

AEC AUTHORIZING LEGISLATION FISCAL YEAR 1971

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HEARINGS BEFORE THE JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES NINETY-FIRST CONGRESS

SECOND SESSION

ON

PHYSICAL RESEARCH, BIOLOGY AND MEDICINE, AND PLOWSHARE

MARCH 3 AND 5, 1970

PART 2

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This has been done and the factory is now in production. Approximately \$33 million have now been committed to this project. We have about \$5.5 million to carry us through the remainder of this fiscal year.

The main elements not shown are the experimental areas and beam switchyard. Phase I construction on these is only now starting.

Dr. Bradbury, who has been a truly great Director, brilliant and far-sighted, made an important promise to this Committee and to the AEC. He promised that the LAMPF would be built within its allocated budget. He further stated that he would donate his blood for the cooling system, if that were necessary to stay within the budget. Assuming that any additional funding delays are properly compensated, Dr. Bradbury shall be able to keep his promise and his blood.

I, too, made a number of promises to this Committee. I predicted that LAMPF would stimulate a more even, geographical distribution of competence in nuclear science and technology. At this moment, two and a half years before the first beam, more than 350 non-LASL people, representing approximately 125 institutions, have requested to become users of LAMPF. Appendix I is a list of the present Users Group and their affiliations. Many of them are already working closely with the LASL staff in the design of experimental facilities. I think it is very important that this trend be nurtured, particularly at this time when forces are at work to alienate the scientific community from the Federal establishment. I very much hope that you can make it possible for Dr. McDaniel to provide adequate support and encouragement to these potential users of LAMPF, for they represent an important segment of the nuclear physics community in this country. In my humble opinion, the long-range war on poverty is fought in our schools and laboratories where new knowledge and new technologies are born. These give rise to novel processes and products and spawn many of the industries which must provide the millions of new jobs we need.

I promised that LAMPF would have immediate practical applications. This has already come to pass—in a strange and wonderful way. The accelerator structures which we invented, in order to accelerate a high-intensity proton beam, in linear trajectory, from 100 to 800 MeV, have proven to be very attractive for the acceleration of electrons. As Dr. McDaniel has already told you, private industry has adopted our designs for the manufacture of economical medical X-ray units of sufficiently high energy to significantly improve the depth-dose distribution over that available from conventional units. One California manufacturer has already built 34 of these units and has delivered 22. Each unit sells for \$130,000. The units already built will permit improved treatment for tens of thousands of patients, suffering will be ameliorated, and some lives will be spared. Furthermore, jobs are being generated. From mining and processing copper for the waveguides, to fabricating klystrons to treating patients.

LAMPF when it is completed, will offer even more dramatic possibilities for improving our national defense posture and the health and well-being of our citizens.

For example, the Division of Isotope Production has expressed considerable interest in an isotope production facility which would permit the extraction of proton-rich radioisotopes, of novel properties, as a by-product of LAMPF operation. I am personally intrigued by the fact that the world market price of aluminum-26 is \$1 million per microcurie. We shall be able to produce one microcurie of aluminum-26 in about 100 hours of running time, and without interference with other uses of the accelerator. Of course, large-scale production of aluminum-26 would probably bring the price down, but I am not greedy. If we can realize \$1 million per 2000 hours of salvaged beam, I shall be quite happy.

Our designers of nuclear weaponry are faced with difficult neutronics problems, many of which can be solved by the use of a very small portion (about 2%) of the LAMPF beam to produce a highly intense pulsed neutron source. The configuration of the weapons facility, presently envisioned but not yet funded, is shown in Fig. 7. In Appendix II, Dr. Fullwood a member of Dr. Agnew's Division, summarizes the hope and expectations of the weapon designers.

In my judgment, the most dramatic possibility for practical applications is in the biomedical area: the provision of negative pion beams of such intensity that they can be used in radiation therapy of deep-seated tumors. The main reason for this can be readily understood by devoting 10 minutes of study to the diagrams in Fig. 8. The central point is that negative pions make possible the local deposition, under controlled conditions, of high-quality radiation, with rein-

STATEMENT OF DR. LOUIS ROSEN, DIVISION LEADER, MESON PHYSICS DIVISION,
UNIVERSITY OF CALIFORNIA, LOS ALAMOS SCIENTIFIC LABORATORY, LOS ALAMOS,
N. MEX.

The presentation by Dr. McDaniel covered, quite beautifully, the construction progress at LAMPF. Since October of 1968, when major funds first became available, the project has moved along very well. I have with me some very recent photographs which will describe better than words where construction stands. Although we suffered, in FY 70, a deferral of \$10 million of construction funds, we shall meet our schedule of achieving a beam in the switchyard area, by July of 1972. However, completion of the experimental areas will be delayed by one year, assuming that funding proceeds as now projected. The photographs I show you illustrate major elements of construction progress. On the back of each photograph is indicated how far toward completion that component has advanced. Included are the Injector Building (Fig. 1); the first injector, already installed therein (Fig. 2); the beam channel (Fig. 3); the equipment galleries (the floor of which is about 30 feet above the floor of the beam channel) which house the rf power sources and mechanical equipment (Fig. 4); and the Laboratory Building (Fig. 5). I have also included an aerial view of the entire project (Fig. 6). Technical and budgetary requirements dictated that we set up a temporary factory to fabricate many of the most complex accelerator components.

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tively low damage to tissue outside the treatment volume. This situation arises because the negative pion is a Dr. Jekyll and Mr. Hyde type of particle. While it is traveling to the tumor site, it has one set of characteristics—its ionization is low and it disturbs the tissue in its path no more than does an electron. However, after it comes to rest in the tumor site, some of its mass converts to energy; it disrupts the nucleus by which it is captured and the fragments of this nucleus become the projectiles which destroy the cell of which that nucleus was a part. The tumor cell thus, in a sense, provides the means for its own destruction. The case for negative pions in radiation therapy has been made by many scientists. I submit, for the record, a transcript of a recent talk to the LAMPF Users Group by Dr. H. S. Kaplan (Appendix III). Dr. Kaplan is Chairman of the Radiology Department at Stanford University and one of the world's most eminent radiotherapists. I provide you also with a reprint of a paper which tells the same story from the standpoint of a physicist (Appendix IV). (See also Appendix V.)

And now comes the commercial—in order to avoid a six-month shutdown of the main LAMPF beam line, when the biomedical facility is authorized, it is essential that some preparatory work be started next year on that portion of this facility immediately adjacent to the beam line.

We have here, gentlemen, a God-given opportunity to demonstrate once again that large scientific enterprises can have immediate and beneficial influence on human welfare. I am sure that this Committee is very much aware that, at this particular juncture in the affairs of science and society, such demonstrations are sorely needed. You have collectively fathered a great scientific enterprise. The importance of the purely intellectual pursuits which this facility will make possible can hardly be overemphasized. However, we should not ignore the practical possibilities—for they can have an immediate impact.

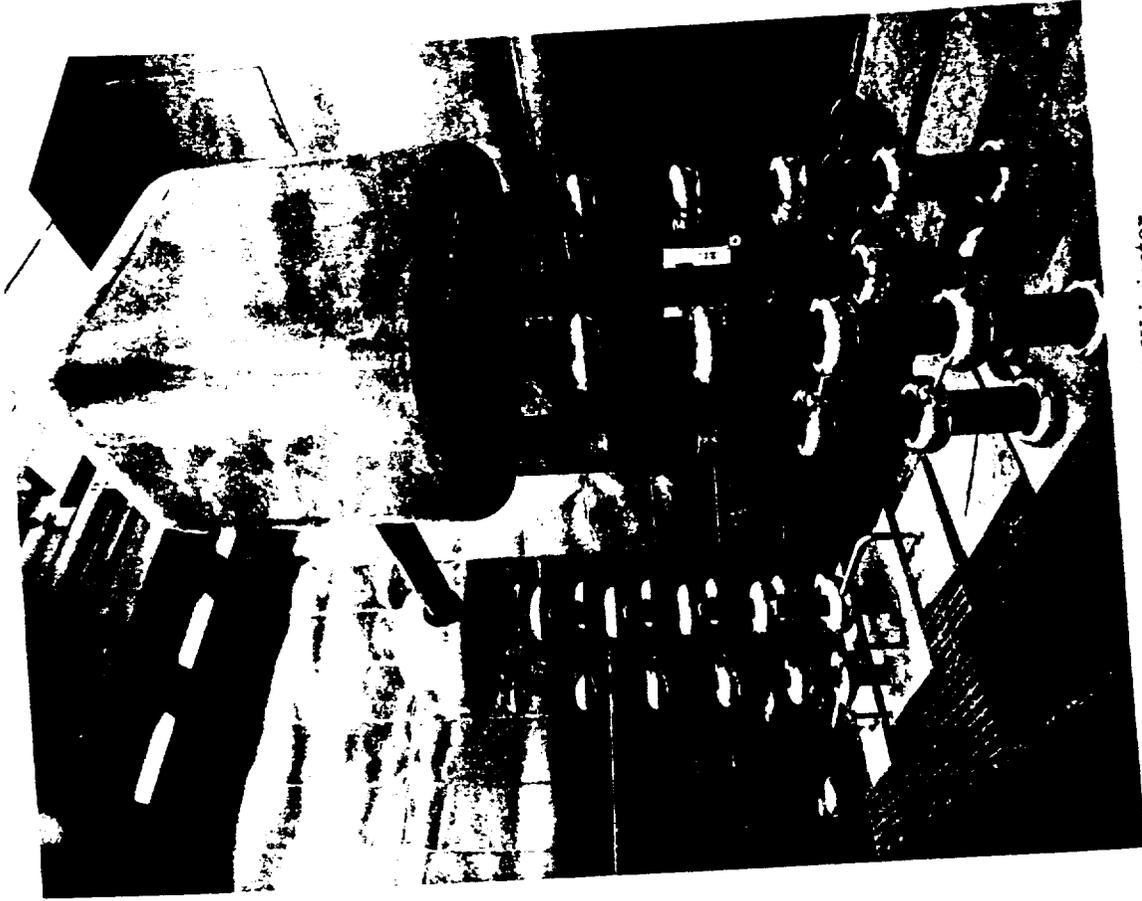


FIGURE 2.—750-keV C-W injector.



FIGURE 1.—Injector building.



FIGURE 5.—Lab-office building.



FIGURE 3.—LAMPF beam channel, 805-MHz beam channel (laser alignment mounts and piers).



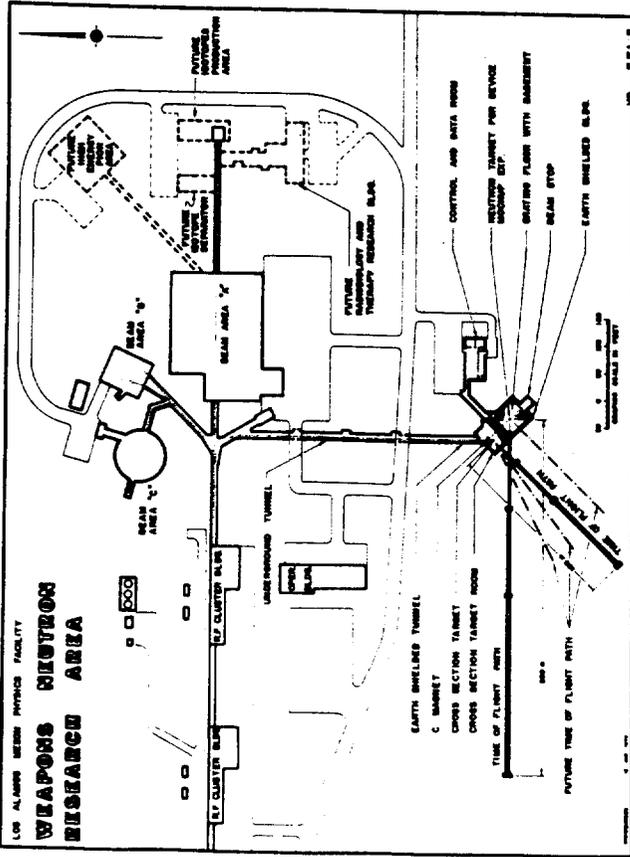


FIGURE 7.—Proposed weapons neutron research facility.

