c/o Clarendon Laboratory,
Parks Road,
O x f o r d.

5th December, 1935.

Professor G.B. Pegram,
Physics Department,
Columbia University,
New York City.

Dear Professor Pegram,

Enclosed I am sending you a manuscript in the hope that it will interest you and those who work with you. It will appear as a letter to " Nature " some time in the future.

The absorption experiments in boron to which the last paragraph refers, have in the meantime been carried out. If we assume that the Fermi, Bethe, Perrin and Elsasser theory holds for boron and lithium, though it does not hold for elements which show a strong radiative capture, we can conclude that indium has a selective absorbing region at a neutron energy of a couple of volts.

With kind regards to all,

Yours sincerely,

These letters by Szilard and Zinn did not actually reach Professor Pegram since in the meantime Professor Pegram decided to release the papers for publication. The hand-written originals are in my files.

L. Szilard

C
O
P
Y

March 27, '39

Dear Professor Pegram:

It seems we shall have to decide today about delaying the letter which Zinn and I sent to the Physical Review. I feel that if we delay this letter now, and if you write to Tate along the lines which Fermi suggested on his return from Washington, we may have a chance, although not a very great one, to get others to cooperate. If we publish now, we cannot ask others to withhold future, perhaps more important, papers. Zinn, I believe, is of somewhat different opinion. It seems that in the circumstances you, as head of the department, will have to take the responsibility for deciding this difficult question, one way or another. I am very sorry to have to worry you with this awkward decision, but it happens only once in a lifetime.

Yours sincerely,

Leo Szilard

March 27th - 39

Dear Professor Peyrou,

It seems we shall have to decide today about delaying the letter which Zinn and I sent to Phys. Rev. -

I feel that if we delay this letter now, and if you write to Tate along the lines which Fermi suggested on his return from Washington, we may have a chance, though not a very great one, to get others to cooperate. If we publish now, we cannot ask others to withhold future, perhaps more important papers.

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Tim, I believe, is of somewhat different opinion.

It seems that in the circumstances you as Head of the Department will have to take the responsibility for deciding this difficult question one way or another.

I am very sorry to have to worry you with this awkward decision but it happens only once in a lifetime.

Yours sincerely

Len Beaton

Columbia University
in the City of New York
DEPARTMENT OF PHYSICS

April 6, 1939

Dr. Leo Szilard,
Pupin Physics Laboratories,
Columbia University.

Dear Dr. Szilard:

I told you that I would write you a letter to put on record my invitation to you to be a guest of the Department of Physics until June 1, 1939 to work on certain researches with Dr. Zinn and to have the privileges that are appropriate for a guest in our laboratory. Laboratory keys have already been issued to you, and I enclose with this a card by the use of which you can obtain a key to the outer door of the building by calling at Room 111 Low Memorial Library so that you may have access to the laboratory at times when the outer door is closed. The key obtained with this card is to be returned on leaving the building.

Sincerely yours,

George B. Pegram

GBP:H

George B. Pegram

WARDMAN PARK HOTEL
Washington, D.C.
CONNECTICUT AVENUE & WOODLEY ROAD
1800 ROOMS

October 21, 1939.

Prof. G. B. Pegram,
Physics Department,
Columbia University,
Broadway at 120th Street,
New York City.

Dear Professor Pegram:

I wish to give you a short account of yesterday's meeting, at which Briggs acted as chairman. I will give you a longer account in the form of a memorandum, which I am now writing and which I will leave with Briggs before returning to New York. This memorandum is essentially a repetition of the statements and recommendations which I made at the meeting, and it serves the purpose of making things easier for Briggs, when he writes his own report.

On the whole everything came off as could be expected. Teller, who returned from New York, where he spoke with Tuve and Fermi, acted in a double capacity - speaking once in his own name and once in the name of Tuve, who was asked by Briggs to attend the meeting but was unable to come. Tuve put forward certain recommendations which he has discussed and on which he has agreed with Fermi. He said that Government funds ought to be made available for our graphite absorption experiment at Columbia, and named a specific sum, which I do not remember. He also named a sum which he thought ought to be given for purposes of isotop-separation to the University of Virginia, and so on. These recommendations, though they were beside the point, had nevertheless a beneficial effect. The diversion of Government funds for such purposes as ours appears to be hardly possible, and I have therefore myself avoided to make any such recommendation. But Tuve's suggestion provoked detailed discussion of the proposed experiments, and the representative of the Army and the Navy almost committed themselves to the extent of providing some four metric tons of graphite for our experiments, if we so desire.

I was astonished how active and enthusiastic Dr. Sachs was during the meeting, and was most favorably impressed. After the meeting he asked me jokingly to confess that I suspected that he was no good, that he would really never get anything done, and that I was surprised, when the time came, that he really became active and started to do things. It seems to me now that he is performing his task efficiently and in the right spirit, and now I am in favor of giving him a fairly free hand, and see what he can achieve.

I expect to be in New York by Tuesday night at the latest.

Yours sincerely,

(Leo Szilard).

December 22, 1939

Dr. Lyman J. Briggs, Director
National Bureau of Standards,
Washington, D. C.

Dear Dr. Briggs:

I wish to acknowledge with thanks your letter of December 18, indicating that your chemical division will make an analysis of samples of graphite to find out whether the carbon content is below 0.01% by weight.

On your question as to whether it would be practicable to design the apparatus to use powdered or granular graphite instead of slabs, I have talked with Professor Fermi and this seems to be the proper answer:

(1) If graphite could be obtained in powdered or granular form that would pack tightly enough to give an over all density as high as that of graphite slabs, it would be quite feasible to use powdered or granular graphite instead of slabs, and in fact the carbon might be handled more easily. From such inquiries as we, particularly Dr. Szilard, have made, it appears that any available powdered or granular graphite would have an over all density less than that of slab graphite by a considerable fraction. This would mean that a larger volume of carbon would be required to carry out with equal accuracy the carbon absorption experiment.

(2) The feasibility of attaining a chain reaction in a mixture of uranium oxide and carbon decreases rapidly with decreasing density of the carbon, and the amount of carbon necessary to try it at all goes up rapidly with decreasing density. Since it would obviously be desirable to use the same kind of carbon in the carbon absorption experiment as in the uranium experiment, and since the chances of the uranium chain reaction experiment succeeding are bettered as the density of the carbon is

increased, we conclude that it would be best to use the graphite slabs in the carbon absorption experiment unless, indeed, it proves feasible to obtain powdered or granular graphite of practically as high a density as the slabs.

Sincerely yours,

GBP:H George B. Pegram

cc to Professor Fermi
Dr. Leo Szilard

copy

U.S. DEPARTMENT OF COMMERCE

National Bureau of Standards
Washington

January 5, 1940

Dr. George B. Pegram
Columbia University
New York, New York

Subject: Graphite.

Dear Dean Pegram:

Upon receipt of your letter of December 9, we requested the National Carbon Company and the United States Graphite Company to submit samples of graphite blocks for determination of the hydrogen content. Neither was able to furnish blocks of the contemplated size, but both companies forwarded samples representing the composition and the state of aggregation of the graphite which they propose to furnish. The samples arrived on January 2nd and tests were started immediately. Our results are as follows:

I. Loss on drying at 105° C

National Carbon Co. (rods) -- 0.01 percent

U. S. Graphite Co. (small slab) -- .007

II. Hygroscopicity

(Increase in weight after exposing dried samples to an atmosphere of 50 percent relative humidity)

National Carbon Co. -- 0.006 percent

U.S. Graphite Co. -- .006 percent

III. Percentage of hydrogen in graphite "as received". (The method of test should yield all of the hydrogen in the graphite, regardless of the form in which it occurs.)

National Carbon Co. -- 0.004 percent

U.S. Graphite Co. -- .002 percent

COPY

IV. Percentage of ash

National Carbon Co. -- 0.075 percent

U.S. Graphite Co. -- .053

It will be noted that the values obtained in the drying and in the hygroscopicity tests are approximately equal, and indicate that the graphite "as received" has reached the equilibrium which will obtain in graphite handled and installed under ordinary conditions. It seems reasonable, therefore, to belive that the percentages of hydrogen indicated in the "as received" graphites represent the hydrogen contents that may be expected. If the blocks could be dried and protected from moisture during installation and use, the percentages of hydrogen would approximate 0.003 for the National Carbon Co. and 0.001 for the U. S. Graphite Co. blocks.

Sincerely yours,

Lyman J. Briggs, Director.

Will you now please advise whether graphite from either source would be acceptable; if so competition bids may be secured.

We are planning to ask for bids on 8,800 pounds graphite
4,400 " paraffin
100 " cadmium

April 7, 1940

Attention of:

Professor G.B. Pegram
Professor E. Fermi

Memo.

Since the experiments on graphite are conducted with government support, and since the result may have a direct bearing on questions of national defense, I should like to raise the following question: Should the value for the absorption cross section of graphite obtained in these experiments come out to be smaller than $10^{-26} cm^2$, the upper limit given by Frisch, Halban and Koch, ought we then

a) within the laboratory freely discuss such a result before its publication, or

b) during the next three months evade questions concerning this value and restrict a free discussion of this value to a limited number of workers in the laboratory?

L. Szilard

COPY

May 8, 1940

Memorandum on the experiments with uranium and carbon that are being done at Columbia University under the direction of Professor Fermi and Dr. Szilard.

I. General

The project of attempting to bring to practical use the release of energy from uranium "by a chain reaction" involving the use of carbon to slow down the neutrons released in the reaction so that they may be picked up by the Uranium-235 involves three rather distinct stages.

A. The first stage is an investigation of the fundamental physics involved in the scheme by which it is hoped to produce and utilize the chain reaction. The experiments in this stage can be done as effectively in a university laboratory as anywhere. Since the whole field is rather new, it is especially necessary at this stage to have the work in charge of physicists of imagination and ingenuity. It would not seem necessary to surround the experiments at this stage with precautions to secure great secrecy. In general the results of the experiments are not immediate but come out only from computations by rather laborious methods and the results of these computations need be known to very few and need not be disclosed to others. Some of the experiments that are needed are such as various physicists may be undertaking and of which they may publish the results. However, since the results are necessary to this project it can hardly wait until some physicist happens to do the particular experiments necessary for a better knowledge of the facts concerned. As these fundamental measurements are made they may at any stage do one of three things, namely, either indicate that the project is hopeless, lie within a range which indicates neither the feasibility nor the unfeasibility of the project, or lie within a range that indicates the project to be feasible and encourages further steps. If the work in this stage is pushed hard it will still take a number of months to get the results that should be well in hand before the final stage is reached.

B. The second stage is that of planning for the third or final stage. Work in this second stage need by no means await the completion of work in the first stage but may well begin at once. This work will start with the assumption that within certain limits of quantities of uranium and carbon the chain reaction with slow neutrons can be made to proceed at a rapid but controllable rate. If this assumption is made then the second stage is really one of engineering planning and designing. The constant advice of physicists will be needed but the designing of the setup of an actual experiment, preferably with the appropriate means for utilizing the energy liberated will involve good engineering judgment and designing. The second stage includes a study of the supply and the means of acquiring uranium, and incidentally carbon, in the proper form. A study of the limit to the supply of uranium is obviously of importance. The results of work in this second stage would presumably be kept confidential by whatever organization does the work. The work in this stage might be done at a university but the desirability of doing so is by no means as obvious as is the case with stage one.

C. The third stage is that of constructing the necessary equipment and setting up an experimental plant for trying out the final experiment if it appears to be justified by the findings in the first stage. If the second stage, that of planning the full scale experiment, goes on simultaneously with the first stage, the final experiment might be tried rather promptly if and after the results of the fundamental experiments in the first stage have indicated the conditions for success of the project. The third stage is an undertaking that should be carried out in some isolated location, certainly not on a university campus.

