHOR(S) R. W. Seidel, IS-DO

SUBMITTED TO Workshop-Decade of Innovation/Los Alamos, Livermore and National Security Decision making in the 1950's,
Livermore, CA
February 19-21, 1992

MASTER

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

THE UNIVERSITY OF CALIFORNIA AND THE MOBILIZATION OF SCIENCE FOR NATIONAL DEFENSE

The discovery of fission gave new urgency to the mobilization of science in World War II. In particular, its potential for an explosive release of subatomic energy, which Albert Einstein pointed out to Franklin Roosevelt in the fall of 1939, gave pause to the scientists who organized the National Defense Research Committee (NDRC) and its successor, the Office of Scientific Research and Development(OSRD). These organizations were responsible for placing the scientific taient of the nation in the service of national defense, for at that time the vast majority of scientists were employed in private industry ana private and public academic institutions.

One of the largest academic institutions to be mobilized was the University of California, which provided the research and development for the electromagnetic method of uranium isotope separation for the first atomic bomb, and operated a new laboratory for the design of nuclear weapons at Los Alamos.

The mobilization of the University of California had far-reaching consequences. The University has operated Los Alamos for almost 50 years, and Livcrmore ever since it was recreated as a second weapons laboratory in 1952. In what follows, I hope to indicate how the partnership between the government and the

University was created, and how this affected national security decision-making in the war and post-war eras.

The Radiation Laboratory

The University of California Radiation Laboratory was already a major scientific resource by 1939, when Ernest Lawrence won the Nobel Prize for his invention of the cyclotron. Lawrence was the ablest scientific entrepreneur of his generation. Like J. B. Conant and Vannevar Bush, who headed the NDRC, Lawrence combined technical expertise with the kind of organizational ability which would be required to develop nuclear weapons. In building up the Radiation Laboratory at Berkeley, he had shown a capability for organizing men to operate machines on a cooperative, team basis. While their individual researches went forward, Lawrence's cyclotroneers worked together to increase the energy and the current of the cyclotron beam. Long days of work were no strangers to these men, and with the funding of the 184-inch cyclotron in 1940, it appeared that another crash program to build the world's largest particle accelerator was on the horizon. The war, however, interrupted this effort and dictated more militant uses of cyclotron technology.

Before putting his machine to work for defense, Lawrence put his organizational talents to work for the NDRC in a number of ways. In the late 1930's, David Sloan had developed the resnatron, a generator of centimeter wave radiation which appeared to promise radar detection of aircraft. Alfred Loomis, who had used his substantial private fortune to aid a number of Lawrence's projects, took a particular interest in this one after he was appointed head of the NDRC microwave committee. When the British physicists Boot and Randall invented a superior microwave generator, the magnetron, Loomis enlisted Lawrence in the U. S. effort to develop microwave radar. They decided to build a special laboratory at M.I.T. to concentrate American talent on the problem. Lawrence was charged with recruiting the personnel for the laboratory, which was named, in honorific obfuscation of the enemy, after his own.

Thanks to his broad contacts with the American physics community, and particularly with accelerator-builders, Lawrence was able to assemble a team to lead the effort. Lee DuBridge, the head of the cyclotron project at the University of Rochester, was approached by Lawrence to direct the laboratory and accepted. From his own crew, Lawrence selected Edwin M. McMillan and Luis Alvarez.[1] Cyclotron builders from many other laboratories were also recruited to staff the MIT Radiation Laboratory.

The Radiation Laboratory at M.I.T. provided a model for the University of California's first large-scale defense effort. When the Naval Underwater Sound Laboratory at San Diego needed skilled technical personnel, Lawrence pulled McMillan out of M.I.T. and sent him to help UCLA's Vern Knudsen operate a University of California facility there. This was the first large laboratory operated by the University of California for the OSRD, involving about 600 employees and conducting secret research. The Secretary of the Regents of the University of California, Robert Underhill, had been made aware of the effort at M. I. T., and organized a Secret Defense Committee at the University in November of 1940 which contemplated similar activity.[2] An institutional capability was thus established at the University of California to respond to national needs.

Lawrence mobilized his own Radiation Laboratory in the effort to build the atomic bomb when the effort launched by Einstein's letter to Roosevelt flagged. When the British MAUD Committee came to the conclusion that the critical mass of uranium-235 needed for a nuclear explosive was considerably smaller than those Americans had supposed, Lawrence, who had privileged access to this information through his British Colleague Marcus Oliphant, became involved directly in the war effort. He persuaded James Bryant Conant, head of the NDRC, and Arthur Compton, head of the Metallurgical Laboratory at the University of Chicago, where Fermi's reactor was under development, to accelerate the program. Told that the need for enriched uranium demanded he accelerate his efforts at electromagnetic separation of uranium isotopes, he turned his 37-

inch cyclotron magnet into a giant mass spectrograph and began development of the electro-magnetic process that was later dubbed the "Calutron", which produced the enriched U^{235} that was later used in the first atomic bomb.

As a consequence of these actions by Lawrence, the University of California was deeply committed to the war effort even before the outbreak of hostilities in December, 1941. This led to a series of contracts with the NDRC and OSRD, listed in Table 1.