DEPTH DOSE DISTRIBUTIONS

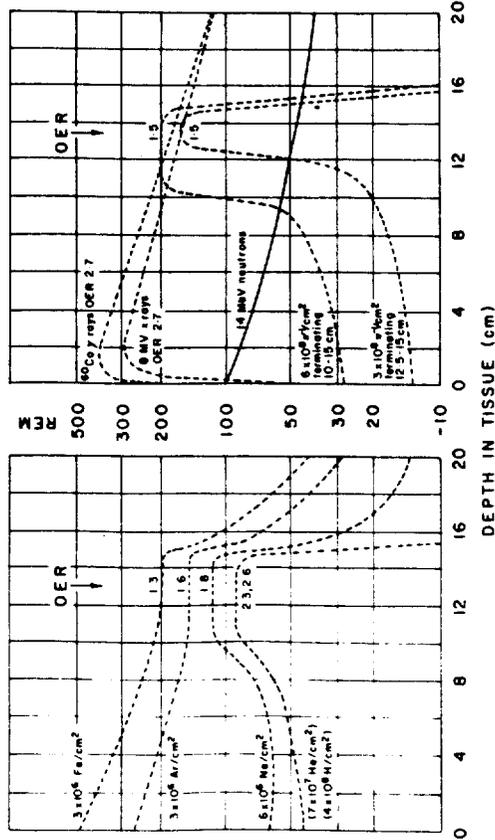


FIGURE 8.—Depth-dose distributions of various particles in tissue.

APPENDIX I

LAMPF USERS GROUP SUBLISTS ACCORDING TO PARTICIPATION IN THE VARIOUS WORKING GROUPS

Users interested in pion physics have formed two working groups, one called energetic pion channel and spectrometer (EPICS), and the other called pion and particle physics (P⁺). Initial meetings of these two groups had the following participation:

EPICS

- Chairman, P. Gugelot, Enrico Fermi Institute
- H. Anderson, U. of Chicago
- P. Barnes, Carnegie-Mellon
- M. Brussell, U. of Illinois
- Eric Cosman, MIT
- K. Crowe, LRL, Berkeley
- J. Friedes, BNL
- E. Gross, ORNL
- R. Kenefick, Texas A and M
- B. Mayes, U. of Houston
- R. Minehart, U. of Virginia
- R. Slemssen, ANL
- S. Sobottka, U. of Virginia
- L. Swenson, Oregon State U.
- B. Zeldman, ANL

LASL

- R. Burman
- R. Macek
- D. Nagle
- H. Thiesse

P⁺

- Chairman, P. Gugelot, Enrico Fermi Institute
- W. Alford, U. of Rochester
- H. Anderson, Enrico Fermi Inst.
- M. Blue, U. of Texas, El Paso
- H. Crannell, Catholic U.
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- V. Hughes, Yale
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- R. Kunselman, U. of Wyoming
- W. McFarlane, Temple U.
- R. Minehart, U. of Virginia
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- H. Piendl, Florida State U.
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- B. Zeldman, ANL

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- P. Gram
- W. Hassenzahl
- R. Hutson
- N. Jarmie
- R. Macek
- E. Martin

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Jon D. Shoop, UNM Medical School
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R. Burman, MP-6
D. Cochran, MP-6
C. Robert Emigh, MP-4
Richard Henkel, P-9
R. L. Hutson, P-DOR
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Albert J. Lieber, J-12
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Donald G. Ott, H-4
Donald F. Petersen, H-4
Louis Rosen, MP-DO
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 Earl K. Hyde, LRL, Berkeley
 Richard L. Kiefer, College of Wm. and Mary
 Ralph Korteling, Simon Fraser U.
 E. Gerald Meyer, U. of Wyoming
 J. M. Miller, Columbia
 Robert A. Naumann, Princeton
 Morris L. Perlman, BNL
 Robert F. Petry, U. of Oklahoma
 Franz Plasch, ORNL
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APPENDIX II

USES FOR THE WEAPONS NEUTRON RESEARCH FACILITY*

(Ralph R. Fullwood, LASL Weapons Division)

The Weapons Neutron Research Facility (WNR) is a proposal for making available to the national defense scientist the power of the Los Alamos Meson Physics Facility (LAMPF), which when operational will be the world's most powerful accelerator. LAMPF is a multi-purpose accelerator and was authorized as such by Congress. WNR is a proposed facility comprising the necessary LAMPF beam forming equipment, shielded enclosures and neutron flight paths for investigating problems relating to nuclear defense. The accelerator beam would be time-shared between the two areas with little compromise of performance for either.

Nuclear weapons have evolved with increased complexity and sophistication requiring more exact understanding of the basic physical processes. The current emphasis is for more effective and more durable weapons.

WNR can be useful to the national defense in several ways:

(1) *Applied Research.*—WNR would be used for testing the complex computer calculations used in designing weapons. These precision idealized experiments would give guidance to correcting any error that may exist in the codes or in the basic nuclear parameters supplied to the codes. These experiments could be especially valuable in the calculations of the vulnerability of a weapon to neutron radiation. It is very demanding to achieve calculations complex enough to represent enough of the real situation. Of course, future calculations will be of sufficient complexity but will still require careful investigation. Even at the present time LAMPF is having impact on weapon problems. An experiment is being prepared for using the electron prototype of LAMPF for testing neutron transport computer calculations. This is only the beginning.

Experiments simulating the complex real-life situation in a reentry vehicle when exposed to attacking radiations can be investigated at the WNR facility. The experimental facilities have been designed for the investigation of just these complex problems.

The final test of a new weapon design is in the underground detonation. In order to obtain the maximum amount of information from these expensive tests, sophisticated instrumentation is required. WNR provides an excellent facility

*For a comprehensive but classified account of how a neutron facility at LAMPF can contribute to our national defense capabilities, see document No. DIR-2191, Oct. 17, 1966 (Schedule 44) "Construction Project Data Sheet for Weapons Neutron Research Facility."

for the test and calibration of the instrument in a radiation environment. Presently most instruments are calibrated for only one neutron energy. Response to other energies must be extrapolated.

Neutron radiography is a new field that suffers from the low intensity of existing neutron sources. The neutron intensity at WNR will be factors of ten higher than existing sources in this range of very penetrating energies. This will be important in the design and inspection of weapon systems and components.

(2) *Basic Research.*—There must be no scientific Pearl Harbor in store for the United States. Besides supplying the required information about the various aspects of neutron and gamma production and interaction with nuclei, it is also necessary to pursue any new areas as they open in the future.

(3) *Education.*—The nuclear defense scientist upon graduation has not studied directly applicable courses as has the reactor engineer. A young scientist commonly enters the weapons field through basic physics and over a few years becomes interested in more applied problems. The WNR facility provides just such a point of entry. It is an excellent facility for the completion of advanced graduate and post-doctoral research.

The cross fertilization through association with scientists from all over the country performing basic meson research can have effects that could only be conjectured at present. Certainly the results of the study of nuclear forces will have direct application.

The idea of applying the capabilities of the world's most powerful accelerator to problems of national defense is very compelling. The present problems provide sufficient reason alone; the future can only strengthen these arguments.

APPENDIX III

POTENTIALITIES OF NEGATIVE γ -RAYS OR BEAMS
IN RADIOETHERAPY OF CANCER

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Historically, it is fair to say that it was not the radiotherapists or the radiobiologists who furnished an impetus for investigations in this area, but the physicists. It was the early publications and statements by Foster,¹ Nicolson,² and others that stimulated interest in the potentialities of γ mesons as a new type of particle suitable for clinical radiotherapy. A number of measurements have now become available that begin to add a little substance to what, at one time, was largely theoretical. This has gradually attracted the interest of people like myself, who are now prepared to take a very serious look at these possibilities.

In this paper, I would like to review the present status of radiotherapy and then to consider some of the reasonable clinical expectations for beams of γ mesons, based on what is now known about their radiobiologic and physical distribution characteristics. I think it would be a mistake to start from the point of view that all patients currently treated with radiotherapy die and that all of them after the advent of γ mesons will be saved. We ought to start from some realistic vantage point. Currently, between 40 and 50 percent of all cancer patients receive radiotherapy at some point during their treatment. However, many of them receive their radiotherapy after they have become known failures of surgical management, at a time when their chance for cure has almost vanished. Perhaps, then, half of this 40 to 50 percent arrive on the doorstep of the radiotherapist as primary, fresh, previously untreated cases, and most of these have some finite chance for cure.

In the last twenty years or so, a number of new kinds of machines have come into general use in the field of radiotherapy, so that today the modality available to us go beyond the one-time standard of the field, such as the old 250-kV x rays

therapy has little to offer. Finally, the type of failure which is perhaps the most distressing of all is that in which the cancer is successfully eradicated, but the patient dies of complications secondary to radiation-induced normal tissue injury.

Recently, Suit⁵ has tried to make a careful and systematic analysis of the probability of local or regional failure for all of the many kinds of cancer. His best estimate was that, at the present time, approximately 98,000 of the 175,000 cancer deaths per year in patients who had been treated with radiotherapy are attributable to local or regional failure. This is, to a first approximation, some measure of the job that remains to be done by improving the efficiency of any radiotherapeutic modality at our disposal—roughly 75,000 deaths in the United States alone every year.

What can we say about the immunological background on which these responses or failures are being seen? It is now generally recognized that, although there may be some immunological reaction of patients to their own tumors, such reactions appear to be extremely weak, so weak that we have no useful way to exploit them as an aid to therapy. At the present time, then, we must assume that it is necessary to destroy every last cancer cell in order to cure the patient. In doing so, we must at the same time maintain the integrity of the normal tissues in the vicinity of the cancer, at least to an extent compatible with a reasonably comfortable and useful life.

Radiobiological studies in recent years have shed light on some of the kinetic aspects of the complex interaction between effects on the tumor and effects on the normal tissues during the course of radiotherapy. A point that must be stressed very strongly and that people have a tendency to lose sight of is that the mere fact that a beam can produce a greater effect, relatively speaking, in a hypothetical tumor is to no avail if it produces the same relative incremental effect on the normal tissues in the immediate vicinity of that tumor. We must look for differential effects. If we cannot find differential effects, there is no reason to expect that the end result will be modified in any way.

