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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO

MANHATTAN DISTRICT HISTORY
PROJECT Y
THE LOS ALAMOS PROJECT

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MANHATTAN DISTRICT HISTORY

PROJECT Y

THE LOS ALAMOS PROJECT

United States of America
WAR DEPARTMENT
ARMY SERVICE FORCES ~ CORPS OF ENGINEERS
Manhattan District

This Certificate is awarded to

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for valuable services rendered to the Nation on work essential to the production of the Atomic Bomb, thereby contributing materially to the successful conclusion of World War II.

Under Secretary of War

Secretary of War

Washington, D.C., 6 August 1945

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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA LOS ALAMOS NEW MEXICO

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MANHATTAN DISTRICT HISTORY
PROJECT Y
THE LOS ALAMOS PROJECT

VOL. I. INCEPTION UNTIL AUGUST 1945

by

David Hawkins

VOL. II. AUGUST 1945 THROUGH DECEMBER 1946

by

Edith C. Truslow
and
Ralph Carlisle Smith

Contract W-7405-ENG. 36 with the U. S. Atomic Energy Commission

This LAMS report has been prepared because of the demand for and interest in the historical information. The two volumes have not been edited except for classification purposes nor verified for accuracy. All LAMS reports express the views of the authors as of the time they were written and do not necessarily reflect the opinions of the Los Alamos Scientific Laboratory or the final opinion of the authors on the subject.

ABSTRACT

These two volumes constitute a record of the technical, administrative, and policy-making activities of the Los Alamos Project (Project Y) from its inception under the Manhattan District through the development of the atomic bomb (Vol. I), and during the period following the end of World War II until the Manhattan District relinquished control to the Atomic Energy Commission as of January 1947 (Vol. II).

Although security regulations have required some deletions in the original text of the two volumes, every effort has been made to retain the original language and expressions of the authors.

Editor's note: The name Los Alamos Laboratory was in use during the period covered by these volumes. In September 1945 the name of the contracting University of California could be made known. The present name, Los Alamos Scientific Laboratory of the University of California, was adopted in January 1947.

PREFACE

Project Y, the Los Alamos Project, has been one of a group of organizations known collectively as the Development of Substitute Materials project, (DSM), devoted to the wartime development of the atomic bomb. This branch of the DSM organization was created early in the year 1943. During the period of its existence it has been the center of activities connected with bomb development and production, as distinguished from the development and production of nuclear explosive materials.

The history of all DSM activities possesses a peculiar interest and importance, not only because of the remarkable achievements and potentialities of nuclear technology, but also because of the wartime character and motivation of its initial development. Because of its large social cost, a scrupulous accounting of the entire venture is required. Project Y has been, of itself, small compared to the other DSM projects. It has, however, occupied a crucial position. The wartime success of the entire undertaking has depended upon its success.

The nature of the present chronicle of Los Alamos is thus determined by the requirement that there exist a careful accounting of its technical, administrative, and policy-making activities. This document is a record, not an interpretation of events. Within the limitations thus implied, however, it has not been forgotten that the events recorded have taken place within a wider context, the evolution of organized scientific research and of world technology. The problems of organization and policy that lie here, sharpened by the advent of control over nuclear energies, will call for the most searching interpretation and analysis. It is hoped that in this record of fact nothing has been omitted or slighted that may be of interest to those who seek light upon questions still to be answered.

Another limitation is inherent in the nature of an official record. This is the necessary omission of many subjective factors. The success of so complex and uncertain a venture as Los Alamos depends upon its ability to extend knowledge of the explicit and publicly accountable sort at which science aims. But this ability depends, in turn, upon an accumulation of experience and skill in technical and human affairs inseparably connected with the qualities, and even the vagaries, of personality. What appears in retrospect as a natural unfolding of possibilities acquired this appearance only through the interaction and on occasion the clash of opinion, in an atmosphere dominated by the problematic and the uncertain. The omission is inevitable in an account which must itself be based upon objective evidence.

It is, however, proper to state here the writer's belief that these necessary omissions do not seriously distort the picture, as they would if important occurrences and tendencies were not objectively justified. That the pattern of development is so largely a rational one is a tribute to the unity of purpose of all concerned: administrators and scientists, civilian and military. A large share of the credit that this has been so must be given to the Director, Dr. J. Robert Oppenheimer, not only for his general leadership, but also more specifically because he understood the necessity for unity and sought in every way to foster it.

The reader will observe from the table of contents that the history of Los Alamos, Vol. I, has been divided into two periods, the first extending to August 1944, and the second from August 1944 to August 1945. This division does not correspond to any major break in the continuity of the Laboratory's work, although it does come at the time of an extensive admininstration reorganization. The real purpose of this division is to permit some chance to summarize and connect activities which, although constantly interrelated in practice, must be written about in separate chapters. And although no distinct separation into phases is possible, the date chosen marks as well as any the transition at Los Alamos from research to development, from schematization to engineering.

At this place I wish to acknowledge the assistance I have received from many members of the Los Alamos Laboratory. In particular I wish to thank the following: J. A. Ackerman, S. K. Allison, E. Anderson, K. T. Bainbridge, C. L. Critchfield, Priscilla Duffield, A. C. Graves, Elizabeth R. Graves, L. H. Hempelmann, A. U. Henshey, H. I. Miller, Emily Morrison, Philip Morrison, N. H. Ramsey, Frederick Reines, Ralph Carlisle Smith, and R. F. Taschek. These persons have materially helped me in gathering data, in drafting various sections of the report, or in extensive criticism of earlier drafts. I wish especially to thank Emily Morrison and Priscilla Duffield for ingenious researches in the records of an organization that was frequently too busy to be concerned with posterity. Mrs. Morrison has prepared the graphical material, has drafted several of the chapters, and has given invaluable general assistance. Finally it must be made clear that all errors of fact in this record are the sole responsibility of the author.

David Hawkins

August 6, 1946

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INTRODUCTION

Objective and Organization

REASONS FOR NEW PROJECT

1.1 During the early period of the DSM project, the most urgent requirement was the large scale production of nuclear explosives. There could be no atomic bomb without usable amounts of fissionable materials. Both the separation of U^{235} and the production of Pu^{239} presented major scientific and industrial problems. Until these problems were on their way to solution, there was little need or time for detailed theoretical or experimental work on the mechanism of the nuclear explosion. This work had in fact not progressed very far beyond what was needed to show the probable feasibility and effectiveness of the fission bomb as a weapon for the present war. By the middle of 1942, however, it had become clear that the scientific and engineering problems connected with the development of such a weapon and its use in combat called for early and intensive effort. At this time over-all responsibility for the physics of bomb development had been given to the Metallurgical Laboratory of the University of Chicago. This organization was geared, however, to its own problems, and in particular to the development of the slow neutron chain reaction as a source of plutonium. Work on fast neutron chain reactions, looking toward bomb development, was going on, but largely under various subcontractors of the Metallurgical Laboratory.

1.2 The first step toward a more concerted program of bomb development was the appointment, in June 1942, of J. Robert Oppenheimer from the University of California as Director of the work. Although associated with the Metallurgical Laboratory, Oppenheimer carried on his work at the University of California with a small group of theoretical physicists. In his coordination of the experimental work on fast neutron physics, he was assisted by J. H. Manley of the Metallurgical Laboratory, and later by E. M. McMillan, who joined his group in Berkeley.

1.3 Late in June, a conference was called in Berkeley to discuss the theory of the bomb and plan work for the future. Present at this conference were Oppenheimer, J. H. Van Vleck, R. Serber, E. Teller, E. J. Konopinski, S. P. Frankel, H. A. Bethe, E. C. Nelson, F. Bloch. A considerable part of the discussion was devoted to a new type of explosive reaction that had been considered by Teller, a thermonuclear reaction in deuterium (1.46). There was some discussion of the theory of the shock waves produced in the chain reaction explosion, on the basis of work that had been done by Bethe and Van Vleck. Another topic was the damage to be expected in terms of energy release. This was discussed largely in a qualitative way, by scaling up from small explosions and by comparison with such disasters as the Halifax explosion. At this conference, there was a thorough review of theoretical and experimental work that had been done. By this time enough information was available so that there were no large gaps in the picture. Rough but qualitatively reliable data were available from work that had been done under Metallurgical Laboratory contracts; a good deal of relevant information had been obtained from British sources, from work done by Peierls, Fuchs, Davison, and Dirac. British theoretical results were also available. Although a fair part of the discussion at the conference was not along what subsequently turned out to be the main line of development, it served to clarify basic ideas and define basic problems. It also served to make clear that the development of the fission bomb would require a major scientific and technical effort.

1.4 Following the summer conference in Berkeley, there were a number of conferences in Chicago with experimentalists. At this time a number of subcontracts had already been let by the University of Chicago, for the purpose of pursuing the investigation of nuclear properties relevant to bomb designs. A loose organization was formed, including the subprojects at Rice Institute, The Department of Terrestrial Magnetism of the Carnegie Institution of Washington, the University of Wisconsin, the University of Minnesota, Purdue University, Stanford University, Cornell University, the University of Chicago, and the University of California.

1.5 By October of 1942, it had been decided that the magnitude of the difficulties involved made necessary the formation of a new project. Even the initial work of providing nuclear specifications for the bomb was seriously hampered by the lack of an organization united in one locality; it was clear that without such an organization the ordnance work would be impossible.

LOCATION

1.6 The site of Project Y was selected in November 1942. It was the Los Alamos Ranch School, located on an isolated mesa in the Pajarito Plateau, by highway about 40 miles north and west of Santa Fe, New Mexico. The reasons for the selection of such a site are of some interest and throw light on the character of the new project. First, there would be need of a large proving ground, with a climate suitable for outdoor work in winter. Second, the site would have to be remote from both seacoasts and the possibility - at that time not negligible - of attack. Locations might have been found which satisfied these requirements but were more accessible. The inaccessibility of Los Alamos, however, would not create serious problems for a small project such as this was intended to be. Its subsequent growth to many times its original size was not foreseen. In the light of the military security policy which prevailed at the time, inaccessibility was a deciding factor in favor of this location.

1.7 During the year 1942, steps were taken to transfer the entire DSM project from the auspices of the Office of Scientific Research and Development (OSRD) to that of the Manhattan District. The highest degree of secrecy had to be maintained throughout the entire program; the new subproject, moreover, was to be its most secret part. The need for an unusual degree of isolation was supported by two considerations. The first was inaccessibility from the outside. From this standpoint the location chosen was excellent. Access from the direction of populated areas is made difficult, except along certain roads and canyons, by a line of cliffs that mark the eastern edge of the Pajarito Plateau. The second consideration was the geographically enforced isolation of project personnel, which would minimize the possibility that secret information might diffuse outward through social and professional channels.

1.8 The choice of a site, determined by the considerations suggested above, was not the responsibility of the project director or his staff. Their views, nevertheless, had a bearing on the selection and served to strengthen in the minds of the military authorities the arguments for isolation. The task that confronted the project was not one of development and engineering in the ordinary sense. It was one of intensive and highly organized research in a region that had been only schematically explored. It required collaboration of physicists, chemists, metallurgists, and engineers in solving difficult problems, many of which could not even be anticipated until the work was well under way. The need for collaboration was made emphatic by the imposition of a definite time-scale: the bomb had to be ready for production by the time usable quantities of nuclear explosive became available. To carry out such a program successfully would require the highest kind of integration and therefore of decentralization and mutual confidence. To this end, free communication within the laboratory was indispensable.

1.9 In contrast with the requirements of scientific organization, as felt and stated by the scientific staff members, the normal military procedure for protecting secret information is one of subdivision. Each individual or working unit has access only to information immediately relevant to the work being pursued. This conflict of scientific and military requirements is, of course, not peculiar to nuclear research. Many members of the potential scientific staff were, or had been, engaged in other war research, and were from previous experience convinced of the evils of obstructing the normal flow of information within a laboratory. They were vigorously opposed to compartmentalization. Clearly, however, no alternative was acceptable which did not in some way satisfy the security requirements of the military authorities. Evidently these requirements could be met by allowing internal freedom and imposing instead more severe external restrictions than might otherwise appear necessary. The adoption of such a policy made necessary the choice of an isolated location for the project.

ORGANIZATION

1.10 The Los Alamos site, together with a large surrounding area, was established as a military reservation. The community, fenced and guarded, was made an army post. The laboratory, in turn, was built within an inner fenced and guarded area, called the "Technical Area." Both the military and technical administrations were responsible to Major General L. R. Groves, who had over-all executive responsibility for the work. The Commanding Officer reported directly to General Groves; he was responsible for the conduct of military personnel, the maintenance of adequate living conditions, prevention of trespass, and special guarding. Oppenheimer, as Scientific Director, was also responsible to General Groves, who had as his technical adviser J. B. Conant. In addition to his technical responsibilities, the Director was made responsible for the policy and administration of security. This provision represented a guarantee that there would be no military control of the exchange of information among scientific staff members, and at the same time fixed responsibility for the maintenance of security under these conditions. In carrying out his responsibilities for security, the Director was to be given the assistance and advice of a Military Intelligence Officer.

1.11 The financial and procurement operations of Project Y were handled by the University of California as prime contractor. During the early period of operations, when these had largely to do with the employment of personnel and establishing a procurement office, the University acted under a letter of intent from the OSRD, effective as of January 1, 1943. This letter was in turn superseded by a formal contract, W7405-ENG-36, effective April 20, 1943, with the Manhattan Engineer District of the War Department. The contract was retroactive to January 1, 1943. This contract, with subsequent supplemental agreements, has been the formal basis of the Project's operation throughout the rest of its history.

1.12 The financial operations of the University of California at Los Alamos were provided for by the appointment of a resident Business Officer, J. A. D. Muncy. The procurement of materials was arranged through a dual organization. In addition to the procurement division of the project, the University established in Los Angeles a special purchasing office. This arrangement was dictated primarily by reasons of security. It might be possible to determine both the nature and progress of the work from a knowledge of the nature and volume of its procurement operations. According to the procedure established, goods ordered through the Los Angeles office were received there and transshipped to Los Alamos. The procurement offices at the site were placed under the direction of D. P. Mitchell. Mitchell had for many years been in charge of laboratory procurement for the Physics Department of Columbia University, and most recently for a National Defense Research Council (NDRC) project at that University.

1.13 A statement of the responsibilities of the military and contractor organizations, and a directive outlining the scope and purpose of Project Y, were set forth in a letter to Oppenheimer dated February 25, 1943, from General Groves and Conant (Appendix 1). This letter contains also a statement of intention concerning the future organization of the project. According to this statement it was anticipated that the Project would remain an organization of the OSRD type during the first period of its operation, when it would be engaged mainly in nuclear research. During a later period of operation, when the project would be involved in the dangerous work of bomb development and assembly, it would be conducted on a military basis, with opportunity for its civilian staff members to be commissioned as officers. This anticipated reorganization proved unnecessary. Difficulties that had been expected with the initial form of organization did not in fact appear, and the plan was dropped.

INITIAL PERSONNEL, MATERIAL, CONSTRUCTION

1.14 The problem of personnel for the new organization was a difficult one. Work began at a time when the scientific resources of the country were already fully mobilized for other war work; many persons who would have been willing to join the project had other commitments which could not be broken. The nucleus of organization came from the groups that had been engaged in fast neutron work under Oppenheimer, and who transferred their work and equipment to Los Alamos. A number of other individuals and groups were released to come, in part through the assistance of Conant as Chairman of the NDRC. The greatest difficulty encountered was that of obtaining an adequate staff of technical and administrative employees, who also came mainly from occupational groups fully employed in war work. Here, moreover, the disadvantages of isolation and restriction weighed heavily, disadvantages largely overcome among the scientific staff by their interest in the work and recognition of its importance.

1.15 The principal groups and individuals who made up the initial scientific personnel are given below. Among those who had worked under Oppenheimer in the preceding period were: from the University of California, Robert Serber, E. M. McMillan, and others of Oppenheimer's group; E. Segre, J. W. Kennedy and their groups; from the University of Minnesota, J. H. Williams and group; from the University of Wisconsin, J. L. McKibben and group; from Stanford University, F. Bloch, H. H. Staub, and group; from Purdue University, M. G. Holloway and group. Among those who came from other parts of the DSM project, or from unrelated activities, were: from the Radiation Laboratory of Massachusetts Institute of Technology, R. F. Bacher and H. A. Bethe; from the Metallurgical Laboratory of the University of Chicago, Edward Teller, R. F. Christy, D. K. Froman, A. C. Graves, J. H. Manley and group; from Princeton University, R. R. Wilson and group, J. E. Mack, and R. P. Feynman; from the University of Rochester, V. F. Weisskopf; from the Bureau of Standards, S. Neddermeyer; from the Ballistic Research Laboratory at Aberdeen, D. R. Inglis; from the University of Illinois, D. W. Kerst; from Barnes Hospital, St. Louis, Dr. L. H. Hempelmann; from Memorial Hospital, New York, Dr. J. F. Nolan; from the National Research Council, C. S. Smith; from Westinghouse Research Laboratories, E. U. Condon; from Columbia University, E. A. Long; from the Geophysics Laboratory, Carnegie Institution of Washington, C. L. Critchfield. Many of these individuals were on leave from other universities, having accepted temporary war-time assignments in the above listed institutions.

1.16 In the procurement of laboratory equipment, machinery, and supplies, there were also difficulties and delays. Even a specialized laboratory requires a great variety of materials and equipment; as a going concern any laboratory depends in large measure upon the accumulation of its past, in stocks and in equipment that can be converted to new uses. Even though much material had been ordered in advance, procurement channels were at first slow, being indirect and newly organized.