TABLE I

NDRC CONTACTS[3]

Number	Project No.	Principal Investigator
NDR rc 138	PDRC-115	Ernest Lawrence[4]
NDR rc 135	PDRC-55	Ernest Lawrence[5]
NDR rc 197	180	Glenn Seaborg[6]
OEM sr 201	PDRC-102	
OEM sr 206	3197	
OEM sr 309	691	
OEM sr 324	SSRC-1	Ernest Lawrence
OEMcmr 111	MRPD-63	John Lawrence
OEMcmr 456	959	Joseph Hamilton
OEMcmr 196	MRPD-104	John Lawrence
OEM sr 687	SSRC-1	Ernest Lawrence
OEMcmr 195	MRPD-132	Robert Marshak
OEMsr 799	SSRC-53	Joseph Hamilton

What was in all this for the University of California? Its overhead charge on these contracts was originally 50%, but was reduced to 30% in the spring of 1942, even though the Regents were concerned about the reduction. Some felt "that a corporation would never dare take a contract on with an overhead of the small sum that we had. From their corporate, legal [and] industrial experience, they were concerned that this was not high enough."[10] In fact, an accounting study showed that the overhead paid to the University of California exceeded the anticipated costs by $2,500,000 although $1,250,000 of this sum could be charged off to pension system payments. The remainder was returned to the federal government.[8] One advantage of mobilizing the University for scientific research and development in support of the war effort was this lower overhead, but it was patriotism, rather than profit, which seems to have motivated Lawrence and other faculty members to offer their services through the University to the OSRD.

In order to accelerate bomb development, OSRD head Vannevar Bush established the program as the S-1 Committee of OSRD on November 28, 1941. Lawrence was program chief for electromagnetic separation, as Arthur Compton was for fundamental physical studies of the chain reaction, and H. C. Urey for gaseous diffusion, while E. V. Murphree headed a planning board to for technical and engineering aspects of the work.

Lawrence was well-positioned, then, to engineer the next expansion of the University of California's effort, into the theoretical effort required for a nuclear weapon. It was this effort that became the Los Alamos Scientific Laboratory, or Project Y.

LOS ALAMOS

The Los Alamos Scientific Laboratory was organized at the University of California in the fall of 1942. It was the outgrowth of early conversations between Robert Oppenheimer, Lawrence's associate at the University of California, and other theorists about the possible designs of a weapon that would make use of nuclear fission to create an explosion.

A National Academy of Sciences (NAS) Committee including Compton, Lawrence, John Slater and John Van Vleck, reviewed the work on fission in the spring of 1941, and encountered the problem of calculating the destructiveness of the bomb. Lawrence discussed the problem with Oppenheimer, who calculated the fraction of available fission energy that would be released in a fission explosion, assuming a simple bomb design. His calculations, confirmed by Compton and George Kistiakowsky, led the NAS committee to conclude that "a fission bomb of superlatively destructive power w[ould] result from bringing quickly together a sufficient mass of element U-235."[9] This conclusion, which relied on Oppenheimer's calculations, reinforced by more the optimistic evaluations of the British MAUD Committee to which we have referred above, propelled the NDRC into a crash program of atomic bomb research on December 6, 1941.

In January 1942, Compton made Oppenheimer responsible for fast neutron research at Berkeley. In May, Gregory Breit, whom Compton had assigned responsibility for overall fast neutron research or "Coordinator of Rapid Rupture" resigned, and Compton replaced him with Oppenheimer. His charge was to coordinate theoretical calculations with experimental data being gathered throughout the project in order to estimate the critical mass of material required for a bomb and the efficiency to be expected. John Manley was assigned to assist him, since Oppenheimer was not well-versed in the art of experiment. Manley coordinated experiments scattered across the country.[10]

In a summer study convened at Berkeley in June of 1942, Oppenheimer and theoretical physicists Edward Teller, Emil Konopinski, Eldred Nelson, S. P. Frankel, Felix Bloch, Robert Serber, Richard Tolman, and Hans Bethe discussed the theoretical underpinnings of both fission and fusion weapons. Although the theoretical problems of fission weapons seemed well in hand, given the experimental data then available, Teller was enthusiastic about the possibilities of igniting the fusion process, which had only recently been found to power the stars. The cross-section for the reaction, however, appeared unfavorable. Teller returned to the University of Chicago to work on the idea further with Konopinski.[11] It would continue to preoccupy him throughout the war and postwar eras.

Meanwhile, Manley found the job of coordinating scattered experiments extremely difficult.

> I don't think that anyone thought that that couldn't be handled by the usual academic business of having these places like D. T. M. [Department of Terrestrial Magnetism]. in Washington and Minnesota and Wisconsin and Rice and people at Stanford and so on, getting the stuff together....I think that both Oppie and I probably came to the conclusion about the same time, and I don't think it took us more than about a month, that it was just impossible to try to run a railroad that way. Trying to get experiments done, even check experiments, with me running around the country and Oppenheimer sitting in Berkeley most of the time, having a good time with the theory.
>
> You couldn't call up anybody to talk to them on the telephone, and writing was complicated, and physicists don't like to write in the middle of an experiment anyway....So that was, to me, the real impetus for getting everybody together in one location."[12]

It was clear that a new laboratory would be required to expedite the work. On September 14, 1942, McMillan, in San Diego, got a cable from Compton asking him to meet with Oppenheimer, Manley, Fermi, and Lawrence a week later to plan the new laboratory.[13] This decision was probably made when the S-1 Committee visited Berkeley on September 13 to recommend ways of expediting the electromagnetic separation work going on there. Three days later General Leslie Groves became head of the

Manhattan Engineer District, which took over S-1's responsibilities.