Studies by Puck⁶ and others have established

the general character of the x ray dose-survival curves for a variety of mammalian and other cells. Typical curves are seen in Fig. 1. Note that the distal part of each curve appears to be exponential, relative to dose. However, the curves do not extrapolate to the origin at 100 percent survival, but instead to a point significantly above 100 percent, indicating that there is an initial "shoulder" region in which there is not an exponential relationship between dose and survival. It is now generally agreed that this shoulder is due to the existence of a recovery system, some type of repair process, which can cope with small degrees of damage but which becomes saturated at relatively low doses. If small doses are given and then a period of time is allowed to elapse, it has been shown that cells return quantitatively to their former state.⁷ Thus, successive fractionated doses are not linearly additive; instead, a considerable amount of the effect of each is repaired.

An important feature of the radiation sensitivity of virtually all cell systems studied to date is their dependence on the oxygen concentration present at the time of irradiation. When irradiations are carried out under nitrogen in an oxygen-free environment, there is a striking, nearly threefold decrease in the slope of the exponential portion of the curve, relative to that of the curve obtained when the same cells are irradiated in air or oxygen (Fig. 1). X- and gamma-ray beams and electrons would all be expected to yield this kind of result.

[Question from the audience: What is the difference between oxygen and nitrogen?]

The oxygen effect has nothing to do with the metabolism or respiration of the cell, but rather is determined by radiobiological reactions which may be influenced to go in a forward direction in the presence of oxygen but have a better chance of going in a reverse direction in the absence of oxygen, so that the cells can restore themselves to the pre-existing state. Injury is increased by roughly a factor of 3 with these types of radiations in the presence of oxygen. This nearly threefold increase in slope is referred to as the oxygen enhancement ratio, or OER. All mammalian cells would be expected to exhibit about the same OER.

Figure 2, taken from the work of Barendsen,⁸ shows similar mammalian cell-killing curves, but for other types of radiations, namely, 2.5-MeV alpha particles, 4-MeV alpha particles, and 15-MeV deuterons. For the low-energy alpha particles, irradiation in an atmosphere of either oxygen or nitrogen yields identical curves. There is thus no oxygen dependence of the low-energy alphas. For the slightly higher energy alphas, Barendsen observed an OER of 1.3. For the 15-MeV deuterons, the ratio rose to 2.6, very close to that obtained for x rays or electrons. This, then, tells us that the rate of deposition of energy per unit length of path of different radiations is related to their oxygen dependence. Barendsen has plotted the quantitative relationship between OER and linear energy transfer, or LET, which is familiar to physicists as dE/dx . The 2-MeV alpha has a dE/dx of 166 keV per micron, whereas on the other end of this spectrum, the deuterons were at 5.6 keV per micron. In general, high LET is associated with low oxygen dependence, and low LET is associated with high oxygen dependence. The oxygen enhancement ratio begins to fall rapidly as LET approaches 100 keV per micron and finally reaches a value of 1, indicating the complete absence of an oxygen effect (Fig. 3).

Another parameter of response that varies with LET is the relative biological effect, or RBE. It is simply the ratio of the doses of two different types of radiations when compared for the same biological effect. The RBE is fairly stable in the low LET stage, but as LET increases, the RBE begins to increase to a factor of severalfold in the LET range of heavy ions, and then falls again.

What relevance do some of these considerations have for us clinically? It is well-known that tumors tend to outgrow their blood supply in focal areas, in which there will then be avascularity and a very low oxygen concentration, often associated with death of focal zones within the tumor. Imagine the situation of a tumor cell lying immediately adjacent to a region which is dead because of lack of oxygen. It will also lack oxygen, but may have just barely enough to stay alive. Such a cell may be expected to be two to three times more radioresistant than well-oxygenated tumor cells. If the rest of the tumor responds to treatment, the tumor will shrivel, bringing the "half-dead" hypoxic cell closer

to its blood supply again, whereupon it will be re-oxygenated and will grow again. On the basis of such considerations, it has been postulated by the late L. H. Gray⁹ that anoxia, or hypoxia, may be an extremely important cause of failure of the local eradication of tumors. Although this is still not proven at the clinical level, it is a very plausible argument. If it is true, it would follow that any radiation that exhibits a significantly lower oxygen dependence than that of x rays might be less vulnerable to this type of failure.

In actual clinical practice, however, radiotherapy treatments are not given as single, massive doses, because they produce rather severe reactions to the normal tissues and better results were achieved when multiple fractionated doses were employed. We have tried to understand for many years why fractionation works. It has recently been discovered¹⁰ that tumors exhibit reoxygenation in the interval between successive fractionated doses of radiation. Thus, the use of fractionated doses of x rays may be one way to circumvent the oxygen effect. If this interpretation is correct, it would tend to diminish the expectation that using a radiation with a lesser dependence on oxygen would significantly improve our results of treatment.

In practice, although we speak about using tumoricidal doses, we have to admit that we seldom deliver a dose that can be expected to destroy all tumors of any given type. What we really deliver is the highest dose that will produce little or no normal tissue injury. Thus, we are really dose-limited by normal tissue injury. Figure 4 shows the situation diagrammatically; dose is plotted against frequency of tumor eradication and of normal tissue injury. More and more tumors are eradicated, in a Gaussian distribution, as the dose increases, but at some level of dose, which usually overlaps the dose range for tumor destruction, another Gaussian curve for normal tissue injury appears. What we try to do in clinical practice is to find a dose at the very beginning of the second curve, where few patients would suffer significant tissue injury. There are certain types of tumors (lymphomas and seminomas) which are more radioresistant; their Gaussian curves for tumor destruction are shifted to a lower dose level, with the result that they can be cured at doses that produce almost no detectable

tissue injury. We also know that normal tissue injury is dependent on the volume of tissue irradiated; the smaller the volume, the greater the dose it is likely to withstand. Thus, if we could confine the high-dose region as tightly as possible to the tumor volume and minimize the volume of adjacent normal tissue that is heavily irradiated, we could increase the dose to the tumor with less fear of normal tissue injury. This should produce a substantial increment of additional cures.

What can we say about the radiobiological and physical properties of π^+ mesons in this context? I am indebted to Dr. Raju for making available to me a preprint of a paper¹¹ he recently presented in Tokyo. I will also draw on some of the data of Fowler,¹ Curtis and Raju,¹² Thiesen,¹³ Rosen,¹⁴ and others. The available data are still sparse, unfortunately, because the intensity of the beams that are currently available, primarily at Berkeley, are still very limiting for this kind of work.

Nonetheless, Raju and his associates have done OER and RBE studies at 4°C and at room temperature for the roots of the plant *Vicia faba*.¹⁵ They found an oxygen enhancement ratio of 1.35 for π^+ meson irradiations at room temperature. However, this was done at a low dose rate, and the OER is sensitive to dose rate. At these very low dose rates, cobalt gamma would have an OER of only 2, instead of the usual 3. Thus, the π^+ meson OER value of 1.35 should be compared with a cobalt value of 2 for this case. When the same irradiations were carried out at 4°C, at which there is a lesser dependence on dose rate, Raju, et al., observed an OER of about 1.5. Curtis has calculated an expected OER for π^+ mesons in the range of 1.6 or 1.9, relative to a normalized value of approximately 3 for x rays or gamma rays. Thus, it would appear that π^+ mesons are indeed advantageous in terms of having a decreased oxygen dependence. However, it should be pointed out that the OER for π^+ mesons is not appreciably better than (and perhaps not quite as good as) that which has been measured for neutrons,⁶ which are certainly a more readily available kind of radiation. Thus, if one had to make an argument for selecting another radiation solely on the basis of OER, it would not be possible to make a compelling argument for using π^+ mesons in radiotherapy.

Raju has also collected data from published and

unpublished sources on the RBE of π^+ mesons in various systems; the reported values of RBE vary rather widely from around 1.6 to as high as 5. RBE will have to be measured very much more carefully in systems that closely resemble clinical radiotherapeutic situations before any actual radiotherapy can be undertaken, because the radiotherapist must know the RBE with great accuracy to estimate the biologically equivalent dose delivered to the tumor. This in turn brings us to the dosimetric aspects of π^+ mesons; that is, their anticipated physical distribution within a patient.

Figure 5 is from the paper of Fowler.¹ Fowler showed that alphas and protons of appropriate energy could be arranged to produce a higher dose at a depth of 10 to 15 centimeters below the surface of the body, relative to the entrance dose or to the dose in the first several centimeters of tissue. The OER to be expected of such radiations would, of course, be similar to that of x rays. The upper two curves of the right half of Fig. 5 are for ^{60}Co gamma and 8-MeV x rays, the types of radiations that we now work with. They have OER's of about 3 and deliver their peak dose very near the surface, after which relative dose decreases exponentially with increasing depth of penetration. In striking contrast are the two lower curves for π^+ mesons, calculated by Fowler and showing a very striking concentration of relative dose at the chosen depth of 10 to 15 centimeters occupied by 8 hypothetical tumor, together with a relatively favorable OER.

The depth at which this concentration of dose occurs is energy-dependent and is due to nuclear capture of the pions which contribute very heavily to the dose in the stopping region, but not at all, of course, to the dose in the first several centimeters (Fig. 6). Thiesen¹³ has recently done some very elegant preliminary work on the optics of π^+ meson beams. His work shows what might be done with the beam at Los Alamos, for example, with a series of lenses and slits to define a parallel beam with properties which could be modified pretty much at will with respect to energy and momentum spread.

Figure 7 and 8 from Thiesen's paper show the hypothetical distribution of dose for π^+ mesons stopping in water, which is of tissue-equivalent

density. The calculations assume that 30 MeV of energy is deposited per star. If nothing were done to alter the characteristic of the beam, it would produce a somewhat higher dose at the proximal end (closest to the entrance point) than at the distal end, yielding an unsatisfactory inhomogeneity of dose across the volume occupied by the hypothetical tumor. There are various ways of overcoming this. One simple way is to direct the beam into the patient from two opposing surfaces, thus canceling out the inhomogeneity in the star region. This is a technique that we often use today with x rays. However, with the π^- meson beam, as Thiesen has pointed out, it is possible to modify the relative energy distribution in the beam by using a trapezoidal cross-section collimator. Figure 8 shows the effect of this; there is now a lesser percentage of low-energy and a larger percentage of higher-energy particles in the beam. This results in a flattening out of the spatial distribution of the stars so that the effective dose in the volume occupied by the tumor can be made extremely homogeneous. Yet, very close to the high dose, high RBE star region the dose falls off so sharply that tissues just one to two centimeters away receive trivial doses. This is a very exciting kind of potentiality of negative π^- -meson beams, and one which I think any clinical radiotherapist would find enormously intriguing.

Naju and Richman¹¹ have summarized the biological and dosimetric attributes of π^- mesons in the "surrounding normal tissues" versus the tumor volume (Table I). The relative dose, because of the physical distribution of the stars and their high RBE, can be made very much higher in the tumor. There is a high oxygen dependence in the low LET region and a moderately low oxygen dependence in the high LET region which encompasses the tumor volume. The factor of recovery is of somewhat debatable significance. One point that I should stress about their summary table is that it lends itself to a serious misinterpretation. It is very easy, looking at a column labeled "surrounding normal tissues," to think that all of the normal tissues are "surrounding" and that "tumor volume" contains nothing but tumor. This, of course, is simply not true. The tumor grows through normal tissues; it permeates normal tissues. There are normal tissues within the tumor and at the margins of the tumor. It is

efforts aimed at this goal are definitely warranted by the evidence already in hand. What are the needs that confront us at this time? First and foremost, we need high-intensity sources of π^- mesons; the developments at Los Alamos, at Vancouver, and at Zurich will begin to satisfy that need. However, even though these machines, which are primarily intended for physics research, will make available facilities with which preliminary biomedical studies can be undertaken, it is clear that \$55 million machines are too costly for general clinical radiotherapy. In the second stage of development, less costly machines which are intended more or less exclusively for medical work will have to be designed. At the present time, some of my physicist colleagues at Stanford and our group are conducting discussions about the possible usefulness of superconducting electron or proton accelerators for this purpose.

