The University of Chicago

THE PROGRAM OF RESEARCH

IN

ATOMIC STRUCTURE AND ENERGY

at the

UNIVERSITY OF CHICAGO

A Confidential Memorandum
September 15, 1945

I. Background of the Program

The release and control of atomic energy has staggered the imaginations of men throughout the world. Because the atomic bomb suddenly brought the Pacific war to an end, public attention naturally has been drawn to the astonishing achievement of American science and industry in producing this terrible instrument of destruction. Mankind now faces the far more important problem of learning to understand and control these gigantic forces.

The atomic bomb is the unexpected result of a long series of investigations of the nature of the atom, started long before the war at a number of universities in different parts of the world. The University of Chicago played a leading role in the investigations in nuclear physics that led to the production of the atomic bomb through its "Metallurgy Project." On this project the Federal government spent $53,000,000 since 1941, and the University employed 4,000 scientists, technicians, and laboratory workers.

The spectacular success achieved by the University in wartime research in the field of atomic energy resulted from close coordination of the efforts of many specialists from several universities in physics, chemistry, mathematics, biology, and related fields. These specialists discovered the basic facts and principles on which the atomic bomb was built.

Now that success has been achieved and the war is over, the University of Chicago feels a great responsibility

to society to see that research in these important fields of investigation is continued, not to discover more powerful bombs but to find solutions to the peacetime problems of mankind. This involves, first of all, keeping together the distinguished team of scientists formed during the war, whose collaboration proved to be so successful. It also involves the establishment of an administrative organization conducive to creative work.

The basic scientific work on atomic energy was located at the University of Chicago by the Federal government for a number of reasons: The first was its geographical position. Locating this important project at Chicago meant that the skies would more probably be free from bombing attacks than if the project were located on either the Atlantic or the Pacific coast. A second important reason was the fact that the University of Chicago possessed a faculty of distinguished physicists and chemists. Third, the University possessed administrative talent capable of organizing and executing projects of large dimensions. Fourth, the University had the courage to accept undertakings on which the calculated possibilities of success were small, the hazards to the health and safety of the research workers were great, and the responsibilities of the University for protecting them were heavy.

In addition to its major contributions in basic scientific research, the University designed, built on its campus and operated the first pilot plant for the production of

plutonium for the atomic bomb. The University designed and operated the semi-work plant at Oak Ridge, Tennessee. As Mr. W. S. Carpenter, Jr., President of E. I. du Pont de Nemours and Company, said in a statement to the stockholders, du Pont "depended heavily" upon the University of Chicago for fundamental research and development, consultation, and advice in completing its tremendous contract for the design, engineering, construction, and operation of the Hanford Engineering works near Richland, Washington.

The University of Chicago recognizes that its peacetime responsibility is the same as its wartime responsibility--to carry out basic research aiming at the discovery of fundamental information about our physical and biological environment and to originate new ideas, not merely to apply old ideas to new situations. Dr. O. E. Buckley, President of the Bell Telephone Laboratories, has recently said,

> "...'pure' or basic research directed at understanding nature's laws and expanding our area of scientific knowledge is almost wholly a function of universities and endowed pure research institutes ... one sure way to defeat the scientific spirit is to attempt to direct inquiry from above."

II. Potentialities of The Research Program

The wartime studies in nuclear physics have revealed many new types of radiations, such as thermal neutrons, fast neutrons, beta rays, and gamma rays. Some of these radiations can be produced by new methods which allow accurate control of radiation intensities. They are new keys with which to open

the secrets of our physical and biological worlds. The scientific tools are dangerous to work with, and man has to learn how to protect himself while using them.

With these radiations man has been able to create new elements such as neptunium and plutonium, thus realizing the dream of the alchemist. Plutonium was used in one of the atomic bombs.

The radiations have been used to destroy matter and to convert it into tremendous quantities of energy. The report of Professor H. D. Smyth, written at the request of General L. R. Groves, giving "A General Account of the Development of Methods of Using Atomic Energy for Military Purposes under the Auspices of the United States Government" states "that if the energy in one kilogram of uranium (2.2 lbs.) were converted entirely into energy, 25 billion kilowatt hours would be released. This is equal to the energy that would be generated by the total electric power industry in the United States running for two months." While the purpose of the research done in the new Institutes at the University of Chicago is the acquisition of greater knowledge -- knowledge for its own sake -- such work will certainly result in discoveries of new and cheap sources of power, heat, light and refrigeration, which will lighten the burden of man's labor and replace other, exhaustible natural resources.