1.17 Certain specialized equipment was brought to the project by the groups that were to use it. The largest single item was the cyclotron on loan from Harvard University. Before coming to Los Alamos, the Princeton group under R. R. Wilson had gone to Harvard to become familiar with the operation of this cyclotron and to disassemble it for shipment. McKibben's group brought with them from the University of Wisconsin two Van de Graaffs (electrostatic generators). Manley's group brought the Cockcroft-Walton accelerator (D-D source) from the University of Illinois. The Berkeley group brought chemical and cryogenic equipment, and all groups brought specialized electronic and miscellaneous apparatus. Because of this initial equipment, work was able to begin at Los Alamos much earlier than would otherwise have been possible.

1.18 The initial plan of the laboratory was drafted by Oppenheimer, Manley, and McMillan. It provided for an expected scientific staff of about one hundred, and a somewhat larger total number, including administrative, technical, and shop employees. The laboratory as planned contained the following buildings: Building T, an office building to provide space for administration, for the theoretical physics group, for a library, classified document vault, conference rooms, a photographic laboratory, and a drafting room; Building U, a general laboratory building; Building V, a shop building; Buildings W, X, Y and Z, specialized laboratory buildings for the Van de Graaffs, cyclotron, cryogenic laboratory, and Cockcroft-Walton accelerator, respectively. (See Appendix 4).

1.19 Oppenheimer and a few members of the staff arrived in Santa Fe on March 15, 1943. Prior to this time the project had been represented locally by J. H. Stevenson, a resident of Santa Fe. Construction work was incomplete. The laboratory buildings were still in the hands of the construction contractors, as was the housing that had been planned to accommodate Project Y and U. S. Engineer personnel. For this reason the first project office was opened in Santa Fe. Since it was undesirable for reasons of security to house the staff in Santa Fe hotels, guest ranches in the vicinity were taken over temporarily, and transportation arranged to the site. While the project office remained in Santa Fe, J. H. Williams lived at the site as acting site director.

1.20 There is no doubt that the Laboratory staff and families faced the prospect of life at Los Alamos with enthusiasm and idealism. The importance of their work and the excitement associated with it contributed to this feeling, as did the possibility of building, under conditions of isolation and restriction, a vigorous and congenial community.

1.21 The actualities of the first months were hard for many to view in this light. Living conditions in the ranches around Santa Fe were difficult. Several families, many with young children, were often crowded together with inadequate cooking and other facilities. Transportation between the ranches and Los Alamos was haphazard despite great efforts to regularize it. The road was poor; there were too few cars and none of them were in good condition. Technical workers were frequently stranded on the road with mechanical breakdown or too many flat tires. Eating facilities at the site were not yet in operation and box lunches had to be sent from Santa Fe. It was winter, and sandwiches were not viewed with enthusiasm. The car that carried the lunches was inclined to break down. The working day was thus irregular and short, and night work impossible.

1.22 Until mid-April, telephone conversations between the site and Santa Fe were possible only over a Forest Service line. It was sometimes possible to shout brief instructions; discussions of any length, even over minor matters, required an eighty mile round trip.

1.23 Frictions developed between the Laboratory members and U. S. Engineer staff mainly because of the slowness of the construction contractor. He was unable to get sufficient labor; he had trouble with the building trades unions; he did not procure or install rapidly enough the basic laboratory equipment. Pressure to accelerate this work had to be brought through, and therefore in part against, the military organization. In some cases technical supervisors were forbidden to enter buildings until they had been accepted formally by the contracting agency (The Albuquerque District of the U. S. Engineers). It was impossible to make minor changes, such as the placing of shelves or the direction of a door; the buildings had first to be completed and accepted as specified in the original drawings.

1.24 The initial problems were elementary and often enough, in retrospect, minute. The difficulties were heightened by an administrative arrangement which presupposed close cooperation without previous acquaintance between two groups of widely divergent background and perspective, namely, the project members and the military organization. Individually and in detail these early troubles are of little moment in the history of Los Alamos. Collectively, they had effects, some good and some bad, upon the spirit and tone of the emerging project organization.

Technical Introduction

1.25 The project offices were moved to Los Alamos in the middle of April; laboratory space and housing became available during April and May. Activities during the month of April can be summarized under three topics: (a) nontechnical adminstrative problems, (b) installation of laboratory equipment, and (c) discussion and planning of work. The present section will be devoted to the last topic. Topics (a) and (b) will be treated with the period following, to which they properly belong.

THE APRIL CONFERENCES

Introduction

1.26 During the last half of April a series of conferences were held at Los Alamos for the dual purpose of acquainting new staff members with the existing state of knowledge and of preparing a concrete program of research. These conferences were attended by the staff which had already moved to the project, by a few others mentioned above who could come permanently only at a later date, and by certain consultants who were specially invited. The last were I. I. Rabi of the Radiation Laboratory, Massachusetts Institute of Technology, and S. K. Allison and Enrico Fermi of the Metallurgical Laboratory, University of Chicago. All three of these men became heavily involved in the work of the Laboratory at a later time. During the conferences the project was visited by the members of a special reviewing committee which had been appointed by General Groves. This committee, whose report will be discussed, consisted of W. K. Lewis, Chairman, Massachusetts Institute of Technology; E. L. Rose, Director of Research for the Jones and Lamson Machine Co.; J. H. Van Vleck and E. B. Wilson of Harvard University; and R. C. Tolman, Vice Chairman, NDRC, secretary of the committee. Members of the committee also took part in the conferences.

1.27 Immediately prior to the conferences a set of lectures was given by Serber as a kind of indoctrination course. A summary of these lectures will provide an introduction and background for understanding the work of the conference. These lectures reflected the state of knowledge at the time. Within the scope indicated, and with much greater assurance and understanding of detail, they still constitute an adequate statement of the nuclear physics background.

Theoretical Background

1.28 Energy Release. The energy release from nuclear fission is about 170 million electron volts per nucleus. For U^{235} this amounts to about 7×10^{17} ergs per gram. The energy released from an explosion of TNT is about 4×10^{10} ergs per gram. Hence, roughly, a kilogram of U^{235} is equivalent in potential energy-release to 17,000 tons of TNT.

1.29 Chain Reaction. The large-scale release of energy from a mass of fissionable material is made possible by a neutron chain reaction. In fission the nucleus splits into two almost equal parts. These emit neutrons, on the average between two and three. Each neutron may, in turn, cause the fission of another heavy nucleus. This reaction can go on until it is stopped by the depletion of fissionable material, or by other causes. U^{238}, the principal isotope in ordinary uranium, fissions only under the impact of high-energy (about one million electron volt) neutrons. Neutrons from fission have more than this energy initially; a large percentage of them, however, are slowed by collisions to an energy below the fission threshold of U^{238}. The result is that each neutron is the parent of less than one neutron in the next generation and the reaction is not self-sustaining.

1.30 Ordinary uranium contains, however, about 0.7 per cent U^{235}. Neutrons of any energy will cause this isotope to fission; in fact, slow neutrons are more effective than fast ones. The result is that a chain reaction is just possible in the normal isotope mixture or "alloy," if a slowing-down material is added to bring the neutrons down to the velocities at which they most effectively cause the fission of U^{235}. It is this chain reaction that is used in the production of plutonium. Surplus neutrons are absorbed by the U^{238}, giving rise to the unstable isotope U^{239}, which decays by successive emission of two electrons to the end-product Pu^{239}.

1.31 If the percentage of U^{235} in uranium alloy is increased, a chain reaction becomes possible with faster neutrons. A concentration is thus reached at which no special slowing-down or moderating is needed other than what is provided by the uranium itself. The fastest possible reaction is obtained from pure U^{235}.

1.32 Critical Size, Tamper, Efficiency. In the fast chain reaction, occurring in, say, metallic U^{235} or Pu^{239}, a further limiting factor becomes crucial. In practice only a fraction of the fission neutrons will cause new fissions. The rest will leak out through the boundaries of the material. If the fraction leaking out is too large, the reaction will fail to sustain itself. If we consider a spherical mass of fissionable material at normal density, the fraction leaking out will decrease with increasing radius of the sphere, until on the average the birth rate of neutrons just compensates for the rate at which they escape from the sphere. For a smaller sphere a chain reaction will die out; for a larger one, it will continue and grow exponentially. This limiting radius is called the critical radius, and the corresponding mass, the critical mass.

1.33 It is intuitively suggested that the critical radius should be of the same order of magnitude as the average distance which neutrons travel between successive fissions. For fast neutrons this distance of flight is much larger than for slow neutrons; it is in fact 10 centimeters. Because of the great cost and limited supply of the materials available, it was essential to reduce the critical size in any way possible. If the sphere of active material were surrounded by a shell of less expensive material, this would reflect at least some of the escaping neutrons back into the sphere, and thus decrease the critical mass. Early calculation had shown that any one of several available reflector or "tamper" materials would give a very substantial reduction of the critical mass.

1.34 What has been said so far concerns only the static aspect of the nuclear bomb. Given a more-than-critical mass of active material, what is the course of the reaction? Once the reaction is started, the rate of fissioning, and hence the release of energy, increases exponentially. From the energy release the material will be heated and begin to expand. From the decrease in density of the active material the path between fissions will increase more rapidly than the radius of the expanding mass, and hence more neutrons will escape. Thus at some point the system will become subcritical and the reaction will be quenched. The point at which this quenching occurs will determine the efficiency of the explosion, that is, the percentage of active nuclei fissioned.

1.35 The time available for an efficient nuclear reaction had been shown to be extremely short. Release of 1 per cent of the energy would give the nuclear particles a mean velocity of about a million meters per second. The reaction would be quenched by an expansion of the order of centimeters; this means that the energy release would have to occur in a time of the order of hundredths of a microsecond. Since the mean time between fast neutron fissions is about 0.01 microsecond, and since the largest part of the energy release occurs in the last few fission generations, a reaction of reasonable efficiency was evidently just possible.

1.36 Cross Sections. Calculation of the static and dynamic aspects of the fission bomb presented difficulties both because of the elaborateness of the theory involved and because of the dependence of these calculations on nuclear constants that were not, as yet, well measured. Within the system a neutron may be absorbed, scattered, or produce fission. The contributions of each process are measured by the corresponding cross sections, or effective target areas presented by the nucleus to an impinging neutron. The total cross section is divided into areas that win, lose, or draw (fission, absorb without fission, or scatter), these areas corresponding to the relative probabilities of the three processes. If the scattering is not isotropic, it is also necessary to specify the angular distribution of scattered neutrons. All of these cross sections, moreover, depend upon the nucleus involved and the energy of the incident neutron. Calculation of critical mass and efficiency depends upon all of these cross sections, as well as upon the number of neutrons per fission and density of material. It was clear that to obtain such measurements with the necessary accuracy would entail an elaborate program of experimental physics and a comparable effort of theoretical physics to make the best use of information obtained.

1.37 Effects of Tamper. The effect of tamper is not only to decrease the critical mass by reflecting neutrons back into the active material, but also to increase the inertia of the system and therefore the time during which it will remain in a supercritical state. These gains are somewhat lessened by the longer time between fissions of neutrons reflected back from the tamper. The lengthening of the time is caused not only by the longer path, but also by a loss of energy through inelastic scattering in the tamper. Calculations of the effect of tamper material depend thus on the absorption and scattering cross sections of tamper material. It is interesting to note that Serber's early calculations gave, for a tamper of U^{238}, a critical mass for U^{235} of 15 kilograms, and for Pu^{239} of 5 kilograms. Both figures are correct to within a reasonable error. This may be regarded as in part good fortune, since many of the assumption made were rough guesses. It nevertheless serves to illustrate the advanced state of basic theory at the time.

1.38 Efficiency, Detonation, and Predetonation. Some indication has been given above of the basis for efficiency calculations. The outcome of such calculations was to show that efficiencies would be low. There is, moreover, another essential factor in efficiency, connected with the problem of assembly and detonation, the early discussion of which is reviewed below.

1.39 It is inherent in the nature of explosive reactions that they can be set off by relatively minute forces, the requirement being, in general, a disturbance sufficiently great to initiate some type of chain reaction. Chemical explosives can be protected with greater or less certainty from such external forces as may initiate a reaction. A supercritical mass of nuclear explosive, however, cannot be protected from "accidental" detonation. Chain reactions will begin spontaneously with greater certainty than in the most unstable chemical compounds. Cosmic ray neutrons will enter the mass from outside. Others will be generated in it from the spontaneous fissions that constantly occur in uranium and plutonium. Still others come from nuclear reactions, most importantly from the (α, n) reaction in light element impurities. The problems presented by this "neutron background" are responsible for a considerable part of the project's history. From the first and weakest source alone (cosmic rays) any supercritical mass will be detonated within a fraction of a second, from other unavoidable sources within a very much shorter time.

1.40 The only method for detonating a nuclear bomb is, therefore, to bring it into a supercritical configuration just at the time when it is to be detonated. The required speed of assembly depends upon the neutron background. As the parts of the bomb move together, the system passes smoothly from its initial subcritical to its final supercritical state. Chain reactions may, however, set in at any time after the critical position has been reached. If the velocity of assembly is small compared to the rate of the nuclear chain reaction, and if predetonation occurs, the explosion will be over before assembly for maximum efficiency has occurred. Thus the explosion may occur, with a widely varying range of efficiencies, at any time between the critical and the final supercritical positions. To decrease the probability of predetonation and consequent low efficiencies requires either a higher speed of assembly or a lower neutron background.

1.41 Gun Assembly, Initiator. The considerations of the last section indicate the magnitude of the assembly problem: to initiate properly and reliably a reaction whose entire course occurs in a fraction of a microsecond, subject to the complementary needs for high velocity assembly and low neutron background. As was mentioned above, the principal source of neutron background is the (α, n) reaction in light-element impurities. To lower this background would require a strenuous program of chemical purification.

1.42 The most straightforward early proposal for meeting these difficulties was the method of gun assembly; the general proposal was that a projectile of active and tamper material, or of active material alone, be shot through or laterally past a target of active material and tamper. For U^{235} both the chemical purity requirements and the needed velocity of assembly were attainable by known methods. Many difficult engineering problems were evidently involved, but they did not appear as insuperable. For Pu^{239} the requirements for purity and speed were both somewhat beyond the established range. It seemed, however, that by rather heroic means they could be met.

1.43 High velocity assembly and the reduction of the neutron background would decrease the probability of predetonation; they would also decrease the probability of detonation at the desired time. Unless material could be assembled so as to remain in its optimum configuration for a considerable length of time, there was a danger that "postdetonation" too would give low efficiency, or that the system would pass through its supercritical state without detonation occurring at all. To overcome this difficulty it would be necessary to develop a strong neutron source that could be turned on at the right moment. Theoretically feasible schemes for such an initiator had been conceived, but their practicability was not assured.

1.44 Autocatalysis, Implosion. Two other methods of assembly had been proposed, and it was a part of the early program to investigate them. One of these was a self-assembling or autocatalytic method, operating by the compression or expulsion of neutron absorbers during the reaction. Calculation showed that this method as it stood would require large quantities of material and would give only very low efficiencies.

1.45 The second alternative method was that of implosion.

1.46 The Deuterium Bomb or "Super." There existed, at the time of the April Conference, one other important proposal to which considerable thought and discussion had been given in the previous months. This was a proposal to use the fission bomb as a means for initiating a nuclear reaction of a different type from that involved in the fissioning of heavy-element nuclei. Fissioning, the disruption of nuclei with liberation of energy, is a somewhat anomalous reaction restricted to the heaviest nuclei. Among the lighter elements the typical exoergic (energy-producing) reaction is the building up of heavier nuclei from lighter ones. For example, two deuterium (H^2) nuclei may combine to form a He^3 nucleus and a neutron, or a tritium nucleus (H^3) and a proton. The energy that is liberated goes into kinetic energy and radiation. If such a reaction occurs in a mass of deuterium, it will spread under conditions similar to those that control ordinary thermochemical reactions. Hence the reaction is called thermonuclear. The cross section for a reaction between two deuterium nuclei is strongly dependent upon the energy of the nuclei. At low energies the probability that the reaction will occur is very small. As the temperature of the material increases, the reaction becomes more probable. Finally a critical temperature is reached, where the nuclear reactions in the material just compensate for various kinds of energy loss, such as heat conduction and radiation. The thermonuclear reaction is in detail more complicated than has been indicated, because of the presence of a variety of secondary reactions.

1.47 Among available materials, deuterium has the lowest ignition temperature. This temperature was estimated to be about 35 kilovolts (about 400 million degrees), and is actually somewhat lower. Once ignited, deuterium is about 5 times as energy-productive per unit mass as U^{235}. Thus 1 kilogram of deuterium equals about 85,000 tons of TNT equivalent. Since it is not more difficult to ignite a large than a small mass of deuterium, and since it is more cheaply produced in usable form than either U^{235} or Pu^{239}, the proposed weapon, using a fission bomb as a detonator and deuterium as explosive, could properly be called an atomic super-bomb. The development of this super-bomb was perforce secondary to that of the fission bomb; on the other hand its potentialities were so great that research toward its development could not be completely neglected.

1.48 It should be mentioned at this point that in the early period of the project the most careful attention was given to the possibility that a thermonuclear reaction might be initiated in light elements of the Earth's atmosphere or crust. The easiest reaction to initiate, if any, was found to be a reaction between nitrogen nuclei in the atmosphere. It was assumed that only the most energetic of several possible reactions would occur, and that the reaction cross sections were at the maximum values theoretically possible. Calculation led to the result that no matter how high the temperature, energy loss would exceed energy production by a reasonable factor. At an assumed temperature of three million electron volts the reaction failed to be self-propagating by a factor of 60. This temperature exceeded the calculated initial temperature of the deuterium reaction by a factor of 100, and that of the fission bomb by a larger factor.