When such beams become available, we will need to do really very careful dosimetric studies. The place where the dosimetry must be most precise is in the transition zone between the essentially pure pion-beam region and the star region. This is the dangerous area in which we will need to know the dose most precisely. We will also need to know how GER and RBE change as a function of dose and of depth inside the patient, with particular attention again to the junction between the low LET region and the star region. This is the point of greatest danger and of greatest interest.

On the clinical side, we must solve the difficult job of finding better ways to delineate the exact dimensions and contours of tumors. I assure you that this is not a trivial problem. If we are to try to envelop a tumor as closely as possible with a negative π^- -meson beam, then surely the first requirement is to know exactly where the tumor begins and ends. We have some reason to hope that as important advances may come from currently emerging techniques for labeling antibodies to tumor-specific antigens with radioactive isotopes. Thus, if the clinicians can indeed learn to delineate the irregular contours of the volume occupied by the tumor

with far greater accuracy and if the physicists can give us a beam which can be made to "wrap around" such an irregular tumor volume with great precision and accuracy, then I believe that the chance that π^- mesons will contribute significantly to cure rates in radiotherapy is a very real one. Of course, this will ultimately require a carefully designed and properly monitored randomized clinical trial, intended to prove whether all of the foregoing is reality or merely wishful fantasy.

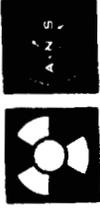
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POSSIBILITIES AND ADVANTAGES OF USING NEGATIVE PIONS IN RADIOTHERAPY

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Table I
Relative properties of π^- mesons in normal tissue vs. tumor

Surrounding Normal Tissue Region	Tumor Region
A. Low dose	High dose
B. Low LET	High LET
C. Low RBE (same as conventional radiation)	High RBE
D. High OER (same as conventional radiation)	Low OER
E. More recovery during fractionated treatment	Less recovery during fractionated treatment

already set in, but in some cases the radiation is inadequate for the purpose at hand. One seeks to overcome these latter difficulties by a better choice of radiation.

The effective treatment of malignancies by radiation involves using types and quantities of radiation adequate for lethal injury to all malignant cells with no more damage to healthy tissue than can be tolerated by the host organism. In practice, and with radiation sources now in use, the radiotherapist must strike a delicate balance between destruction to healthy and tumorous cells, and frequently the dose delivered to the tumorous cells is limited by the viability of healthy tissue following irradiation.

The ideal mode of tumor treatment would be one that destroys all the malignant cells, without in any way affecting surrounding tissue or healthy tissue in the tumor volume. This cannot be achieved, even when radioactive substances can be implanted within the tumor. However, this ideal situation could be best approached if one were to use negative pions as the radiation source. This was initially shown by Fowler¹ in an analysis in which he compared negative pions to electrons, gamma rays, x rays, protons, and heavier ions. More recently, I have made calculations for K^- and antiprotons. Although these latter have some of the virtues of π^- , they are not superior as cancer therapy. In fact, they are not quite as effective because the energy deposition of their reaction products is less localized.

As of this moment, it is not feasible to use π^- beams in cancer therapy. To do so would require the beams from all pion-producing accelerators in the world, focused on a single patient, and even then the irradiation time would be excessive (months to years). However, some of the high-flux proton accelerators now being designed, referred to as "meson factories," will permit

Recent advances in accelerator technology make possible the attainment of very-high-intensity beams of pions at energies well above the pion-production threshold. It appears that both circular and linear machines will be useful for this purpose. The latter promise beams of ≥ 1 mA under well-controlled conditions. Such proton beams are adequate for providing pure high-intensity beams of negative pions for radiation therapy, under conditions of favorable geometry and of variable size and energy distribution. With π^- beams, it is feasible to deposit, at essentially any depth in the human organism, at least 100 rad/min of high-linear-energy transfer radiation. This is quite sufficient for radiation therapy on deep-seated tumors and is accomplished under more favorable conditions than attainable with other radiation sources.

INTRODUCTION

Information from England, where reasonably good records are kept for the entire population, indicates that ~40% of cancer cases are now treated primarily by radiation, 40% primarily by surgery, and the remainder by chemotherapy.¹ Of the 80% of cases treated by radiation or surgery, combined treatment accounts for a substantial fraction. Therefore, even a small improvement in radiotherapy techniques would benefit a large number of patients.

A substantial proportion of radiotherapy treatments are apparently total or partial failures. Often this comes about because metastasis has

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radiation therapy with negative pions and in reasonable times.

THE PHYSICS OF CANCER TREATMENT BY RADIATION^{4,5}

All ionizing radiation affects mammalian cells through ion pair production and excitation of atoms and molecules. On the average, ~30 eV is dissipated per ion pair. Since the ionization potential for atomic constituents of cells is ~13 eV, this leaves ~20 eV to be dissipated by exciting atoms and molecules to bound states and by heat generation. Most of this 20 eV produces atomic excitation followed by dissociation, fluorescence, or energy transfer. However, in complex molecules, such as are abundantly found in tissue, a substantial fraction of the excitations will appear as kinetic energy of the atoms in the molecules.

The specific ionization produced by radiation depends on the type and energy of the radiation. Gamma rays produce ~10 ion pairs per micron along their path, while alpha particles, near the end of their range, produce ~500 times as many. There lies the difference between low- and high-linear-energy transfer (LET) radiations. This difference manifests itself in many ways and has profound effects on the response of cells to radiation.

Some quantitative understanding of the effects of ionizing radiation on cell survival has been obtained from analysis of a great variety of experiments. Typical results of such experiments are shown in Fig. 1, which displays cell survival probabilities as a function of radiation dose for human kidney cells. A change in curve shape is apparent and the sigmoid curves at low LET are indicative of cell death due to accumulated sublethal injury that is subject to early repair while the exponential curves at high LET are indicative of cell death due to single irreversible events.^{6,7} Cell survival depends in the following way on the kind and quantity of radiation:^{8,9}

$$S = \exp\left(-\frac{D\sigma_1}{1.6L}\right) \left\{ 1 - \left[1 - \exp\left(-\frac{D\sigma_2}{1.6L}\right) \right]^n \right\}$$

where

- S = survival probability for a uniformly irradiated cell population
- D = dose in rads; σ_1 and σ_2 = inactivation cross sections in μ^2
- L = linear energy transfer in MeV cm²/g; n = 6.

The σ 's are cell inactivation cross sections.⁸ If

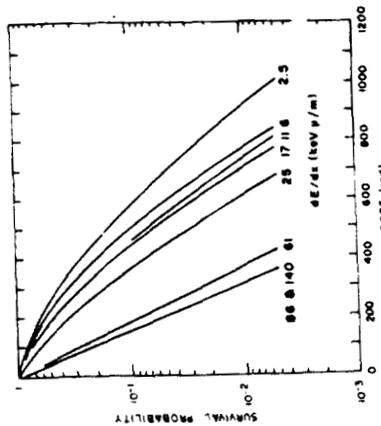


Fig. 1. Survival curves for human kidney cells irradiated with beams of particles with the various values for dE/ds .

appears that σ_1 increases more rapidly than does σ_2 as a function of LET. The relative biological effectiveness (RBE) of a given type of radiation, defined as the ratio of the dose of 200-keV x rays to produce a given biological effect to the dose of the type of radiation under consideration for producing the same effect, is known to be much greater for high-LET than for low-LET radiation. This is specifically true for cell survival following radiation, but is also true for many other cell processes.

The objective of radiation therapy is to injure all tumorous cells. In a given volume, to such an extent that not one of them will be able to initiate regrowth of the tumor. At the same time, one must minimize damage to the reproductive capacity of surrounding tissue.

⁸They are empirically determined parameters that relate to the average probability for a lethal encounter of a quantum (or particle) with a cell when a specific cell population is subjected to a given type of radiation. There are two σ 's because of the assumption, implicit in the above equation, that the effect of radiation containing a spectrum of LET can be reduced to that of two idealized radiations—one of high LET and one of low LET.

⁹Radiations of constant LET, if such were achievable, would be represented by a single σ , the magnitude of which would be the probability for a lethal encounter when one quantum (or particle) per cm² impinges on a target comprising one cell per cm².

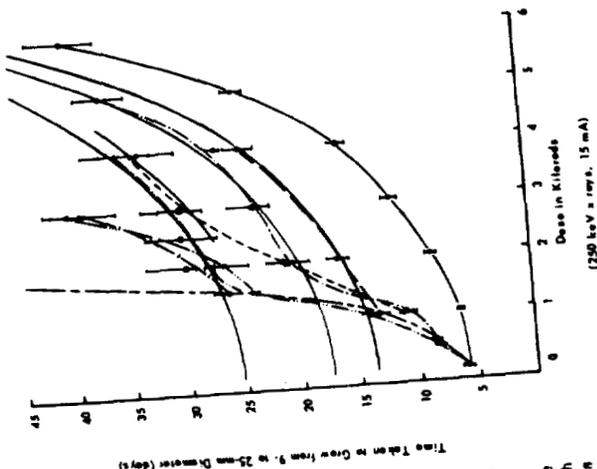
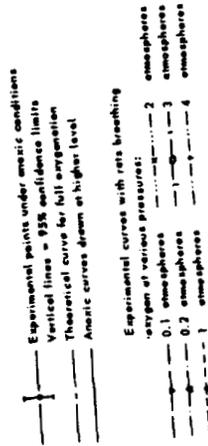


Fig. 2. Effect of oxygenation of tumor on total dose required. The effect is represented by the time taken to grow from the 9-mm diameter unirradiated to 25-mm diameter. The delay in radiated tumors take six days. The delay induced by radiation is the result of the reduction of numbers of clonogenic cells, altered growth of survivors, and damage to the vascular stroma.¹⁰

the repopulation of tumorous cells. Success or failure therefore depends on the leeway one has as a result of the differences in radiation sensitivity and in healing characteristics of tumorous and normal cells.

However, in the best of circumstances, the reproductive capacity of tumorous cells is never more sensitive to radiation than that of dividing healthy cells. Often the tumor contains anoxic regions and these are, in fact, less sensitive to low-LET radiation by perhaps a factor of 3 than are normal cells. A measure of this effect is the oxygen enhancement ratio (OER), defined as the ratio of the dose required to produce a given effect (e.g., 50% survival) in anoxic cells to that in oxygenated cells. Experiments indicate that it varies from ~3 for lightly ionizing radiation to 1 for multiply-charged ions.

Figure 2 shows that the oxygen effect is significant. Also from Fig. 2, it can be seen that the OER is ~3 in a pair of mouse-tumor survival curves, one fully oxygenated and the other anoxic. Figure 3 indicates that high LET can remove the sensitivity difference between oxygenated and anoxic cells. This constitutes one very important advantage of this highly ionizing radiation: the injury is not subject to modification by oxygen or recovery.