II. Experiments of the First Stage

In the first or physics stage a more accurate knowledge of certain properties of the materials used is the objective. The chief of these properties are the following:

(a) The magnitude of the "capture cross-section" of a carbon atom with slow neutrons. If this capture cross-section is too great, the carbon would swallow up so many of the slow neutrons in the mixture of uranium and carbon that there would be no hope of a chain reaction.

Since this capture cross-section was known with less accuracy than any of the other quantities involved it was the subject of the first experiment. Preliminary results have been secured. Further results will be ready by the end of this week. The indications are that carbon does not capture slow neutrons at so rapid a rate that the feasibility of a chain reaction is excluded. It is not certain yet whether another more elaborate experiment using a sphere of carbon should be carried out with the hope of somewhat greater accuracy in the measurement of the capture cross-section of carbon.

(b) The average number of neutrons that are given off when a fission of a Uranium-235 atom takes place after its capture of a slow neutron. Additional experiments to determine more accurately this fundamentally important number need to be done. The previous experiments, particularly those of Anderson and Fermi, and those in France of Joliot, are not in very good agreement.

(c) Improved measurements of the fission cross-section of Uranium-235. Measurements of this quantity have been made but it would be advantageous to have the results more accurately worked through.

(d) The resonance capture cross-section of Uranium-238. The capture of neutrons at a certain velocity (semi-slow) by Uranium-238 is quite the worst obstacle to getting a chain reaction between the slow neutrons and Uranium-235 to proceed. Anderson, who by the way is Professor Fermi's research assistant, in this laboratory, and others, have made some measurements on this resonance cross-section. Experiments to check the results would be desirable.

(e) Other capture cross-sections. Professor Fermi is inclined to suspect the existence of one or more other kinds of capture of neutrons by uranium than the fission capture and the resonance capture.

(f) A good many questions relating to the chemistry and metallurgy of uranium will need to be investigated. This investigation may partly belong to stage one but will also be prominent in stage two in connection with planning for obtaining uranium in the necessary form for use in the final experiment.

III. Resources needed to speed the work on the project.

Stage 1. The first or physics stage of the project needs in order to expedite the work at least the following: For research assistance, four young physicists who are acquainted with this type of work, men who would have salaries of approximately $3,000 each for at least a year. If it were felt necessary to proceed very cautiously, considerable progress might be made through the summer months from June 15 to September 15 by the employment of physicists from university staffs who might be willing to work through the vacation period. In addition, there would need to be funds available for supplies for the expense of shop work and construction of various pieces of equipment. It is difficult to estimate what the cost of these items would be, probably of the order of a $1,000 a month for the better part of a year. Very likely too it would be necessary to rent a gram of radium which surrounded by beryllium would furnish a steady concentrated source of neutrons. I believe that a gram of radium can be rented for about $300 a month.

Stage 2. I am not prepared to suggest any estimate as to the cost of stage two. Engineers to do most of the work with physicists to advise would be the chief requirements.

Stage 3. No estimate is submitted at this time as to the cost of stage three.

George B. Pegram

May 10, 1940

To Professor Pegram:

An experiment using a sphere of graphite may be carried out within the frame-work of a general survey of all nuclear constants involved. If such a survey is started we might then make use of the steel spheres using a modification of our old scheme in which the inside of the steel spheres would be covered with a spherical wooden shell about two inches thick. I therefore suggest that the steel plates which have already been cut and welded remain the property of the Government provided that this solution can be fitted in without inconvenience within the frame-work of Government regulations.

Sgn. Leo Szilard

Columbia University
in the City of New York
DEPARTMENT OF PHYSICS

May 13, 1940

Dear Professor Pegram:

Would you be kind enough to advise Dr. Briggs on my behalf that, in view of the results of the measurements carried out with a graphite cube which have now reached their conclusion, it does not seem necessary to start an experiment now with a graphite sphere. Should we, however, succeed in organizing the large-scale experiment, then as a first step of such an experiment we would wish to carry out a general survey of all nuclear constants and attempt to reduce the limits of experimental error of all constants involved.

I am very anxious to carry out an experiment with a graphite sphere within the framework of such a survey, ~~and for that reason I would advise that the Government retain the title to those steel discs which are cut and welded, provided that this can be arranged in a convenient way.~~ [illegible] think it advisable

Yours sincerely,

LS:H

Leo Szilard

June 19, 1940

Rear Admiral H. G. Bowen
United States Navy
Naval Research Laboratory
Anacostia Station
Washington, D. C.

Dear Admiral Bowen:

In response to your letter of June 13 the following is submitted:

I. ISOTOPE SEPARATION EXPERIMENTS--CENTRIFUGAL METHOD

Professor Urey has been away from New York since we were in Washington last week. On receipt of your letter Saturday I conferred with Professor Karelitz, and he saw no reason for any change in the figures that I gave you on June 12 as tentative figures for the centrifugal separation experiment to be done here under Professor Urey's direction. The procedure you suggested as to a proposal under which these experiments could be carried out, namely: that it be a proposal from Columbia University or from the Department of Chemistry of Columbia University to the Naval Research Laboratory to carry out certain experiments and report results; that the Naval Research Laboratory would probably prefer to employ the personnel directly on recommendation of Professor Urey; that the Naval Research Laboratory would probably prefer to provide all larger items of equipment that need to be purchased; that only minor items of unavoidable miscellaneous expenses should be put into the sum ~~set~~ to be paid to the Department of Chemistry; and in general that the whole proposal be as detailed as possible.

In the absence of Professor Urey, Professor Karelitz has already written out in considerable detail the proposal as to the mechanical part of the apparatus. Professor Urey will have that on his return to New York tomorrow and can start at once to work out a proposal. The overall figures as they stand at present for these centrifugal experiments are:

Personnel	$17,400
Laboratory space, preparation of	2,000
Equipment	10,300
Total	$19,700

II. THE FERMI-SZILARD EXPERIMENTS AT COLUMBIA

A. Experiments to determine more accurately the fundamental physical constants of uranium and carbon that bear upon the chain reaction.

In our memorandum of May 9, 1940, it was proposed to perform certain experiments that might be completed within twelve months and were estimated to cost $12,000 for salaries of physicists and $12,000 for apparatus plus the cost of purchasing or renting one gram of radium mixed with beryllium.

Since May 9 there has been much more thought and discussion given to the problem. The scientific committee appointed by Dr. Briggs spent five hours in discussion of the subject in Washington last Thursday. Since my return I have spent all the time I could in further discussion with Fermi and Szilard. It appears that it will require very careful and tedious measurement by any experimental means that have as yet been designed to evaluate the physical constants involved with enough accuracy to enable a valid calculation to be made of the amounts of uranium and carbon that will be needed in order to sustain a chain reaction. Indeed by measuring the constants separately, using relatively small amounts of materials, it will be difficult to prove definitely that the chain reaction can be made to go, and still more difficult to prove that it cannot be made to go. Our present estimate on a series of seven experiments now runs the figures up to the following estimate:

6 physicists' salaries	$18,000
Equipment and supplies	12,000
One gram of radium mixed with beryllium	25,000
Uranium oxide, two to four tons . . .	10,000 to $20,000

(The owners of uranium oxide ought to let it be used free of charge for these experiments.)

Rental of two grams of radium in order to expedite work by using strong sources, possibly $3,000
(Again the producers of radium ought to furnish this free of charge or at a nominal rate for these experiments.)
Four tons of graphite . . . . . 2,000 ?

B. An intermediate experiment.

The idea has been developing that an intermediate experiment on a scale larger than experiments under A preceding, but not large enough to give a chain reaction, could probably be used to obtain measurements bearing directly upon the chain reaction and the amount of material to be used to maintain such a reaction, and that this would in a sense be a method of short-circuiting, so to speak, some of the tedious experiments for measuring the constants of uranium. In its conference last Thursday, the scientific committee came to the conclusion that it would recommend that an experiment be done right away using not less than one-fifth of the material that would be estimated as necessary for maintaining a chain reaction.

The materials needed for such an intermediate experiment would be:

50 to 100 tons of graphite . . . . . $25,000 to $50,000
5 to 10 tons of uranium metal at $8.00 a lb. . . . . $80,000 to 160,000

The figures just given are doubtless too high. The carbon has been figured at $500 a ton, the rate paid for the graphite we have at present. It can probably easily be obtained for $400 a ton or less. The figure of $8.00 a lb. for metallic uranium is the lower figure given here last week by Mr. Alexander, who thought that in ton lots it would not be difficult to furnish metallic uranium at $15.00 to $12.00 a lb., or possibly $8.00. Chemical opinion seems to be that it ought to be possible to purchase uranium at $5.00 a lb., but perhaps that is a little too optimistic.

It is believed that this intermediate experiment which would be on the way of the final experiment might well furnish results that would make feasible a fairly accurate calculation of the amount of uranium and carbon necessary to sustain the chain reaction. The same materials could, of course, be used as far as they would go in setting up the final experiment.

If the intermediate experiment is to be done the question will arise as to whether it would be better to do it here or to do it in some place where it can be more carefully guarded.

C. The full scale experiment.

The estimate on the materials required for this is still fairly indefinite. Probably an outside estimate would be to say:

200 tons of graphite	$100,000
25 tons of uranium metal	400,000
Other expenses difficult to estimate but small by comparison with the main items	

These figures, of course, are pretty large, but it must be remembered in the first place that the material will certainly be by no means worthless, even if the experiment failed of its object and that further knowledge may indicate that a considerably smaller amount of material would suffice for the chain reaction.

- - - - - - -

I hope that the above will be sufficient to answer your immediate purposes. We shall work on a more detailed statement and send it to you as soon as we can. It is necessary for me to be at the meeting of the Physical Society in Pittsburgh tomorrow and Friday. Fermi left Monday night to keep a long standing engagement of a month at the University of Chicago, and we shall need to exchange correspondence with him before putting in a definitive proposal.

I am sorry that I did not make it clear that I was referring to uranium metal in saying that it would be procurable at $12.00 to $15.00 a lb. Fortunately the price of uranium oxide is only about $2.50 a lb.

In closing let me say that there has been one very hopeful development about which I shall not attempt to write now but which we shall be glad to explain to you at an early opportunity.

Very sincerely yours,

George B. Pegram

GBP:Z

36.3.8

September 10, 1940

Memorandum for Professor Pegram

In February 1939 it appeared advisable to find out as quickly as possible whether neutrons are emitted from splitting uranium. In view of the bearing of such a phenomena for questions of national defense it was desirable to find out whether it existed as speedily as possible. It seemed to me that the only way for obtaining reliable information on this point consisted in performing the projected experiments with photo-neutrons from beltium rather than with any other type of neutron. I have therefore asked Dr. Benjamin Liebowitz, 110 Riverside Drive, to lend me $2000 so that we may rent a large quantity of radium and cover other expenses connected with the projected experiments. It was understood that we would refund these $2000 to Dr. Liebowitz if and when we succeeded in obtaining the financial assistance of the Government for the projected work. It is therefore proposed that if funds for the purpose of our work are put at the disposal of Columbia University the items specified below be paid by the University direct to the recipient who would than be put in the position to refund to me the sum which I have advanced out of the $2000 lent to me by Dr. Liebowitz.