These same radiations are now available for studying the fundamental geometrical arrangements of atoms in metals

and metallic alloys. Such geometrical patterns determine such metallic properties as tensile strength, ductility and ability to resist fracture.

These radiations can also be used to control and induce chemical reactions. A whole new world of nuclear chemistry is to be explored. The plastic industry will be interested in many applications of nuclear chemistry.

The application of these radiations to living tissues, organisms, and biological systems is in its infancy. Under some conditions they are highly injurious to living tissues. These injurious effects should be studied from the points of view of (a) mammalian biochemistry, since it offers the possibility of finding the effects of radiations on the various chemical systems of the body; (b) mammalian physiology, since a study of changes in function due to radiation should eventually lead to important practical discoveries; and (c) cellular physiology and biochemistry, since the primary damage from radiation is to individual cells.

The use of these radiations for the destruction of bacteria offers many opportunities for research. It is entirely possible that radiations may selectively kill one strain of bacteria leaving others intact, or may even be used as a method for identification of bacterial strains. In short, here is a physical agent, like heat, capable of accurately controlled selective destruction of matter. It would be surprising if many applications in bacteriology were not found. Applications for sterilization of various biological

products such as vaccines immediately suggest themselves.

It is well known that the common elements, such as carbon, hydrogen, or nitrogen are made up of atoms. The individual atoms of any given element have weights which differ slightly. It is now possible to do two things to these atoms of the different elements:

First, The heavy and light atoms of any given element may be separated from each other. (An important part of the war effort was to separate uranium-235 from uranium-238.)

Second, By bombarding the elements with neutrons, they may be rendered radioactive. Science knows how to detect these radioactive atoms, even when they occur in extremely small quantities.

These facts allow us to make new attacks on disease.

Science now knows some two hundred chemical compounds which, when injected into animals, will cause cancer. By replacing the normal atoms in these compounds by radioactive atoms of the same elements, these compounds may be followed in the animal body, and the mechanisms by which they produce cancer may possibly be discovered. The same type of study can be carried out by replacing the common atoms by the so-called "heavy isotopes," which can also be detected in very small quantities. Up until this time it has been very difficult to follow the action of drugs in the animal body. Using these radioactive materials as "tracers," it is now possible to

follow the action of drugs. These are a few examples of the types of problems to be studied.

As a result of the great potentialities in this field, and after prolonged discussion and consideration of all alternatives, the decision has been made to establish four closely-related Institutes within the Physical and Biological Sciences Division of the University of Chicago to carry on a program of research in atomic structure and radioactivity. They are the Institute of Nuclear Studies, the Institute of Metals, the Institute of Applied Mathematics, and the Institute of Radiobiology and Biophysics.

III. The Institute of Nuclear Studies

This Institute has now been organized, and the University has added to its staff a number of scientists who are distinguished for their contributions to man's knowledge of atomic structure and energy. These appointments are:

Samuel K. Allison, Director, Professor in the Department of Physics

Enrico Fermi, Charles H. Swift Distinguished Service Professor of Physics

Harold C. Urey, ______________ Distinguished Service Professor of Chemistry

Edward Teller, Professor of Physics

Joseph E. Mayer, Professor of Chemistry

Philip W. Schutz, Professor of Chemical Engineering

Walter H. Zinn, Associate Professor of Physics

Robert F. Christy, Assistant Professor of Physics

Donald J. Hughes, Assistant Professor of Physics

John A. Simpson, Instructor in Physics

Maria Goeppert Mayer, Research Associate in Physics

The University is now arranging the appointment of eight additional men who have outstanding reputations in the field of nuclear chemistry. These new members of the faculty, taken together with the strong natural science faculty already possessed by the University, will undoubtedly form the strongest group of investigators in the world in the field of atomic structure.

The personnel requirements of the Institute of Nuclear Studies are projected as follows:

Theoretical physicists	7
Experimental physicists	10
Chemists	20
Electronic engineers	3
Service and technical personnel	32
Machinists	16
Fellowships, pre- and post- Ph.D.	50

Because of the nature of the work, no existing building can safely be used for experimentation in atomic energy. A specially constructed laboratory building with massive concrete walls and other unusual features is required. In order that the basic scientific purpose of the Institute may be pursued without deviation, it is desirable that the core of its work, involving annual operating expenses of approximately $500,000, be endowed or supported with long-term grants. Support is needed for several professorships, research funds, and numerous fellowships to attract the younger scholars who will receive

training in the field. The University expects the Federal government to continue to finance part of this work. In his report, "Science, the Endless Frontier", Dr. Vannevar Bush has made a strong plea for pure research, and has outlined a way in which it can be carried on by government subsidy. Congress is now considering bills for the support of fundamental research.