One school of thought holds that for low-LET radiation, most of the cell deaths result from chemical reactions of peroxides on long chain molecules in the cell nucleus. In anoxic cells, peroxides are less readily produced by radiolysis, and this may account for lesser sensitivity. Cells irradiated with highly ionizing particles are killed mainly by direct interaction of these particles with long chain molecules, depolymerizing these molecules. High-LET radiation therefore interacts with anoxic and oxygenated cells in approximately the same way. However, it should be emphasized that the high effectiveness with which densely ionizing radiation damages the reproductive capacity of cells is not well understood.^{11,12}

In radiation therapy, one usually relies on dose fractionation (aubdivisio). Total doses with x rays comprise ~5000 rad delivered in ~20 doses during a four-week interval. Dose fractionation is effective because recovery of healthy tissue, between irradiations, takes place at a faster pace than does recovery of tumorous tissue. Experience indicates that, in general, surviving healthy tissue responds better to altered conditions than do tumorous cells and repopulates faster.

The race between repopulation of normal cells and of tumorous cells favors the normal cells because many tumorous cells die as a result of poor nutrition, but it also favors the tumors because they usually contain anoxic cells which are more resistant to radiation.

For dose fractionation to succeed, it is essential to increase the total dose at appropriate intervals and in precisely the right amounts so that the repopulation of normal cells can overtake

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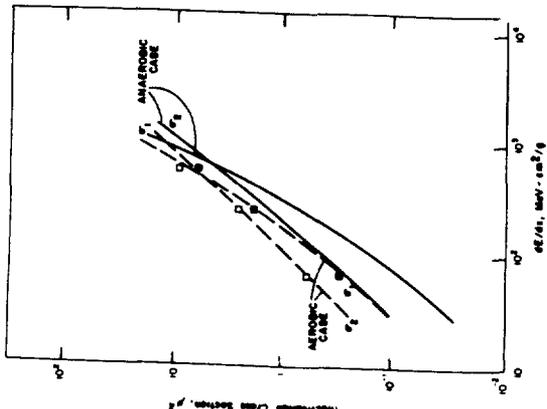


Fig. 3. Dependence of inactivation cross section on LET for oxygenated and anoxic cells.¹¹

CHARACTERISTICS OF NEGATIVE PIONS

The potential therapeutic properties of negative pions have been long recognized.^{3,15-17} These therapeutic properties result from the unique characteristics of negative pions and their interactions with atomic nuclei.

Pions have positive, negative, or zero charge. The charged pion with which we shall be concerned is an unstable particle of mass ~140 MeV. It has zero spin, an isotopic spin of unity, and a mean life of $\sim 2 \times 10^{-8}$ sec. If uncaptured, it will decay into a muon and a mu neutrino. The muon in turn decays into an electron, a mu neutrino, and an electron neutrino. The range-energy relation¹⁸ for negative pions is shown in Fig. 4. It is apparent that for purposes of therapy, pions must have energies of 25 to 200 MeV. Now, pions of this energy have a long mean-free-path for nuclear collisions. The uncharged member of the species lives a very short time ($\sim 10^{-16}$ sec mean life) and decays into two gamma rays. The positively charged member almost always comes to rest without undergoing nuclear interaction and then

decays. The negatively charged pion also comes to rest before interacting. However, it is captured in an outer orbit of a heavy atom (e.g., an oxygen atom, assuming the slowing down medium is water), replacing an electron in that atom. In a time of $< 10^{-16}$ sec, the pion cascades down from one orbit to the next, causing the emission of low-energy x rays, and finally comes to rest in the lowest orbit of the capturing atom. In this orbit, the wave function of the pion overlaps that of the nucleus, and the negative pion is captured by the nucleus.¹⁸

REACTION PRODUCTS FROM THE CAPTURE OF NEGATIVE PIONS BY OXYGEN

Oxygen accounts for the major fraction of the mass of atoms contained in tissue and is responsible for the capture of most negative pions coming to rest in tissue. A small fraction of the negative pions is captured by carbon and nitrogen, but the resulting energy deposition is not much different from that for oxygen. We will, therefore, confine our attention to ¹⁶O. Upon capture of a π^- by ¹⁶O, the mass of the pion is converted into energy with the consequent violent disruption of the ¹⁶O nucleus. From this nucleus emerge neutrons, protons, alpha particles, ¹¹Li, Be, B, and C ions. The neutrons, although they carry off a sizable fraction of the total kinetic energy, account for a relatively small portion of the energy deposition in the vicinity of pion capture. The charged particles, on the other hand, create ionization all along their trajectories. Furthermore, since the ¹⁶O nucleus is equivalent to multiple alpha particles, the dominant mode of decay involves the emission of one or more alpha particles among the reaction products, and these are almost always of short range, as is the case

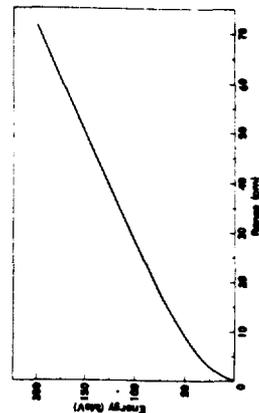


Fig. 4. Range-energy relation for negative pions in water.

for the heavier ions. Figure 5 shows the disintegration of an ¹⁶O nucleus following capture of a negative pion. The oxygen was contained in nuclear emulsion. A complete accounting of the energy deposition along the path of a negative pion beam as it traverses and comes to rest in water is shown in Fig. 6. Approximately 30 MeV of energy is deposited in the immediate vicinity, within a few millimeters, of the capturing nucleus. Most of this energy produces high specific ionization (high LET), and it is this ionization on which one relies for destroying the cancer cells.

Figure 7 shows the distribution of specific ionization resulting at the point where negative pions of 96-MeV energy are stopped in water.

Although a significant amount of energy is deposited by neutrons, one should recognize that this is neutron therapy at its best, from the standpoint of depth-dose distribution. The depth-dose distribution is now more favorable than for neutrons from an external source. The neutrons can be imagined to focus on the tumor site from all directions while the elastic and inelastic interactions occur at high energy, where the therapeutic effects of neutrons are at their best.

To recapitulate, absorption of a π^- in tissue involves new phenomena that have no counterpart with more conventional types of radiation. At the end of its path, a π^- is captured by a nucleus of O, C, or N. Of the total rest mass of the pion, ~40 MeV is expended in overcoming the binding energy of the nucleus, 70 MeV is carried off by neutrons, and ~30 MeV appears in the form of

protons, alpha particles, and heavier ions. The particles of $Z \geq 1$ are mainly of short range and high-ionization density and produce local high-level energy deposition in the immediate vicinity of capture. By appropriately adjusting the energy of the pions, this intense high-LET, high-RBE local radiation can be deposited within the tumor region with minimal effect on surrounding tissue.

Table 1 shows the energy inventory resulting from a beam of negative pions that comes to the end of its range in water.

For a tumor situated ~10 to 15 cm from the surface, a π^- beam that uniformly irradiates the tumor may be expected to deposit about three times as much energy per unit path length in the tumor as along its path leading to the tumor. For conventional x radiation and also for irradiations with fast neutrons, the entrance dose will exceed the tumor dose by a factor of ~2. In addition, the energy along the path of the pion beam is delivered at low dE/dx , while the dose deposited in the tumor is at high dE/dx due to the heavy ion component of the star. This makes the RBE for pions better than for x rays by a factor of ~3. Furthermore, the tumor-to-entrance dose ratio is a function of depth of tumor, becoming more

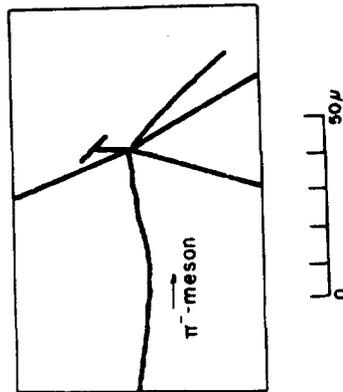


Fig. 5. Tracings of photomicrographs showing the capture of negative pions in ¹⁶O contained in nuclear emulsions.¹⁸

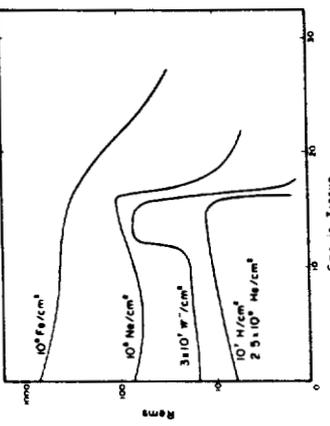


Fig. 9. Depth-dose distribution for irradiation with various kinds of charged particles.

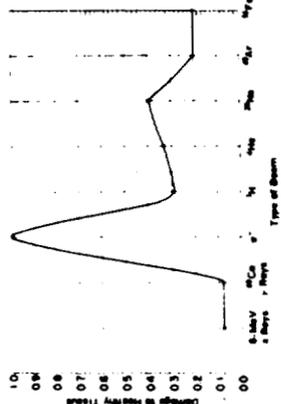


Fig. 8. Figure of merit for various types of radiation in terms of the relative damage to tumor and healthy tissue.²

The designs of accelerators for such purpose have been discussed previously.³

There are today three meson factories authorized and partially or completely funded: one in Switzerland, one in Canada, and one in the United States. Table II gives the main parameters for these facilities. Biomedical work has not been a major justification for any of these facilities, but I suspect they will all be involved, to some extent, in biomedical research and in negative pion therapy. In fact, we have proposed that a clinical facility be built as part of the Los Alamos Meson Physics Facility. This has not yet been approved. One milliamperes of 800-MeV protons will pass sequentially through various targets in the main vault. Most of the beam will be transported to a beam dump, preceding which we can have a thick meson-producing target. The fluxes achievable will permit irradiation of patients with an intensity of 100 rad/min. The beam handling will be as shown schematically in Fig. 10 and the exposure room as shown in Fig. 11. Detailed calculations by Thiessen show that it will be possible to tailor

TABLE II Comparison of Proposed Meson Factories

	H ⁻ Cyclotron TRIUMF ^a	Ring Cyclotron Zurich	Linear Accelerator LASSI
Energy (MeV)	200-500	510	100-800
Average current (mA)	0.1	0.08	1
Beam extraction (f)	100	90	100
Beam emittance (milliradian cm)	0.2	21	55
Cost of facility (millions of \$)	27	Funded	Partially funded
Funding situation	Partially funded 1973-74		
Completion date			1972

^aTRI-University Meson Facility, Vancouver.

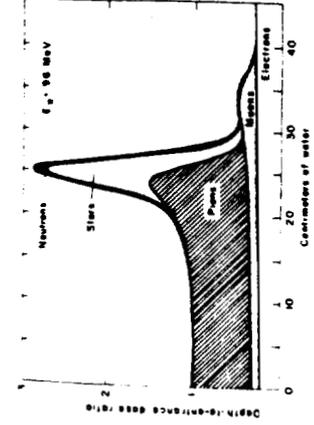


Fig. 6. Depth-dose curve in water for negative pions of the incident momentum 190 ± 5 MeV/c.²⁶

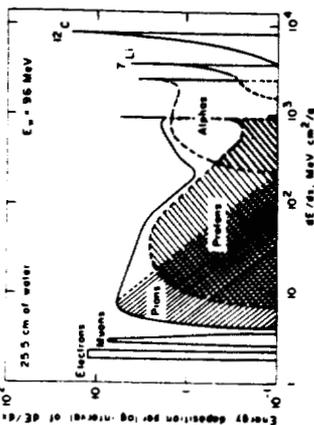


Fig. 7. Distribution of specific ionization for negative pions stopping in water.²⁶

favorable for pions than for x rays or neutrons the greater this depth.