1.49 The impossibility of igniting the atmosphere was thus assured by science and common sense. The essential factors in these calculations, the Coulomb forces of the nucleus, are among the best understood phenomena of modern physics. The philosophic possibility of destroying the earth, associated with the theoretical convertibility of mass into energy, remains. The thermonuclear reaction, which is the only method now known by which such a catastrophe could occur, is evidently ruled out. The general stability of matter in the observable universe argues against it. Further knowledge of the nature of the great stellar explosions, novae and supernovae, will throw light on these questions. In the almost complete absence of real knowledge, it is generally believed that the tremendous energy of these explosions is of gravitational rather than nuclear origin.

1.50 More immediate and less spectacular global dangers to humanity arise from the use of thermonuclear bombs, or even fission bombs, in war: principally from the possible magnitude of destruction and from radioactive poisoning of the atmosphere (13.14).

1.51 Damage. So far we have reviewed only the early discussion of energy release. Since, however, the purpose of the project was to produce an effective weapon, it was necessary to compare the atomic bomb with ordinary bombs, not merely as to energy release, but more concretely as to destructive effects. Damage could be classified under several headings: The psychological effects of the use of such a weapon; the physiological effects of the neutrons, radioactive material and radiation produced; the mechanical destruction produced by the shock wave of the explosion. Estimation of the first was not of course within the means or jurisdiction of the project. Of the second, it was estimated that lethal effects might be expected within a radius of 1000 yards of the bomb. The radioactivity remaining might be expected to render the locality of the explosion uninhabitable for a considerable period, although this effect would depend on the percentage of activity left behind, which was as yet an unknown quantity. The principal damage would be caused by the mechanical effects of the explosion. These effects were difficult to estimate. Some rough data on the effects of large explosive disasters were available. More reliable information was available concerning the effects of small high explosive bombs, but it was not known for sure how these effects should be scaled upward for high energy atomic bombs. Serber's report gives an estimate of a destruction radius of about 2 miles for a 100,000 ton bomb. Members of the British mission who came to the project somewhat later were able to add to the understanding of this topic from their national experience and their research of recent years.

DEVELOPMENT OF PROGRAM

Introduction

1.52 From the previous outline of the state of knowledge at the beginning of Project Y, it is clear that the greatest problems were bound to arise on the side of development and engineering. There was still much work to be done in nuclear physics proper, but enough was known to eliminate great uncertainties from this side of the picture. It should not be concluded, however, that the stage of research was past its prime, to be dominated in turn by problems of application. The normal meanings attached to "research," "development," and "engineering" are altered in the context of wartime science generally; that is particularly true of the atomic bomb project. Two features have determined its general character. The first is the domination of research schedules by production schedules; the second is the nature of the weapon itself. Time schedules for the production of U^{235} and Pu^{239} were such that the laboratory had before it about two years until explosive amounts of these materials would be available. After that time every month's delay had to be counted as a loss to the war. The practical consequence was that many kinds of information had to be gotten at the earliest possible date, with greatest difficulty, even though at a later date the same information could be gotten more easily and reliably. The micrometallurgy of plutonium was investigated at Chicago, for example, because it was vital, among other things, to know the density of the new material as soon as possible; the first measurement was made with great labor, from a sample of only a few micrograms. The value of such information depended upon its capacity to influence decisions which could not be postponed. This meant a heavy dependence upon theory and upon measurements of the type needed to answer theoretical questions. To some extent reliance was placed upon theoretical anticipations because of the all-or-none character of the weapon. A purely experimental nuclear explosion would involve the dissipation of at least one critical mass of material that might have been used against the enemy. If tests were to be made at all, only one or two would be possible. For so small a number of tests to be meaningful, they would have to have a large a priori probability of success. Although this question of tests was not decided at the beginning of the project, certain general implications were clear: The bomb's component parts and phases of operation had to be designated and tested separately, with reliance upon theory to supply a picture of its integral operation.

1.53 It is not remarkable, in the light of what has been said, that the initial program, personnel, and equipment of the Laboratory gave it the appearance of a purely research organization. That it had this appearance was partly a matter of previous history; nuclear research was the most advanced part of the program, and its personnel and equipment were most easily available. In part, however, the research character of the organization was a matter of considered policy. Normally, the engineer is the "practical man" who translates ideas into practice. Here, not only the ideas but also the standards of practice were new. To keep the center of policy in the research group was not to minimize the importance of the engineering work, but to emphasize its difficulty. Secondary problems undeniably arose from this policy, which displaced the engineer from his normal position, and only through trial and error created for him a new place in the division of project labor.

Theoretical Program

1.54 Enough has been said to indicate the central position in the Laboratory of its theoretical program. As it emerged from the conferences this program had as its main goal to analyze the explosion and develop the associated techniques of calculation, and to give nuclear specifications for the bomb with increasing reliability and accuracy as new physical data became available. Calculations had to be made for three materials: U^{235}, Pu^{239}, and also a new compound, a hydride of uranium, which seemed to have certain advantages over metallic uranium as a bomb material. Calculations also had to be made for a variety of shapes of the active mass, and for different combinations of bomb and tamper material. For critical mass calculations the theory of neutron diffusion in bomb and tamper had to be refined, and account taken of the energy distribution of fission neutrons, as well as the dependence of nuclear cross sections upon those energies. For efficiency calculation, further study was needed of the hydrodynamics of the explosion, taking account of the effects of the large amounts of radiation liberated in the process. Further investigation was needed of the problems connected with time of assembly, detonation, and predetonation.

1.55 In addition to these problems relating to bomb design, the theoretical program included a variety of analyses and calculations connected with the experimental program, ranging from ordinary service calculations to the design of a slow chain-reacting unit with U^{235}-enriched uranium.

1.56 The program included, finally, the further investigation of bomb damage, of the possibility of autocatalytic methods of assembly, and the proposal to amplify the effect of fission bombs by using them to initiate thermonuclear reactions.

Program of Experimental Physics

1.57 The program of experimental physics formulated during and immediately after the conferences falls under two main headings: Detailed and integral experiments. Detailed or differential experiments are those which attempt to observe the effects of isolated nuclear phenomena. From a sufficient number of experimental data gained in this way, an integral picture of the operation of the bomb could be built up within a framework of theory. Integral experiments, on the other hand, were - at least in their early conception - attempts to duplicate in experimental arrangement some of the over-all properties of the bomb. Experiments of the two kinds were intended to supplement each other wherever possible, on the one hand to sharpen the interpretation of integral experiments, on the other to show up possible omissions of elements from the detailed picture. In practice, it has proved extremely difficult to devise integral experiments which in any way duplicate the conditions obtaining in the bomb. The integral experiments that have been performed have had rather the effect of checking theory in situations in some ways similar to the bomb.

1.58 A brief outline of the program as first developed will serve also to indicate the state of experimental knowledge carried over from the previous period.

1.59 Differential Experiments.

Neutron Number. The average number of neutrons per fission had never been measured directly, although the Chicago project had measured the number of neutrons from U^{235} per thermal neutron absorbed. The number of neutrons per fission could be calculated from this measurement and from the ratio of fissions to captures, which, however, was not known reliably in the region of thermal energies. The neutron number of Pu^{239} was completely unknown although it was expected to differ but little from that of U^{235}. The first experiments planned were, in fact, measurements of neutrons from Pu^{239}.

1.60 These latter measurements were of intrinsic importance, and were needed at the earliest date possible to confirm the wisdom of heavy commitments already made for the production of plutonium in quantity.

1.61 Fission Spectrum. The energy range of neutrons from the fission of U^{235} had been investigated by the British, and by the Rice Institute and Stanford subprojects. These measurements suffered from the large dilution of isotope 235 by 238 in normal uranium. Work had already been begun at Minnesota with enriched material, and this program was to be continued at Los Alamos.

1.62 Fission Cross Sections. Fission cross sections had been measured by the subproject under N. P. Heydenberg at the Department of Terrestrial Magnetism of Carnegie Institute, by McKibben's group at Wisconsin, and by Segrè's group in Berkeley. These measurements - for U^{235} - covered the neutron energy range above 125 kev, and the range below 2 ev. When the curve for fission cross sections over the high energy was extrapolated downward, a figure was obtained for thermal energy that was much larger than the cross section actually observed. Since the extrapolated region covered the important range of neutron energies in a bomb of uranium hydride, measurements were planned to investigate cross sections at these intermediate energies and resolve the apparent anomaly. Fission cross sections of Pu^{239} were already known at thermal energies and at a few high energies. Here also measurements were planned to cover the entire range of energies up to about 3 Mev.

1.63 Delayed Neutron Emission. Experiments at Cornell had shown that there was no appreciable delay beyond 10 microseconds in the emission of neutrons from fission; one of the initial experiments planned at Los Alamos was to push this time down to 0.1 microsecond; on theoretical grounds it was expected that the number delayed even for this time would be small.

1.64 Capture and Scattering Cross Sections. At the beginning of the project little was known about capture and scattering cross sections. Some measurements of capture and inelastic scattering cross sections had been made at Chicago for normal uranium. Experiments by the Minnesota group had given values for elastic and inelastic scattering in uranium for high energies. The Wisconsin group had measured large-angle elastic scattering in a number of potential tamper materials. Capture cross section measurements were made by Segrè at Berkeley. The principal work planned for the Los Alamos Laboratory was on the scattering and absorption cross sections of U^{235} and Pu^{239}, and the capture and scattering cross sections of various tamper materials.

1.65 One new type of scattering measurement, not previously undertaken, was planned for this Laboratory. This was the measurement of scattering into different solid angles. When so averaged as to give the effective scattering in a given direction, this average is the so-called transport cross section.

1.66 Integral Experiments. Certain integral experiments had been performed at Chicago, in connection with the development of the slow neutron chain-reacting pile. These were not of direct interest to the bomb project. Two types of integral experiments were, however, planned in the early experimental physics program.

1.67 Integral Tamper Experiments. Several experiments were planned to measure the scattering in potential tamper materials; these were designed to imitate the scattering properties of a tamper in the actual bomb.

1.68 The "Water Boiler." At the April Conferences there was some discussion of the possibility of constructing a slow chain-reacting unit, using uranium with enriched U^{235} content in water solution. The construction of such a unit would provide a useful neutron source for experimental purposes, and would also give practice in the operation of a super-critical unit. The decision to make such a unit was not reached until some time later.

1.69 Experimental Techniques. A large subsidiary program was called for, to investigate techniques for producing and counting neutrons of a given energy, for measuring fissions in various materials, and for measuring neutron-induced reactions other than fission. The systematic recording of nuclear properties entailed by the experimental program required both accuracy and standardization of a number of difficult techinques; the program of instrumentation represented therefore a major activity of the Laboratory.

Program of Chemistry and Metallurgy

1.70 During the course of the DSM Project a large amount of research had been carried out on the chemistry and metallurgy of uranium. The microchemistry and micrometallurgy of plutonium were investigated at Chicago as soon as small amounts of the material were available. The chemical investigations were necessary as a basis for designing methods of recovering plutonium from the pile material and "decontaminating" it, i.e., separating it from radioactive fission products.

1.71 At the beginning of the Los Alamos Project the exact division of labor between its chemistry laboratory and other laboratories had not been settled. There were objective difficulties and uncertainties of program. It was not known whether U^{235}, Pu^{239} or both would be used, or whether the bomb material would be metal or compound. U^{233}, producible from thorium by a process of "breeding" similar to that by which Pu^{239} is made from U^{238}, was also a possibility. Mechanical requirements for the bomb material could not yet be specified. Here also a characteristic difficulty appeared, in that the time for research with gram and kilogram amounts of material would have to be as short as possible, in order to avoid delay in bomb production.

1.72 One certainty was a schedule of purity requirements for U^{235} and Pu^{239}. Because of the large alpha radioactivity of the latter substance, light impurities had almost to be eliminated. Most light elements had to be present in not more than a few parts per million. For U^{235} these tolerances could be greatly relaxed. Although it was not yet determined whether the work of final purification would be carried on at Los Alamos or elsewhere, an analytical program was necessary to develop techniques for measuring small amounts of impurity in small samples of material.

1.73 A radiochemistry program was needed to prepare materials to be used in nuclear experiments and in the development of a neutron initiator for the bomb.

1.74 The metallurgy program included research and development on the metal reduction of uranium and plutonium, the casting and shaping of these metals and compounds such as uranium hydride, as well as various possible tamper materials. Investigation of the physical properties of uranium and plutonium was needed, and a search had to be made for alloys with physical properties superior to those of the unalloyed metals. As its main service function, the metallurgy group would be called upon to prepare materials for physical and ordnance experiments, particularly projectile, target, and tamper materials for the gun program.

1.75 As a somewhat autonomous part of the chemistry program, plans were made for the construction of a deuterium liquefaction plant at Los Alamos. This was to supply liquid deuterium for experimental purposes and for eventual use in the thermonuclear bomb, should its development prove feasible and necessary.

Ordnance Program

1.76 It had been recognized from the beginning that the most difficult of all problems facing the project was to find means for the assembly of several critical masses of material, fast enough to produce a successful high-order explosion. Subsidiary but still very difficult problems were those of incorporating active material, tamper, and assembly mechanism into a practical airborne bomb. These were the problems of the ordnance division of the project, a division which could hardly be said to exist at the beginning. As a matter of fact, no pre-existing group could have had much success in this work. A new field of engineering was being explored; experience has shown that those successful in this work come from a variety of technical backgrounds, all of which contribute to the field and none of which dominate it: physicists, chemists, and electrical and mechanical engineers.

1.77 A corollary feature of the ordnance program has been its simultaneous investigation of alternative methods. The uncertainties of nuclear specification, and the possibility that one or another line of investigation might fail, have made such a policy unavoidable. Of the three methods of producing a fission bomb (autocatalysis, the gun, the implosion) that have been discussed, the last two were singled out for early development. Autocatalysis was not eliminated; but it was not subject to development until some scheme was proposed which would give a reasonable efficiency. This did not occur during the course of the project, although autocatalytic methods continued to receive considerable theoretical attention. Of the remaining two methods, the gun appeared the more practical; it used a known method of accelerating large masses to high velocities. The problem of "catching" a projectile in a target and starting a chain reaction in the resulting supercritical mass was obviously a difficult one, but it seemed soluble.

1.78 The method of implosion, on the other hand, was much farther removed from existing practice. The requirement of simultaneous detonation over the surface of a high explosive sphere presented unknown and possibly insoluble difficulties; the behavior of solid matter under the thermodynamical conditions created by an implosion went far beyond current laboratory experience. As even its name implies, the implosion seemed "against nature." Its investigation was at first undertaken as something to fall back on in case the gun should, contrary to expectation, fail. Credit for the early support and investigation of this method should be given to S. H. Neddermeyer, who at the beginning was almost alone in his belief in the superiority of the method. At a meeting on ordnance problems late in April, Neddermeyer presented the first serious theoretical analysis of the implosion. His arguments showed that the compression of a solid sphere by detonation of a surrounding high-explosive layer was feasible, and that it would be superior to the gun method both in its higher velocity and shorter path of assembly. Investigation of the method was begun almost immediately. It subsequently received two increases of priority, until at the end of the project it had become the dominant program throughout the Laboratory.

1.79 During the April conferences, the discussion of ordnance served mainly to outline the problems. Considerable attention had been given to the problem of gun design by R. C. Tolman. One member of the reviewing committee at Los Alamos in April was E. L. Rose, an expert in problems of gun design. Rose showed that by the sacrifice of durability, a quite inessential property, the otherwise prohibitive size and weight of a large gun could be reduced to a point where, together with the target, it could be included in a practical bomb. Other elements of the ordnance program discussed were: internal ballistics of the gun, external and terminal ballistics (guiding and seating of the projectile, initiating of the chain reaction), safety, arming and fuzing devices, release, and trajectory of the bomb from a plane.

1.80 It is inappropriate to discuss in detail the experimental program of ordnance at this point. Experimental work did not get under way for several months. On the agenda for immediate action were the prior problems of obtaining test guns and high explosives, of building a proving ground, and of employing or training personnel to carry on the research.

Report of the Reviewing Committee

1.81 The reviewing committee referred to in paragraph 1.26 was appointed by General Groves to report on the organization of the Los Alamos Project and on the status and program of its technical work. The chief question before this committee was the status of the ordnance program. The initial conception of the project's general program was that research in nuclear physics should be virtually completed before undertaking a large-scale ordnance development. In March 1943, however, Oppenheimer had written a memorandum on ordnance, in which he urged that experimental work be undertaken as early as possible, and that it receive recognition as one of the most urgent of the project's outstanding problems. Tolman recognized the importance of the issue thus raised, and recommended the appointment of Rose to the reviewing committee as an expert on ordnance matters.

1.82 The report of the reviewing committee, dated May 10, 1943, was concerned with the administrative organization of the project, and with the status and program of the technical work. Since certain of the recommendations of the committee had an important bearing on the further development of the project, the main features of its report are outlined below.

A. NUCLEAR PHYSICS RESEARCH

1.83 After an extensive review of the program of nuclear physics, the committee stated its approval of all of this, the most advanced part of the work. It took note of the newly discovered possibility for use of uranium hydride. Pointing out that the existence of the hydride had been learned of at Los Alamos somewhat by accident, the committee recommended a more systematic technical liaison between this and other branches of the larger project. It also recommended that the study of U^{233} as a possible explosive material be continued.

B. LESS DEVELOPED PARTS OF THE PROGRAM

1.84 The committee reported on the program for investigation of the thermonuclear reaction, the chemistry and metallurgy program, and on the program of engineering and ordnance.

1.85 As for the thermonuclear bomb, the committee recommended that its investigation be pursued, but along mainly theoretical lines, and with priority subordinate to that of the fission bomb. This confirmed the Laboratory policy already established.