On September 19, the conference began in Chicago.[14] It lasted four days, during which a number of decisions were made which were crucial to the future of the new laboratory.[15] It was decided that equipment would be purchased, leased, or borrowed to set up a fast neutron laboratory in a remote location, to which the theoretical and experimental studies Oppenheimer and Manley had been overseeing would be removed.[16] At the end of the meeting, Lawrence took McMillan aside and said, "We'll make you director of that place."[17] Compton wrote John Tate, the Vice Chairman of the OSRD Division for which McMillan was working at San Diego, that McMillan was "urgently needed to take charge of an important division of our project."[18]

The director was selected, however, by Groves in the fall of 1942. It was his first opportunity to select a laboratory director and he was determined to select one who had sufficient prestige to command the allegiance of the scientists who would be recruited for the project. He preferred Oppenheimer. He found little enthusiasm for the theorist among the MED scientists. The Military Policy Committee, composed of Groves, Conant, Bush, and Admiral W. R. E.. Purnell was unable to suggest an alternative, however, and, after several weeks, Groves decided upon Oppenheimer.[19] Lawrence, who had known Oppenheimer for some 15 years, expressed strong disagreement with Groves's selection of the theorist as administrator of the laboratory to Lee DuBridge, whom he had recruited to run the M. I. T. Radiation Laboratory:

> Ernest told me that he was appalled that General Groves had appointed Robert Oppenheimer as director of Los Alamos because he did not think that Robert would be the proper person to hold this important appointment. He did not explain to me why, but I simply got the feeling that he had somehow lost his confidence in Oppenheimer, particularly for this position as directing a large laboratory."[20]

McMillan was not surprised: "Lawrence and Oppenheimer were such different people: Lawrence was a practical man of a ion....and didn't have much sympathy for the dreamer type of p son."[21] Oppenheimer had core of inner strength which Lawrence did not sense that made him a successful director at Los Alamos. Despite his dilettante air, Oppenheimer was very serious about physics, and transferred this seriousness to his directorship at Los Alamos. To Lawrence and Manley's surprise, he turned out to be an able and charismatic administrator.[22]

Oppenheimer immediately took steps to organize the new Laboratory. Its physical design depended upon the selection of a site appropriate to its purpose. Colonel Dudley of Groves's staff made a preliminary survey of Western sites that were sufficiently remote and isolated to insure security of the work, and recommended Jemez Springs, NM. Groves, Oppenheimer and

McMillan visited the site with Dudley on November 16, and found it wanting. Recalling the Los Alamos Ranch school from his visits to New Mexico, Oppenheimer recommended that they visit the school and consider it for the site. Groves agreed with its virtues, especially for the small laboratory then being planned, and after another visit by Oppenheimer, McMillan and Lawrence a week later, the Los Alamos site was selected.[23]

The Los Alamos Ranch School learned in the first week in December that it was being taken over under the War Powers Act, and completed the school term by January 21 by canceling Christmas holiday and working right through. The Army took over the site on February 8, 1943.[24]

Oppenheimer, McMillan and Manley decided that three fundamental instruments would be required to equip the laboratory: a pressurized Van de Graaff accelerator, a Cockcroft-Walton machine, or "D-D tube," and a "good cyclotron." Three candidates suggested themselves: one of R. G. Herb's pressure-insulated Van de Graaff machines; the University of Illinois Cockcroft Walton machine and the Harvard cyclotron. Oppenheimer thought it best to justify his choices by reminding Compton "that there are now three cyclotrons, 5 VanderGraafs [sic] and a D-D tube working on the fast neutron projects."[25]

There would not be time to build these accelerators, so they would have to be moved to the new laboratory from other sites. McMillan scouted out cyclotrons:

> I was looking at all these machines to see which ones looked the most well built and most suitable for dismantling and moving and so on. Some cyclotrons in those days were pretty junky....They were hand-made and the kind of thing that if you once took them apart, you'd probably never get them back [together] again....I recommended Harvard's as the best choice, and Harvard was the one that was used.[26]

Manley, apparently, had little difficulty in persuading the University of Illinois to release the Cockcroft-Walton accelerator which he had built there and which was not in use.[27] Both of the pressurized Van de Graaff accelerators at the University of Wisconsin were added, and Manley assisted Stone and Webster, the architect and engineering firm Groves selected, in designing the laboratory facilities to house them.[28]

After machines, men. To run the Harvard cyclotron, McMillan approached the group led by Robert Wilson at Princeton. On instructions from Oppenheimer, he interviewed each member of the group and evaluated their fitness for Los Alamos.[29] All had been working on electromagnetic separation processes for the NDRC under Section S-1, which project Lawrence canceled early in 1943, in favor of his Calutron. He recommended that "Oppenheimer should have right of way" in recruiting its scientific staff.[30] As a result of their earlier work, Wilson and his colleagues understood the nature of the project, and were ripe for plucking. Wilson recalled that after the electro-magnetic project was canceled,

> "We became...what I suppose is the worst of all possible things, a research team without a problem, a group with lots of spirit and technique, but nothing to do. Like a bunch of professional soldiers we signed up, en masse, to go to Los Alamos, which was just then being formed."[31]

Manley, who recruited other experimentalists from the groups that had been working on fast neutron problems at Minnesota, Wisconsin, Chicago, Purdue and Cornell, also found them "quite willing to continue their work at the new location."[32]

His greatest difficulty was at his alma mater, the University of illinois, where D. W. Kerst, was perfecting his betatron. The need for the machine was pressing, but it took until August of 1943 to persuaded University of Illinois President Willard to release Kerst.[33] Kerst took the first of his 25 MeV betatrons, manufactured by Allis-Chalmers, to Los Alamos to take stop-action x-ray pictures of explosions.

Oppenheimer recruited theorists for the project from the Berkeley Summer Study and from other universities. Since many to the best scientists were already engaged in war research, Oppenheimer had to convince the leaders of these projects to release them. He also tried to convince scientists like Robert Bacher and I. I. Rabi to come to a military laboratory. When they balked at this, a compromise was worked out which brought in the University of California.