One should not overestimate the value of a high tumor-to-entrance dose ratio. However, it should be kept in mind that there are side effects of radiation and some of them may be quite subtle. For example, effectiveness of radiation may be enhanced by the immune-defense mechanism of the body. One must, therefore, try to avoid adverse effect on the immune-defense mechanism. It is reasonable to suppose that one is more likely to retain natural immunity if one minimizes the total radiation exposure.³¹

There are also late effects of radiation. Sublethal cell injury can apparently result in uncontrolled proliferation of cells (e.g., cancer, leukemia) and life-shortening in general.³²

TABLE I Energy Partition for π^- Capture in Water²⁸

	MeV
Average binding energy	40.0
Kinetic energy $Z > 2$	4.5 ± 0.5
$Z = 2$	8.0 ± 0.4
$Z = 1$	16.5 ± 0.6
Neutrons	70.0 ± 5.0
Total	139.0 ± 5.1

Mass of π^- 139.6 MeV

A second major implication for cancer therapy of the high-LET distribution achievable with negative pions at the tumor site concerns the oxygen effect, as previously indicated. The OER decreases from 3 for x rays to 1 for heavy ions. For π^- (and also for neutrons²⁹), this effect appears to be ~1.5.^{18,24} The effect for neutrons is somewhat substantiated by experiment, whereas the effect for π^- is calculated.

COMPARISON OF VARIOUS TYPES OF RADIATION FOR THE TREATMENT OF CANCER

It is not easy to make a meaningful comparison of the efficacy of various types of radiation. The figure of merit varies with the type of tumor, its depth, and the characteristics of the surrounding tissue. It is taken to be the ratio of damage done to cells in the tumor region to damage done outside this region. In Fig. 8, it is assumed that the figure of merit includes the oxygen-enhancement ratio, which is estimated to be 1.0 for heavy ions, 1.5 for π^- , and 3.0 for electromagnetic radiation. The definition of figure of merit is, of course, open to some argument. However, all other things being equal, one should certainly try to minimize the body burden and the side effects associated therewith.

Figure 9 illustrates the depth-dose distribution of various kinds of charged particles. In calculating REM, the values used for RBE correspond to a degree of injury that destroys cellular reproductive capacity. Although the calculations on which these curves are based necessarily contain approximations, the trends shown are certainly meaningful.

PROSPECTS FOR INTENSE PION BEAMS

What are the prospects that pion beams will one day be adequate for therapeutic purposes?

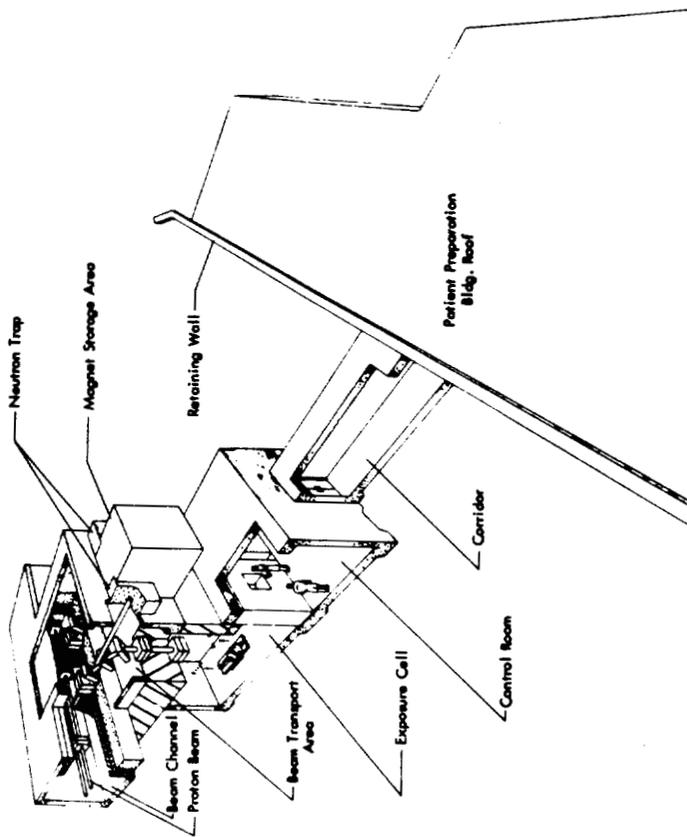


Fig. 11. Proposed arrangement of pion therapy facility.

the pion beam to any desired configuration and to adequate purity by judicious use of electric and magnetic fields. Figure 12 shows isodose curves calculated on the basis of present magnet technology. Note the flatness of energy deposition.

There is, of course, the problem of delineating the volume to be irradiated and determining the pion energy distribution that will produce stopped pions uniformly in that volume. It may well be possible to determine the precise volume where the pions stop by determining the direction of emitted neutrons and x rays. Alternatively, one might direct positive pions of identical energy distribution into the specified volume and use the positrons from μ^+ decay to produce a map of the density distribution of stopped pions.

CONCLUSIONS

The above arguments indicate that negative pions would be the treatment of choice in many applications of radiation to the treatment of cancer. The essential points are few and simple:

- 1) High-LET radiation damages anoxic cells more readily than does low-LET radiation for the same damage to normal tissue.
- 2) The physical distribution of energy deposition can be much more favorable and more controllable for negative pions than for uncharged radiation, because charged particles are susceptible to electromagnetic steering and focusing.

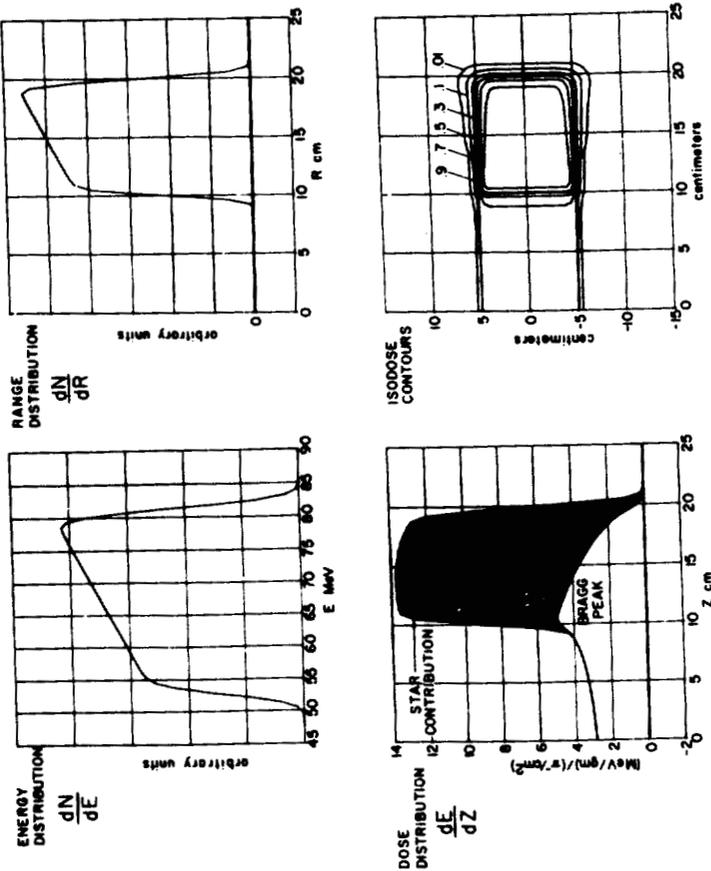


Fig. 12. Energy deposition for pions stopping in water.¹⁸

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- 3) Negative pions provide a very favorable depth-dose distribution, compared to other forms of radiation, because of the Bragg ionization peak and the conversion of mass into energy upon capture by one of the heavy-atom constituents of tissue.
High-intensity monoenergetic beams of π^- mesons will therefore make possible large localized deposition of high-LET radiation with minimal damage to surrounding tissue, and this is an objective of radiation therapy.
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ACKNOWLEDGMENTS

This work was performed under the auspices of the U.S. Atomic Energy Commission.
I am indebted to Stanley B. Field for calling my attention to Ref. 23.

CANCER STATISTICS FOR 1970 - A PROJECTION

Source: 1970 Cancer Facts and Figures, published by the American Cancer Society
Basic data:
1. Cancer is a disease entity dealing with greater than 200 clinical-pathological entities occurring in plus-minus 58 sites.

2. 1970 Expected new cases, diagnosed for the first time - 2/3 million or 625,000 cases of which 4,000 will be less than 15 years of age and half of these will be leukemia.

3. 1 in 4 persons will eventually have cancer or 2 of 3 families.

4. In 1969 deaths in 3 categories were as follows:

- a. 40,000 in the armed forces in Viet Nam
- b. 470,000 or 1/2 million in traffic accidents
- c. 323,000 or 1/3 million with cancer.

5. The expected deaths in 1970 from all sites will be 330,000 patients, which is an increase of 7,000 over 1969, or 30,000 from 1966.

6. Nearly 1 million or 960,000 Americans will be under care for cancer in 1970.

7. The survival rate with current therapy is 1 in 3, or 208,000 cases.

a. 1930 - 1 in 5
b. 1940 - 1 in 4
Since 1956 and up to date, it is now 1 in 3. Of six patients with cancer, number 1 and number 2 will be cured. Number 3 will die but could be saved. Numbers 4, 5, and 6 are incurable. The goals of the American Cancer Society is 1 in 2, or 1/2 of 625,000 new cases, or 313,000.

8. 1/2 of cancer deaths are less than 65 years of age.

9. There are 55 males to 45 females. In those age groups less than 15 years of age, leukemia leads. Between 15 and 34 years of age, leukemia and lymphomas lead, and breast cancer enters. Between the ages of 35 and 54, breast and lung cancer come to a peak. Between the ages of 55 to 74, breast and lung cancers decline in incidence and cancers of the colon-rectum begin their rise in incidence. After the age of 75, cancer of the colon and rectum and prostate are the most common.

10. In females, cancer of the breast leads.
In males, cancer of the lung leads.
In both males and females as a conglomerate, cancer of the colon and rectum leads.

11. In surveying the field:

- a. Two essential figures to remember for 1970 for the U.S.A.
 1. 625,000 new cancer cases (all sites) 1970
 2. 330,000 deaths from cancer (all sites) 1970
- b. Leading cancer sites in 1970:
 1. Skin - 112,000 new cases.
 2. Colon-rectum - 75,000
 3. Breast - 69,000
 4. Lung - 68,000
 5. Uterus - 42,000
 6. Prostate - 35,000
 7. Kidney and bladder - 32,000

ROSEN NEGATIVE IONS FOR RADIOTHERAPY

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24. Based also on a recent calculation (unpublished) by the author.
25. Calculations performed by H. A. THIESSEN, Los Alamos Scientific Laboratory.

8. Lymphomas - 23,000
9. Leukemia - 19,000
10. Stomach-17,000
11. Head and neck - 14,000
12. Larynx - 7,000

Please note: Of these 12 cancer sites, 9 are treated essentially with X-ray therapy.