These recipients are (1) The Radium Chemical Co. from whom I rented amounts of radium varying between .9 grams and 2.3 grams between March 1939 and March 1940 as specified below. (2) Dr. Walter Zinn of the City College of New York who took at my request a leave of absence with reduced pay for the period of March 1939 to September 1939 and to whom I assured that he would be compensated for his loss of salary at City College. (3) Mr. S. Krewer, physical chemist, who helped in collecting information and material necessary for our work and in particular assisted in the experiment carried out by Anderson, Fermi, Szilard on 500 pounds of uranium oxide.

The radium rented from the Radium Chemical Co. was used in the experiments of Anderson, Fermi and Hanstein; Szilard and Zinn; Anderson, Fermi and Szilard as well as in a number of other experiments.

The following bills have been rendered:

By the Radium Chemical Corporation

for rental of radium and insurance covering a period from March 1939 to March 1940 $1301.85

By Dr. Walter Zinn

for loss of salary arising out of leave of absence at City College for the period from March to September 1939 400.00

By Mr. S. Krewer

for his collaboration in the Anderson-Fermi-Szilard experiment	320.00	[illegible]
for other services in connection with the work on uranium	204.00	[illegible]
for expenses in connection with procuing material and information	170.60	
total		694.60

total of bills - $ 2396.45

The following sums have been actually paid by Dr. Szilard towards settlement of the above bills:

To the Radium Chemical Corporation	1181.02	
To Dr. Zinn	400.00	
To Mr. S. Krewer	630.90	
		2211.92

L. Szilard

September 10, 1940

Memorandum to Professor Pegram

I understand that $140,000 forthe sum which we may obtain for the purpose of carrying out ( ) further measurements of the nuclear constants involved (2) an intermediate scale experiment with large amounts of uranium and graphite.

If it is not possible to arrange matters so that Columbia can draw freely within one year on the sum of $140,000 as the need arises, and if for instanct separate grants are given for salaries and materials, and particularly if it is intended to purchase the greater part of the materials required through some Government agency rather than through Columbia University, then it bec mes important to bear in mind the following: (a) the projected work will undoubtedly stretch over a period exceeding one year and it will therefore be necessary to enter into obligations during that year for services which will not be rendered during that year but rather at a later time. For instance we shall probably need about six months time the assistance of further collaboratoss for whom a salary will have to be assured for a period of one year but whose services will partly fall within the second year of the work. The projected salary for such men will obv ously have to be included in the first years budget. Taking this point of view into account we are led to the conclusion that we have to be free to make commitments during the first year for part (a) of the work up to $50,000.

A fund of $90,000 would be required for (b) the intermediate scale experiment. It would be desirable for us to be able to call upon this fund as the need arises and to be able to place orders directly with firms. However, if this does not seem feasible then we ought to be able to be free to call as the need arises upon a sum up to $20,000 while the remaining $70,000 could represent a sort of contractual facility and be used for the purchase of materials through some Government agency. It appears quite essential to have at least $20,000 free for salaries, labor, and in particular for the placing of experimental orders for materials.

Summary:

It is proposed that out of the scheduled $140,000 $50,000 be assigned to part (a) and $90,000 be assigned to part (b). It is further proposed that as much of this fund as possible should be obtained free without any strings attached to it and be called upon as the need arises. If for one reason or another part of the funds have to be used in the form of orders for materials through some Government agency then the funds so tied up should not exceed one-half of the total, i.e., it should not exceed $70,000 and it should then be ear-marked for purchasing materials for part (b).

ESTIMATE OF COST

Part (a), nuclear measurements for the purpose of determining the optimum conditions for maintaining a chain reaction in uranium.

	Materials	Labor Constructional Cost Apparatus	Salaries Staff and Research Assistants
Expenses involved in mixing and separating one gram of radium borrowed from the U.S. Navy with beryllium		$ 250	
Rent for one year for two grams of radium to be used as a photo neutron source during the period from Jan. 1941 to Jan.1942	$ 5,000		
Equipment for such a neutron source		100	
Rent on an additional gram of radium to be mixed ith beryllium (for a period of 1 yr. starting March 1,1941)	2,500		
Cost of separating		400	
Experimental orders for materials such as uranium oxide, graphite, etc. in varying purity	10,000		
Labor, constructional cost and apparatus for the projected nuclear measurements		12,500	
Contribution to the salary of Dr. Szilard as proposed in Dr. Pegram's memorandum of Aug.14, 1940 covering a period of 1 yr.			4,000
Salaries for four research assistants at the average rate of 3,000			12,000
Salary for one additional research assistant covering a period of Feb.1941 to Feb. 1942			3,000
Totals	$ 17,500	$ 13,250	$ 19,000

Grand total $ 49,750

Part (b), intermediate scale experiment.

	Materials	Labor Construc-tional Cost Apparatus	Salaries Staff and Research Assistants
For one research assistant at the rate of $3,000 per year			3,000
For labor, constructional cost and apparatus		2,000	
For experimental orders for materials in particular uranium metal	15,000		
For bulk orders of material such as graphite and uranium metal	70,000		
Totals	$ 85,000	$ 2,000	$ 3,000

Grand total $90,000

420 West 116th Street
New York City

October 6, 1940

Professor G. B. Pegram
Columbia University
New York City

Dear Professor Pegram:

Since I missed you Friday afternoon and was not able to reach you over the telephone this evening I am writing you this letter in order to keep you informed. You may not find it necessary or desirable, though, to make use of this information during your present visit to Washington.

A few days ago I saw Mr. Pollion of the Research Corporation. When I had previously seen him, I believe in February, I had told him of the intention to enlist, if possible, the support of the Government for carrying out a major project concerning uranium, which had been worked out in great detail. This time I told him that pending a decision on this major project I proposed to start a specific minor experiment on uranium and wondered if it were possible for me to obtain from the Research Corporation a grant of about $ 5000.- for the purposes of such an experiment in the immediate future, which would enable me to start the experiment without further delay.

Mr. Pollion advised me that if I made an application right away they might make it possible for me to start in about three weeks. A description of the experiment would have to accompany my application, but Mr. Pollion would restrict the number of persons to whom this description would be disclosed to three

members of their committee, i.e. Dr. Bush, Dr. K.T. Compton, and Dean Barker of Columbia University. The executive committee would then decide whether to make the grant on the basis of the recommendation of these three members of the advisory committee without concerning themselves with the details of the proposed experiment.

All these precautions are hardly necessary since it is the result of the proposed experiment rather than the method which is used for obtaining it which ought to be kept secret, but it is perhaps just as well to keep the number of persons informed as small as possible.

It seems to me that in the circumstances there can hardly be any objection on the ground of secrecy to my making an application to the Research Corporation. However, if you should think that the matter ought to be mentioned in Washington before I actually make an application to the Research Corporation, then perhaps you would want to make use for this purpose of the opportunity which your present visit to Washington may afford.

With best wishes,

yours sincerely,

(Leo Szilard)

December 2, 1940

National Carbon Company, Inc.,
Office Supervisor
Carbon Sales Division
1217 Carbide and Carbon Building
30 East 42nd Street
New York, N. Y.

Our reference: G.B.P.-Szi/H.

Dear Sir:

We are interested in carrying out certain experiments for which about forty tons of graphite blocks will be required. The graphite will need to be quite pure, with an ash content not greater than .1%, and there are also certain restrictions as to the form of the graphite blocks which we could conveniently use. Blocks of a size 12" x 12" x 1" or 12" x 12" x 2" would be quite suitable. We should need four tons of this graphite for immediate tests preliminary to a decision as to using the larger amount of forty tons.

In July 1939, in a letter to Dr. Leo Szilard, you quoted a price on a quality of graphite which would possibly meet our requirements. A copy of your letter dated July 21, 1939 is enclosed for your information. Again in January 1940 you submitted a bid of $1500 for four tons of graphite of this quality to the National Bureau of Standards.

We shall be glad to know the best price at which you can supply four tons of graphite blocks as specified, and also the time required for delivery. We should like also to have your price and delivery time on forty tons of similar graphite blocks.

If you are able to make a bid on a purer graphite, having an ash content not greater than .07% or .05% and free particularly of vanadium oxide, such an alternative bid might be of interest to us since purity of the graphite is of high importance for our work.

We should be glad to have you specify also the limit of variation in the dimensions of the graphite blocks.

Very truly yours,

Encl. George B. Pegram

420 West 116th Street
New York City

December 5, 1940

Professor G. B. Pegram
Physics Department
Columbia University
New York City

Dear Professor Pegram:

Enclosed you will find a rough sketch of the next experiment which, according to our present plans, I am preparing to perform. This experiment will have to be carried out with and without beryllium, and it is expected that it will give information on the chances of performing a chain reaction in a system composed of uranium, and graphite, or uranium, beryllium and graphite.

We might perhaps be able to adjust conditions so that the thermal neutron flow from the graphite into the paraffine should be zero or negligible. If this condition is fulfilled an increase in the integral of the thermal neutron density $\int \rho r^2 dr$ in the paraffine brought about by the introduction of uranium into the system might be of a rather direct significance concerning the chances of a chain reaction. However, we shall measure apart from this integral other quantities, some of which were set forth in detail in my memorandum dated October 5, 1940, which you have in your files. A second memorandum dated November 3, 1940, which is also in your files, contains the data on preliminary experiments for the purpose of finding out if we can obtain beryllium oxide or beryllium metal in a form suitable for the purposes of this experiment by applying high pressure to powders of such material.

As a result of these tests we have put in a request for 150 lbs. of beryllium metal to be used in this experiment and to be tested also by Fermi in an arrangement which he had been using for other purposes and which is now ready and available to be used for testing beryllium.

We shall naturally test the material, the beryllium metal or the oxide, also for its thermal neutron absorption, but this will necessarily be a rough test only since we know of no way to carry out an accurate test on such a comparatively small amount of material.

Yours sincerely,

L. Szilard

(Leo Szilard)

Copy for Dr Szilard

COPY

COPY

THE UNIVERSITY OF CHICAGO

Ryerson Physical Laboratory

January 26, 1941

Professor G. B. Pegram
Department of Physics
Columbia University
New York City

Dear Dr. Pegram

As you know, I have requested the National Research Council to keep me informed on beryllium trough their Committee on the availability of materials. I have just received the following information from them:

Recently the Foote Mineral Company, 1609 Summer St, Philadelphia, has sold beryllium in lots of 25 lbs. at $47 per pound. The analysis is 97.25% Be, 1.09% Mg, 1.05% F. I write you this just in case you have not already explored this source. They might have considerable amounts stored away somewhere.

I am assuming that your group and Dr. Briggs are keeping after the beryllium, and that eventually we can get quantities of the order of 25 lbs out here for our experiments. If I am wrong on this please let me know and I will push on Be from this end. We plan to work with BeO at first.

We are proceeding as fast as possible.

Yours sincerely,

Signed: Samuel K. Allison

CC: 1 - Szilard
2 - Mitchell

cc for Dr. Szilard

January 29, 1941

Professor Samuel K. Allison
Ryerson Physical Laboratory
University of Chicago
Chicago, Illinois

Dear Professor Allison:

Thanks for your letter of January 26.

It will be of interest to learn where the Foote Mineral Company obtained the beryllium that it has. The analysis indicates that it might be some of the beryllium previously made by the Beryllium Company of America.

We are keeping after the Beryllium Company of America and hope that they can promise us some rather pure beryllium at an early date. We shall let you know how the matter develops, because we realize your need of a considerable quantity of the metal in order to obtain the best results from your experiments.

Sincerely yours,

GBP:H George B. Pegram

CC: 1 - Pegram
1 - Szilard
2 - Mitchell

Copy for Dr. Szilard

January 27, 1941

Dr. Walter H. Zinn,
454 Riverside Drive,
New York, N. Y.