The Los Alamos Contract

On February 13, 1943, Oppenheimer and Groves met with Robert M. Underhill, the Secretary of the Regents of the University of California to negotiate a contract for the University to operate Los Alamos. The arrangements for the Los Alamos Contract had first been laid out in a letter from Irvin Stewart on January 23,1943, which called for an OSRD contract with the University of California for "certain investigations to be directed by Dr. J. R. Oppenheimer," at a cost of $150,000 covering the period January 1, 1943 to July 31, 1943.[34] The fact that this occurred after the site, equipment and men for the project had been selected suggests that the contract was an afterthought. It was, in fact, a compromise between those who would only work for a civilian project and Groves, who wished the bomb design to be done under military auspices.

The nature of the compromise was outlined in a letter to Oppenheimer from James Bryant Conant and Groves, dated February 25, 1943:

> "The work of the laboratory will be divided into two periods....During the first period, the laboratory will be on a strictly civilian basis, the personnel, procurement and other arrangements being carried on under a contract arranged between the War Department and the University of California. The conditions of this contract will be essentially similar to those of the usual OSRD contract....When the second division of the work is entered upon...which will not be earlier than January 1, 1944, the scientific and engineering staff will be composed of commissioned officers. This is necessary because of the dangerous nature of the

work and the need for special conditions of security. The explicit comparison of the work to an OSRD contractual effort made the effort seem no great departure from past university practice. That work, Groves and Conant spelled out, was to "be concerned with the development and final manufacture of an instrument of war....certain experimental studies in science, engineering, and ordnance: and only at a later date with "large scale experiments involving difficult ordnance procedures and the handling of highly dangerous materials."[35] Neither Underhill nor the Regents were told the purpose of the project.[36] Underhill was told only that the Los Alamos project would never include more than 250 people and that it would have an annual budget not exceeding $7,500,000.

Bringing in the University of California in 1943, as today, made recruiting for the work of the Laboratory easier. Groves convinced the University of California President Robert Gordon Sproul that the contract was "the best solution to a crucial problem." The university was experienced in research and could do the job. Groves had a "big problem in getting good people" because "the scientific resources of the country, particularly in this general area, were already fully engaged on important war work. Because they were civilians, the scientists had complete freedom in their choice of jobs."[37] A university patron would be more comfortable than the military or industry.

Nevertheless, Groves clung to the notion of military control, insisting that once development was begun, the military would take over the project. At least one scientist, Robert Bacher, who headed the theoretical physics division, submitted a resignation that would become effective upon that transition.[38]

Concerned that the project was outside the state of California, Underhill approached the finance committee of the Regents who instructed him to investigate the possible liabilities. On February 20, in a meeting in the Baltimore Hotel in New York, Underhill agreed to take the contract for Los Alamos.[39]
The final MED contract, W-405-ENG-36, was entered into on April 15, 1943, in order to provide business management and technical procurement. For reasons of security, the university had no representative at Los Alamos with authority comparable to Oppenheimer or the military commander.[40] Only Oppenheimer, Lawrence, McMillan and other members of the University of California faculty recruited for "Project Y" understood the true implications of the work. The University had to rely upon the judgment of its faculty as to its propriety and importance.

These men and groups from Stanford, Cornell, Chicago, Rochester, and other governmental and industrial research laboratories, assembled at Los Alamos in April, 1943. Robert Serber summarized what was known about the energy release, the chain reaction, the critical mass of fissionable material required, the time available, and the cross sections for neutron interactions with various nuclei in an nuclear explosion.[41] An Advisory Committee headed by Warren K. Lewis of M. I. T. then recommended what ought to be done in order for the laboratory to accomplish its mission.

THE LOS ALAMOS RESEARCH PROGRAM

The advisory committee set the schedule to match the rate of production of plutonium and U-235: it was estimated that two years would be required to produce enough of these materials to make a bomb. The theoretical program, they decided, required calculations of the explosive properties of U^{235}, Pu^{239}, and a uranium hydride compound that might also serve as a fissionable material, of a variety of shapes of the critical mass to estimate which would have the greatest efficiency, and of the properties of different combinations of bomb and tamper material to see which provided the most reflected neutrons. The theory of neutron diffusion in bomb and tamper material had to be refined to determine the energy distribution of fission electrons and the dependence of the cross-sections upon these energies. A study of the hydrodynamics of the nuclear explosion and the effects of the large amounts of radiation that would be liberated, and an investigation of problems connected with time, detonation, and predetonation of the critical assembly were also recommended by the Lewis Committee.

The experimental physics program would seek to build up an integrated picture of the operation of the bomb from detailed experiments to observe nuclear phenomena including: the average number of neutrons per fission for U^{235} and Pu^{239}, the energy range of the neutrons, fission cross sections for U^{235} and Pu^{239}, the delay between the onset of fission and the emission of neutrons, and neutron scattering and capture cross sections.

The chemistry and metallurgy program focused on purity requirements for U^{235} and Pu^{239}, the preparation of materials for nu ear experiments and of a neutron initiator for the bomb, the reduction to metal of uranium and plutonium and investigation of their physical properties.

This research program was significantly augmented when it was decided to build an implosion-type weapon, in addition to the gun-type weapon originally contemplated. This led to a vast expansion of the Laboratory, changing tne nature of the contract as originally contemplated.

IMPLOSION STUDIES

The use of plutonium as a bomb material seemed possible after its neutron number-the average number of neutrons produced in each fission- was measured in the summer of 1943. This was true only if the plutonium were of high purity, with less than one part per million of light element impurities, which might produce neutrons that would predetonate the bomb when they were irradiated by alpha particles from plutonium-239. In the same summer, Los Alamos scientists learned that Frederic Joliot-Curie, in Paris, had found a neutron emission from the alpha radiation of polonium, and began experiments to see if polonium, which was intended to initiate the fission reaction, or plutonium itself, emitted too many neutrons to be assembled without predetonation.