- c. The calculated estimated number of new cases for all sites by areas:
 1. Western Area of 17 states, which includes Kansas and Nebraska - 180,000 new cases.
 2. Los Alamos area of 10½ states, including the lower half of California - 94,000 cases.
 3. Rocky Mountain states - 9 states - 49,600 new cases.
- d. If you view the Western Area of 15 states, skin cancer is number 1 except in Hawaii, then lung and breast, then colon-rectum, and least is stomach and head and neck.
12. In females, cancer of the ovary, lung, and leukemia are rising. In males, cancer of the lung, pancreas, and leukemias are rising. There is a sweeping rise in the incidence of cancer of the lung, with a comparable sweeping decline of cancer of the stomach and uterus. Cancer of the ovary, pancreas, and leukemias are steadily rising, but on a slow level.

STATEMENT OF DR. LOUIS ROSEN, DIVISION LEADER, MESON PHYSICS DIVISION, LOS ALAMOS SCIENTIFIC LABORATORY

Chairman HOLIFIELD. The committee is encouraged by the progress obtained on your project out there and the many promising achievements which may be obtained once the facility is in operation.

Your statement contains a proposal at the bottom of page 4 which should be of considerable interest to the committee, one which would prevent a 6-month shutdown of the main LAMPF beam line and provides for the start of a new biomedical facility.

Will you please tell us first what is the implication of this new radiotherapy which Dr. McDaniel mentioned on page 13 of his statement? Will you give us a little background on that?

Then tell us what is going to be necessary for changes in the facility in order to fully implement this.

Dr. ROSEN. Well, as this committee may remember, we promised that LAMPF would have very significant practical applications.

As Dr. McDaniel has indicated to you, the first of these, quite unexpected, has already emerged. As he said, 40 units of an X-ray machine based on Los Alamos design are being built—well, they are in the process of being built right now. Twenty-two of them have been delivered to hospitals, I understand, already.

Chairman HOLIFIELD. What is the theory behind this? They are using these in the place of cobalt or radium?

Dr. ROSEN. As you stated, the LAMPF accelerator is one for protons. An electron prototype has been built and this has been miniaturized and adopted for medical use only.

Now, it was impossible to build a prototype proton accelerator to assure ourselves that the new concept and principles which we developed will actually work. Not all of us want to retire 3 years from now. So, we took the next best course of action. We decided to build an electron prototype accelerator. We have done so.

Dr. McDaniel told you how we already are using that electron accelerator for other purposes. In particular, it demonstrated that the achievements and developments which we made were valid, that not only was the theory correct, it worked in principle.

Now, this came to the attention of industry. We make every effort to make available our developments to industry on the basis that they are in the public domain and in fact two companies are now building electron accelerators of 4 Mev. energy for radio therapeutic purposes.

If I may read you this 1-minute statement I have on that, it may make obvious to you why this is being done.

Chairman HOLIFIELD. Go ahead.

Dr. ROSEN. In my judgment, the most dramatic possibility for practical application is in the biomedical area: The provision of negative pion beams. Now, this is in contrast to electron beams which we now use. The LAMPF facility will make available a new modality of treatment by way of negative pion beams, the provision of negative pion beams of such intensity they can be used in radiation therapy of deep-seated tumors.

The main reason for this can be readily understood by devoting 10 minutes of study to the diagrams in figure 8 (p. 526) which I believe you have.

The central point is that negative pions make possible the local deposition under controlled conditions of high quality radiation with relatively low damage to tissue outside the treatment volume. This situation arises because the negative pion is a Dr. Jekyll and Mr. Hyde type of particle. While it is traveling to the tumor site, it has one set of characteristics—its ionization is low and it disturbs the tissue in its path no more than does an electron.

However, after it comes to rest in the tumor site—and you can determine where it comes to rest; you have this under your control—Representative HOSMER. By choosing the proper energy you use to begin with?

Dr. ROSEN. (continuing). Exactly so, sir.

Some of its mass converts into energy. It disrupts the nucleus by which it is captured, usually an oxygen nucleus, and the fragments of this nucleus become the projectiles which destroy the cells. The tumor cell thus, in a sense, provides the means for its own destruction.

The case for negative pions in radiation therapy has been made by many scientists.

I submit for the record a transcript of a recent talk to the LAMPF users group by Dr. H. S. Kaplan. Dr. Kaplan is chairman of the Radiology Department at Stanford University and one of the world's most eminent radiotherapists.

I provide you also with a reprint of a paper which tells the same story from the standpoint of a physicist.

And now comes the commercial to which the chairman has referred. In order to avoid a 6-month's shutdown in the main LAMPF beam line when the biomedical facility is finally authorized, it is essential that some preparatory work be started next fiscal year on that portion of this facility immediately adjacent to the beam line.

We have here a God-given opportunity to demonstrate once again that large scientific enterprises can have immediate and beneficial influence on human welfare.

I am sure that this committee is very much aware that at this particular juncture in the affairs of science and society such demonstrations are sorely needed. You have collectively fathered a great scientific enterprise.

The importance of the purely intellectual pursuits which this facility will make possible can hardly, in my view, be overemphasized. However, we should not ignore the practical possibilities, for they can have an immediate and I think very beneficial impact.

Chairman HOLIFIELD. Dr. Rosen, are you within your budget, your planned budget?

Dr. ROSEN. What we are suggesting to this committee—

Chairman HOLIFIELD. I am talking about the money which has been allotted to you so far. Have you overrun?

Dr. ROSEN. (continuing). No, sir; we are within our budget at the present time.

Chairman HOLIFIELD. This suggestion you are making is a request for an additional amount for an additional purpose?

Dr. ROSEN. Yes, sir.

Chairman HOLIFIELD. How much would it be?

Dr. ROSEN. The complete biomedical facility we believe will eventually run to \$2.9 million, including patient facilities, doctor facilities, nurses facilities, et cetera.

Representative HOSMER. You are not asking for it at this point?

Dr. ROSEN. That is right.

Representative HOSMER. You are asking for some changes so that you can take off a beam for such a facility?

Dr. ROSEN. That is right.

Representative HOSMER. How much is that going to cost?

Dr. ROSEN. We are asking you to permit us to spend up to \$300,000 of existing funds insofar as we can make them available, and I cannot guarantee at this moment we can make them available but we want to vary much.

Representative HOSMER. If you take this tap off there now, you don't have to shut down?

Dr. ROSEN. And get in trouble with contractors whose radiation doses to their people are very stringently limited.

Chairman HOLIFIELD. This overall facility is going to cost how much?

Dr. ROSEN. The overall biomedical facility will run close to \$2.9 million.

Chairman HOLIFIELD. I am talking about the overall meson facility.

Dr. ROSEN. The overall meson facility is now budgeted by the Commission at \$56 million, not including the weapons facility which DMA wants, not including the biomedical facility or other practical applications such as isotope extraction which looks very promising.

Representative HOSMER. What, if any, type of action would be required by this committee to permit the reallocation of the \$300,000?

Mr. ARBADESSA. It would be very helpful, Mr. Hosmer, if the committee could put some language in the report which would authorize us to spend both the \$270,000 for the porthole for the military facility, and the \$300,000 to permit this facility to be added at a later date.

We think we have full authority to do that within the data sheet that we submitted on the initial project, but it is close enough that some words in your report will be helpful. That is all we need.

Representative HOSMER. I doubt if you will have much trouble with it, Dr. Rosen.

Mr. ARBADESSA. The original authorized cost for this project was \$55 million. Our estimate now is \$56 million. This is a \$1 million overrun.

Chairman HOLIFIELD. This is undoubtedly due to inflation and not change of design or problems.

Mr. ARBADESSA. That is exactly correct.

I should point out that we ran into several delays in funding and that Dr. Bradbury and Louis Rosen deserve an awful lot of credit for bringing this in at \$56 million.

Chairman HOLIFIELD. The committee agrees with you. We know what your problems have been in delayed funding. We feel that you are doing a good job in keeping this as close as you are to the original amount.

I think, along with Congressman Hosmer, that there is merit in this new practical application—which really, I guess, we did not anticipate, did we, Doctor?

Representative HOESMER. With cryogenics, you might be—

Dr. ROSEN. I think you will cut that in half with cryogenics. Representative HOESMER (continuing). Do you think that there is a reasonable possibility of, say, being able to cut it in half again by the time you get your \$2.9 million and get this facility in?

Dr. ROSEN. That, I think, is probably not in the cards right now. Representative HOESMER. You see, we are testing you against an alternate source here.

Dr. ROSEN. Let me explain. The Stanford people are making most of their advances on electron accelerators. With an electron accelerator, the beams have to be almost a hundred times as intense in order to achieve the same pion production that one achieves with protons. This is not yet possible. It is an enormously difficult problem.

Chairman HOLIFIELD. Will it take a lot more electricity?

Dr. ROSEN. With the superconducting accelerator, the electrical power goes away as a difficulty, because the superconducting accelerator's main advantage is, that it takes almost zero power to activate the cavities. All the power goes into the beam. We use more than two-thirds of our power to activate the cavity. Less than one-third for the beam. That is the enormous advantage of superconductivity.

On the other hand, it is going to take at least 5 years and maybe quite longer to develop and build superconducting structures which are applicable to protons rather than electrons.

Representative HOESMER. That is what I am trying to pursue, if we can get some cut-rate proton burp gun real soon.

Dr. ROSEN. The \$2.9 million has to be spent no matter what.

Representative HOESMER. If we can get some machine that does it for \$200,000, there is no need to build it.

Dr. ROSEN. No, sir. I did not make myself clear. We will have the pi mesons. They will cost essentially nothing, because they will be there. They will be a byproduct of the use of the machine.

Representative HOESMER. I understand. I am just thinking of an alternative to this \$2.9 million.

Dr. ROSEN. That money must be spent, no matter what machine you use. You cannot get around that. That is for the patient treatment, for the beam transport. That expenditure must be made, no matter what kind of machine you use.

Representative HOESMER. Even if you got the pi meson from that burp gun you would still have to have \$2.9 million. The only thing you would have to throw away is the \$300,000 for the beam takeoff.

Dr. ROSEN. That is so. I did not understand your question.

Representative HOESMER. I did not put my question very well. Chairman HOLIFIELD. You say you need \$300,000 to make these openings?

Dr. ROSEN. To keep that option open.

Chairman HOLIFIELD. If you have to go back in later to do this, you will have to shut the machine down because of radioactivity, probably 6 months?

Dr. ROSEN. That is so. That will be expensive because the operating cost of the machine is seven and a half million dollars a year, and most of this goes on whether the machine is used or not because the people are on board.

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Dr. ROSEN. Not in full. I alluded to it in some of my testimony to your committee 3 or 4 years ago. I alluded to it but we were not anywhere as near certain of its coming to fruition as we are now, sir.

Chairman HOLIFIELD. You know that the committee has always approved of multiple use of these facilities. Wherever possible, we have approved the improvement of a facility in order to get additional benefits from the basic facility itself.

I think we feel the same way about this and we are very excited about this new medical use of this device.

As I understand it, some of these entries into the tube of the linear accelerator are going to be for military purposes.

Dr. ROSEN. One of them is for military purposes.

Representative HOESMER. How many others are involved?

Dr. ROSEN. Then there will be one for biomedical, as I have just discussed, and another for isotope production.

Chairman HOLIFIELD. There will be three openings that you had not planned originally?