The financial requirements of the Institute of Nuclear Studies may be summarized as follows:

Investment in Laboratory Building	$2,000,000
Annual Operating Expense	$1,500,000

IV. The Institute of Metals

The implications of discoveries regarding the nature of matter are highly important for the science of metallurgy. The newer knowledge of atomic structure and radioactivity points to startling possibilities for altering the structure and properties of metals. The University has established an Institute of Metals for the purpose of investigating these problems as well as supplying the Institute of Nuclear Studies with highly purified materials. Two outstanding appointments have already been made to this Institute: Cyril S. Smith, Director of the Institute and Professor of Metallurgy, and Clarence M. Zener, Professor of Metallurgy.

The research program of the Institute of Metals will concern itself primarily with research into the fundamental aspects of metallurgy and will not, except indirectly, develop

its technology. In particular, it is proposed to encourage those phases of metallurgy bordering on physics. The research staff of the Institute will be composed of metallurgists, physicists, and chemists, selected because of their interest in various fundamental phases of metallurgical science, and they will be given every encouragement to follow their studies without regard to commercial considerations. It is hoped at the outset to work in each of the following subjects in the fields of physical metallurgy: elasticity, plasticity, and fracture, including high velocity strains; structure of pure metal and alloy phases; ferromagnetism; nature and mechanism of allotropic transformation and precipitation; and the theory of the metallic state. In addition to these physical fields, it seems highly desirable to cultivate work on the physical chemistry of corrosion and of metal reduction. The latter in particular has been neglected by scientific workers, and developments in the field for many years have been almost entirely of a practical, industrial nature.

To avoid the training of scientists in the whole art of metallurgy, there will be a staff of professional metallurgists, graduate students, and technicians who, on approved request, will undertake the preparation of samples of any specified composition and treatment required by the scientific staff or designed to meet requirements specified by them. This "Metals Technology Section" will also institute its own studies of fabrication methods and will aim in particular at the development of methods of purification,

reduction, and fabrication of those rare and little-known metals which cannot be satisfactorily procured commercially, such as beryllium, and of unusual combinations of common substances. The availability of such metals and alloys should greatly aid the work of the Institute of Nuclear Studies. The new metals and methods should eventually be of great value to industry, but the primary aim of the staff of the Institute will be an increased understanding of metals.

The scientific personnel requirements of the Institute of Metals will be as follows:

Research Section

Metallurgist - interested in crystal structure metallography.
Metallurgist - steel transformation, age hardening, etc.
Metallurgist - allotropy, transformation, solid solution structure.
Physicist - elasticity, "anelasticity," plasticity, and fracture.
Physicist - structure of intermetallic phases, solid state theory.
Physicist - structure of intermetallic phases.
Physicist - theory of metallic state.
Physicist - ferromagnetism.
Physicist - high velocity strains.
Physicist - metal reduction.
Physical Chemist - corrosion.

Technology Section

Metallurgist - to direct work of section.
Chemist - preparation and purification of metallic compounds.
Metallurgist - reduction (thermal methods).
Electrochemist - reduction (electrolytic methods).
Metallurgist - vacuum casting (special techniques).
Metallurgist - fabrication (rolling, drawing, etc.).
Metallurgist - powder metallurgy.
Metallurgist - mechanical testing (metallographer).
Analytical Chemist: 3 needed.
Ceramist - experienced in "super" refractories.

The financial requirements of the Institute of Metals are:

Investment in Laboratory Building	$500,000

Annual operating Expenses $500,000

Like the Institute of Nuclear Studies, the Institute of Metals will, it is expected, derive annual income from the Federal government and from industry with respect to certain parts of its work. The central part of the work, involving annual outlays of $250,000, requires endowment or long-term grants in order to provide it with the necessary stability and freedom from external control.

V. The Institute of Applied Mathematics

A third Institute stemming from the basic work carried on in the Institutes previously referred to will be established to investigate the mathematical problems involved. Walter Bartky, Professor of Applied Mathematics and Associate Director of the "Metallurgy Project," is already working in this field, and the University plans to appoint to its faculty other distinguished mathematicians with the requisite skill and interests.