Other experimental studies suggested that the plutonium-239, produced from uranium 238 irradiated in nuclear reactors at Clinton and Hanford, might contain a heavier isotope of plutonium with an atomic weight of 240. Pu^{240} might spontaneously fission, making assembly by the gun method impossible because the velocity required to avoid predetonation would be too high.

To test this hypothesis, a sample of plutonium produced at Clinton was re-irradiated in the reactor there, and sent to Los Alamos in August 1944. Los Alamos scientists used a mass spectrometer to examine the sample. The resulting mass spectrograph showed a peak at the 240 position, confirming the presence of Pu-240.

This result was important, because it meant that plutonium could not be used in a bomb if it had to be assembled using the gun method. A second method, implosion, would have to be used. Seth Neddermeyer had proposed it in April, 1943, arguing that theoretical analysis showed that the compression of a solid sphere by detonation of a surrounding high-explosive layer was feasible and would be superior to the gun method because the critical mass would be assembled more quickly. This method had been examined as a lower priority than the gun by Neddermeyer and McMillan in the summer of 1943. At that time, John von Neumann, who had previous experience in the use of shaped charges for armor penetration, visited the laboratory, and proposed a fast implosion process using a larger ratio of high-explosive charge to the critical mass, which might avoid the need for extreme purification of plutonium to remove light elements. Teller and Hans Bethe pointed out that this would also have the advantage of compressing the plutonium and increasing the efficiency of the chain reaction.

When the possibility of a neutron-emitting isotope of plutonium was suggested, the implosion program was given higher priority, and experts like George Kistiakowsky were hired to develop the appropriate high explosives to uniformly compress a plutonium sphere, which was designed by Robert Christy, by implosion.

The need to measure the behavior of the implosion process with different high-explosive designs led to the development of new experimental methods including using a highly radioactive gamma source inside the high-explosives to produce a measure of compression, the use of flash x-rays to x-ray the implosion, and the use of a magnetic field that changed when the imploding metal altered it. The expansion of the implosion research also led, among other things to the founding of S-site in the winter of 1943.

By the summer of 1944, it became clear that the organization of the Laboratory itself would have to be changed in order to accomplish the development of an implosion device. Instead of one small group, it came to occupy the attention of two new divisions, G and X.

Senior consultants, like I. I. Rabi and Enrico Fermi, joined a Technical Board which helped Oppenheimer develop policies to guide the work. A Cowpuncher Committee was set up to ride herd on the implosion process. By February, 1945, Groves and members of the Technical Board decided to freeze the technical program in order to meet a July deadline for the first bomb test, and concentrate all further work on the lens implosion with a modulated nuclear initiator.

"The "modulated nuclear initiator" would have to ignite the plutonium bomb at the precise moment when the implosion assembled and compressed the critical mass. It used beryllium and polonium, which produce neutrons when mixed with each other, in a device that kept them apart until implosion crushed it. Both were hazardous to work with and polonium existed only in laboratory quantities before the war. Monsanto Chemical, however, separated enough polonium for the initiators in Dayton, Ohio, and several dozen different designs were made and evaluated.[42] This involved extensive testing, procurement and preparation of polonium, and development of special fabrication techniques, all in the period between February and June 1945, when the first service unit was developed. To set off the high explosives, the division also developed new electric detonators under Luis Alvarez after the nature of the high explosive to be used was determined, i.e. at virtually the last moment. G (or Gadget Division) thus took on and solved some of the most difficult experimental physics problems of the implosion weapon design.

The preparation of the plutonium itself was a challenge for the Chemistry Division under Joe Kennedy and Cyril S. Smith. Eric Jette was one of a number of metallurgists who turned the liquid syrup of plutonium nitrate into a metal that could be melted in special magnesium oxide crucibles made by John Manley to make the hemispheres of the critical mass.[43]

Plutonium hemisphere shots were planned for April 25, 1945, and full scale plutonium spheres had to be built and tested for their degree of criticality by June 15, 1945. The Trinity spheres had to be fabricated beginning July 4. Despite the fact that plutonium's properties were almost completely unknown, and that it was found to behave like five different metals at five different temperatures, these deadlines were met.

On the suggestion of James Tuck and Kistiakowsky, explosive "lenses" were designed to convert multiple point detonations into a converging spherical detonation wave to compress the plutonium into a supercritical mass. Experimentation involved exploding assemblies of lens castings to find out whether they uniformly compressed metal. It became clear that if an explosive charge was detonated simultaneously from several points, at the point where two detonation waves met, a metal core was squeezed into a high velocity jet and complete chaos developed. The explosive lenses used different detonation velocities in different high explosives, and put them together in the right way to shape the wave, so that instead of expanding, it converged.[44]

Both the uranium bomb and "Fat Man," the plutonium bomb, were ready by July, 1945, less than eleven months after the reorganization of the Laboratory and twenty-six months after the founding of Los Alamos. The uranium bomb was not tested before use, but because of the difficulties of the implosion technique, the Trinity test was held on July 16, 1945, to determine if the gadget would work. Los Alamos provided diagnostics for the tests. Many instruments were used to measure the results, including geophones and counters. Needless to say, these instruments registered success, and Fat Man was available for use on Nagasaki on August 9, 1945, three days after Little Boy was dropped on Hiroshima.