1.86 Concerning both the chemistry and engineering programs, the committee recommended a substantial revision of earlier policy. One of the principal organizational questions at the time was the jurisdiction of the chemistry purification program. As stated above, the purification of active material, particularly Pu^{239}, presented a major technological problem. The chemistry of plutonium was first investigated by Kennedy, Seaborg, Segrè, and Wahl, its discoverers. The investigation was pursued and would first be practiced by the Metallurgical Laboratory chemists, in connection with their problem of separation and decontamination of plutonium produced in the piles at Oak Ridge and Hanford. It was arguable that the further step of purification, upon which such stringent requirements were placed, should be carried out by the same group. The committee recommended, however, that the purification program be carried on at Los Alamos instead. Its reasons for this recommendation were not only that the Los Alamos Project would be responsible for the correct functioning of the ultimate weapon, but also that a considerable amount of repurification work would in any case be a consequence of the experimental use of material at this project.

1.87 The second major recommendation of the committee was in agreement with the earlier statement of Oppenheimer - that the work of ordnance development and engineering should be undertaken as soon as possible. The committee stated its opinion that the time had arrived for close connection between nuclear and engineering research. While there remained from the side of nuclear specifications a wide range of possible designs for the final weapon, the committee believed that further determination of design would have to depend as well upon engineering specifications. The committee also pointed out that engineering research was needed in connection with the development of safety, arming, firing, and detonating devices, portage of the bomb by plane, and determination of the bomb trajectory.

1.88 Both the above recommendations entailed a major expansion of project personnel and facilities. For the purification program, the estimated increase of chemists and technicians was thirty, and a corresponding increase of laboratory facilities. For ordnance and engineering work, the committee estimated that this would require a two-fold increase of project personnel, with an extensive increase of offices, drafting rooms, shops, and test areas for ballistic and explosives work.

C. ADMINISTRATIVE RECOMMENDATIONS AND GENERAL CONCLUSIONS

1.89 The committee's recommendations on matters of organization and administration fall under the headings of personnel, procurement, security, and morale. Under the first the committee gave strong commendation to Oppenheimer as director. The creation of three administrative positions was recommended, as soon as competent persons could be found to fill them. The first was a director of ordnance and engineering, to take charge of the recommended program. The second was an associate director, a man in charge of some major phase of the scientific work and able to assist the director and take charge in his absence. The third was an administrative officer, to take charge of nontechnical administrative matters; in particular, to maintain cordial and effective relations with the military administration. On the general personnel situation the committee reported favorably, both as to the competence and the work assignments of scientific personnel.

1.90 The committee was dissatisfied with the organization and functioning of the procurement system. The procurement officer, Mitchell, they found to be well qualified for the position by technical training and experience. Their principal criticism was directed toward the operation of the University of California Purchasing Office in Los Angeles, which in their opinion had been responsible for serious and avoidable delays. The committee recommended establishment of a second purchasing office in New York under separate contract.

1.91 The security policy established by the Director under the authority granted him met with the committee's approval.

1.92 The final administrative recommendation of the committee, one which in its nature could not be entirely specific, concerned morale and the maintenance of the "special kind of atmosphere that is conducive to effective scientific work." The committee recognized that this was made difficult by the isolation and military character of the post, and it was therefore in the achievement of better relations between the military and technical organizations that the committee saw hope for the maintenance of morale.

SUMMARY

1.93 The period of the April Conferences and of the reviewing committee's examination of program and organization provides a natural introduction to the problems of the new project. Enough has been said to indicate that the greatest problems were connected with the need to develop a new type of engineering research, translating the schematic conception of an atomic bomb into an effective military weapon. Both objectively and subjectively, these problems were rendered more difficult by the newness and isolation of the Laboratory, and by the duality of military and technical organizations.

Chapter II

THE BRITISH MISSION

2.1 In December 1943 the first representatives of the British atomic bomb project came to Los Alamos. Their arrival marked the climax of a long series of negotiations between the British, Canadian, and American governments seeking to integrate the scientific work being done in all three countries on atomic bomb research (1.3). These first representatives were O. R. Frisch and E. W. Titterton.

2.2 Although Britain's T. A. Project (The Directorate of Tube Alloys) had had a very high priority in 1942, so many of her physicists and so much of her industrial capacity were engaged in other urgent war work that it was impossible to undertake as large a program as the United States had launched. The British organization decided to limit itself to particular phases of the problem, and established research teams in various university and industrial laboratories.

2.3 In the summer of 1942, sufficient progress toward collaboration had been made so that the British reports on the theory of fission and the fission bomb were accessible to Oppenheimer's group in Berkeley, as well as reports of experimental measurements of nuclear constants. At that time the British analysis of the bomb mechanism was somewhat more advanced than in the United States, so that access to these reports was of substantial value. In November 1942 a memorandum was written by Oppenheimer to R. E. Peierls describing the theoretical work that had been done at Berkeley and discussing certain points of difference between British and American theoretical work. The incompleteness of collaboration at this time is indicated by the fact that in the memorandum referred to there could be no mention of the deuterium bomb.

2.4 In the fall of 1943 President Roosevelt and Prime Minister Churchill had discussed the possibilities for closer collaboration between the two countries in hastening the production of atomic bombs. As a result of their discussions a Combined Policy Committee was set up in Washington. One of this committee's decisions was to move a large number of British scientists to work in American laboratories. Evidence of the genuineness of cooperation that resulted from this sacrifice on Britain's part is the fact that British scientists were given assignments in all parts of the American project, especially at Los Alamos, the most highly classified section of all.

2.5 At this time Niels Bohr, the eminent Danish physicist, escaped from Denmark to England, where he was appointed adviser on scientific matters to the British Government. His scientific advice was made available to the United States as well. Bohr and his son Aage came to Los Alamos in December 1943, a short time after Frisch and Titterton. To ensure his personal safety and as a security precaution, Bohr was known as Nicholas Baker and his son as James Baker. Great care was taken to prevent any reference to their real names, even in classified documents. The Bohrs did not become resident members of the Los Alamos Laboratory, but made several extended visits as consultants.

2.6 When Bohr came to the Laboratory he found there a large number of his former students, and his coming had a very healthy influence on research. He came at the right moment. The exigencies of production, the innumerable small problems which confronted the physicists, had led them away from some of the fundamental problems of the bomb. The study of the fission process itself, for example, had been neglected, and this obstructed reliable predictions of important phenomena, such as the energy-dependence of the branching ratio between fission and neutron capture (6.44). Here Bohr's interest gave rise to new theoretical and experimental activities which cleared up many questions that were left unanswered before. Some of the most important experiments on the velocity selector were made at his instigation (6.38). His influence was felt strongly in research on the nuclear properties of tamper materials.

2.7 Bohr's criticism and his concern for new and better methods enlivened the discussion of alternative means of bomb assembly. Although these discussions showed in the end that the "orthodox" implosion was still the best method, their value was to prove that its choice was, despite its many difficulties, the correct one. Bohr participated very actively in the design of the initiator.

2.8 Last but not least, his influence on the morale of the Laboratory must be mentioned. It went further than having the great founder of atomic research in the Laboratory, and farther than the stimulus of his fresh suggestions. He saw the administrative troubles of the Laboratory in a better and longer view than many of those enmeshed in them. His influence was to bring about stronger and more consistent cooperation with the army in the pursuit of the common goal. And what can be least overlooked, he gave everybody who was in contact with him some of his understanding of the ultimate significance of the control of atomic energy.

2.9 Another of the Laboratory's most useful British consultants was Sir Geoffrey I. Taylor. Los Alamos was staffed primarily with nuclear physicists, who lacked experience with hydrodynamical investigations. In investigating the hydrodynamics of the implosion and the nuclear explosion, therefore, their work suffered from being too formal and mathematical. Apart from the contributions of the American consultant John von Neumann (7.54), most of the simple intuitive considerations which give true physical understanding came from discussions with Taylor. His most important general contribution was the understanding of the "Taylor instability," which is the generalization that when a light material is pushing a heavy material, the interface between them is unstable (5.26). This principle was important in the theory of jets, in the interpretation of high-explosive experiments, in the design of the initiator, in the design of the implosion bomb, and in the predictions about the nuclear explosion (5.43). To him also was due the stimulus for serious theoretical investigation of the "ball of fire" phenomena (11.20).

2.10 Technical contributions of the resident staff of the British Mission are mentioned in appropriate parts of the text on the same basis as the work of their American colleagues.

2.11 Sir James Chadwick of the Cavendish Laboratory, scientific adviser to the British members of the Combined Policy Committee in Washington, came to Los Alamos early in 1944 to head the British Mission. It was not certain at first whether the British group would work under Chadwick on the problems of his choosing, or whether they would be assigned to existing groups in the Laboratory. The latter arrangement was adopted, and eventually British scientists worked in nearly all of the Laboratory divisions. Seven were experimental nuclear physicists, two were electronics experts, five were theoretical physicists, and five were experts in the properties and effects of explosives.

2.12 Lord Cherwell, Churchill's personal adviser on scientific matters, visited Los Alamos in October 1944.

2.13 Chadwick stayed in Los Alamos only a few months. His successor as head of the Mission was Peierls.

2.14 Apart from the consultants already mentioned, the British Mission staff consisted of the following: E. Bretscher, B. Davison, A. P. French,

O. R. Frisch, K. Fuchs, J. Hughes, D. J. Littler, Carson Mark*, W. G. Marley, D. G. Marshall, P. B. Moon, W. F. Moon (secretary), R. E. Peierls, W. J. Penney, G. Placzek, M. J. Poole, J. Rotblat, H. Sheard, T. H. R. Skyrme, E. W. Titterton, J. L. Tuck.

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*Although several members of the Mission came to Los Alamos via the Canadian and United Kingdom Laboratory in Montreal, all were attached to the British staff except Mark, who remained in the employ of the Canadian Government.

Chapter III

THE PERIOD APRIL 1943 TO AUGUST 1944, GENERAL REVIEW

General Administrative Matters

LABORATORY ORGANIZATION

3.1 The first period of the Los Alamos Laboratory's existence presented the problems common to organizational beginning: the definition of program, the division of responsibilities, and liaison. Of these the first has been discussed in the first chapter. The division of responsibilities follows that of the program: Experimental Physics, Theoretical Physics, Chemistry and Metallurgy, Ordnance. Each of these was organized as an administrative division, consisting of a number of operating units or groups. Group Leaders were made responsible to their respective Division Leaders, and Division Leaders to the Director. In a position of responsibility parallel to that of the Director was established a Governing Board. This consisted of the Director, Division Leaders, general administrative officers, and individuals in important technical liaison positions.

3.2 The building of the Laboratory was more than the planning and implementing of its technical work. Especially at first the Governing Board meetings were the only regular occasions for viewing in a general political way the many questions that appeared. As a center for planning and policy-making, the Board considered a wide variety of topics.

3.3 On the technical side the Board provided a means for relating the work of the different divisions, and for relating the program of the Laboratory to other Manhattan District activities. It heard reports of the latest nuclear calculations and measurements, and on the basis of these set basic specifications for Ordnance and Chemistry. As experimental and design data became available from Ordnance, the Board set fabrication requirements for the metallurgists to meet.

3.4 The progress of procurement and production was frequently reviewed, particularly of active materials and separated isotopes needed in the program. The Board supervised the liaison with other project laboratories on these and related matters.

3.5 For the first eight months perhaps two-thirds of the Governing Board's time was devoted to lay matters. Frequent topics were housing, construction and construction priorities, transportation, security restrictions, personnel procurement, morale, salary scales, and promotion policy. In most of these discussions, the Governing Board again provided a link, here between technical program and general administration.

3.6 The adversities of the first months are illustrated by a few very minor items chosen at random. In the first meeting of March 30, 1943, it was mentioned with some triumph that a calculating machine had finally been obtained, on loan from the Berkeley Laboratory. The scarcity of transportation is illustrated by the fact that a request for assignment of one pickup truck was brought, for decision, as high as the Governing Board. In May, the housing shortage was so serious that the Board took upon itself the assignment of the six remaining apartments.

3.7 The membership of the Governing Board was: Bacher, Bethe, Kennedy, Hughes (3.20), Mitchell, Parsons (7.3), and Oppenheimer. Later additions were McMillan, Kistiakowsky (7.55), and Bainbridge (7.4).

3.8 A short time after the beginning of the Laboratory, a Coordinating Council was established, whose membership was at the Group Leader level or above. In contrast to the Governing Board, the Coordinating Council was not a policy-making body, although at times policy problems were delegated to it; for example, the Coordinating Council was asked to establish criteria for deciding which members of the Laboratory should be classed as staff members with unrestricted access to classified information. Its meetings were generally informative rather than deliberative, consisting of reports of an administrative and technical character. Since its members were the heads of operating groups and were collectively in contact with all members of the Laboratory, it served also as a vehicle of general opinion concerning technical, administrative, and - on occasion - community affairs.

3.9 Divisions and groups, in turn, held their own regular meetings and seminars. These, together with informal discussions and regularly published reports, were the main vehicles of technical information in the Laboratory.

3.10 There was, finally, a weekly Colloquium which all staff members were privileged to attend. Staff members, as distinguished from other

Laboratory employees, were defined as those with scientific degrees or equivalent training in the field of their work, and therefore presumed capable of giving or receiving benefit in general discussions of the technical program. The Colloquium was less a means of providing information than an institution which contributed to the viability of the Laboratory, to maintaining the sense of common effort and responsibility.

3.11 Among all these channels of communication the Colloquium raised the most serious question of policy. From a narrowly technical point of view it was the least easy to justify; on the side of military security it appeared to present the greatest hazard. Regular attendance would give any staff member a generally complete and accurate picture of the problems and progress of the Laboratory. Just this, however, was its purpose. Any essential withholding of scientific information from the Colloquium would have defeated this purpose, and would have represented a compromise of basic policy. In practice, the relatively scientific and academic tone of Colloquium discussions made it possible to avoid mention of many matters of relatively small scientific, and relatively great tactical, value; where this was not possible the tactical value of information was sometimes lessened by omission of quantitative details. Despite these qualifications it remains true that the policy adopted concerning communication represented a considerable departure from the customs normally surrounding the protection of military secrets.

LIAISON

3.12 The last organizational problem, establishment of liaison, presented somewhat unusual difficulties, reflecting the complexity of Manhattan District organization. As the reviewing committee had pointed out (1.83), it was important that some machinery be established for the interchange of pertinent information between this and other branches of the project. The isolation of Los Alamos even from other branches of the project was a basic policy of the Manhattan District. Apparently it was difficult to separate the virtues of this isolation from its vices: the needed liaisons were achieved to any extent only after the most earnest representations.

3.13 The procedure established in June 1943 for liaison with the Metallurgical Laboratory at Chicago is fairly typical. Permission was given for the exchange of information by correspondence between specified representatives of the two projects or by visits of the Los Alamos representatives to Chicago. Information was restricted to chemical, metallurgical, and certain nuclear properties of fissionable and other materials. It was permissible for the representatives to discuss schedules of need for and availability of experimental amounts of U^{235} and Pu^{239}. No information could be exchanged on the design or operation of production piles, the design of weapons, or to permit comparison of schedules of need for and availability of production amounts of active materials. Three members of the Los Alamos Laboratory were to be kept informed of the time estimates for production of large amounts of these materials. In addition to the above, it was agreed that special permission would be granted by the office of General Groves for visits to Chicago by other members of this Laboratory to discuss specific matters.

3.14 As the program developed, a number of topics were of great interest to the workers at Los Alamos. Information was needed on the results of chemical and metallurgical research at the Metallurgical Laboratory and at the University of California and Iowa State College. This work was concerned with the chemistry and metallurgy of uranium and plutonium and methods for the analysis of impurities in these substances. Information was needed on results of nuclear research at the Argonne Laboratories at Chicago. It was important to know when materials would become available from the production plants at Oak Ridge (Site X), the form in which the material would be received, and the processing which it would have undergone. It was also essential to know the analytical procedures to be used by the production plants in determining the impurities and active content of this material.

3.15 The need for careful information on time schedules of production was the most urgent and difficult part of this problem. The estimates received during the first summer of the Laboratory were vague, incomplete, and contradictory, so that it was difficult to make sensible schedules of bomb research and development. The Governing Board in fact said that with the existing state of information scheduling was impossible, and that unnecessary delays would certainly result from this kind of blind operation. It was strongly urged by the Board that Los Alamos maintain a full-time representative at Oak Ridge. An agreement was finally reached in November 1943, by which Oppenheimer was permitted to visit the production plants at Oak Ridge. When material began to arrive at Los Alamos in the spring of 1944, the situation improved somewhat of itself.

3.16 The need for getting information required by the Ordnance and Engineering Division presented special difficulties. Most of this information had to be sought in agencies outside the Manhattan District. Knowledge of the purpose and even the existence of Los Alamos had to be concealed from them. Many devices were used: blind addresses, a Denver telephone number, NDRC identification cards. The office of Dr. Tolman, Vice-Chairman of NDRC, was instrumental in obtaining reports for this Laboratory on such subjects as gun-design, armor plating, explosives, detonators, bomb damage, etc. The liaison with Army and Navy Ordnance, and with the Army Air Force, will be discussed later (7.67ff and Chapter XIX).

3.17 Among the more troublesome and less obvious liaison needs were those required with the University of California and within Los Alamos itself. Although the work was to be carried out under a more or less standard type of War Department contract, the University of California was, in matters of policy, virtually unrepresented at the site. Security regulations and practices were such, moreover, that its officers were excluded from discussions of technical and administrative policy, and were allowed to concern themselves almost exclusively with a rather narrow range of legal and contractual affairs. At the Los Alamos site there were two administrative offices, that of the military and that of the Laboratory. Even though the division of labor was defined in a general way, most of the difficulties of dual organization had to be lived through before effective cooperation was established. Because of security policy, the officers charged with administering the community and post were for the most part in ignorance of the Laboratory's work. Thus, although the Manhattan District was the basic organization in the DSM project, its local military representatives were excluded from the sphere of Laboratory policy. Added to these difficulties, and complicated by them, were the troubles of life in an isolated and unpractised community.