Dear Dr. Zinn:

The reply that I got from Washington about getting clearance for you for the work here after the first of February, was that it should really not be necessary to have clearance for you, that I could take the responsibility of engaging you to work on the job, and that it probably would be better to do that than to start the process of getting clearance.

This being the case, there seems to be no reason why you should not go right ahead with securing your leave of absence from City College to begin work here by February 1, 1941.

Sincerely yours,

GBP:H George B. Pegram

cc: Dr. Leo Szilard

February 14, 1941

Dr. Irvin Stewart, Secretary
National Defense Research Committee
1530 P Street, N.W.
Washington, D. C.

Dear Dr. Stewart:

This is to acknowledge your letter of February 1 asking for naturalization information about Dr. Walter Henry Zinn. I had thought that, in accordance with my letter of January 4 answering yours of January 2, the matter of clearance for Mr. Zinn had been dropped. In any case, however, I am very glad to furnish the requested information which is as follows:

Place of Entry	Detroit, Michigan
Court and date of naturalization proceedings	District Court of U.S., New York, N.Y., August 11, 1938
Naturalization certificate number	No. 4317762

Mr. Zinn has been busily at work with us since February 1.

Very truly yours,

GBP:H

George B. Pegram

cc: Professor Fermi
Dr. Szilard

February 15, 1941

Dr. Lyman J. Briggs, Chairman
Uranium Committee
National Defense Research Committee
Washington, D. C.

Dear Dr. Briggs:

There are sent you with this two copies of additional pages, namely pages 7 to 14, to complete the memorandum on an "Intermediate Scale Uranium Carbon Experiment, with Cost Estimate" of February 14, 1941", which was mailed to you on the evening of February 13. These additional pages consist of notes on items of the cost estimate and on a comparison of the present estimate for the intermediate experiments, first with uranium oxide and then with metallic uranium, as compared with the tentative estimates for the intermediate experiment with the metal submitted to you on October 16, 1940.

May I add the remark that Professor Fermi thinks that the importance of the experiment with uranium oxide and graphite on the intermediate scale is such that it might well receive even more emphasis than it is given in our memorandum.

At the same time I am sending you with this the following reports:

1. A brief progress report on the work we have been doing under the contract between N.D.R.C. and Columbia University.

2. A report prepared by Professor Fermi in December, 1940, entitled "Memorandum on an intermediate experiment for determining the possibility of a chain reaction with uranium and carbon". The memorandum discusses both the experiment with o - and the experiment with metal.

3. Copy of an extensive report by Mr. Anderson and Professor Fermi dated January 17, 1941, on "Production of neutrons by uranium". This report of nineteen pages, with an appendix of ten pages, also seven pages of tables and three photostats of diagrams, covers in detail much of the work , experimental and theoretical, on which Professor Fermi, Mr. Anderson and Mr. Weil have been engaged since November. Perhaps the most important single outcome of this work has been a more reliable value for the average number of neutrons produced by uranium upon capture of a single thermal neutron, which number is given on the first page of the report as 1.73, a figure that is not discouraging as to the possibility of a chain reaction.

I trust that these memoranda and reports will put at your disposal all the information that you may need in presenting this proposal for pushing ahead rapidly with the intermediate experiment to the N.D.R.C., and that the N.D.R.C. will be convinced of the importance of going ahead with this.

Sincerely yours,

GBP:H George B. Pegram

February 14, 1941

To Dr. Lyman J. Briggs from George B. Pegram

Subject: An Intermediate Scale Uranium-Carbon Experiment with cost estimate.

An experiment to test the possibility of a uranium fission chain reaction using uranium masses (without separation of the isotopes) distributed through a much larger mass of carbon, on a scale which while not as large as required for actually producing the chain reaction will be large enough to give much clearer indications of conditions for a chain reaction than can be got from measurements on an ordinary laboratory scale.

Materials

For the success of this experiment both the uranium and the carbon should be in as pure and as dense a form as can be obtained. For the most decisive results the uranium should be in the pure metallic form and as dense as it can be obtained by melting, sintering or by highly compressing the powdered metal. Metallic uranium in powder form can be obtained and we have a bid on ~~pound~~ ton lots of it. When made it contains hydrogen which has to

be removed by heating. No one is now able to furnish case uranium. Experiments on sintering are in progress. One of the major tasks of the experiment and one of the largest costs will be that of obtaining the uranium in metallic and dense form. The possibilities are being investigated, but it will certainly be a matter of months before a satisfactory solution can be expected.

While investigations are in progress on the production of the solid metallic uranium it is proposed to go ahead actively with the work by running through the experiment with uranium oxide, U_3O_8, compressed in molds to the highest practicable density, without waiting until the metal itself in suitable form will be available. Such an experiment, using carbon and uranium oxide, will not be as advantageous as one using the metal with the carbon, but it will be a great advance above anything that can be done on a small laboratory scale, and it may indeed give a definite answer to the problem of attaining chain reaction conditions with uranium and carbon. In any case, running through the experiment with uranium oxide will greatly expedite the progress of the similar experiment with uranium metal when that becomes available. The uranium oxide experiment is therefore proposed as the most effective means of expediting progress toward an answer to the question of the practicability of a uranium-carbon chain reaction.

Carbon for the experiment, in the form of graphite, is satisfactory and is relatively cheap, but we have discovered that much attention will need to be given to its purity, especially to freedom from boron, which element has a high capture cross section for slow neutrons.

Estimate of Cost

For the experiment on an intermediate scale, approximately from one-quarter to one-sixth of the amount of material estimated to be needed to obtain a chain reaction, the chief materials needed will be three tons of uranium metal, five tons of uranium oxide, forty tons of graphite. In addition there will be salaries, equipment, supplies, labor and incidental expenses. The following is what seems to be a reasonable estimate of cost.

(See next page)

1.	For investigations on the process of securing metallic uranium in suitable form		$ 3,000.
2.	For four tons of uranium oxide to be converted into metal	$17,000.	
3.	Cost of reduction of three tons of metal from the oxide		60,000.
4.	For investigations to improve the purity of the graphite		3,000.
5.	35 tons of graphite (five tons more will be on hand already)	15,000.	
6.	Salaries of physicists and assistants		18,000.
7.	Special apparatus and equipment, also constructions necessary for supporting and moving the forty tons of graphite, etc.		7,000.
8.	Running expenses and overhead, 12 months		12,000.
9.	Five tons of uranium oxide for the experiment with oxide pending the delivery of the uranium metal	21,500.	
	Total for non expendable materials	$ 53,500.	
	Total for services and expendable materials		$103,000.
	Grand Total		$156,500.

Place of Experiment

It is proposed to perform the intermediate scale experiment in a large room in University Hall, Columbia University, a central unfinished building of the University which is close to the Pupin Physics Laboratories. The room in University is large and has a high ceiling and is much better for the purpose than any room in the Pupin Laboratories.

Time of the Experiment

It is hoped that the assembly of the uranium oxide experiment could be begun in April, 1941, before which time much would be done on necessary apparatus. A period of one year is indicated for the uranium oxide experiment followed by the metallic uranium experiment.

Question of Some Possible Hazard

The question of any possible hazard has been carefully examined by Professor Fermi. There seems almost no chance that a chain reaction could start in 40 tons of carbon in 3 tons of uranium but even if that were possible, the possibility would be detected long before that much material was piled up. The procedure of the experiment calls for making measurements of neuton density throughout the mass of carbon and uranium as it is gradually brought together. The measurements naturally

would not proceed further if the density should begin to show a rapid increase with the adding of more materials.

Notes on Items of the Cost Estimate, Page 4

Item 1. If three tons of metallic uranium in solid, spherical or bulk form were purchasable in the market, it would be very easy to set up the experiment on the intermediate scale. However, metallic uranium has never been produced in large quantities. In America it has been produced only in amounts of a few pounds and that in the form of fine powder, which when first produced has much hydrogen with it. The hydrogen may be driven off by heating in a vacuum. The remaining powder is then very likely to become pyroforic and be difficult to handle. The firm that does make metallic uranium in powdered form is the Metal Hydrides Incorporated, Beverly, Massachusetts, of which firm Mr. P. P. Alexander is the active head. Mr. Alexander is cooperating with us very actively in studying the question of how to get uranium in a form suitable for these experiments and at a reasonable cost. The Bureau of Standards is working on another method of production of uranium which may give solid castings of the metal. The research laboratories of both the General Electric and the Westinghouse companies are assisting us in studying the possibility of sintering powdered uranium into a solid and reasonably dense form. In the contract with Columbia

University at present there is an item of $5,000 for investigations of the metallurgy of production of metallic uranium in a form desired. It is doubtful that this will be enough. Hence the additional item of $3,000 is entered in the cost of the intermediate experiment.

Item 2. It appears that there will be no difficulty in obtaining from the Eldorado Gold Mines, Ltd. uranium oxide in amounts of several tons, coming from the Canadian pitchblende deposits which seem to be quite free of any rare earths which might have a high absorption of neutrons. From our last discussions with representatives of Eldorado Gold Mines, Ltd. it appears that we should be able to secure the uranium oxide, U_3O_8, at slightly more than $2.00 a pound, although the market price for lots of a few hundred pounds is about $2.50.

We have put down four tons of uranium oxide because we do not know how complete a reduction of this oxide to the metal may prove practicable, but this amount of the oxide would probably be quite enough to give us at least three tons of the clean metal beyond any wastage.

Item 3. It is impossible to predict just what the reduction of three tons of metal from the oxide will cost. Mr. Alexander of Metal Hydrides Incorporated thinks that the processing in quantities of several tons could be

brought down to $10 a pound above the cost of the oxide. Hence for the three tons we have put down the cost of reduction as $60,000.

Item 4. By reducing to ash and measuring the neutron absorption of the ash of some of the graphite that Professor Fermi has been using since last Spring, it is found that, although the ash content is small, it is sufficient to account for a considerable fraction of the total slow neutron absorption. If the ash content can be reduced and thereby the absorption of the slow neutrons in the graphite decreased, it will be very advantageous. We have already been very much aided by the National Carbon Company and by the Division of Chemistry of the National Bureau of Standards in analyzing the ash of graphite, and we hope that further investigations will lead to at least some reduction in the amount of ash of the graphite manufactured especially for these experiments. We believe the item of $3,000 is not more than will be needed, and that it will be very well invested in attempts to improve the purity of obtainable graphite.

Item 5. The amount of 35 tons of graphite is specified, rather than the 40 tons that will be required, because we shall have on hand more than 5 tons of graphite from the experiments that are now being carried on. The

estimate of cost of the 35 tons is at a figure somewhat less than the market price in 4 ton lots, but we have reason to think that on 35 tons a better figure can be quoted and that $15,000 should cover the cost.

Item 6. This is an estimate of the salaries of physicists and assistants for twelve months at the rate of $1,500 a month. This will cover the salaries of two men at a rate of $333.33 a month; two at $250 a month; one at $150 a month; and two at approximately $100 a month. It is to be expected that with this staff it would be possible to carry out both the uranium oxide experiment and the metallic uranium experiment within the course of a year.

Item 7. It is certain that a good deal of special equipment and apparatus will be needed in carrying out the measurements on the proposed experiments, and that in handling 40 tons of graphite considerable construction of one kind and another will be necessary for supporting the graphite and for moving it about readily. For example, it would probably be desirable for at least half of the pile of graphite and uranium or uranium oxide to be mounted on rollers in such a way that it could be separated from the other half of the pile in order that measurements can be taken as the parts are separated or

brought together. An allowance of $7,000 for this is included.