The magnitude of the technical accomplishment first revealed to the world on August 6, 1945, can only be suggested here. Many of the accomplishments of wartime Los Alamos remain to be detailed. The development of the electro-magnetic separation technology made possible adequate supplies of U^{235} for the uranium bomb, but will require another historical treatment to adequately capture the technical challenges encountered and overcome. In both of these efforts, the University of California played a strategic role.[45]

THE CONTINUING LINK

Once the war was over, the contract called for the University of California to terminate its involvement in a matter of months. As early as March 1944, Underhill told Oppenheimer to plan a "tapering off" of the Los Alamos project.[46]
At the end of the war, MED District Engineer Colonel K. D. Nichols ordered the University to plan for rapid termination of the contract and told Underhill "that a government agency w[ould] continue operations." He ordered Underhill to terminate the contract as of March 2, 1946, with 90 days' notice to the staff at

Los Alamos.[47]

The long Congressional debate over the nature of the proposed Atomic Energy Commission, however, led to continued postponements of the contract termination. When the Atomic Energy Act was finally signed into law on August 1, the Regents announced that they wished to turn Los Alamos over to the AEC on or about October 1946. When the MED asked that the contract be extended until the Commission could be appointed, Underhill told the Regents that "this was not an unreasonable request" and they agreed to leave the matter in his hands and those of University President Robert Gordon Sproul. Sproul agreed with the Regents that "if we get rid of bomb making, plutonium, and New Mexico, I will be very happy," but added "I want to keep Lawrence as close to Atomic Energy as I can."[48]

After the Commission took Office, Underhill gave notice that the contract would be terminated on June 30, 1947. "The Atomic Energy Commission," he told the Los Alamos area manager, "should be using this time in...setting up another organization to make commitments beyond June 30." The General Manager of the AEC, Carroll Wilson, responded that the University of California was "uniquely qualified to operate the Los Alamos laboratories which must continue in operation without interruption," and asked the University to extend the contract for another year. He promised "the greatest possible local responsibility consistent with the national program in running the laboratory."[49]

Underhill agreed to the extension, although he felt Wilson was coaxing him "into the back room in order that they could continue under the guise of the University of California at Los Alamos." He insisted, however, that the Armed Forces Special Weapons Project at Sandia base be placed under other auspices and "that there should no longer be...direction by the government of University technical personnel." To the laboratory's new director, whom Groves had appointed without so much as a bow to the University of California, he wrote that "we are definitely in our last year of this operation." The Chairman of the Atomic Energy Commission of the Regents, John Neylan, reiterated this to AEC Chairman David Lilienthal in August, 1947.[50]

This whole history of postwar negotiations suggests the the Regents never had any intention of continuing the contract and that the University of California, like the University of Chicago at Oak Ridge, was determined to disentangle themselves from weapons production.

Enter our hero, Ernest Lawrence. Up to this point, he had merely urged Underhill and Sproul to extend the Los Alamos contract in the face of the difficulties the MED and the AEC were having in setting up the postwar atomic energy complex. In the fall of 1947, however, he became very interested in securing the good will of the AEC in order to fund his latest accelerator, the

Bevatron, a proton synchrotron based on the principle of phase stability discovered by McMillan and designed by Radiation Laboratory engineer William Brobeck.

Lawrence was at first confident of winning support for this project, as he had been well-treated by Groves and the AEC. At a meeting of the Commission and its General Advisory Committee (GAC) which Lawrence sponsored at Bohemian Grove in August 1947, their genial host had persuaded them to provide $15 million for accelerator development in the United States. When he subsequently submitted a modest proposal for $9.6 million of this sum for his Bevatron, he was surprised to find competition from an upstart AEC national laboratory, Brookhaven. Its patron on the GAC, I. I. Rabi, persuaded the Committee to defer a decision until Brookhaven could submit a proposal. Underhill reported to Sproul that Brookhaven might well get their machine rather than Lawrence getting his, since some felt it was "time to break the University of Califor a atomic trust."[51]

At the same time, Underhill reported, "the government has done nothing to relieve us of Los Alamos, and...arrangements were now under way whereby I would be requested by the President of the United States to come to the White house [where] pressure would be applied [on] the University [to] continue to operate the project." Carroll Wilson was en route to Berkeley with the

Secretary of the Army to urge Sproul to continue at Los Alamos, Underhill warned, and since it was unlikely that the University could resist such pressure, . must seek an understanding "that our responsibilities are decreased...and that all concerned would understand that we are simply lending a name and holding things together in the best way possible."[52]

Lawrence's interest, Underhill believed, would be served by doing this, and this could sway the Regents. "The Regents have always declared that they wished to be relieved of this burden," he reminded Sproul," but "there is now some thought that they might be able to cooperate, particularly if it would assist in the University's obtaining its desires in the matter of the proper financing of the [Bevatron] project. Mr. Wilson has informed Dr. Lawrence that he is now prepared to give the University very broad authority over the project, rather than take it away as has been the situation in the past."[53]

Although Underhill proposed very tight conditions on any Los Alamos contract, Lawrence persuaded him to relax them if the AEC would accept all but nominal responsibility for Los Alamos. When Carroll Wilson met with Sproul on January 9, 1948, he told him that the University would simply act as the Commission's agent at Los Alamos, although the AEC would "welcome the services of University scientists in a consultative capacity and will give

Mr. Lawrence...a free run of the place. Lawrence "expressed himself as heartily in favor of a cooperative arrangement between the University and the Commission."[54] He got his arrangement and his Bevatron.

The involvement of the University of California in the permanent mobilization of science resulting from World War II was less straightforward than one might have assumed, and although the significance of that involvement can be debated, it seems clear the University of California support and personnel made a crucial difference in the development of the first nuclear weapons. The actual operation of Los Alamos and Livermore, however, has only nominally been by the University of California, which supplies procurement and personnel services, but which does not, in any meaningful way, direct work at these institutions.

In the changing historical situation that the laboratories find themselves, it is possible that the stewardship of the University of California can be broadened to make a greater contribution to the strategies that will allow them to serve a broader concept of national security.

NOTES

1. Alvarez led the effort on the B-18 radar system from December 1940 to February 1941, and then became a group leader in the development of the experimental radar installed in the A-20 fighter plane. After developing a ground-controlled approach system system, he became division head of the Division 7, which developed a interrogated radar transmitter which supplied aircraft with azimuth and range information, a ground radar for long-range detection or control of aircraft which allowed continuous plotting of multiple targets, the microwave early-warning radar, identification systems(IFF) and pulsed glide-path landing system for instrument aircraft landing.