3.18 Under such circumstances a very great administrative burden fell upon the shoulders of the Director. Whereas his primary responsibility was the success of the scientific program, it was equally his concern that this success not be jeopardized by extraneous difficulties. The administrative recommendations of the Reviewing Committee had been aimed principally at improving this situation. Apart from the specific difficulties of the procurement office, the committee's main concern had been the need to improve relations between the Laboratory and the Post Administration, and to relieve the Director of as many nontechnical administrative responsibilities as possible. At the beginning, the job of operating the project was taken over by a temporary organization of scientific staff members and technicians. The important thing was to avoid delay in research work. In the way stood a host of small problems: transportation, warehousing, procurement, planning of laboratory construction, and housing. The enthusiasm with which these jobs were undertaken was notable, as was the esprit that developed in the process. There was in it, nevertheless, an element of antagonism between the Laboratory and the military organization. However justified or unjustified this antagonism may in particular cases have been on either side, it set a general problem for the future. For those who have lived through the course of the project, what stands out is not this initial element of conflict, which only reflected the diversity of

American life, but the fact that through common purpose and by the measure of actual accomplishment, this conflict was reduced to secondary importance.

3.19 The members of the staff were considerably heartened by a letter which Oppenheimer read at a colloquium early in July. The letter dated June 29, 1943, was from President Roosevelt and said, in part: "I wish you would express to the scientists assembled with you my deep appreciation of their willingness to undertake the tasks which lie before them in spite of the dangers and the personal sacrifices. I am sure we can count on their continued wholehearted and unselfish labors. Whatever the enemy may be planning, American science will be equal to the challenge. With this thought in mind, I send this note of confidence and appreciation."

3.20 Apart from the business and procurement offices, the administrative organization of the Laboratory had only two officers other than the Director. These were E. U. Condon of Westinghouse Research Laboratories, and W. R. Dennes of the University of California. Of these, neither had fully determined to remain with the Project, and both did in fact leave, Condon in May, and Dennes in July of 1943. The reviewing committee had recommended the appointment of an associate director, and of an administrative officer to coordinate nontechnical administrative functions and to act as liaison with the Post Administration. It was possible to fill neither position at the time. Certain urgent requirements were met, however, by the appointment of new administrative officers. David Hawkins of the University of California came in May 1943 to take the position of liaison with the Post Administration. D. L. Hughes, Chairman of the Department of Physics, Washington University, St. Louis, Missouri, was made Personnel Director in June. B. E. Brazier, formerly of the T. H. Buell Company, Denver, came to the site in May to take charge of construction and maintenance. In January 1944, David Dow of the legal firm of Cadwalader, Wickersham and Taft, New York, was appointed Assistant to the Director, in charge of nontechnical administrative matters.

3.21 By July 1944, the Administration of the Laboratory was organized into the following groups:

A-1	Office of Director	D. Dow
A-2	Personnel Office	C. D. Shane (Assistant Director)
A-3	Business Office	J. A. D. Muncy
A-4	Procurement Office	D. P. Mitchell (Assistant Director)
A-5	Library, Document Room, Editor	C. Serber, D. Inglis
A-6	Health Group	Dr. L. H. Hempelmann
	Maintenance	J. H. Williams
	Patent Office	Major R. C. Smith

Personnel Administration

3.22 The administration of the Laboratory was faced at the beginning with a conflict of form and content. Because of the newness of large-scale organized research, there does not exist for it a class of professional scientific administrators. In the main a choice had to be made between a large administrative organization staffed with persons unacquainted with the peculiarities of scientific research, and a system by which the major share of administrative responsibility fell to the scientists themselves. Here again as with the engineering program it was partly a matter of expediency and partly of policy that the center of gravity remained in the scientific staff. The policy adopted meant, especially at the beginning, a gain of unity in the Laboratory. It entailed, undeniably, a loss of administrative efficiency.

3.23 The Personnel Office, in particular, illustrates these remarks. The Director, Hughes, was a physicist with administrative experience as Chairman of the Department of Physics, Washington University. The organization of the Laboratory was such that the Personnel Office was almost entirely dependent upon the representations of Divisions and Group Leaders.

3.24 Apart from its connection with the Divisions and Groups of the Laboratory in matters of employment and salary, the Personnel Office had charge of a Santa Fe office of the Laboratory (for receiving and employment), and of the Housing Office at the site. Under its jurisdiction fell personnel security, draft deferment, placement of military personnel assigned to the Laboratory, and certain miscellaneous matters. Although the scope of the present history does not include the affairs of the Los Alamos Community, the Laboratory became administratively involved in a number of these - particularly when, through their effects on the morale of the Laboratory staff, they had a bearing upon the success of the work. Although these matters were not all under the direction of the Personnel Office, they belong by their content to the present section.

HOUSING AND OTHER COMMUNITY AFFAIRS

3.25 One of the most urgent community problems at the beginning was the construction and organization of a school for the children of Los Alamos residents. There had been at the old Los Alamos Ranch School a small public elementary school for the children of its employees. In view of the Laboratory's small original size it was believed that the old building would be adequate for the project's elementary school, and that a high school could be established, making use of another of the original Los Alamos buildings. This plan soon proved unfeasible, and a school committee was appointed by the Director and the Commanding Officer, Col. J. M. Harmon, succeeded shortly thereafter by Lt. Col. Whitney Ashbridge. The committee made plans for a school building, and supervised the planning of curriculum and employment of teachers. The committee employed W. W. Cook of the University of Minnesota as consultant. A building to house the elementary and high schools was designed by Cook and Brazier. Construction was begun late in the summer of 1943, and by virtue of a high construction priority was completed in time for the opening of a fall school term. The committee was continued as a school board.

3.26 The elementary and high schools were operated as free public schools, salaries and procurement expenses being borne by the Government through the contractor. A nursery school, for which a building had been provided in the original plan of construction, was operated on a partially self-supporting basis. This school made possible the part-time, or more rarely full-time, employment of women with young children. In this case the financial deficit was also carried by the Government.

3.27 Another matter in which the Laboratory administration was interested was that of community representation in the civil affairs of Los Alamos. In June 1943, a "Community Council" was established and its members elected by popular vote. This superseded an earlier appointed committee. It was intended to be purely advisory in its function. In its first form it was a body elected only by the members of the Laboratory and their wives, and did not represent the entire community. It was advisory, not to the Commanding Officer, but to the Laboratory administration. In August 1943 a more representative council was approved by the new Commanding Officer, Lt. Col. Whitney Ashbridge, and the Laboratory Director. This council met with representatives of the Laboratory and the Commanding Officer. The Council was regarded by some as a thorn in the side of the community administration. At times it was. The council sought, however, to guide its deliberations and recommendations by the single standard of the success of the project. Sometimes its recommendations could not be carried out because of limitations of manpower and material. Sometimes the limitations derived from the customs of army administration. On the other hand many recommendations were accepted. Under the guidance of the council a system of small community play areas were built for the children of the Post. Traffic laws were written with the advice of the council, which also acted as a traffic court under a voluntary fine system. Other topics frequently considered were: the operation of post exchange, messes, commissary, milk supply, maid service, public transportation, and hospital.

3.28 A major community problem, which dogged and in many ways hampered the Laboratory from the beginning, was housing. Los Alamos was originally conceived as a small community of research scientists, more or less stationary in character, whereas in fact it developed into a large and complex industrial laboratory. Much of this development could not be foreseen, coming as it did from self-development of the research program. The housing problem was such as to put a constant drag upon the efforts of the Laboratory to get and keep an adequate staff.

3.29 Construction at Los Alamos was not easy. Growth of population strained power and water supplies. Construction was expensive of critical manpower and materials; the presence of a large group of construction workers put a further strain on community facilities. These difficulties, moreover, plus a constantly shortening period of amortization, necessitated corresponding cheapening of construction. To the shortage of housing, therefore, was added a troublesome inequality.

3.30 The drag upon Laboratory expansion caused by the difficulties of maintaining an adequate rate of housing construction is illustrated by the fact that it was twice necessary, and a third time almost necessary, to make use of outside housing facilities. It has been mentioned that at the very beginning of the project members of the Laboratory had to be housed temporarily in nearby "guest ranches." By the beginning of summer, 1943, the original housing accommodations were filled, and new housing was not yet provided. For the period of June 19 to October 17, therefore, the project acquired from the Park Service, and operated Frijoles Lodge at the Frijoles Canyon headquarters of the Bandelier National Monument, fourteen miles from Los Alamos. After its acquisition for the purpose by the Albuquerque District Engineers, Frijoles was operated under the jurisdiction of the Personnel Office. For this purpose the Laboratory obtained the services of S. A. Butler, Assistant Manager of La Fonda, Santa Fe, who later became Assistant Personnel Director. Frijoles Lodge was used again from July 17 to August 5, 1944, when the project faced another critical housing shortage.

3.31 Another facility in which the Laboratory had an administrative interest was the community hospital. This hospital was operated for the benefit of military and civilian personnel at Los Alamos, under the jurisdiction of the Chief of the Medical Section of the Manhattan District. The existence and excellent record of this hospital was an important contribution to project morale. Another important function of the hospital was its cooperation with the health and safety program of the Laboratory, whose work is discussed in detail in a later section (3.87ff).

SECURITY ADMINISTRATION

3.32 It would be difficult to exaggerate the security precautions that were taken at the beginning of the project, particularly in connection with personnel. During the early period, moreover, the administration of security policy was a matter of importance not only in safeguarding information, but also because of the effects of restriction on morale, and the possibility that serious breaches of security might lead to the imposition of even more stringent external control.

3.33 Formal clearance of personnel for work on the project was arranged through the Intelligence Officer stationed at the site. This procedure was slow and cumbersome, especially in the first months. In September 1943, a plan was approved to supplement clearance where necessary by an interlocking system of vouching for the loyalty and good faith of the members of the Laboratory.

3.34 The administration of security matters pertaining to Laboratory personnel and their families was delegated to Hawkins as Contractor's security agent, with the assistance of a security committee composed of himself, Manley, and Kennedy, meeting with the Intelligence Officer.

3.35 Recurring topics of discussion in the security committee were the pass and badge system, the monitoring of the Laboratory for classified material left unattended, the means of preventing classified discussions in the presence of outsiders, the publication and revision of security regulations.

3.36 The most irksome restrictions placed on the Laboratory staff were those affecting personal freedom. Travel outside a limited local area and any contact with acquaintances outside the project were forbidden except on Laboratory business or in cases of personal emergency. In the main these restrictions were accepted as concessions to the general policy of isolation. A small group thought they were not strict enough, and no one was satisfied with the working definitions of "personal emergency." The removal of these restrictions in the fall of 1944 was a cause of general relief after a year and a half of extreme restriction. Another feature of the security policy of Los Alamos was censorship of mail. This was unusual in itself, and amusing in the circumstance from which it began, namely, the suspicion of unannounced censorship. Not long after the Laboratory began, this suspicion spread as a rumor. A certain amount of evidence that letters had been opened was presented, varying considerably in quality. Once started, such a rumor would no doubt have spread in any case. The Director, who was in no position to guarantee that such censorship was not occurring, made strong representations to the office of General Groves. An investigation was instituted by General Groves, which brought a negative result. Under the circumstances, however, it was urged by many members of the Laboratory that official censorship be instituted and this was done in December 1943. Once begun, censorship did serve as a deterrent to the inadvertent spreading of information about the project, of a sort which might contribute to consistent rumors and continuing public interest in its activities. Censorship was carried on by a standard military censorship office located in Santa Fe, under the direction and with the advice of the Intelligence Officer, Captain P. de Silva.

SALARY POLICY AND ADMINISTRATION

3.37 The most pressing problem of personnel administration in the early months of the Laboratory was that of salaries. Salaries for scientific employees were determined by either of two standards. One standard was the OSRD scale, based upon scientific degrees held and number of years since their conferment. The other was the "no loss no gain" principle, with provision that individuals from academic positions, whose salaries are normally based on a ten-month year, be paid at twelve-tenths their previous rate. One source of difficulty was that men from industry had received a higher rate of pay than those from academic positions. Another was that technicians, men without academic degrees but often with considerable technical skill, had to be employed at the prevailing rates in this labor market. Although technicians ranked below the younger professional scientists, they often received higher salaries. A final difficulty was that a general commitment had been made to a policy of length of service and merit increases, but that no administrative mechanism existed to implement it.

3.38 The first major responsibility of Hughes, upon his arrival in June 1943, was to prepare a set of recommendations on salary policy, based upon a survey of this and other comparable laboratories. This statement of policy proposed within the regulations of the National War Labor Board a salary scale for the various classes of Laboratory employees, and a plan for wage and salary increases. According to this plan the younger scientists would be employed at a rate determined by the OSRD scale previously followed, and their rate of salary increase determined accordingly. No provision was made for increase of salaries above $400 per month, which were virtually frozen.

3.39 The proposed salary scale and schedule of increases was presented for approval to the Manhattan District and the University of California in June. Approval was, however, postponed. A further effort to obtain approval was made in October and again in December. At this time it was learned that certain formal changes had to be made because of changes in national policy. After appropriate modifications had been made, approval was further postponed until January, when a conference was held on the subject at Los Alamos. Approval was finally granted February 2, 1944, after a year of operation. During this period no system of promotion was possible, although the proposed policy was followed in determining the salaries of individuals newly hired.

3.40 The chief difficulty in matters of salary increase and promotion concerned the younger scientific group who had been hired under the OSRD scale. This scale, being based on length of time since conferment of academic degrees, made provision for an annual salary increase, which however would not be approved by the Contracting Officer, Lt. Col. S. L. Stewart, in the absence of an approved Laboratory salary policy. Inequities, as measured by the degree of responsibility and usefulness of various individuals, were numerous both within this OSRD group and between it and those who had been employed on a "no loss no gain" basis.

3.41 Final agreement about salary policy was not reached until the end of the war, but improvement resulted from a reorganization in July 1944 (3.56ff) at which time a new working agreement was reached.

DRAFT DEFERMENT

3.42 The Laboratory policy of draft deferment reflected its general personnel and security policies. Because of the absolute scarcity of trained scientists and technicians in the United States during the war years, every effort had to be made to prevent induction of men in these categories whose services were essential and satisfactory. It was desirable from the standpoint of security that the turnover of such personnel be kept at an absolute minimum. On the other hand, the requirements of secrecy made it impossible to give Selective Service any real information concerning the nature and importance of the Laboratory's program, or of the work of an individual. The average age of scientific and technical employees, moreover, was under thirty, which placed the great majority in the draft-vulnerable category. (See Graph 1 in the appendix section.)

3.43 Because of the very importance of the project, paradoxically, deferment of Laboratory employees was a matter of some complexity.

Dennes came to the Laboratory empowered to act in deferment matters as representative of the University War Council. The position was later assumed by Hawkins. By the time of his departure Dennes had rescued relations with Selective Service from the confusion unavoidable in the first days of Laboratory organization.

3.44 The most essential Selective Service liaisons were with the New Mexico State Director of Selective Service and the Selective Service Agencies of the Manhattan District. From the former the Laboratory enjoyed the utmost cooperation in all matters pertaining to Selective Service rules and policies, and their interpretation. From the Selective Service Office of the Manhattan District and from the Washington Liaison Office the Laboratory received the greatest consideration in difficult individual cases.

3.45 Most developments in draft deferment procedure were only technical and did not reflect a change of policy. As the war progressed and the needs of the Army and Navy increased, deferment requirements became more stringent. The Laboratory therefore depended increasingly upon official certification of its needs by the Manhattan District. In February 1944, the War Department adopted a policy forbidding the deferment of men under 22 years of age in the employ of the Department or its contractors. There was in the Laboratory a small but highly trained and essential group under 22. Under the circumstances they could not be deferred. When these men were inducted, therefore, there was no choice but to have them reassigned to the Laboratory as members of the Special Engineer Detachment.

PERSONNEL PROCUREMENT

3.46 Some mention has been made in Chapter I of the difficulties in staffing the original Los Alamos Laboratory. Its subsequent growth, moreover, was such that the working population doubled, on the average, about every nine months. Although a declining proportion of new employees were of scientific staff classification, the absolute number increased month by month until almost the end of the war. (See Graph 2.) At the same time the difficulty of finding competent scientists increased. The difficulty was greatest in the upper technician and junior scientist brackets. Senior scientists were needed in small numbers, and were usually well known to members of the Laboratory. They were, in many cases, anxious to join the Laboratory, and releases from less critical work, or in some cases from other Manhattan Projects, could be obtained through the efforts of the Washington Liaison Office. Junior men were needed in great numbers; recruiting trips to universities, however, were impossible because of security regulations. In November 1943, the assistance of Dean Samuel T. Arnold of Brown University was obtained in these matters. An arrangement was also made with M. H. Trytten of the National Roster of Scientific and Technical Personnel by which he could spend a part of his time visiting universities and employing young scientific personnel for the Laboratory. Trytten was of assistance to the Laboratory for a period of several months. Arnold remained as liaison in Washington in personnel matters throughout the course of the project.

MILITARY PERSONNEL

3.47 A small number of officers of the Army and Navy with scientific training were obtained at various times for work in the Laboratory. The largest group of military personnel in the Laboratory came, however, from the Women's Army Corps, and as enlisted men in the Special Engineer Detachment (SED). The latter detachment was originally established as a small detachment (about 300 for all Manhattan projects) in which men essential to the work of the Manhattan District could be placed in cases where deferments were no longer possible. At a time when junior scientific personnel were extremely difficult to find (November 1943), the Laboratory was informed that a group of new graduates of the Army Specialized Training Program would be available at the beginning of the year and could be assigned to the Laboratory in the SED.