Item 8. For carrying out an experiment of this kind there will be many incidental expenses and there will be the university overhead. For this an allowance of $1,000 a month is included in the estimate.

Item 9. Seven tons of uranium oxide will, according to present plans, be used in the experiment with graphite and uranium oxide which is believed to be so important for immediate attention. Only 5 tons of the oxide at $21,500 are put in the estimate because we shall either have another 2 tons of uranium oxide secured under the present contract for experiments, or use 2 tons of the 4 tons called for under Item 2 above before these 2 tons are converted into metal. In any case the uranium oxide is material that has a definite market value, so that if at the end it is not needed the loss on it will be comparatively small. In fact we have been offered a contract under which this oxide will, at the expiration of a stated period, be taken back and sold for us by the Eldorado Gold Mines, Ltd.

Comparison of the Cost Estimate, Page 4, with a previous Tentative Estimate

In an estimate of cost for the intermediate scale experiment submitted to Dr. Briggs as Chairman of the Uranium Committee on October 16, 1940, as a basis for a possible second contract between the N.D.R.C. and Columbia University, the figure for the total was $100,200., as follows:

4 tons of U_3O_8	$ 20,000.
Metallurgical expense to get metal from oxide	40,000.
36 tons of graphite	18,000.
10 tons of paraffin	1,600.
400 lbs. sheet cadmium	1,000.
Rental of radium for neutron source	3,300.
Constructions for handling graphite and uranium	2,000.
Salaries, six months	8,300.
Running expenses, six months	6,000.
Total	$100,200.

The present estimates on page 4 total $156,500. The increases over the October figures are as follows:

For investigation to secure metallic uranium	3,000.
Increase in item for reduction of uranium oxide to the metal (This increase now seems in accord with the present prospects, though this is still quite the most uncertain item)	20,000.
Investigation to improve the purity of carbon	3,000.

Additional 5 tons of U_3O_8 for the experiment with U_3O_8 in place of the metal	21,500.
Increase in item for salaries, chiefly through increasing the period from six months to twelve months to cover both the oxide and the metal experiments	9,700.
Increase in running expenses, six months to twelve months	6,000.
Special apparatus and equipment and constructions - Increase	5,000.
Total increase over October estimate	$ 68,200.

Decreases as compared with October estimate are:

On the cost of 4 tons of U_3O_8	3,000.
In the estimate of cost of graphite	3,000.
Omission of rental of radium	3,300.
Omission of cost of paraffin	1,600.
Omission of sheet cadmium item	1,000.

(Something will be necessary for the three items just preceding, but it is expected that such expenditures as will need to be made on these can be made either under the present contract or within the estimate for running expenses of the intermediate experiment)

Total decrease	$11,900.

Total increase	68,200.
Total decrease	11,900.
Net increase	$56,300.

Since starting to draft this letter I have received a copy of the letter from Mitchell to Alexander asking for a bid on 1000 pounds of uranium metal, which I take it is partly at least to establish a record as to whether any other producers are able to bid on uranium metal at all. Whatever the bid received for 1000 pounds, it could probably be considerably bettered by Alexander if the amount were made three tons. He then would know just how to plan to produce such an amount in the least expensive manner.

If this plan of asking Alexander to bid on three tons appeals to you, we should be glad to know when you write him about this, and shall be glad to do whatever we can from this end to influence him to do the very best he can on the bid.

Sincerely yours,

GBP:H George B. Pegram

cc: 1 - Pegram
1 - Fermi
1 - Szilard
2 - Mitchell

COPY

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TELEGRAM		ORDINARY	
DAY LETTER		URGENT RATE	
SERIAL		DEFERRED	
NIGHT LETTER		NIGHT LETTER	
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WESTERN UNION

1217-B

R. B. WHITE
PRESIDENT

NEWCOMB CARLTON
CHAIRMAN OF THE BOARD

J. C. WILLEVER
FIRST VICE-PRESIDENT

CHECK
ACCOUNTING INFORMATION
TIME FILED

Send the following message, subject to the terms on back hereof, which are hereby agreed to

July 29, 1941

Dr P P Alexander
Metal Hydrides Company
Beverly, Mass.

Confirm authorization for you to proceed until further notice on experimental production of metal at rate of 35 to 50 pounds per week on Bureau of Standards contract.

George B. Pegram

COPIES
1 Pegram
1 Fermi
1 Szilard
2 Mitchell

CLASS OF SERVICE DESIRED			
DOMESTIC		CABLE	
TELEGRAM		ORDINARY	
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Patrons should check class of service desired; otherwise the message will be transmitted as a telegram or ordinary cablegram.

COPY OF WESTERN UNION TELEGRAM

1941 Jul 29 AM 12 40

BC 1106 28 NT XC-Beverly Mass 28

Doctor G P Pegram
Columbia University NYK

Kindly confirm that we can go ahead with experimental production of uranium at average rate of 35 to 50 pounds per week without waiting for boron free calcium.

METAL HYDRIDES CO

P. P. Alexander

COPIES
1 Fermi
✓1 Szilard
2 Mitchell

Pegram to Briggs

February 15, 1941

Progress Report on Work done under the Contract between the National Defense Research Committee and Columbia University for Investigations in connection with the Fission of Uranium.

This contract went into effect on November 1, 1940. Since that time the work has been carried on by Professor Fermi, Dr. Szilard, Mr. Herbert L. Anderson, Mr. George Weil, and since February 1, Dr. Walter H. Zinn, with administrative and technical aid from Professor Dana P. Mitchell and the undersigned. The work has been of two quite different kinds: (1) The experimental and theoretical work in connection with measurements made on neutrons in graphite, uranium and other substances. (2) Work directed toward the obtaining of uranium metal, pure graphite, with some attention also to the question of obtaining beryllium metal. The following is a brief statement of the work under these two heads.

(1) a. Slowing down process of neutrons in graphite.

This process was investigated by studying the intensity of activation of various detectors (Rh, In, I) obtained at various places inside a square graphite column of 3 x 3 x 8 feet, with the source of neutrons placed on the axis. With suitable use of cadmium screens the effect of resonance and thermal neutrons has been investigated separately.

A mathematical analysis of the experimental results has been carried out taking as a general basis the assumption that the process of slowing down of the neutrons may be described as a diffusion process and determining from the

experiments the corrections to be applied in the various cases. (This method is developed in reports Oct.40. and (Jan.41 Sect. 1).

Also the diffusion of thermal neutrons has been investigated mathematically. The results described in this section enable us at present to calculate with a fairly good accuracy at any point in a carbon mass of a given shape the number of thermal or resonance neutrons to be found at any position.

b. Determination of the number of secondary neutrons emitted when a thermal neutron is absorbed by uranium.

This measurement was performed by slowing down the neutrons in a graphite column. At a convenient distance from the source it is possible to have an appreciable intensity of thermal neutrons originated in the source and only a very small number of neutrons of higher energies. Some uranium placed at this position absorbs therefore mostly thermal neutrons and re-emits fast neutrons that can be easily distinguished from the primary thermal neutrons and can be measured thereby on a very low background. The analysis of this experiment is described in sections 2 and 3 of this report.

c. Extensive calculations have been performed on the "intermediate experiment". The main purpose was to determine the law of variation of the number of neutrons

escaping from a reticular mass of uranium and carbon when the dimensions are varied. Part of these results is summarized in the curves attached to our report of Dec. 20 1940 copy of which is sent with this.

d. Consideration has also been given to other types of experiment to assist in arriving at some of the needed nuclear constants. Dr. Zinn is getting under way with an experiment that will make use of a spherical mass of powdered uranium metal weighing about 20 lbs. For a neutron source he will use the deuterium-deuterium reaction with the equipment which he has developed in the past few years.

(2) The problem of pure materials.

Much time and thought have been given to the question of securing materials of sufficient purity and in suitable form.

Graphite

The graphite obtained last Spring from the U.S. Graphite Company of Saginaw, Michigan, is of high purity for a commercial product. The neutron absorption of the ash from combustion of some of this graphite has been tested in the laboratory and found to be rather high, i.e. the material in the ash will account for a considerable fraction of the total absorption in the graphite. The presence of boron in the ash has been proven. Analytical work in testing the boron content has been done for us by the National Carbon Company, by the National Bureau

of Standards and by a commercial firm of analysts. The boron content seems to be about one part in 500,000, which may be tolerable but is undesirable. So far it has not been possible to make arrangements for the supply of graphite free of boron, but further efforts are being made in this direction.

Uranium

The production of metallic uranium in dense form seems to be the major problem in our line of experiment, but uranium in solid form is not yet available from any source. We are receiving cooperation in several directions particularly the Metal Hydrides Incorporated of Beverly, Massachusetts, the National Bureau of Standards, the research laboratories of the Westinghouse and the General Electric companies.

For the experiment with uranium oxide and carbon it would really be quite advantageous if we could use the uranium dioxide rather than the ordinary oxide, U_3O_8, because the dioxide has a much higher density and of course it contains less oxygen. We are working with the Linde Products Company and with other firms on experiments with the production of the uranium dioxide.

Beryllium

We have given some attention to the question of obtaining a supply of pure metallic beryllium. Since last

summer we have discussed the possibility of using comparatively small amounts of beryllium, together with uranium and graphite, if it should appear that the uranium and graphite alone would just fail to reach chain reaction conditions. It is possible that an amount of beryllium about equal in volume to that of the uranium, placed immediately around the uranium masses, might serve as enough of a booster to bring about conditions for the chain reaction. This, of course, is a very different thing from using uranium mixed with beryllium as the slowing down material, which would require very large amounts of beryllium.

COPY FOR DR. SZILARD

April 5, 1941

Dr. John W. Marden
Assistant Director of Research
Westinghouse Electric & Manufacturing Company
Bloomfield, New Jersey

Dear Dr. Marden:

Professor Fermi, Dr. Szilard and I have discussed together your letter of March 28. It seems to us that the suggestion that you act in an advisory capacity on the question of obtaining solid metallic uranium is a more immediately helpful suggestion than your second one of an arrangement under which you could try out experiments on this subject on a cost plus basis.

If, therefore, you are willing to act in an advisory capacity, we think it would be well to arrange for a conference with you and Mr. Alexander of the Metal Hydrides Incorporated for a discussion of methods that may be feasible for producing metallic uranium in fairly large quantities.

We have not yet communicated with Mr. Alexander about this, but he has from time to time referred to your work, and I know that he would be much pleased to meet you. May we then proceed to try to arrange such a conference? Of course if Dr. Rentschler could also be present so much the better.

Sincerely yours,

GBP:H

George B. Pegram

cc: 1 - Pegram
1 - Fermi
1 - Szilard
2 - Mitchell

COLUMBIA UNIVERSITY

May 3, 1941.

To Arthur H. Compton, Chairman-from George B. Pegram

Memorandum

on the Uranium-Carbon Experiments

Proposal: To investigate the possibility of a chain reaction in a system of ordinary uranium and carbon; then if possible to demonstrate the liberation of energy by a controlled fission chain reaction; also to determine the conditions for practical utilization of the energy.

It is expected that such a chain reaction can be utilized for the following prime purposes:

1. A source of heat for a power plant.

2. The production of chemically separable elements that will show fission with neutrons.

3. A source of neutrons and gamma rays.

This research divides itself into several stages:

1. Measurement of the nuclear properties and constants of uranium, carbon, and other elements, which relate to the fission experiments.

2. An "intermediate experiment" on a scale which, though not large enough to produce a chain reaction will be large enough to give much clearer indications of conditions for the chain reaction than can be got from measurements on an ordinary laboratory scale.