    McMillan worked in systems tests and field experimentation on the AI-10 S- band interception system, and B-18 aircraft to surface vessel (ASV) systems. Radiation Laboratory Staff Members, 1940-1945 (Cambridge, MA: M.I.T. Radiation Laboratory, June, 1946.),2, 71.

2. "Robert M. Underhill: Contract Negotiations for the University of California," An Interview conducted by Arthur Lawrence Norberg, (History of Science and Technology Program, the Bancroft Library, University of California, Berkeley, 1979) pp. 4, 12. For the work of the San Diego Laboratory see James Phinney Baxter 3rd, Scientists Against Time (Cambridge, MA: M.I.T. Press, 1968), pp. 174, 180.

3. "NDRC Contract Data," January 9, 1943 and February 11, 1943, 22:4.

4. The first contract, for the production of miscellaneous isotopes, e.g. radio-iodine and radioisotopes for experiments at Caltech, was issued by January 1941, supported five research assistants and a 50% overhead rate, and provided new equipment for chemical separations, and mechanisms for remote handling of radioisotopes. John L. Heilbron and Robert W. Seidel, Lawrence and His Laboratory, volume I of A History of the Lawrence Berkeley Laboratory (Berkeley: University of California Press, 1990), p. 512.

5. The second contract was issued after Lawrence, dissatisfied with the pace of the Briggs Committee on Uranium, had himself appointed to the committee in March 1941. He hoped to produce a second nuclear fuel, plutonium, which Glenn Seaborg, following up the work of Edwin McMillan on neptunium, had discovered in his Laboratory. The early costs

of this work, $835 for making plutonium by cyclotron bombardment, and $8,310 for testing its fissionability, were charged to his first contract. Contract NDRrc 135 paid for an additional $4375 of Radiation Laboratory expenses. Heilbron and Seidel, Lawrence and His Laboratory, p. 507, 512; W. B. Reynolds to James Corley, Aug. 29, 1941, MED files 76/160, box 4031 (LBL).

6. Negotiated by Lawrence in May, NDR rc 197 paid for continuation of the work on plutonium and neptunium. It was issued on June 9, 1941 in the amount of $2000 to cover the period May 1-June 5, 1941. Seaborg, Early History of Heavy Isotope Research at Berkeley, August 1940 to April 1942, LBL Pub 97 (June 1976), 47.

7. OEM sr 206 was issued on August 1, 1941, to pay for measurements of slow neutron fission of plutonium and uranium-233. It paid $ 21,500.

8. Robert M. Underhill Interview vol. 1, pp. 34(quote), 36, 47.

9. Heilbron and Seidel, Lawrence and His Laboratory, 512. Arthur Holly Compton, Atomic Quest: A Personal Narrative (New York: Oxford University Press, 1956), 57-59. Quotation from Baxter, p. 427; Alice Kimball Smith and Charles Weiner (eds.) Robert Oppenheimer: Letters and Recollections (Cambridge: Harvard University Press, 1980), 223.

10. Ibid., Oppenheimer to Compton, December 8, 1941, EOL 19:27. J. H. Manley, 'Assembling the Wartime Labs," Bulletin of the Atomic Scientists 30:5 (May 1974), 43.

11. Teller to Oppenheimer, September 5, 1942, JRO.

12. "Los Alamos Scientific Laboratory: John H. Manley," An Interview Conducted by Arthur Lawrence Norberg, (History of Science and Technology Program, Bancroft Library, University of California, Berkeley, 1980), pp. 42-3.

13 Edwin M. McMillan, "Early Days at Los Alamos," in Badash, et al., (eds.) Reminiscences of Los Alamos, 1943-1945 (New York: D. Reidel, 1980), 13.

14 A. H. Compton to Edwin McMillan, September 14, 1942 and September 17, 1942, Edwin M. McMillan Files, Lawrence Berkeley Laboratory. I am grateful to Dr. McMillan for permitting me to examine his files pertaining to this period. A report of

the meeting dated September 23, 1942, is in AEC Files. See Hewlett, New World, 104n.

15. Interview with E. M. McMillan, April 17, 1985, by Robert W. Seidel.

16. J. R. Oppenheimer to A. H. Compton, September 29, 1942, McMillan Files.

17. McMillan Interview. McMillan doubted whether even Lawrence could swing this. He was too junior a man for the job, and knew Lawrence was capable of impetuous suggestions.

18. Arthur Compton to John T. Tate, October 12, 1942, McMillan files.

19. Leslie R. Groves, Now it can be told, (New York: Da Capo, 1983) p. 60-61. No doubt he consulted Lawrence, whom he felt was the most capable of the physicists in the project, but if McMillan was suggested as an alternative to Oppenheimer, he was not found acceptable.

20. Interview with Lee DuBridge by James Culp, October 1981.

21 Interview with E. M. McMillan.

22 Manley, "Assembling the Wartime Labs," p. 45. Interview with McMillan.

23. Testimony of J. R. Oppenheimer and Colonel John Lansdale, In the Matter of J. Robert Oppenheimer: Transcript of Hearing before Personnel Security Board and Texts of Principal Documents and Letters (Cambridge: M. I. T. Press, 1971), 12, 261. Groves had representatives of the Stone and Webster engineering firm examine the site in July 1942. Groves, p. 51; John H. Dudley, "Ranch School to Secret City," and Edwin M. McMillan, "Early Days at Los Alamos," in Lawrence Badash, et al. Reminiscences of Los Alamos (New York: D. Reidel Publishing Co., 1980), pp. 1-5; 13-15.