3.48 Although it remained the basic policy of the Laboratory that its work should be carried out on a civilian basis, it had become clear that young civilians, of the type most urgently needed, were increasingly difficult to find. They were in fact being rapidly inducted into the Army, where in many cases their assignment would be less appropriate to their training than if they were transferred to the SED. The inconsistency and potential personnel difficulties involved in obtaining these men were fully appreciated. In view, however, of the Selective Service policy that resulted in the induction of many men from essential fields already seriously undermanned, there was no choice but to welcome into the Laboratory all technically trained enlisted personnel for whom civilian counterparts could not be found. From a tabulation made in May 1945, it was found that 29 per cent of all SED personnel held college degrees, including several Doctor and Master degrees. Most of the degrees were in the fields of Engineering, Chemistry, Physics, and Mathematics. (See Graphs 2, 3 and 4.)

3.49 In the case of the WAC detachment also, several competent scientists were obtained, as well as a larger number of technical and office workers. (See Graph 4.)

3.50 The personnel policy regarding enlisted men and women was in essence identical with that for civilians, with obvious adjustments. After arrival at the site and assignment to the Laboratory, all further matters of placement, job classification, transfer, and promotion within the Laboratory were under the jurisdiction of the Laboratory Personnel Office.

3.51 The establishment and rapid growth of the SED at Los Alamos brought a number of administrative problems connected with the morale, accommodations, and working conditions of the group. The most serious problem arose from the shortage of multiple unit housing, which made it impossible for the Post Administration to provide quarters for married enlisted men. Further, Major P. de Silva objected to the hiring (except as nurses) of the wives of enlisted men, although they could have been quartered in the dormitories for women workers on the project. Also security regulations made it impossible for them to bring their wives to Santa Fe or other nearby communities. Security restrictions against travel and association with persons away from the project worked therefore a very much greater hardship on enlisted personnel than on civilians, whose wives and children lived at Los Alamos.

3.52 Another problem was created by the fact that military promotions, which were the responsibility of the SED Commanding Officer, were also the only material means available for recognition of responsibility and excellence in technical work. The SED Table of Organization permitted promotion of one-third of the men to each of the grades T/3, T/4, T/5, with the provision that about one-tenth of those in T/3 could be promoted to the ranks of Technical and Master Sergeant. Since the great majority of the men arrived with a rank no greater than T/5, there was, at least in the first period, ample opportunity for promotion. The ground for and rate of promotion had, however, to be agreed upon between the SED Commanding Officer and the Laboratory, and for several months no such policy was firmly established or consistently followed.

3.53 A third difficulty arose from the conflict of military and technical duties. Although the official hours of work in the Laboratory were eight hours a day for six days a week, it was the practice of many groups in the Laboratory, particularly research groups, to work more irregular and usually much longer hours. This practice created conflict with barracks duties and formations.

3.54 The presence of other detachments (engineer and military police) required some consistency of treatment of the military personnel in accordance with the usual military organization. However, a number of steps were taken which improved the position of the SED, although they did not entirely solve its problems. In June 1944, general supervision of the military administration of SED matters was given to Major P. de Silva. As Intelligence Officer his work brought him into close connection with the Laboratory Administration. In August, the regulation forbidding travel and outside social contact was relaxed for military personnel in the Laboratory so that they might visit their wives and families on furlough. In August, also, Major T. O. Palmer was appointed Commanding Officer of the SED. A large part of the credit in maintaining SED morale under difficult conditions must be given to Major Palmer. A system of promotion recommendations by Group and Divisions was soon worked out which was satisfactory to him and to the Laboratory administration. The problem of conflicting duties was not and perhaps could not be solved adequately. The amount of overtime work done by many groups and individuals required essentially civilian conditions of life.

CONCLUSION

3.55 The Laboratory personnel department found itself confronted by an unusually broad range of difficulties. To the problems of a peacetime urban laboratory were added those of a special military and civilian community, the whole being complicated by a corresponding duality of jurisdiction.

3.56 The greatest single difficulty was undoubtedly that of salary policy. The facts as stated are by no means self-explanatory. As the matter appeared to those charged with personnel responsibilities at Los Alamos, the underlying reasons for these difficulties were somewhat as follows: The Laboratory did not enter the scene as a going concern, such as would have been the case with a large contracting corporation or a university operating with its own staff in its own plant. The University of California was, on the contrary, remote from the concrete problems of Laboratory administration. Both the general salary policy and its detailed administration, moreover, were under the supervision and subject to the direct veto of the Contracting Officer, Lt. Col. Stewart. He, however, on whom the responsibility devolved, found it impossible, because of his situation, to discharge it to the satisfaction of the Laboratory. He was stationed in Los Angeles where his services were urgently needed in connection with procurement matters (3.78): he had only general and over-all acquaintance with the problems of the Laboratory. Either of two conditions would have remedied the situation: (1) that the

Laboratory have a strong, well-organized personnel office, capable of representing its need with sufficient consistency, detailed justification, and vigor to compensate for the Contracting Officer's remote position; or (2) that the Contracting Officer be stationed at Los Alamos, where he would be in a position to understand the detailed needs of the Laboratory (cf 3.17, 3.22). As matters finally developed, it was the partial satisfaction of both conditions that tended to solve the Laboratory's salary problems.

3.57 In fact, by June 1944 it was apparent that a considerable administrative reorganization was necessary. Hughes' previous experience and Los Alamos function had been primarily in the building of a competent scientific Laboratory staff. The rapid expansion of the Laboratory and its ramification in many directions not covered by the term "research" created personnel problems of a new and different order. After a year spent in building up the scientific staff of Los Alamos and seeking to formulate and work out its personnel policies under increasingly difficult conditions, Hughes returned to his previous position at Washington University. His position was taken by C. D. Shane of the Radiation Laboratory, Berkeley. As his general assistant Shane brought Roy E. Clausen of the University of California. Armand Kelly, formerly at the Metallurgical Laboratory of the University of Chicago was brought as an expert in matters of salary and salary control. Hawkins, who had until this time been only loosely connected with the Personnel Office, was made responsible under Shane for draft deferment and for military personnel matters.

3.58 The most serious personnel problem at this time was still that of salaries. After reviewing the situation in the Laboratory in June, Shane had accepted the position as Personnel Director with the understanding that in matters of salary control he and his office would have a reasonable degree of autonomy, not subject to veto by the Contracting Officer except in terms of Federal salary policy and regulations. As was stated above, an agreement with the Contracting Officer to this effect was reached in July 1944.

Other Administrative Functions

BUSINESS OFFICE

3.59 In February 1943, shortly before the administration of the Laboratory moved to Santa Fe, the University of California appointed J. A. D. Muncy as Business Manager for the Laboratory. His responsibilities included all the normal activities of a business office, but security restrictions put quirks into its operations and added a number of unusual functions. For security reasons it had already been decided to locate the Purchasing Office in Los Angeles (1.12). It was considered desirable to have the Accounting Office physically connected with the Purchasing Office. For this reason a general business office in Los Angeles for the most part took over operations from the Business Office at the point where money was disbursed. Complete records of all transactions were kept in that office, and government and university audits were made there. In practice, however, a small account maintained in the Santa Fe bank for emergency purchases, travel advances, and for cashing personal checks for Contractor's employees reached considerable proportions. It was, in fact, the second largest account in the bank, and since it was in Muncy's name, he frequently received circulars from charitable organizations suggesting large contributions.

3.60 The "normal" functions of the Business Office were payroll control, issuance of travel advances and preparation of travel expense bills, procurement of materials on the emergency purchases fund, maintenance of records for workmen's compensation and for the California State Employees' Retirement System, to which employees of the University were obliged to contribute after six months of employment.

3.61 Scientific workers were not permitted to maintain accounts in the local bank to avoid giving the bank a list of Laboratory personnel. This rule was maintained for all monthly salaried employees. The Business Office at the site therefore made up the monthly payroll and forwarded it to the Los Angeles office where checks were written and mailed to the banks designated by the employees. However, in 1943 the Contractor employed a large group of laborers and construction workers who were paid on an hourly basis, and beginning in January 1945 the salaries of machinists and other shop workers were computed on an hourly basis. These payrolls were made up and checks written by the Business Office at Los Alamos. Approximate monthly payroll figures of $50,000, $160,000 and $175,000 for the months of June 1943, 1944, and 1945, respectively, indicate the tremendous growth of the staff of the project. The payroll for hourly workers in June 1943 was roughly $23,000; in June 1945 it was approximately $130,000. The figure for 1944 is negligible, covering substitute school teachers and some part-time clerical workers. (See Graph 2.)

3.62 In keeping payroll records at the site there was considerable difficulty with accurate records of attendance. The university procedure of having a supervisor certify monthly that all employees in his charge were present with the exceptions noted was not considered adequate by the Manhattan District. On the other hand, certifications by the Group Leader as to attendance by days and half-days was considered completely impractical by the direction of the Laboratory for a number of reasons: personnel was too scattered, particularly in those groups doing field work; scientific workers frequently worked at night though not on regular shifts. Scientific workers often worked a good deal more than 48 hours a week, and since the contract did not allow for overtime payments it was felt that deductions for absences could not reasonably be made. The only procedure used until September 1945 for the scientific and administrative staff was a negative report made monthly by each employee, without any Group Leader certification. Although this system was never considered satisfactory, it is probably true that a more rigorous control would have imposed an almost prohibitive administrative burden, and would have had an unfortunate effect on the morale of scientific workers who were actually giving more than 48 hours a week to project work.

3.63 Reimbursement for travel on project business was handled in the same manner as the payroll. Although advances were issued from the local account, travel expense bills were forwarded to the Los Angeles office and checks mailed from there to the bank of the payee.

3.64 The emergency purchases fund was used for materials for which it was not practical to route the request through the Los Angeles Purchasing Office, either because of the urgency of the request or because of the character of the materials. The bulk of the material purchased on this fund in 1943 fell into the former category, since it was mostly construction supplies needed immediately for work being done by the Contractor. The amount of disbursements from this fund in June 1943 was approximately $23,000, and in June 1944 it had dropped to $4,000. In the latter year the materials purchased were principally batteries, dry ice, and cylinders of gas, items not suitable for shipment from Los Angeles. In June 1945, during the preparations for the Trinity shot, some $38,000 were spent for miscellaneous items, ranging from radio tubes to canvas water bags, plus an increased volume of the normal batteries, gases, etc. Among the unusual purchases made with this fund were 88 cows which apparently had suffered radioactive burns during the Trinity test.

3.65 One of the first of the somewhat extraordinary duties of the Business Office was handling the financial end of the temporary housing mentioned in Chapter I. The cost of opening and operating the ranches used made the expenses to employees considerably greater than they would have been at the site. It was felt that the project should assume this extra cost, since housing was not ready at the site as had been promised. The Contractor therefore operated the ranches and billed each individual or head of family for the amount of his living expenses at the site (rent plus $25 per month per person for food). In all, five ranches were operated from the end of March to the end of May 1943 at a cost of some $7,000. Claims for damage to the temporary housing occupied by Contractor's personnel were also settled by the Business Office, with the assistance of the Contracting Officer.

3.66 Other unusual functions of the Business Office stemmed for the most part from the attempt to prevent a list of personnel accumulating outside the project. Thus personnel were requested not to cash personal checks in Santa Fe, and check cashing facilities were provided at Los Alamos. By 1945 the daily average of checks cashed was between $3,000 and $4,000. All personal long distance calls and personal telegrams were charged to a Business Office account, and the daily telephone bill increased from $57 in June 1943 to $745 in June 1944. When New Mexico income tax returns were due, the Business Office assigned a number to each employee, and reported to the income tax bureau the amount of income paid to that number in New Mexico during the year. The employee then used his number instead of his name on his return.

3.67 It can be seen from this brief account that the volume of work handled by the Business Office grew considerably beyond what had been anticipated. In spite of the limitation imposed by the availability of housing, the staff increased to some 15 people by mid-1945. It is clear, however, that the decision to keep the main accounting office in Los Angeles was a wise one, both because of the advantage of proximity to the Purchasing Office, and because its staff, which grew to some 70 people, would have required a housing project all its own at Los Alamos.

3.68 Because security regulations made it impossible for personnel to take out new life insurance and because of the extra-hazardous character of the work done at the project, the problem of providing insurance for employees proved extremely complex and was never adequately solved, although a long series of efforts were made by the Director's Office in cooperation with the Business Office. When the project was organized, employees of the technical area were covered by an OSRD health and accident policy covering injury, illness or death, placed with the Fidelity and Casualty Company of New York. In September 1943 this policy was replaced by Manhattan District Master Policy 1 with the Sun Indemnity Company, which offered additional benefits including extra-hazardous insurance. In July 1944 Master Policy 1 was replaced by Master Policy 2, with premiums to be paid by the individual or the contractor rather than by the government. Master Policy 3 provided for accidents not arising out of employment. At about this time there was considerable discussion of the fact that the extra-hazardous insurance policy in effect for people working on radioactive substances was inadequate, since no provision was made for the fact that injuries might not appear for 10 or

15 years after they were received. Eventually this problem was solved in part by a special arrangement made with the University of California. A fund of $1,000,000 was deposited with the University by the Government to be used for payment by the University with the consent of the Government of up to $10,000 for injuries resulting from a number of specified extra-hazards listed in a secret letter to the University. Statutory Workmen's Compensation of the State of New Mexico was provided by the Contractor for all persons assigned permanently to work in New Mexico. The total of claims paid under Workmen's Compensation through December 1945 was only $18,000, of which $12,000 covered death benefits for two laborers killed in a motor vehicle accident in 1943. Accident policies, essentially the same as Master Policies 2 and 3 which expired, were made available in September 1944 for purchase by individual employees. For some time there was no coverage for travel on noncommercial, nonexperimental aircraft used by project employees, but eventually this was covered by a personal accident policy with Aero Insurance Underwriters for civilian employees.

PROCUREMENT

3.69 The community's isolation created many problems but the most acute and serious of these were faced by the Procurement Office. Supplying a large research laboratory from the ground up is in itself a difficult task; doing this secretly, in wartime, 1200 miles from the nearest large market and 100 miles from the nearest rail and air terminal would appear to be an impossible one. Yet the Procurement Office succeeded in overcoming all the obstacles of time, space, and security, and in satisfying the exacting and apparently insatiable demands of the laboratory. The fact that the Laboratory was able to meet its tight time schedule is a tribute to the competence and efficiency of its Procurement Office, guided from the beginning by D. P. Mitchell of Columbia University.

3.70 In February 1943, Mitchell, Oppenheimer, and several other scientists met with representatives of the Army and of the University of California to discuss purchasing policies. At the insistence of the University, it was agreed that all matters of purchasing and payments would be administered directly by members of the University staff, and within their entire discretion as to appointees but subject to the general supervision of the Contracting Officer. In effect, this meant that while Mitchell was in charge of ordering materials for the Laboratory, the actual purchasing would be done by University appointees. This organizational complication brought with it an additional security complication - the University's purchasing office would have to be located in Los Angeles, and its employees would not be permitted to come to Los Alamos to deal directly with persons placing orders, or to know anything about the work of the Laboratory.

3.71 At about this time, the basic policies which were to govern Mitchell as Procurement Officer were outlined. He was to be guided primarily by the necessity for speed and was not to be held responsible for the kind or quality of items to be purchased. He was to be authorized to place orders by requisitions signed by qualified members of the scientific staff, such requisitions to show quantity, description of item, date required, urgency, and suggested source. On the basis of the ordering individual's statement of urgency, Mitchell would judge the degree of priority required, and the means of communication and transportation to be used in order to meet the delivery date. Primarily the policy of the Procurement Office was to supply the needs of the technical staff as promptly as possible, and with as little red tape as possible. On the whole, this policy was maintained successfully.

3.72 A great many things had to be ordered before the Laboratory could begin to function, and until the Los Angeles Purchasing Office was established, such purchases were made through the Purchasing Office of the Radiation Laboratory at Berkeley.

3.73 The Los Angeles office was organized by D. L. Wilt and was in operation March 16, 1943. After September 1943, A. E. Dyhre was in charge of this office. In early discussions about procurement it was proposed that branch purchasing offices be established in New York and Chicago, to be subordinate to the Los Angeles office. These were set up in April 1943. Except in cases of unusual emergency the Laboratory's Procurement Office dealt directly only with the Los Angeles Office, either by mail or teletype. Requisitions for items not readily available in the Los Angeles area were forwarded to the New York and Chicago branches from Los Angeles. The three offices together employed a total of about 300 at their peak, including 33 buyers and 22 expediters. An average monthly dollar volume was about $400,000, covering an average of about 6,000 items purchased. However, in the peak month (May 1945) these figures were over a million dollars for more than 10,000 items. (See Graph 7.)

3.74 A certain amount of local purchasing was permitted. At first "local" was defined as a radius of 500 miles including Denver, but as security restrictions tightened, "local" was limited to a radius of 100 miles, including Albuquerque. Originally local purchases were intended to satisfy only emergency needs for items not obtainable in time through normal channels, and authorization for such purchases had to be secured from the

Business Office. Later, however, local purchases became a regular function of the Procurement Office, and included not only emergency items but also many bulk items such as fuel and building supplies, which could be purchased advantageously from local suppliers. In no case was it possible to place items on back order or ask local vendors to place orders for the Laboratory. For security reasons, purchases were made in Muncy's name. The Post Supply Section, under the able direction of Major Edward A. White, was frequently called upon to supply various items for the Technical Area. A system was set up whereby the Technical Area could requisition on Major White's office and this channel of procurement was of no small help to the technical work.