3. An experiment on a scale calculated to demonstrate a self maintaining chain reaction, with controls, using approximately 4 times as much material as in 2.

4. The design and construction of equipment for utilizing the energy of the chain reaction (i.e. power plant, etc.)

In normal times these stages would be attended to in succession. In the present emergency time should be saved even at the cost of some wasted or imperfectly guided effort, therefore work on all

four stages should proceed simultaneously as rapidly as possible.

Stage 1. The measurement of nuclear constants has been in progress since the summer of 1940 and since November 1, 1940 has been well supported through a contract of the N.D.R.C. with Columbia University, the contract running to November 1, 1941. This work may need to be continued beyond that time. To continue it there will be needed the services of a number of physicists and funds for current expenses of the experiments undertaken and also something for experimental orders for materials of improved purity, particularly graphite. An amount of $7,500 for salaries and of $10,000 for materials and apparatus would enable this work to be carried on for six months after November 1, 1941.

Professor Fermi has made several reports on the progress of these measurements. No more need be said of them here than that they have shown no reason for discouragement as to the feasibility of a uranium-carbon chain reaction.

Stage 2. The Intermediate Experiment will require for most rapid progress approximately the following:

Materials			
40 tons of graphite	$23,000		
8 tons of U_3O_8	33,000		
4 tons of uranium metal	48,000	(?)	
15 tons of paraffin	3,000		
		$107,000	
For incidental materials and construction		$ 12,000	
Salaries			
5 physicists at $3,000 for a year	$15,000		
2 chemists or equivalent	6,000		
3 mechanics at $2,400	7,200		
3 helpers at $1,500	4,500		
		$ 32,700	
Radium rental		$ 3,300	
Beryllium metal, 150 lbs.		$ 7,000	(?)
Running expenses and overhead		$ 12,000	
			$174,000

The primary materials for this experiment, amounting as indicated above to $107,000, can be mainly supplied out of the sum of $100,000 already appropriated and at the disposal of Dr. Briggs. Dr. Briggs has already ordered 40 tons of graphite and 8 tons of uranium oxide. The cost of uranium metal is not certain. The cost of beryllium is uncertain, it may be less, and it may not be necessary to decide at once to buy it.

It is expected that a suitable laboratory room for the Intermediate Experiment will be available so that work on the experiment can proceed as rapidly as the materials arrive provided a contract is arranged.

Stage 3. Demonstration of the Actual Chain Reaction.

An approximate statement of what will be needed for this is as follows:

Materials	
Graphite 120 tons (With 40 tons from Intermediate Experiment will make the total of 160 tons)	$ 60,000
Uranium Oxide 50 tons	200,000
Reduction of 15 tons to metal in desired form	150,000
(The uranium oxide will have a market value not much below its cost.)	

Site and buildings

This experiment will need to be done in a somewhat isolated place that can be kept well guarded. One large room will be needed, about 30 x 30 feet by 25 feet high, with 3 or 4 smaller rooms for laboratories, shop and storage. The building should be equipped with such light shop machinery as may be needed and with other standard laboratory furniture and apparatus. It will of course have to be supplied with electric power, water, gas of some kind, and should be easily accessible by truck.

Salaries

5 or 6 physicists will be needed on the site and perhaps 5 other persons, mechanics and helpers. An allowance will have to made for special materials and constructions. These items might be covered by the sum of $50,000.

Stage 4. No definite estimate of the cost of Stage 4 can be attempted at present. The designing of methods of making practical utilization of the energy from uranium fission will require both physicists and engineers. The construction of the equipment will need to be carried out by firms that are able to do such work. All that needs to be said about Stage 4 at this time is that immediately or before long arrangements should be made for the problems that will arise in attempting to put the chain reaction, if it is obtained, to practical use to be considered by physicists and engineers who are qualified to tackle these problems.

May 19, 1941

Dr. Lyman J. Briggs, Director
National Bureau of Standards
Washington, D. C.

Dear Dr. Briggs:

I have read the letter from Professor Mitchell to me under date of May 17 and write to express my approval of the procedures set forth in this letter.

On paragraph (1) of Mr. Mitchell's letter I may remark that, while we shall certainly need the $2,000. worth of paraffin before we need the metal, the paraffin item is comparatively small in cost and delivery can be made promptly. Therefore that should take a quite secondary place, and whether it should be bought at all from the money now in your hands is a question to be decided after we know what the cost of the metal will be.

As to (4) of Mitchell's letter, I am proceeding to have Mr. Pregel deliver to us at once the four tons of oxide that he can supply from stock, since we now have access to the room where the oxide will be used. As soon as possible we shall send samples to the Bureau of Standards for moisture content test and shall, if practicable, make arrangement for a similar determination at Columbia.

As to (b) and (c) of (4), I am assuming that Mitchell will give instructions to Dr. Alexander about calcium for analysis, and that the testing of the metal sample now at the Bureau of Standards, to see if it is pyroforic, will be taken care of.

We shall take full possession of the large room at the east end of the basement of Schermerhorn Hall as soon as the movers have finished taking out the furniture and cases that are now in the room and our carpenter shop has

done a small amount of re-arranging of partitions, etc. Fermi and I spent some time over there this morning studying out details of arrangements.

Sincerely yours,

GBP:H George B. Pegram

cc: 1 - Fermi
1 - Szilard
2 - Mitchell

June 2, 1941

Dr. Lyman J. Briggs, Director
National Bureau of Standards
Washington, D. C.

Dear Dr. Briggs:

I have gone over with Fermi and Szilard the tentative figures that we made up in the committee meeting last Thursday for the intermediate carbon-u experiment. The figures as we had them seem to be about as close as can be estimated. If they were cut down somewhat we could still go on with the work but could not push it as fast. If they were augmented we might be able to go a little, but probably not very much, faster.

Attached is a schedule of the items and the estimated allowances of which you may wish to make use in checking up your figures for submission with your recommendations to Dr. Bush.

Sincerely yours,

GBP:H
Encl.

George B. Pegram

June 2, 1941

Estimates for cost of carrying out the Uranium-carbon "Intermediate Experiment", July 1, 1941 to December 31, 1941:

Materials already on hand or ordered:

40 tons graphite	($23,000.)
8 tons uranium oxide	($33,000.)
3 1/2 tons uranium metal, reduction only	($40,000.)
15 tons paraffin	($ 3,000.)
Total	($99,000.)

Additional materials to be provided:

10 tons of uranium oxide	$ 41,000.
3 1/2 tons uranium metal, reduction only	40,000.
Incidental materials and constructions	12,000.
	$ 93,000.

Salaries — 27,000.

Approximately:

10 physicists and chemists	$15,000.
4 mechanics	4,000.
4 helpers	3,000.
For special consultant or short-time work on pressing oxide, melting metal, etc.	5,000.
	$27,000.

Running expenses of research (including overhead items) — 9,000.

Rent of radium — 5,000.

Dies and other special equipment — 4,000.

Total for Intermediate Experiment for six months beginning July 1, 1941 — $138,000.

Also - Experimental orders for graphite, etc., looking to "Chain reaction" stage so as not to lose months of time — $ 10,000.

June 7, 1941

Mr. Boris Pregel, President
Canadian Radium and Uranium Corporation
630 Fifth Avenue
New York, N. Y.

Dear Mr. Pregel:

In accordance with your letter of June 5, 1941, following our conversation of June 3 and further conversation with Dr. Szilard, we are sending you a Columbia University order worded as follows:

"For preparation only of 5 tons (10,000 lbs.) of black uranium oxide at 30 cents a pound for the use of Columbia University until July 15, 1942, and subject to later purchase, all in accord with letter of June 5, 1941, from Canadian Radium and Uranium Corporation, $3,000."

"Delivery of the uranium oxide to be made within a period of six weeks."

The arrangements which you have explained in your letter seem to us entirely satisfactory, and indeed we are very appreciative of your helpfulness in making such an arrangement in order that we may not run the risk of delay in the progress of our experiments.

Very truly yours,

GBP:H

George B. Pegram

cc: 1 - Pegram
1 - Fermi
1 - Szilard
2 - Mitchell

July 23, 1941

Memorandum for Professor Pegram:

Please read the enclosed letter. Would it be possible for you to telephone Briggs and get his okay for this experimental production so that we can arrange matters without further delay?

L Sz

(Leo Szilard)

cc: 1 - Pegram
1 - Fermi
1 - Szilard ✓
2 - Mitchell

August 1, 1941

Dr. P. P. Alexander, President
Metal Hydrides Incorporated
Box 816
Clifton, Massachusetts

Dear Dr. Alexander:

In response to your telegram of July 29, I replied on Tuesday evening by telegram as follows:

> "Confirm authorization for you to proceed until further notice on experimental production of metal at rate of 35 to 50 pounds per week on Bureau of Standards contract."

Before sending the telegram I discussed the subject with Dr. Briggs, Director of the National Bureau of Standards, who was entirely in favor of your going ahead with this somewhat experimental work even if we had to accept some of the uranium metal which might have so much boron in it as to make it not very useable for our experiments.

When I was in Washington on Wednesday I confirmed with Dr. Briggs the receipt of 70 pounds of uranium metal already delivered to us on the Bureau of Standards contract, so that he can go ahead with payment of your bill.

Dr. Szilard has given me a copy of your interesting letter of July 30 to him about your succeeding in fusing the uranium powder in vacuum. I suppose since the fusion took place at a temperature of 1200°C that there must have been a good deal of hydrogen in the metal, which would presumably be freed to a large extent while the metal remained molten. It would be interesting to have an analysis of the ingot for hydrogen.

Sincerely yours,

GBP:H

George B. Pegram

August 19, 1941

Memorandum for Professor Pegram:

The enclosed page was included in the "Preliminary Report on the Melting of Uranium Powder" of August 16, 1941, instead of Page 5 which is contained in your copy.

(Leo Szilard)

LS:MEB

Enclosure

August 20, 1941

Memorandum for Mrs. Teele
Physics Stockroom

Please send a requisition against 970-5002 as follows:

Metal Hydrides, Inc., Beverly, Mass.

35 pounds of thorium metal in powder form

at $20.00 a pound $700.00

George B. Pegram

GBP:MEB

CC: 1 Pegram
1 Fermi
1 Szilard
2 Mitchell

August 20, 1941

Metal Hydrides, Inc.
Box 816
Clifton, Mass.

Gentlemen: Attention: Dr. P. P. Alexander

I am sorry that there has been so long a delay in sending you a formal order for the thirty-five pounds of metallic thorium. The delay was caused by our efforts to get the purchase made from other funds than those available at the University. This letter will accompany a regular order from our Purchasing Department.

Very truly yours,

George B. Pegram

GBP:MEB

Enclosure

CC: 1 Pegram
1 Fermi
1 Szilard
2 Mitchell

December 20, 1941

Memorandum for Professor Pegram:

Mr. Pregel has just telephoned Port Hope at my request, and confirms that the black oxide cannot be dissolved on an industrial scale except in nitric acid. This makes it impossible to use the black oxide for preparing the pure uranium oxide according to the recipe on which Mr. Pochon, Dr. Rodden and I agreed. [The operation of three times leaching, which also appears to lead to a considerable degree of purification, can be performed on black oxide, but there are no five tons of black oxide in stock either in New York or in Canada. Mr. Pregel tells me that they have discontinued the manufacture of the black oxide.]

Would it not be best to call Briggs and if necessary ask Pregel subsequently to call Briggs and arrive at some arrangement. Pregel will leave on Monday for a vacation, and an order should be placed with him by that time.