The work of this Institute should produce inventions of time-saving mathematical machines with uses quite outside the realm of nuclear studies. These devices could conceivably play an important role in the enlargement of our knowledge of meteorology and astronomy, as well as in the biological and social sciences. By making possible rapid calculations, they can greatly reduce the cost and speed the progress of research. This Institute will make use of the instrument section of the Institute of Nuclear Studies to build electronic calculating

devices. No additional building is required.

The personnel requirements of the Institute are:

Director
4 Mathematicians
3 Electronic engineers
Service personnel

The financial requirements are:

Annual Operating Expenses	$100,000

All of the work of this Institute should be financed with University funds.

VI. Institute of Radiobiology and Biophysics

The Institute of Radiobiology and Biophysics will to a large extent make use of the results of the Institute of Nuclear Studies to investigate fundamental problems of biology. It will have two principal objectives:

(a) To provide facilities and technical personnel for research in radiobiology which cannot be prosecuted in the biological departments or pursued there only with difficulty.

(b) To promote through the departments the teaching necessary to train future radiobiologists and biophysicists.

During the course of the "Metallurgy Project" it proved necessary to develop special techniques for monitoring laboratory workers handling lethal radioactive materials and for protecting them from harm. As the use of radioactive materials becomes more general in industry, such techniques will need to be perfected, and medical practitioners will need to be trained in

their use.

This Institute will also make fundamental biological studies. Very little is known about the effects of the radiations which are given off by radioactive materials on living matter. It is now possible to render some of the very common elements radioactive by the processes which have been discovered. These common elements can be incorporated into hormones, vitamins, drugs, and foods. They may be followed in the living organism by following their radioactive properties. This enables the tiologist to "tag" foods and drugs so that he can follow them in the complex environment of the living organism. What are the details of the chemistry of the body? Just how, for example, are sugars and fats burned within the body? The tracer elements will make studies of this kind possible in a way that has never before been possible. It is reasonable to believe that new light will be shed on the problems of aging and heredity.

The scientific staff of the Institute will include the following specialists:

General radiobiologist
Mammalian physiologist
Clinical biochemist
Hematologist
Histologist
Instrument physicist
Radiation physicist
General biochemist
Radiation biochemist
Nuclear chemist
Statistician and mathematical biophysicist
Tumor biologist
Radiation geneticist
Cellular physiologist
Organic chemist

Plant physiologist
General biophysicist
Microspectroscopist
Nerve biophysicist
Membrane biophysicist

A number of these specialists are now in various departments of the University and will receive part-time appointments in the Institute.

The financial requirements for the establishments of the Institute of Radiobiology and Biophysics are:

Investment in Laboratory Building	$1,000,000
Annual Operating Expenses	$ 500,000

As in the case of other Institutes, the central activities of the Institute, involving annual expenditures of $250,000, should be endowed or supported by very long-term grants.

VII. Conclusion

In undertaking to erect these four Institutes and to assemble a competent staff for research in the problems of nuclear physics, radiobiology, metals, and applied mathematics, the University of Chicago has made very large commitments. These commitments were made because the eminent scientists who worked so effectively as a team in producing the atomic bomb want to work together in times of peace, and, in the environment of a great independent university, to explore the new sciences of nuclear physics, nuclear chemistry, and their applications to problems in biology. They hold firmly to the conviction that only in the universities exists the freedom and flexibility necessary to the pursuit of fundamental research.

Therefore, while it is hoped that the Federal government and industry will contribute generously to the support of these Institutes, it is believed that the University of Chicago should carry a large share of the financial responsibility in order to give the stability and independence essential to success. The University seeks the aid of donors who grasp the tremendous potentialities for human welfare that lie in these fields, and who desire to be associated with their development. The University will gladly name any Institute, Professorship, Fellowship, or Research Fund in honor of a donor or someone whose name he may wish to perpetuate.

SUMMARY OF FINANCIAL REQUIREMENTS

	Investment in Laboratory Buildings	Annual Operating Expenses: Central Activities*	Annual Operating Expenses: All Activities	Endowment Needed for Central Activities
Institute of Nuclear Studies	$ 2,000,000	$ 500,000	$ 1,500,000	$12,500,000
Institute of Metals	500,000	250,000	500,000	6,250,000
Institute of Applied Mathematics	-	100,000	100,000	2,500,000
Institute of Radiobiology and Biophysics	1,000,000	250,000	500,000	6,250,000
TOTALS	$ 3,500,000	$ 1,100,000	$ 2,600,000	$27,500,000

*Central Activities of the Institutes are basic on-going researches for which the University seeks support in the form of endowment or long-term grants. Other Activities of the Institutes might be financed on a shorter-term basis by industry or the Federal government.