3.75 As has been mentioned before (1.17), the first groups of scientists brought with them a cyclotron, a Van de Graaff generator, a Cockcroft-Walton accelerator, and a certain amount of electronic equipment. Aside from these things, there was nothing at Site Y to constitute a laboratory. Most of the scientists had come from universities where they had fairly well-equipped laboratories and stockrooms which had been building up supplies in specialized fields for years. Within a few months, the Procurement and Purchasing Offices had completely to equip physics, chemistry, and electronics laboratories as well as machine shops, and also to prepare stockrooms of supplies for these laboratories and shops. The range of materials required for this task was incredibly great - everything from women's work clothes to 10-ton trucks. It has been stated, without exaggeration, that in variety of items the requirements of this laboratory exceeded those of Bell Laboratories, one of the largest research organizations in the world. The Procurement Office bought such things as rats, meteorological balloons, sewing machines, restaurant equipment, jeweller's tools, and washing machines in addition to what might be considered standard items of shop and laboratory equipment. At the time the Procurement Office for site Y was organized, early in 1943, the nation's industry had been thoroughly converted to war production. Stockpiles were running low in many items considered standard for research laboratories but not important for any other wartime use. Some things were almost completely unavailable; others could be secured only with high priorities. Project Y was assigned AA-1 priority by the War Production Board (WPB), but often it was necessary to request the District's help in securing higher priority or a WPB directive for particular items. The Procurement and Purchasing Offices succeeded in having equipment on hand almost as soon as there were buildings to house the various laboratories. Stockrooms were ready in short order - one for chemical supplies - K stock, one for general laboratory supplies - S stock, one for special electronic supplies, and one for each of the shops.

3.76 Once the various laboratories were established, the task of the Procurement Office became that of meeting the continuing demands of the scientific and technical staff for equipment and keeping stockrooms adequately supplied. Responsibility for the electronic and shop stockrooms was turned over to the various operating groups. The duties of procurement could never become routine, because of the Laboratory's continuous expansion and because of the constant and necessary changes in the technical program. Since the Laboratory was operating on a rigid time scale, time was always the most critical factor, and shipping instructions made by the Procurement Office on requisitions sent to the Purchasing Office were often extremely important. Occasional failure of the Purchasing Office to carry out shipping instructions precisely was one of the minor sources of friction between the two offices. On several occasions the Procurement Office was obliged to re-order by air express an item that was being shipped by freight contrary to instructions. Waiting for freight delivery would have meant holding up vital experiments that would cost much more in time and money than the cost of duplicating an order.

3.77 Second only to time in importance was the question of security, and this too caused innumerable difficulties to the Procurement and Purchasing Offices. For security reasons Site Y was located far from any large city, and therefore separate purchasing offices had to be established in marketing centers. For security reasons, the employees of these purchasing offices could have no direct contact with the using groups at the Laboratory, could know nothing about the work of the Laboratory, and therefore could not understand its significance or appreciate the urgency and responsibility of their own work. Employees of the Chicago and New York offices dealt directly only with the Los Angeles office, except in emergencies. For security reasons, using groups were almost never able to deal directly with manufacturers and dealers; when questions about design or fabrication arose, these questions had to be transmitted through the New York or Chicago Purchasing Offices to the Los Angeles Purchasing Office, from there to the Los Alamos Procurement Office, and finally to the using groups; the answer had to be sent back along this same path to the supplier. For security reasons no direct shipments could be made to Site Y; all suppliers were instructed to ship goods to Chicago and Los Angeles warehouses, from where they had to be transshipped to Y with their original labels removed in order to prevent unauthorized persons from learning what kinds of things were being received. Originally the Los Angeles and Chicago warehouses did nothing but transship orders, and the Site Y warehouse checked shipments and approved invoices. Because of government regulations insisting upon prompt payment of bills to avoid loss of discount, procedure was changed so that invoices were checked against shipments at Los Angeles and Chicago and approved there. This procedure led to minor difficulties: goods would be received that were neither usable nor returnable, items would be missing from the shipment but checked on the invoice, packages of photographic film would be opened for inspection.

3.78 Periodically, technical groups in the Laboratory submitted criticisms of the Los Angeles Purchasing Office to the Director, and periodically the Director would transmit these criticisms to the appropriate Army and University officials. The theme of most of these criticisms was that the Los Angeles office was staffed by inefficient and inexperienced buyers. For some time these offices were seriously understaffed, and some of these criticisms may have been justified; on the whole, however, circumstances made unavoidable much of the apparent inefficiency. The University and the Purchasing Office maintained with considerable justice that much of their difficulty was directly traceable to the strict security regulations under which they operated. Statistics compiled from time to time by the Contracting Officer, Lt. Col. Stewart, on the efficiency of the Purchasing Office show fairly commendable results. To some extent the criticisms of the Purchasing Office by using groups in the Laboratory were caused by their isolation from and unfamiliarity with the actual state of the market. They had come from universities whose equipment had largely been purchased under peacetime conditions, when time was not at a premium and manufacturers' catalogues actually represented stock on hand. During the war many manufacturers stopped publishing current catalogues, and those catalogues which were available in no way represented existing conditions. Men had been in the habit of designing apparatus, starting to build it, and then ordering parts they did not have on hand. This habit nearly proved disastrous on several occasions. For example, one group designed a special kind of camera to be used in connection with the Trinity test, proceeded to work on construction, and ordered necessary parts. After the work was well under way, the group was notified that the particular lenses they had ordered were not on the market, would have to be ground to order, and might not be ready in time to be useful. Also, the particular kind of plate backs which they had incorporated into the camera design were no longer available on the market and were not being manufactured. Purchasing Offices scoured the country, and succeeded in finding about one-third of the required number of plate backs. To secure the rest, it was necessary through the Washington Liaison Office to get a WPB directive ordering the former manufacturer of these items to stop his current production and make the necessary amount for the Laboratory. The cameras were ready in time for Trinity, but only after a tremendous expenditure of effort by all concerned. Such incidents were not frequent, but serve to illustrate some of the difficulties encountered by the Purchasing

Office. From the very beginning, the Procurement Office had made an effort to teach the using groups the importance of finding out about the availability of certain materials before completing designs and starting work, but it was difficult to change old habits and difficult for men to realize that a small loss of time spent in studying the market might mean a large saving of time in completing a satisfactory piece of equipment.

3.79 Just as the Laboratory groups were hampered by their unfamiliarity with the state of the market, so the Purchasing Offices were hampered by their unfamiliarity with the kind of work being done at the Laboratory. Knowing nothing about the work, they could know nothing about the uses for which particular items were needed, and therefore could not understand which specifications were critical and which were simply listed for convenience. A buyer in New York receiving an urgent request for some item ordinarily made of metal might be notified by the manufacturer that other users were accepting wartime substitutes made of plastic. The buyer would see no obvious difficulty with this substitute - no reason to ask the Los Angeles office to check with the Y office to check with the user - and would place the order. He could not be expected to know that for the scientist's purpose, size, color and shape were convenient but not indispensable, whereas the chemical composition of the material was the one all-important criterion. Such incidents occurred again and again, and the only possible solution was to have members of the technical staff make their specifications as complete and explicit as possible without revealing the nature of their work. The local Procurement Office made a serious effort to have the using groups prepare accurate and complete specifications, and the Procurement Office itself checked such specifications closely before transmitting them to Los Angeles.

3.80 The organization established at Y to handle some of the complex problems outlined above was in itself rather simple. In accordance with its policy of eliminating red tape and supplying the Laboratory as quickly and efficiently as possible, Mitchell organized his department into two main sections - Procurement, under the supervision of E. E. Olsen, and Service and Supplies under the supervision of H. S. Allen. The Procurement Section consisted at first of two groups, Buying and Records. Later a third - Property Inventory - was added. The Buying Group was responsible for checking specifications on purchase requests, suggesting a possible manufacturer or vendor to the Los Angeles office, justifying high urgencies, and answering questions initiated by the Los Angeles Purchasing Office. Essentially the local buyers existed to give the Los Angeles buyers the information they required to purchase the things needed at the Laboratory. The Records Group was responsible for maintaining files of correspondence and purchase requests, and also Kardex files of expendable and nonexpendable goods on hand. When one understands that for every purchase request an average of sixty pieces of paper was involved, including printed forms and teletypes, the importance of the Records Group becomes evident. The Kardex files were later transferred to the Property Inventory Section (9.24). The Service and Supplies section consisted of four groups - the stockrooms, receiving, shipping, and records. Originally one man was in charge of all the stockrooms - the general laboratory supply, the chemical supply, electronic, machine shop, and a few small specialized supply rooms. The Receiving Group was responsible for opening packages, identifying items with purchase orders, and directing distribution either directly to Laboratory groups or to the appropriate stockroom. The Records Group maintained files of purchase orders for follow up purposes, files of stocks on hand, and various receiving record files.

3.81 Certain special procurement channels by-passed the University Purchasing Office in Los Angeles. These concerned parts for the completed bomb-mechanism, materials including uranium and plutonium coming from other branches of the project, and materials obtained directly from the Army or Navy such as electronic components and completed devices of an electronic nature, guns, propellants, and high explosives.

LIBRARY AND DOCUMENT ROOM

3.82 One of the minor but extremely important groups in the Laboratory was the Library. No research laboratory can exist without a library well stocked with standard technical reference works, files of technical journals, and reports of work in progress, especially when that laboratory is isolated from all other universities and libraries. The Los Alamos library served its purpose well, and was one of the few administrative groups in the Laboratory about which there were substantially no complaints from the scientific staff. The library was organized and directed by Charlotte Serber.

3.83 Like the Procurement Office, the Library faced the problem of providing in a few months a comprehensive collection of books and journals on physics, chemistry, engineering, and metallurgy that had taken other libraries years to accumulate. A large part of this initial problem was solved by loans, chiefly from the University of California library. A tentative list of book requirements submitted by various staff members planning the laboratory consisted of approximately 1200 books and 50 journals (complete files from 1920 for the most part). Many of these were impossible to secure on the market, but fortunately the University library was able to supply nearly all of the rare out-of-print titles. New publications were bought, but only through a circuitous route, because of security restrictions. Orders from the Los Alamos Library were sent to a forwarding address in Los Angeles, and from there to the University library in Berkeley; from Berkeley, orders were placed with book publishers and dealers to be sent to the Los Angeles receiving warehouse, and from Los Angeles the books were forwarded to Los Alamos. By July, 1945, the Library included approximately 3,000 books, 160 journals per month, and 1500 microfilm reproductions of specific articles and portions of books.

3.84 The largest part of the Library's work, however, was that of reproducing and distributing reports of work in progress. For this purpose, the Library staff included two small subgroups, known as the workshop and the document room. The workshop typed, reproduced, and assembled technical reports and manuals submitted by the various scientific groups of the Laboratory. The workshop group collaborated very closely with the editorial section and with the photography and photostating shop. Completed reports were turned over to the document room for distribution in accordance with security regulations, since nearly all of the work of the project was classified. The Laboratory's guiding policy for distributing information among its own workers was simply that in no case should information be withheld from anyone who could work more effectively if information were in his hands, or who would be in a better position to maintain a high level of security in his possible dealings with outside workers if he were more fully informed. To carry out this policy, the document room of the Library was supplied with a list of personnel entitled to have access to all or certain catagories of classified documents, and this list was kept up to date by advice from group and division leaders. In general, comparatively few documents were distributed to individuals; the majority were kept in the document room to be read there or borrowed temporarily by qualified persons. In addition to maintaining a complete and current file of Los Alamos reports, the document room kept a file of documents received from other Manhattan District projects. Some notion of the amount of work handled by the document room can be gained from the fact that by January 1945 there were 6090 reports on file, exclusive of extra copies of the same report, and that approximately 10 per cent of the total circulated each week.

3.85 Among minor duties of the Library was that of instructing the secretarial staff in the preparation of reports for reproduction, and the handling of classified documents. In January 1945, the library document room assumed from the Patent Office (3.123) the duty of issuing patent notebooks, keeping a record of notebooks issued, and collecting them from individuals upon separation from the project.

EDITOR

3.86 From the beginning the Los Alamos Laboratory produced large quantities of reports. Whole fields of research were amplified by the results of work done here so that regularly published papers in these fields were made obsolete, and reports written here became standard reference works for this and other Manhattan District projects. It was therefore necessary to have experimental results reported speedily and accurately in a form that would be readily accessible to other employees requiring the information for their own work. It soon became apparent that responsibility for the editing and reproduction of all reports should be centralized to insure accuracy as well as speed. Early in 1943, D. R. Inglis of Johns Hopkins University was appointed Project Editor. All reports of completed work (known as documents) or of work in progress (known as manuscripts) which were to be reproduced in any form went through the office of Inglis. The reports were checked thoroughly from both a technical and editorial point of view. An appropriate form of reproduction was then selected, and when finished they were routed to the workshop or photostating shop. Through Inglis' efforts the Laboratory was assured a series of technically accurate, and editorially consistent, reports of work completed and in progress.

HEALTH AND SAFETY

3.87 A Health Group reporting to the Director was part of the Laboratory administration from the beginning. Throughout the present history this group was under the supervision of Dr. L. H. Hempelmann.

3.88 Health problems of the Laboratory may be classified as (1) standard industrial health and safety problems, (2) the definition of health standards in relation to special hazards, (3) the establishment of safe operating procedures, and (4) routine monitoring and record keeping. At the beginning all of these were part of the Health Group's responsibility with Dr. Hempelmann acting as chairman of the Laboratory's Safety Committee. By April 1944 this committee felt that it had become too unwieldy to handle effectively the increased safety problems resulting from the rapid growth of the project, and suggested that the Director accept its resignation and organize a new committee better qualified to handle the problems. Mitchell, Procurement Office leader, became head of the new committee whose function was defined to be supervision of all safety installations, inspections, and activities connected with the Technical Area and the outlying sites. This was to include fire, general safety, and maintainance as well as technical safety. Dr. Hempelmann remained a member of the committee representing the Health Group. Later the execution of safety policies was taken over by the Safety Group under a full-time safety engineer (9.37). The establishment of safe operating procedures and routine monitoring and record keeping remained under the Health Group's general jurisdiction, but such duties were delegated, wherever possible, to the operating groups or appropriate subcommittees of the Safety Committee.

3.89 The central responsibility of the Health Group was the establishment and dissemination of health standards, specifically, of safe tolerance levels of exposure to radiation and to radioactive and chemical poisons. In this and in its general supervisory work, the group was concerned primarily to protect the health of Laboratory employees. Secondarily, it sought also to protect the legal interests of employees and of the Contractor. To this end it kept records of the hazards to which individuals were exposed, the extent of exposure, accidents, and tests for overexposure. In addition it obtained and recorded pre-employment medical examinations for all technical personnel. It made complete examinations, including necessary tests, of all employees on termination. Ordinary industrial accident records, however, such as shop injuries, were kept by the Post Hospital.

3.90 In the original plan of Laboratory activities it was assumed that biological and physical research related to health problems would be entirely the responsibility of other laboratories within the Manhattan District. Reliance on the work of others did not, however, always provide necessary information at the time it was needed. Research sections were set up as needed within the Health Group or by its request in other groups. Thus the development of apparatus needed for monitoring was undertaken at Los Alamos in the spring of 1944, and a large share of the instruments were built in the Electronics Group. Again, in August 1944 it became necessary to investigate biological methods of testing for overexposure to radioactive poisons, and this work was undertaken by a section of the Health Group (9.30).

3.91 During its first year the work of the Health Group was relatively uncomplicated. A semi-research problem which appeared almost immediately was to discover the extent of variation in normal blood counts. It was discovered that variations which were at first thought symptomatic of overexposure to radiation were, in fact, common in normal blood.

3.92 Operation in this period was confined largely to the hazards of external radiation from accelerating equipment and radioactive sources. The danger of heavy-metal poisoning from uranium had to be guarded against, as did other chemical hazards, but these problems were not serious.

3.93 The really serious problems of the Health Group appeared in the early spring of 1944, with the arrival at Los Alamos of the first quantities of plutonium. The nature of these problems is suggested by the following brief account of the toxicology of plutonium.

3.94 The metabolism of plutonium is similar to that of radium in that it is deposited in the bone where its alpha radiation may cause bone sarcoma. But while radium is deposited with calcium in the living bone, plutonium is deposited in the surface membranes of the bone, and is presumably not overlaid by subsequent calcium deposition. Among other body organs the heaviest deposition occurs in the kidneys, where in sufficient quantities its radiation causes destruction of tissues responsible for kidney function. This effect, however, will not become serious except for dosages considerably greater than those needed (over a sufficient period) to cause bone injury. Another unfavorable circumstance in the comparison of plutonium with radium is the much slower rate of elimination from the body in the case of plutonium. In compensation for these bad qualities, plutonium has a much lower alpha activity than radium, and is less easily absorbed from the digestive tract. In general, the problems of handling plutonium are comparable with those of handling radium, with the allowances for the vastly larger quantity of the former material that is processed, and for the fact that empirical information on the toxic effects of small amounts over a 10- or 20-year period is not available.

3.95 Although not all this information was available at the time, the general similarity with the radium hazard had just been discovered; as a result Hempelmann and representatives from Chicago and Oak Ridge visited a luminous paint company in Boston to learn how the radium hazard was handled in that industry. On his return three committees were established in the Chemistry and Metallurgy Division to develop methods for control of the plutonium hazard. An instrumentation committee was appointed to design counters suitable for measuring the radioactive contamination of laboratories and personnel. A second committee was responsible for the design of apparatus and equipment for handling plutonium. Apparatus was designed by this committee in consultation with the chemists concerned, and was built or procured by the Chemistry and Metallurgy Service Group. A third committee drew up rules and recommendations for the safe handling of radioactive materials. The procedures recommended were put into effect in March 1944, with the understanding that willful noncooperation would result in immediate dismissal from the Laboratory. A section of the Service Group was established under W. H. Popham to enforce these procedures. It had the positive functions of providing personnel with proper protective equipment, laundering this equipment, monitoring the laboratories and decontaminating them when necessary, and of keeping complete records. The group worked very closely with the Health Group.