Leo Szilard

June 24, 1942

Columbia University
Attention: Professor G. B. Pegram
Pupin Physics Laboratory
Columbia University
New York, New York

Gentlemen:

While I was employed by Columbia University I signed a statement concerning inventions made by me during my employment at Columbia University. Since I am now asked to sign a similar statement in connection with my employment at the University of Chicago, and since I do not remember the exact text of the statement which I signed at Columbia University, I would very much appreciate receiving an explicit confirmation from Columbia University to the effect that the statement which I signed did not intend to cover in any way inventions made by me after leaving the employment of Columbia University, that is, February 1, 1942.

I would also appreciate your letting me have a copy of the text of the statement which I actually signed.

Very truly yours,

L. Szilard

LS:g

June 29, 1942

G. B. Pegram
Pupin Physical Laboratory
Columbia University
New York City

Dear Professor Pegram:

Many thanks for your kind letter of June 27th. The matter seems to be perfectly clear now and I shall advise Mr. Stearns that the Columbia group is free to sign a patent agreement with the University of Chicago.

Sincerely yours,

L. Szilard

LS:MA

The University of Chicago
Metallurgical Laboratory

MIDWAY 0800
EXT. 1290

SECRET

December 17, 1942

Professor G. B. Pegram
Pupin Physics Laboratory
Columbia University
New York, New York

Dear Professor Pegram:

I was sorry I was not able to tell you about happenings in Chicago when I was in New York, but I have in the meantime obtained the permission of Professor A. H. Compton to do so. This is the news I would have liked to tell you:

The "egg boiling" experiment took place on December 2nd and everything went exactly as predicted in the early days of our work. Namely, if enough cadmium is pulled out to make the multiplication factor rise above 1, the intensity of the radiation rises slowly with time, and the rate of rise is determined by the delayed neutron emission. In the actual experiment on December 2nd the intensity of the radiation doubled about every 6 minutes.

Very sincerely yours,

Leo Szilard

g

The urgency of delivery of this document is such that it will not reach the addressee in time by the next available office-courier. The originator, therefore, authorizes the transmission of this document by registered mail within the continental limits of the United States.

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U. S. C. 50:31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Dear Professor Pegram,

For reasons which I shall attempt to explain further below I think it might be desirable that I should put on record certain inventions which I have made within the last two years before I actually start to work under the contract with Columbia University on experiments for which the funds are being provided by the Government.

If you see no particular objection to the following ~~x~~ I would propose to chosse the form of patent applications which I would file before starting the projected experiments at Columbia. I would submit copies of these patent applications through you to Dr. Briggs and state in an accompanying letter that I would be glad to assign these patent applications now or at any time later during my work under the proposed contract with Columbia to such agency ~~with~~ of the Government as may be suggested by you or the chairman of the uranium committee, without expecting any financial compensation from the Government, but with the understanding that these patent applications would be re-assigned to me at my request if at some future date the Government abandons the project in support of which it has now granted the sum of $40.000. In that case I would first try to obtain the support of the Rockefeller or Carnegie Foundation for the continuance of the work, and if that fials I would ask for a re-assignment of these patents in order to use them for inducing some industrial corporation in the United States or in Candda to support the project further until its successful conclusion. If you or Dr. Briggs should feel that in this case the Government ought to have the use of these patents even after their re-assignment to me free of royalty, I should be glad to give an undertaking to that effect.

I shall, of course, see to it that no patent is issued as long

as the Government feels that secrecy is desirable, and such secrecy could be assured if Dr. Briggs wrote to the Commissioner of Patents, asking him to take the steps to this effect, which are prescribed by the law. This can be done even if the patent is not, or not yet, assigned to any agency of the Government.

If Dr. Briggs does not see any objection I might apply for a secret patent in Canada and in England, which I would assign without financial compensation to the respective governments, but I shall, of course, refrain from doing this unless I hear from Dr. Briggs that there would be no objection on his part or on the part of any other Government agency which is interested in the matter.

Of course, I should like to remain free to withdraw this patent application at a later date as long as it has not been assigned to the Government.

My reasons for the above proposal are the following: In July last year I formed the conviction that it will be possible to maintain a chain reaction with uranium under conditions which are satisfactory from an engineering point of view, that is under conditions in which it is possible to have the reaction take place at high temperatures and accordingly at a high rate on an industrial scale. One of the primary objects is the construction of an engine which allows it to utilize the heat liberated in the chain reaction for purposes of power production, primarily perhaps for a locomotion. A number of problems arises in this connection, in particular problems of heat transfer and regulation, which present considerable difficulties but which seem capable of a satisfactory solution.

Having contacted a number of my colleagues in July and August last

year, a consensus of opinion developed that an attempt should be made to enlist the support of the Government for carrying out a certain project until its successful conclusion. It may be ~~a~~ half a million to a million dollars will have to be spent before the first engine of this type can be made to work, at least to the extent as todemonstrate the liberation of nuclear energy on an industrial scale.

I now understand that a certain sum has been granted by the Government for the support of experiments which will be carried out at Columbia University under the immediate direction of Fermi and myself. I need not emphasize how very happy I am that we shall thus be put into the position of starting to work along the lines which discussed at carious times with carious representatives of the Government. While we have at present no assurance that further support will be forthcoming we have to base the work on the hope that this project will be supported by the Government until its successful conclusion, i.e. until the construction of the first engine working with nuclear energy is completed.

I personally have repeatedly expressed great confidence that it will be possible to have a nuclear chain reaction in unseparated uranium, and in accordance with this conviction I propose to dedicate the next five or ten years to this task.

I realize, however, that it is difficult to convey this faith in the ultimate success of the work with unseparated uranium to others, and that others take now, or will take after some of the set-backs which we may suffer at one time or the other in the future, a considerably less optimistic view. For this reason we have to envisage the possibility of ~~h~~ not being able to get adequate Government support for certain rather expensive experiments which may become necessary. In that case I should be in favor of applying for support to the Rocke-

feller or Carnegie Foundation rather than to transfer this work within the framework of some industrial corporation. If such support is not obtainable then I would, as a last resort, be in favor of using the proposed patent application as an inducement to some industrial corporation in this country or in Canada for taking up this development, thereby giving them the hope that they might recover the expenses of development through profits which they might make in the future.

I fully understand that any development arising out of the work which we shall carry out under the contract between Columbia University and the Government will become the property of the Government and that no patents may be taken out by those who are engaged in this work.

Dear Professor Pegram:

A project for an experiment involving perhaps 100 tons of graphite and 10 to 30 tons of uranium was worked out in detail in July of last year and an attempt to obtain the assistance of the Government for carrying out such an experiment was made with the moral support and through the good offices of Dr. Wigner, Dr. Teller, Professor Einstein, and Dr. Sachs. I have repeatedly emphasized that I would be glad to share with Fermi the responsibility for carrying out this experiment but apart from this I have never said anything from which one could infer that I did not propose to keep this experiment in my hands; i.e., that I was prepared to hand it over to some organization and confine myself to advising xxx on the best ways in which the experiment could be carried out. I feel now that some confusion is about to arise from the fact that right in the first meeting with the Government representatives on October 21, 1939 I emphasized the interest which the Physics Department of Columbia in general and Fermi in particular is taking in this project. Though I made it clear that I am not speaking for the Physics Department the Government representatives ~~in this matter~~ are probably increasingly under the impression that I am in this matter definitely associated with the Department and that consequently you are speaking in my name as well as Fermi's in your capacity as head of the Physics Department. This in itself

would do no xxx harm if it were possible to arrange everything to the satisfaction of all concerned but it might lead to a very awkward situation if this is not the case. Therefore, should further developments justify the fear that it will not be possible to arrange for the performance of the experiment under the joint direction of Fermi and myself, would you then be good enough to make it clear to the Government representatives that

Dear Professor Pegram:

~~I believe that I have repeatedly stated~~ may I repeat once more that I would be very glad to share with Fermi the responsibility for carrying out a large scale experiment on a system containing large quantities of uranium and graphite. I hope ~~very much~~ that it will be possible to find a set-up in which Fermi and I can jointly direct this experiment as well as conduct a series of measurements which are necessary to find optimum conditions for a chain reaction working with unseparated uranium.

However, in view of the conversations which we had on this subject during the last few days I feel that ~~I should leave no~~ it would not be fair to leave my any doubt about the fact that if a set-up were chosen in which the experiments were conducted by Fermi, and I was ~~expected~~ asked to act as one of his several collaborators or in an advisory capacity I would then, rather than to collaborate within such a frame-work, prefer to keep the experiment (for which I have been trying to enlist the assistance of the Government since July of last year) in my own hands and to perform the experiment either with the assistance of the Government if that were possible or ~~if that should prove impossible, then without~~. Naturally, I realize that this would be an awkward situation and that quite possibly I would not succeed in either obtaining the assistance of the Government or sufficient private funds but this is a consideration of expediency which I am inclined to disregard for the present.

Naturally, I do not want to interfere with a favorable course of your negotiations with the Government by raising any such

question at this juncture. On the other hand the Government representatives are probably under a misapprehension in so far as they do not know the exact relationship between the Physics Department and myself they may think that as the head of the Physics Department you represent me as well as Fermi. This misapprehension will remain harmless if all goes well but it could also lead to a very awkward situation if, at the last moment, we would have to inform the Government representatives that the Physics Department and I propose to act independently of each other in this matter.

May I therefore ask you to be good enough to watch the situation and to explain my point of view or arrange for me to explain it directly as soon as you have reason to fear that the Government proposes to have the large scale experiment carried out within a frame-work which excludes the possibility of Fermi and myself acting in collaboration, corresponding to the conception which I had previously explained to you and discussed with Fermi in greater detail.

To Prof. Bergman
from L. Szilard May 4. th

In order to demonstarte a chain reaction in which nuclear energies are liberated we propose to carry out the large scale experiment using up to 160 tons of graphite and 35 tons of uranium oxide or alternatively 15 tons of uranium metal. It is believed that if the facilities can be obtained, such an experiment can be carried out within a year and has a reasonable chance of success, and it is hoped that the quantities of materials actually required will be less than those quoted above.
It is proposed that the Government secures the 50 tons of uranium oxide by placing an order for this amount as soon as possible. Delivery could be expected at the rate of 1 ton per week so that the total amount could be secured within a year.

As the first step towards this large scale experiment it is proposed to carry out an experiment on an intermediate scale with 40 tons of graphite and 6 tons of uranium metal. Since it will take 3 to 6 months to obtain delivery of such an amount of uranium metal it is proposed to start the experiment with 8 to 12 tons of uranium oxide and to carry out measurements on this system pending the delivery of the metal. It is considered likely that the chain reaction can be made to work in a system consisting of spheres of uranium metal embedded in graphite and there is also a chance that a similar system composed of uranium oxide and graphite can be made to work.

The system might be improved by surrounding the uranium metal spheres with shells of beryllium metal, choosing the total weight of uranium and beryllium to be about equal, but it is not at present believed that such an improvement will be necessary. Nevertheless, this line of thought will be pursued by laboratory experiments carried out on 150 pounds of beryllium metal.

Eight tons of uranium oxide and 40 tons of graphite have already been ordered out of an existing appropriation of 100,000 dollars, which is at the disposal of the National Bureau of Standards and it is believed that 3 tons of uranium metal can be obtained within the frame-work of this appropriation. An additional 6 tons of uranium oxide out of which 3 tons should be converted into uranium metal might be required for the purposes of the intermediate scale experiment.

It is proposed that, during the performance of the intermediate scale experiment and large scale experiment, laboratory experiments for measuring nuclear quantities involved should go on uninterrupted and it is assumed that about 5 out of a staff of 10 physicists or chemists will be engaged in the actual performance of the intermediate and large sclae experiments while the other 5 will carry on laboratory experiments. It is further proposed that a small appropriation of not more than 15,000. dollars be set aside in the contract covering the intermediate scale experiment for the purpose of preparing the large scale experiment which is to follow.