24. A. J. Connell, Director, Los Alamos Ranch School, to Jerome Rich, March 16, 1943, Los Alamos Historical Society.

25. Oppenheimer to Compton, September 29, 1942; for the Herb Van de Graaff, see R. G. Herb, C. M. Turner, C. M. Hudson and R. E. Warren, "Electrostatic generator with concentric electrodes," Physical Review 58 (1940), 579. McMillan,

"Early Days at Los Alamos," 16.

26. Interview with E. M. McMillan. The cyclotron remained at Los Alamos after the war, and is now in the collections of the Bradbury Science Museum.

27. G. M. Almy, "A Century of Physics at the University of Illinois, 1868- 1968," A talk given before the History of Science Society in December 1967, during the Centennial Year of the University of Illinois, revised, 1975, Center for History of Physics, American Institute of Physics.

28. Manley, 'Assembling the Wartime Labs," p. 43. Cf. Manley, "A New Laboratory is Born," in Badash, p. 28. For the smaller Van de Graaff machine, see D. B. Parkinson, Herb, E. J. Bernet, and J. L. McKibben, "Electrostatic generator operating under high air pressure,--operational experience and accessory apparatus," Physical Review 53 (1938), 642.

29. Interview with E. M. McMillan.

30. Ernest O. Lawrence to H. D. Smyth, February 16, 1943, H. D. Smyth Papers, American Philosophical Society, Philadelphia.

31 R. R. Wilson, "My Fight Against Team Research," in G. E. Holton, (ed.) The Twentieth Century Sciences: Studies in the Biography of Ideas (New York: Norton, 1972), 475.

32. Manley, "Assembling the Wartime Labs," p. 45. Cf. Manley, "A New Laboratory is Born," 28-29.

33. Manley, "Assembling the Wartime Labs," p. 45. Almy, "A Century of Physics at the University of Illinois, 1868-1968," p. 20. The betatron is described in D. W. Kerst, "The Acceleration of Electrons by Magnetic Induction," The Physical Review 60 (1941), 47-53; reprinted in M. S. Livingston, The Development of High-Energy Accelerators, 188-199.

34. Irvin Stewart to Underhill, January 23, 1943, LANL Archives.

35. The second phase referred to was carried out without recourse to commissioning the scientific staff. James Bryant Conant and Leslie R. Groves to J. R. Oppenheimer, February 25, 1943, LANL Archives.

36. It was not until November of 1943 that Lawrence came into

his office, shut the door, and asked "You know what they're doing down in Los Alamos?" and told him that an atomic bomb was being designed there. Underhill was forbidden, however, to tell the Regents. "Interview with Robert M. Underhill," p. 19.

37. Groves, pp. 149-151.

38. Interview of Robert Bacher by Lillian Hoddeson, July 30, 1984, Oral History 45, Los Alamos National Laboratory, p. 24. Cf. John H. Williams to Oppenheimer, 2 March 1943, A84-019, 63-4

39. "Interview with Robert M. Underhill," p. 39.

40. Vincent C. Jones, Manhattan: The Army and the Atomic Bomb (Washington, D. C.: United States Army: Center of Military History, 1985), p. 87.

41. E. U. Condon and Robert Serber, Los Alamos Primer, Report LA-1 (April 1943).

42. Stephane Groueff, Manhattan Project: The Untold Story of the Making of the Atomic Bomb (Boston: Little Brown, 1967) 326-327. With this and other exceptions noted, the treatment below is drawn from David Hawkins Manhattan Project History: Project Y: The Los Alamos Project LAMS-2532 (Vol. I) which has been reissued as volume II of The History of Modern Physics Series 1800-1959 by Tomash publishers.

43. Groueff, Manhattan Project, pp. 324-325

44. George B. Kistiakowsky, "Reminiscences of Wartime Los Alamos," in Badash, Reminiscences, p. 52.

45. The Laboratory has sponsored a project to document in detail the history of the wartime technical accomplishment, which Roger Meade, Lillian Hoddeson, Catherine Westfall, and Paul Henriksen are preparing. In addition, the Bradbury Science Museum sponsored a colloquium on the transfer of technology from wartime Los Alamos to peacetime research. As a result of these studies, much more will be known about the contribution Los Alamos made to process of doing science, as well as the technical hurdles that had to be overcome to build the first nuclear weapons. I am preparing the second volume of the history of the Radiation Laboratory, which will cover the war and post-war eras, including the

development of the Calutron.

46. Underhill to Oppenheimer, March 22, 1944, Underhill Files, Transmittal 709, LANL Archives.

47. K. D. Nichols to Underhill, August 20, 1945; Underhill to Norris Bradbury, September 26, 1945, loc. cit.

48. Excerpt of Minutes of the Regents Finance Committee, September 27, 1946, in Interview with Robert M. Underhill, Vol. 2 Documents, Bancroft Library, University of California, Berkeley, CA.

49. Underhill to Colonel H. C. Gee, Feb. 7, 1947, Carroll Wilson to Underhill, February 15, 1947, Underhill Files.

50. A. E. Dhyre to Underhill, February 26, 1947, Underhill to Bradbury, June 24, 1947, Underhill memorandum of September 10, 1947, Underhill files.

51. Underhill to Sproul, December 15, 1947, Underhill files; see also Seidel, "Accelerating Science: The Postwar Transformation of the Lawrence Berkeley Laboratory," Historical Studies in the Physical Sciences 14:2 (1983), 394.

52. Underhill to Sproul, December 29, 1947, Underhill files.

53. Underhill to Sproul, December 29, 1947, Underhill files.

54. Sproul's memorandum of a meeting with Wilson, Robert Bacher, Carroll Tyler, Lawrence and Underhill, January 9, 1948.