3.96 In addition to organizing the safety measures described above, the Health Group carried on an extensive educational campaign among the groups working with plutonium. Lectures were given on the toxicology of plutonium, and numerous conferences were held with operating groups to work out the application of general recommendations. The Health Safety Handbook was given new members of the Division.

3.97 Despite these precautions the members of the Health Group and of the Chemistry and Metallurgy Division were not satisfied with the progress of biological studies on plutonium made by the other projects responsible for this work. This dissatisfaction was crystallized by an accident which occurred in August 1944, when by a minor chemical explosion a number of milligrams of plutonium were thrown in the face of one of the chemists. A research program was undertaken, aimed primarily at developing tests for detecting overdosage of plutonium (9.30).

3.98 Another continuing difficulty was the lack of adequate monitoring equipment. Alpha ray counters lacked either sensitivity or portability, and were not received in adequate numbers. The lack of sensitive portable meters made it necessary to wipe surfaces suspected of contamination with oiled filter paper and to measure the activity collected with stationary counters. Contamination of hands and nostrils was measured in the same fashion. Because instruments received from Chicago did not meet the local monitoring requirements, development of such equipment was begun in the Electronics Group of the Physics Division in May 1944 (9.31).

3.99 One further activity of the Health Group in this period was the control of the danger of poisoning in the work of high explosive casting. Standard protective measures were put into effect, and no serious trouble was encountered in the period covered by the present history. The medical group performed monthly examinations of all exposed personnel and gave periodic lectures as to the dangers of toxic effects from high explosive work. The education of the workers was aided by the fact that all of the plant supervisors were seasoned in this type of work. The number of cases of TNT dermatitis was in keeping with the number exposed. This is an allergic reaction which cannot be entirely prevented in any plant operation.

SHOPS

3.100 The principal shop facilities of the Laboratory were machine shops, drafting rooms, a glass shop, and photographic shops. Although for the most part these were service groups of a standard type, it was true at least of the machine shops that they encountered a number of administrative and technical problems of an unusual kind. Although the machine shops did not become part of the Administrative Division until after the general reorganization in September 1944, they are discussed in this chapter because their problems were related and can be more logically treated here than under the separate Divisions in which they were organized at first.

3.101 In the original program of the Laboratory, plans were made for a drafting room and machine shop (known as V shop), for the design and fabrication of laboratory tools and instruments, primarily to serve the Experimental Physics and Chemistry-Metallurgy Divisions. The glass shop was an adjunct of the Chemistry groups. Two photographic shops were added during 1943, one mainly for routine recording and duplication, the other as an adjunct of the ordnance research program, responsible for technical photography and a considerable program of optical research (15.48).

3.102 After the beginning of the ordnance program, additional plans were made for an ordnance drafting room and large ordnance machine shop (later called C shop). A number of small student shops or special shops were built at various times. The largest of these was the Graphite Shop of the Miscellaneous Metallurgy Group (8.52).

3.103 Responsibility for organizing the first shops was assumed on an interim basis by Mack (1.15). The Laboratory was fortunate in obtaining Gus H. Schultz, from the University of Wisconsin Shops, as foreman of the Laboratory shop (V shop). Schultz was not only thoroughly familiar with the requirements of a laboratory shop, but also had a substantial background of industrial experience.

3.104 The original area of V Shop was 8000 square feet, planned for 30 toolmakers and machinists, representing an expected shop load of about 1500 man-hours per week. This goal was reached in October or November of 1943, by which time, however, the goal had been set considerably higher. (See Graph 10.)

3.105 In July 1943 Mack resigned as shop supervisor and set up the Optics Shop and research group in the Ordnance Division. His place was taken by E. A. Long, head of cryogenic research in the Chemistry and Metallurgy Division.

3.106 In March and April of 1944 some rescheduling of shop work became necessary, because of the rapidly increasing load in V Shop. At that time about half of the load came from the Chemistry and Metallurgy Division, whose requirements were rapidly increasing. This problem was met by shifting some of the Metallurgy work to C Shop, and in May adding about 500 square feet to V Shop. Introducing a night shift would have been an alternative, but it was difficult at the time to find machinists willing to work in the night shift.

3.107 Three examples may be given of outstanding fabrication problems solved in V Shop. One was the fabrication of beryllium oxide bricks for the Water Boiler (13.29): the dies were developed in V Shop as well as the technique of facing the bricks. Another was the development of apparatus and technique for welding the thin stainless steel envelopes of the Water Boiler. Another was the machining and grinding of tungsten carbide. In all cases the primary responsibility was borne by the operating group, but the actual development work was done by shop personnel.

3.108 Construction of C Shop was begun in July 1943 and completed in October. Its area was 8800 square feet, planned for about 40 machinists and toolmakers, representing a load of about 2000 man-hours per week. Its foreman was Rex Peters, under the supervision of C. Cline.

3.109 The career of the experimental shop was relatively smooth and harmonious, while that of the ordnance shop was full of crises. Some of the reasons for this contrast came from the nature of the work of each. The experimental shop was organized after a familiar pattern, staffed and supervised by men with adequate training and experience. C Shop, by contrast, was designed for a type of work that was not completely anticipated. Both the equipment and personnel proved inadequate to the demands that arose. By the time the difficulties were fully appreciated, the rate of growth of the Laboratory had become so large that it was impossible fully to overcome the existing lag.

3.110 In May 1944 Cline was transferred to the Engineering Group, and his place was taken by W. M. Brower. Whereas Cline had relatively little experience in shop supervision, Brower was a man with considerable experience in handling difficult shop situations in Berkeley and Oak Ridge, who it was thought would be able to represent shop needs and problems in the councils of the Ordnance Division. Brower obtained support for the rapid procurement of needed equipment and made some reorganization of shop procedure. Despite these efforts the problems of C Shop deepened, and Brower left the Laboratory in the middle of August 1944.

3.111 The nature of the C Shop difficulties may be illustrated in three ways. The first point is that very little of its work was routine production. Most items were produced singly or in small lots. Every item had to be given detailed specifications in the engineering drafting room. This created an enormous load of work and involved close cooperation between detailers and the scientists preparing rough drawings. This is a common problem in laboratory shops, where as a result machinists become very skilled at working from rough drawings supplemented by informal consultation with users. In C Shop this was impossible because of its size and because few of the machinists had the necessary training. The result was more or less constant complaint about delays in the drafting room and inadequate checking.

3.112 A second symptom of inadequacy was that even a rigid priority system was insufficient to prevent delays of urgent work. There were constant small irritations connected with this priority system, in deciding for example between two such unrelated programs as the gun and the implosion.

3.113 Lack of experience with peculiar fabrication problems added to the difficulties. As one example, the machining of hemispheres may be mentioned. The implosion program called for a large number of hemispheres of various materials and sizes. A 60-inch lathe was acquired for turning large hemispheres, which proved useless for this work. Peters finally solved the problem of producing these hemispheres with a specially rigged boring machine. Eventually, the lathe was needed for other jobs; the point is that none of Peters' immediate superiors knew how this work, which is nonstandard, should be done.

3.114 As the above illustrations would suggest, the problems of C Shop had their roots in the more general difficulty of developing an adequate Ordnance Engineering Group. Although the shop had a competent foreman, he was not in a position to overcome the general lack of foresight in obtaining men and equipment. This lack, moreover, was not solely the responsibility of Peters' superiors in the Engineering Group; these were in a poor position to understand the emerging needs of the ordnance research and development groups, who in turn were not yet geared to their role as weapon designers (1.53).

3.115 It is not true, however, that the shop and engineering difficulties were inseparable. They were connected primarily because of organizational arrangements. The original plan, by which the C Shop was placed under the Engineering Group of the Ordnance Division, was plausible in terms of the contemplated narrow range of the ordnance program. As that program broadened out to include not only the gun program but also the rapidly expanding implosion program, such arrangements became less plausible. The C Shop became in fact a service organization doing work for a number of semi-independent organizations. Throughout the Laboratory the emphasis of work began to shift toward development work. The line of division between the two big shops became less well defined. In the end, therefore, it became clear that the proper remedy for shop troubles was to place both C and V Shops under unified management. This would not only make for greater flexibility in the division of labor between shops, but would also give to C Shop the strong leadership needed to overcome its constant difficulties and to prepare it for the even more difficult days ahead. Such a step, moreover, would simplify the remaining problems of the Engineering Group, being a step away from the conception of the latter as a key administrative organization, and toward concentration on the increasingly difficult problems of design-development, of engineering in the narrow sense.

3.116 At the time of the August 1944 reorganization, accordingly, the C Shop was moved from the Ordnance Division to the V Shop administration of Long and Schultz.

CONSTRUCTION AND MAINTENANCE

3.117 Some of the construction problems have already been described in Chapter I, and in particular the construction situation at the time Laboratory personnel began to arrive. The procedure used for the construction of the original buildings was standard for Army installations. Specifications for the original buildings had been given to the Manhattan District Engineer's Office in New York by Oppenheimer, McMillan, and Manley. Plans were drawn by the Stone and Webster Corporation of Boston since it was originally expected that they would do the construction. The drawings were transmitted to the Albuquerque District Office of the U. S. Engineers, and a contract was let by this office to the M. M. Sundt Company. On completion of the buildings the Sundt Company transferred them to the Albuquerque District, which in turn transferred them to the Santa Fe Area Office of the Manhattan District Engineers, in theory the "using service." The actual using service, the technical staff, had no official position in this process, and since during the critical period of actual construction they were still scattered about the country, liaison was totally inadequate. The Albuquerque District remained in formal charge of construction until early 1944, at which time the Manhattan District assumed complete responsibility.

3.118 By May 1943, the original buildings had been occupied and were in process of being expanded. The Sundt Company had undertaken two relatively large structures: a new warehouse and an addition to the cyclotron laboratory, but was not going to be able to complete the necessary work in time. Ordinarily the Army was responsible for providing additional construction workers, but in this early period was not able to do so, and the Contractor (University of California) had employed a number of carpenters, plumbers, electricians, and laborers. Under contract regulations, these workers could not be employed for any permanent construction, but only for maintenance work and the construction of shacks and "lean-to's." These men at first worked under the direction of members of the scientific staff, and later under Brazier who was employed by the Technical Area as supervisor of construction and maintenance. Brazier's responsibilities were not altogether well-defined at any time, but it can be said that he was responsible for the preliminary design of the major expansion program which began in June and which included a new office building, offices and laboratories for the ordnance program, and a heavy machine shop. Brazier's staff grew from about a dozen men in May to 264 in January 1944, when he left the site.

3.119 General Groves had wanted for some time to have all construction handled by the Army Engineers, and his final decision in this matter was hastened by a series of complaints made by the War Manpower Commission, the United States Employment Service, and the American Federation of Labor, that there were certain irregularities in the project's procedure of employing construction workers. In January 1944, Brazier's entire staff was turned over to the Army payroll with the exception of three foremen who remained on the University of California payroll. The scientific staff saw considerable advantage both from the point of view of security and that of efficiency in having a separate construction and maintenance group for the Technical Area. Although it was not found possible to keep the entire group on the University of California payroll, the three key men, Charlie Stallings, Melvin Foley, and Dan Pfaff - in charge, respectively, of carpenters, plumbers, and electricians - were kept, and their assistants assigned permanently to the Technical Area. The group, under the direction of John Williams, was responsible for the maintenance, repair, and installation of all scientific equipment or machine tools under the jurisdiction of technical personnel, and also for building and remodelling apparatus and equipment of a scientific nature.

3.120 The construction and maintenance group under the jurisdiction of the Army Engineers was responsible for all alterations and additions and repairs to buildings, including services and installations, and for the installation of new, and repair of existing, utilities. The Army also found it necessary to establish separate organizations for the maintenance and construction of the Technical Area and outlying sites and for the post, housing, and administrative areas. Separate priority lists were maintained for both groups in accordance with urgency ratings assigned by those requesting service.

3.121 Nearly all major new construction was handled by contractors under the supervision of the Post Operations Division. The original contractors, M. M. Sundt Company, remained in charge until the end of 1943. They were succeeded by the J. E. Morgan Company which built a section of the housing area during the first three months of 1944. They in turn were succeeded by R. E. McKee who remained in charge of construction with an average force of between 700 and 1000 men. The architect, W. C. Kruger, whose contract was originally issued by the Albuquerque District, was retained by the Manhattan District throughout the life of the project. (See Graph 8 for rate of growth of technical construction.)

3.122 Requests for all but the most minor construction had to be made by group leaders or their superiors, and urgency ratings assigned in the same way as those for orders on the Procurement Division. Such requests were submitted to the office of David Dow who acted as liaison between the using groups and the Post Operations Division. Frequent conferences were held to determine priorities and set up tentative completion schedules. One of the most frequent causes of difficulty between the using groups and the construction services was the inability of the former to foresee their needs very far in advance, since construction depended in many cases upon the results of experiments in progress.

PATENT OFFICE

3.123 In accordance with procedure outlined by the Office of Scientific Research and Development for the protection of Government interests in scientific research, the Contractor was required to "report the progress of all studies and investigations undertaken, disclose to the Government all inventions made in carrying out the work of the contract, and furnish a complete final report of findings and conclusions." Here again security was an important factor in determining administrative organization. Since few Contractor's representatives were permitted to visit the Laboratory or to know much about the technical details of the work being done here (3.17), they could not make the necessary reports for patent purposes. Consequently, the University turned over much of its responsibility for protecting Government interests to Major Ralph Carlisle Smith, the Patent Officer, who arrived in July 1943 to establish the Patent Office.

3.124 The work of the Patent Office was conditioned in many ways by considerations of security. The most serious effect was the limitation of personnel of this office to the absolute minimum. Since it was the duty of the Patent Division to report the progress of all the scientific work done on the project, and since this was the only office where all of this information would necessarily be compiled in language understandable to an individual having a general scientific background, the Director and the Security Officer felt that only a few absolutely trustworthy individuals could be permitted to work here even in a clerical capacity. For some time Major Smith had no assistants at all, but eventually he obtained among the enlisted men and women already employed on the project a minimum staff which had to be trained on the job. Only after a year and a half was he able to secure two legally trained, scientific assistants.

3.125 In addition to limiting the staff of the Patent Office, security considerations increased its burden to include responsibility for all patent matters affecting subcontractors or involving project employees who had come here from other projects. Thus, the Patent Office assumed responsibility for the early subprojects such as those at Purdue University and Stanford University (1.4), as well as for the later subcontractors, such as F. Flader and the California Institute of Technology (9.15). Furthermore, employees who had transferred here from other government projects were not permitted to communicate directly with their previous colleagues in the patent field, and therefore any unfinished patent matters had to be transferred to this project for completion.

3.126 The Patent Office established the methods and procedure of recording work done and secured the cooperation of the technical staff in keeping the necessary records. Numbered notebooks were issued, originally by the Patent Office and later by the Library document room, and in these staff members currently recorded the details of experiments and the exact dates of the various stages of development of inventions and discoveries made. Completed notebooks and those turned in by people leaving the project were kept on file by the Library document room. Through the Business Manager's Office, patent agreements were secured from every employee, subcontractor, and consultant of the University of California. The Patent Office obtained special patent agreements from military personnel and civilian employees of the War and Navy Departments, and special patent contracts from individuals on loan directly to the Manhattan District from other employers. Employees of foreign governments were not required to sign agreements, but did prepare records of inventions and executed U. S. applications to the benefit of the U. S. Government. Monthly reports of the activities of foreign personnel were prepared by the Patent Division. These and similar reports of visits by consultants and foreign personnel were sent to General Groves' office. All terminating personnel were required to appear before the Patent Officer and assert that they had made no inventions without recording them with the Patent Office, and they had turned in all original records to the document room, or other appropriate depository.

3.127 The most important duty of the Patent Office was, of course, that of preparing patent applications to protect the Government and to prevent outside interests from later dominating the pertinent fields of research and development. Circumstances at this project made it necessary for Major Smith and his staff to be not only experienced patent attorneys, but also expert in a variety of technical subjects. Experiments covered much more than nuclear physics; they included chemistry, metallurgy, ordnance, and explosives and electronics, to mention only the largest fields. Patent cases submitted can be classified into five principal groups: the production, chemistry, and metallurgy of fissionable materials; isotope separation; power reactors; electronic equipment; and the bomb itself with its various developments and improvements. Altogether there were about 500 patent cases reported to Washington OSRD Headquarters covering work done at this Laboratory, and about 300 handled in connection with work done on other projects. Of these, a substantial number have been filed in the U. S. Patent Office.

3.128 Because of the pressure of time and the very limited staff of the Patent Office, it was not possible to write cases in the usual manner. Ordinarily an inventor or research scientist prepares invention reports of things he considers new and useful and submits these to a patent attorney for approval and the preparation of a formal application. Here the members of the Patent Office read the daily records and other reports of research workers, inspected the laboratories and test sites, held periodic discussions of work accomplished with various individuals, and attended seminars and conferences of the various groups and divisions. In all of these sources, the Patent Office found ideas and practices that were new and useful, prepared the applications so as to give maximum scope to the inventions in their relation to the entire project and associated fields, and submitted these applications to the inventors for final approval. Since members of the technical staff were pressed for time and, in any event, were reluctant to take time from research for preparing reports, this rather unorthodox procedure proved to be extremely helpful. An additional complicating factor in the work of preparing cases was the fact that by reason of the nature of the work, a great many developments had to be covered before there was any physical embodiment proving that the inventions were workable - before any "actual reduction to practice," in legal jargon. The test shot at Trinity was the first reduction to practice for many inventions, the success of which was long before anticipated by the completion and filing of a series of patent applications. Completed cases were transmitted by Army courier to the OSRD Washington Patent Headquarters, headed by Captain R. A. Lavender, USN, and filed with the U. S. Patent Office.