At the same time leaving fully considered

~~Dear Professor Pegram:~~

~~Having fully considered~~ the question which you raised in conversations during the last fortnight I have come to the following conclusions:

If the Government should propose to have the projected experiments carried out within some frame work which would make it impossible for Fermi and myself jointly to conduct these experiments and if, for instance, the idea would be that the experiments should be conducted by Fermi and that I ~~should~~ only be asked to act in an advisory capacity or as one of his several collaborators I would not be able to consider this a satisfactory solution, ~~either from my personal point of view as well as from the point of view of an efficient and successful realization of the project.~~

If no satisfactory set-up could be found I would then definitely prefer to keep the experiment (for which I have been trying to enlist the assistance of the Government since July of last year) in my own hands and to be free, if the Government does not propose to assist it, to turn for assistance ~~ex~~ elsewhere. I am quite confident that I can make a chain reaction with slow neutrons work if given enough rope and if I can carry out certain experiments which I have in mind and though I would find it rather distasteful to work for a private corporation which is actuated by the profit motive, from the ~~national~~ national point of view it is more important that this development should be carried out speedily, than any question of private profits which may be involved.

Dear Professor Pegram:

I am happy to learn that it will now be possible to carry out certain experiments under a contract between Columbia University and ~~the~~ a Government committee. I note that all results arising out of this projected work will become the property of the Government and that no patents may be taken out by those who are engaged in this work.

In this connection I should like to raise the question whether it would not be advisable for me to put on the record ~~s~~uch inventions as I have made without the assistance of the Government before actually starting to work under the proposed contract. Perhaps it would be wisest to have this record in the form of a patent application filed at the patent office, and if this form is chosen I would propose to submit a copy through you to Dr. Briggs. If this should be desired I would be glad to assign this patent application to such agency of the Government as you or Dr. Briggs may select, with the understanding that the application be re-assigned to me if, at a later date, the Government should ~~desire~~ decide to abandon our project. If you or Dr. Briggs should think it desirable I would be glad, however, to give an undertaking to the effect that the Government would retain, after it re-assigns to me the patent application, the use of the patent free of royalties.

The object

These inventions were made within a period between January 1939 and July 1940, and had as their object methods which may make it possible to maintain a nuclear chain reaction in unseparated uranium under conditions which may be satisfactory from an engineering point of view. The utilization of the heat liberated in the chain reaction for purposes of power production, primarily perhaps for locomotion, is one of the main objectives. A number of problems arise in this connection relating to regulation of the reaction and to the necessity of transfering a large quantity of heat across comparatively small surfaces, and these problems seem to be capable of a satisfactory solution.

Since July of last year I have displayed great confidence that it will ultimately be possible to have a chain reaction in unseparated uranium in the near future if the facilities for this work can be obtained. Being convinced of this I personally propose to devote the next five or ten years to this work. It may be, though, that half a million to a million dollar will have to be spent by the time of a demonstration on an ind
Since the Government has now decided to support the initial scale becomes possible.
stages of this work, it seems to be best to proceed on the assumption that it will be possible to carry out this work within the present frame until its successful conclusion. Should, at some future date, it become impossible to obtain further Government support for our work, then we could first approach the Rockefeller or Carnegie Foundation for further support. Failing this we would then have to approach some industrial corporation in this country or in Canada, using the proposed patent applications as an inducement for their financing the proposed work.

Dear Professor Pegram,

For reasons which I shall attempt to explain further below I think it might be desirable that I should put on record certain inventions which I have made within the last two years before I actually start to work under the contract with Columbia University on experiments for which the funds are being provided by the Government.

If you see no particular objection to the following ~~x~~ I would propose to chosse the form of patent applications which I would file before starting the projected experiments at Columbia. I would submit copies of these patent applications through you to Dr. Briggs and state in an accompanying letter that I would be glad to assign these patent applications now or at any time later during my work under the proposed contract with Columbia to such agency ~~xixh~~ of the Government as may be suggested by you or the chairman of the uranium committee, without expecting any financial compensation from the Government, but with the understanding that these patent applications would be re-assigned to me at my request if at some future date the Government abandons the project in support of which it has now granted the sum of $40.000. In that case I would first try to obtain the support of the Rockefeller or Carnegie Foundation for the continuance of the work, and if that fials I would ask for a re-assignment of these patents in order to use them for inducing some industrial corporation in the United States or in Canada to support the project further until its successful conclusion. If you or Dr. Briggs should feel that in this case the Government ought to have the use of these patents even after their re-assignment to me free of royalty, I should be glad to give an undertaking to that effect.

I shall, of course, see to it that no patent is issued as long

as the Government feels that secrecy is desirable, and such secrecy could be assured if Dr. Briggs wrote to the Commissioner of Patents, asking him to take the steps to this effect, which are prescribed by the law. This can be done even if the patent is not, or not yet, assigned to any agency of the Government.

If Dr. Briggs does not see any objection I might apply for a secret patent in Canada and in England, which I would assign without financial compensation to the respective governments, but I shall, of course, refrain from doing this unless I hear from Dr. Briggs that there would be no objection on his part or on the part of any other Government agency which is interested in the matter.

Of course, I should like to remain free to withdraw this patent application at a later date as long as it has not been assigned to the Government.

My reasons for the above proposal are the following: In July last year I formed the conviction that it will be possible to maintain a chain reaction with uranium under conditions which are satisfactory from an engineering point of view, that is under conditions in which it is possible to have the reaction take place at high temperatures and accordingly at a high rate on an industrial scale. One of the primary objects is the construction of an engine which allows it to utilize the heat liberated in the chain reaction for purposes of power production, primarily perhaps for a locomotion. A number of problems arises in this connection, in particular problems of heat transfer and regulation, which present considerable difficulties but which seem capable of a satisfactory solution.

Having contacted a number of my colleagues in July and August last

year, a consensus of opinion developed that an attempt should be made to enlist the support of the Government for carrying out a certain project until its successful conclusion. It may be a half a million to a million dollars will have to be spent before the first engine of this type can be made to work, at least to the extent ~~as to demonstrate~~ of demonstrating the liberation of nuclear energy on an industrial scale.

I now understand that a certain sum has been granted by the Government for the support of experiments which will be carried out at Columbia University under the immediate direction of Fermi and myself. I need not emphasize how very happy I am that we shall thus be put into the position of starting to work along the lines which we discussed at various times with various representatives of the Government. While we have at present no assurance that further support will be forthcoming we have to base the work on the hope that this project will be supported by the Government until its successful conclusion, i.e. until the construction of the first engine working with nuclear energy is completed.

I personally have repeatedly expressed great confidence that it will be possible to have a nuclear chain reaction in unseparated uranium, and in accordance with this conviction I propose to dedicate the next five or ten years to this task.

I realize, however, that it is difficult to convey this faith in the ultimate success of the work with unseparated uranium to others, and that others take now, or will take after some of the set-backs which we may suffer at one time or the other in the future, a considerably less optimistic view. For this reason we have to envisage the possibility of not being able to get adequate Government support for certain rather expensive experiments which may become necessary. In that case I should be in favor of applying for support to the Rocke-

feller or Carnegie Foundation rather than to transfer this work within the framework of some industrial corporation. If such support is not obtainable then I would, as a last resort, be in favor of using the proposed patent application as an inducement to some industrial corporation in this country or in Canada for taking up this development, thereby giving them the hope that they might recover the expenses of development through profits which they might make in the future.

I fully understand that any development arising out of the work which we shall carry out under the contract between Columbia University and the Government will become the property of the Government and that no patents may be taken out by those who are engaged in this work.

These letters by Szilard and Zinn did not actually reach Professor Pegram since in the meantime Professor Pegram decided to release the papers for publication. The hand-written originals are in my files.

L. Szilard

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Dear Professor Pegram:

Dr. Szilard has shown me the note he has written concerning the publication of our letter. I dislike very much imposing on you to the extent of asking you to decide this question. However, Szilard and I do take opposite views. My opinion may be summed up as follows:

Withholding publication cannot now keep the matter from becoming generally known among physicists here and abroad. A small rumor to certain people would start them off on experiments just as quickly as a full publication.

Joliot's paper already provides them for an excuse to begin work.

Our fears apparently are not shared by the French workers and I can hardly believe that they are ignorant of the possibilities. Withholding publication can, at most, delay the discoveries we fear for some months, in which case secrecy would be impossible. On the other hand, publication would accelerate research work in several laboratories and I feel that this country will not be put on the "spot" by its research workers failing to do their job.

Finally, withholding publication sets a new and undesirable precedent among physicists.

Despite the above arguments I would be influenced a great deal by Professor Fermi's opinion. My reason for this is that he inevitably will be forced to accept the major part of blame or honor which might result from these publications. Columbia University also has a vital interest in the matter from this viewpoint and therefore I am inclined to give your opinion great weight.

W. H. Zinn

Nat'l Bureau of Standards

Briggs

Date?

COPY

COPY

Dr. Pegram

This is a preliminary report on Dunning's samples.

L.J.B.

Memorandum for Dr. Briggs:

Impurities in samples of uranium (metal) and uranium oxide.

Metallic Uranium: (a) Total Hydrogen - 0.054%

This value was obtained by burning the material in pure, dry air.

(b) Hydrogen present as water - 0.001%

This value was obtained by heating the sample at approximately 800°C in dry Helium.

(c) Hydrogen present as "fixed Hydrogen" - 0.003%

This value is obtained after the sample, at first heated in dry He to remove moisture, was burned in dry air.

Remarks: The sample "as is" contains ten times more hydrogen than the allowable limit (0.005%). Most of this hydrogen is apparently present as adsorbed hydrogen or thermally unstable hydrides, and can be brought below the allowable limit by heating in pure, dry helium (0.003% as compared with the allowed limit of 0.005%).

Spectroscopic Examination of Samples of

Uranium Metal and Uranium Oxides.

	"Metal"	"Belgian Oxide"	"Canadian Oxide"
Fe	Moderate*	Faint Trace*	Very Weak*
Si	Very Weak*	Faint Trace (?)*	Faint Trace (?)*
Ca	Weak*	Trace	Faint Trace
Al	Weak	Not Detected*	Not Detected*
Ni	Very Weak	" " *	" " *
Cd	(?)	(?)*	(?)*
Rare Earths		*	*
Barium		*	*
Gadolinium		*	*
Samarium		*	*
Mo	Not Detected	Moderate	Weak
V	Weak	Trace	Very Weak
W	Trace (?)	Trace (?)	Trace (?)
Ti	Trace (?)	Trace (?)	Trace (?)
Mg	Very Weak	Faint Trace	Faint Trace
Cr	Faint Trace	Not Detected	Not Detected
Mu	Very Weak	Trace (?)	Trace

* Indicates tests requested.

In the absence of definite standards for impurities in uranium, the relative designations in the foregoing table may be roughly taken as follows: Moderate indicates quantities amounting to several tenths of a per cent; weak indicates amounts of perhaps a few hundredths of a per cent; traces and faint traces indicate quantities of the order of 0.01% or less.

With regard to the Rare Earth elements, barium and cadmium, it will be necessary to effect a partial chemical separation before attempting a spectroscopic examination.

Note: J. F. Goggin, J. J. Cronin, H. C. Fogg and C. Jar Industrial Eng. Chem. 18 p. 114 (1926) claim to have produced metallic U with Fe content of less than 0.01%.