Dr. ROSEN. There will be three openings that were not included in the original budget estimates; yes, sir.

Chairman HOLIFIELD. How does the military feel about the portion that you will be using for their purpose?

Dr. ROSEN. They are very enthusiastic about this. In fact, in the submission which I gave to the committee, to your staff, there is a short paper by one of Dr. Agnew's people setting out their reasons for wanting the military applications portion of that facility.

Representative HOESMER. What is the third one for isotope production going to cost?

Dr. ROSEN. That is quite small. It is under a half million dollars. I don't know exactly.

Representative HOESMER. Dr. Rosen, do you know that this biomedical facility is one which involves or is primarily for the purpose of treatment?

Dr. ROSEN. That is right.

Representative HOESMER. Not particularly research?

Dr. ROSEN. Some research has to go on before we can start treating patients. You must do preclinical work.

Representative HOESMER. Right. Let me ask you this. If one wanted to duplicate such a facility, would it be necessary to build another meson factory of the size and cost that you are building?

Dr. ROSEN. No, sir. As you realize, the facility we are building is the first ever built of this kind. It is multipurpose.

Representative HOESMER. Would it be possible to get an alternate source of pi mesons required for this kind of medical treatment?

Dr. ROSEN. Yes, sir. There are several developments going on right now looking to much less expensive sources of pi mesons specifically for this kind of treatment. At Stanford, they are developing a superconducting linear accelerator. If that comes to fruition, it will be possible to build just the meson production part for medical purposes for a very small fraction, perhaps less than \$5 million, in order to treat many thousands of patients a year.

Our own structures, if we were to adapt them for this particular purpose, could be built right now for \$10 million. We could build you a 500 Mev high-intensity pion producer for that purpose alone for approximately \$10 million with what we know already.

Chairman HOLIFIELD. I think you will get the support of this committee. Talk to John Abbadessa. He can find the money. I have never seen a fellow like him. He can find money anywhere.

Mr. ABBADESSA. Mr. Chairman, I am not sure I need that kind of publicity.

Chairman HOLIFIELD. We are very encouraged by this progress. We want to thank you for the good job you are doing down there.

Representative HOESMER. Mr. Chairman, I had a chance last September to visit the facility and speak with Dr. Rosen about it at Los Alamos. I was totally impressed by not only the brick and mortar there, but the people and the enthusiasm with which they appeared to be operating.

Dr. ROSEN. Thank you, sir.

Chairman HOLIFIELD. I, too, was out there and got the same sales talk.

Dr. ROSEN. May I say the enthusiasm is a product of how many visits we have such as the ones you refer to.

Chairman HOLIFIELD. Is there anything else you wanted to say?

Dr. ROSEN. That is all.

Chairman HOLIFIELD. Go ahead, Dr. McDaniel.

Dr. MCDANIEL. The Electron Linear Accelerator Facility at Massachusetts Institute of Technology is scheduled for completion in mid-fiscal year 1972. We expect that a beam of between 50 and 100 Mev will be available in mid-fiscal year 1971, and that some initial experiments will then be undertaken, if they can be accomplished without interference in assembly of the full accelerator. There has been some problem with leaks in the buildings, particularly around penetrations, but this is being treated by means of pressure grouting which is expected to be effective. The major technical problem concerns switch tubes being fabricated by Litton Industries. These tubes are necessary for operation of the modulators, which are being fabricated by Energy Systems, Inc. Litton has demonstrated the capability to build these tubes, but has experienced some difficulty in meeting performance and repeatability standards on a production basis. A review of this matter with Litton and Energy Systems was recently conducted by MIT. Litton has now produced four tubes meeting all standards and specifications and two more are under test. Tube design will be finalized and production initiated in early April. Energy Systems, Inc. will use two of the tested tubes to initiate fabrication of the accelerator modulators. Litton is therefore no longer holding up Energy Systems, Inc., and MIT now has scheduled full-scale modular tests for July 1971. The situation regarding funding remains unchanged from that summarized in our correspondence to the committee dated October 30, 1969.

In order to provide for the increases in operating expenses outlined above—\$965,000 LANS and \$100,000 LAMPF users—decreases totaling \$715,000 must be effected at Ames, Argonne, Columbia, Lawrence Radiation Laboratory, Oak Ridge, and at universities supported under the offsite program. This results in a net increase of \$350,000 for the medium energy physics program for fiscal year 1971.

Representative HOESMER. You mean you are taking part of it from other uses?

Dr. MCDANIEL. That is right. It is a total net increase for appropriations of \$350,000 above last year, although we needed \$965,000 plus \$100,000. We had to take \$715,000 of it away from other medium energy facilities.

Representative HOESMER. Was this construction-related research for which the \$965,000 is needed something that was overlooked to begin with or came as a surprise? How did it assume this proportion?

Dr. MCDANIEL. No. This is the estimate which we have had in our minds all along, that in order to develop the accelerator and to get ready to do the experiments with the accelerator when it is completed, we will need to build up, as Dr. Rosen said, to an operating level of several million dollars each year. This has been a part of the plan all along.

Representative HOESMER. It is construction-related research that the item is for, the \$965,000?

Dr. MCDANIEL. Yes; but all during the construction phase on all of the accelerators we have always planned and we continue to plan for the LAMPF accelerator the necessary R. & D. that must be done in order to develop the accelerator.

Representative HOESMER. I understand. We have done it on the devices that Varian is using. What is this going to go toward, some of the beam takeoff experimental things that are a part of construction? The beam takeoff experimental things that are a part of construction?

Dr. MCDANIEL. Any research and development work that is required before one can design the apparatus to put out on purchase orders under the construction contract must be paid for out of the research and development operating funds.

Dr. ROSEN. May I answer that, please. There are two aspects here. One is the supervision of construction, the checkout of components. We have components being made by 100 vendors throughout the country today. These vendors must be monitored very closely. The equipment they produce must be tested. Now, all this we do in our research organization and it is legally research—

Representative HOESMER. That is construction-related research?

Dr. ROSEN. Yes. These must go on until the accelerator is completed. In addition, one does not design an accelerator and stop design and then construct it. The procedure is to continue design from one portion of the accelerator to the other. As funds become available, you go out on contracts for the design portion. Right now, 80 percent of the accelerator has been designed. We still have about 20 percent.

Representative HOESMER. Then the purpose for which this money goes was not unanticipated?

Dr. ROSEN. No, sir.

Representative HOESMER. It just simply had not been heretofore provided for and you are working a scheme to try to provide it without increasing the total budget.

Dr. MCDANIEL. That is correct.

Chairman HOLIFIELD. Dr. McDaniel, you know that a late member of this committee, William Bates, was a real champion for this MIT accelerator. I was wondering if there has been any consideration given to naming that facility after Bill Bates.

Representative Hosmer. Somebody might ask us what that money in chemistry is for.

Dr. McDANIEL. I have in preparation a more elaborate written statement which I can submit for the record at this point.

Representative Hosmer. We must obviously have some supporting material.

Dr. McDANIEL. That is almost ready to be submitted.

Chairman HOLIFIELD. I am going to jump over here for just a few minutes, because we are going to have to leave pretty soon and go to the floor. I have a few questions that I want to discuss with you.

I understand from your testimony that the United States will have, or might have the following devices in the near future:

1. An ORMAK 0 and an ORMAK 1.
2. An ALCATOR.
3. A Doublet II.
4. A Texas Tokamak, and
5. A Stellarator C-Tokamak.

All of these devices, in one way or another, seem to emulate an existing Soviet system or device which is in the process of being significantly improved. We received a letter from the AEC dated February 13, 1970, which sets forth your plans in some detail. We will insert the letter in the record at this point.

(The letter referred to follows:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., February 13, 1970.

Mr. EDWARD J. BAUSER,
Executive Director, Joint Committee on Atomic Energy, Congress of the United States.

DEAR MR. BAUSER: The low-beta toroidal research sector of the Controlled Thermonuclear Research program has recently undergone a series of changes. These have been communicated to you in a series of recent letters and were the subject of some questions at the beginning of the FY 1971 authorization hearings. The purpose of this letter is to explain the rationale behind these changes.

The systems under study in low B toroidal research are the following:

- (1) Multipoles, which include levitrons and spheratrons (one internal conductor), quadrupoles (two internal conductors), and octupoles (four internal conductors). In these systems the magnetic fields are produced by internal conductor current plus externally applied fields (levitrons and spheratrons). The simplicity, comparatively low cost, and flexibility of multipoles are such as to make them very attractive from both an experimental and theoretical point of view. Indeed, the first demonstration of classical plasma confinement in a low B toroidal system was made in the GGA Octupole. It is generally agreed that multipoles per se are not an attractive reactor configuration because material conductors would rapidly deteriorate inside of a hot, radiating thermonuclear plasma. Nevertheless, the physics gleaned from multipoles is directly applicable to other toroidal configurations.

- (2) Stellarators. In these systems the magnetic fields are produced by a complex set of external windings. The stellarator configuration has always been considered potentially attractive for the reactor application.

- (3) Tokamaks. The magnetic configuration in the tokamak is produced by a combination of simple external coils and a current flowing within the plasma. Its performance characteristics are interdependent and therefore often difficult to isolate. The tokamak is considered a potentially attractive reactor configuration.

The goal of toroidal research is to understand plasma confinement in closed systems and to thereby contribute directly to the development of reactor-level confinement. This is best accomplished in simple, flexible experiments both because of ease of operation and ease of analysis. For this reason the U.S. CTR program has placed major effort on multipoles, and recent successes in under-

Dr. McDANIEL. We certainly have the greatest respect for Mr. Bates and the consideration which he has given to the Commission and particularly to my division and particularly to this accelerator. We understand that at the Massachusetts Institute of Technology there have been some discussions about an appropriate name for the site. They have not yet reached the stage of making formal recommendations. We have some information that would lead us to believe that they are giving serious consideration to naming it in honor of Mr. Bates.

Chairman HOLIFIELD. There certainly would not be any resistance from any member of this committee.

Dr. McDANIEL. There would not be resistance from my division, I assure you.

Chairman HOLIFIELD. We would not want this to be considered as a direction at all, but there would be no resistance. We remember how interested he was in the facility, and it being up in his area, I think it would be fitting.

Dr. McDANIEL. We understand that MIT has considered the idea very warmly, but has not reached the stage for formal recommendations.¹

Chairman HOLIFIELD. All right, you may proceed.

Dr. McDANIEL. At this point, Mr. Chairman, I would like to depart from our usual statement of program discussion and move to the controlled thermonuclear research program.

May I introduce Dr. Roy Gould, who is now employed at the California Institute of Technology as professor of physics. On April 1, he will replace Dr. Amasa S. Bishop, who has been assistant director for controlled thermonuclear research. Perhaps later on we can call on him for some comments.

Should time permit, I will return to our other programs as necessary.

Chairman HOLIFIELD. Dr. McDaniel, we may accept this change in procedure more readily than we may be willing to proceed with the change in direction you are proposing for the CTR program. As you well know, this committee and the Congress continuously have provided funds said to be necessary for this CTR program. We support this program because of its great promise for the future. Nonetheless, the abrupt shifts which have occurred over the past few months, regardless of motivation, require justification. And we will expect you to justify your decision.

Dr. McDANIEL. We will be very happy during these hearings and later for the record, if you like, to complete our justifications.

Representative Hosmer. Are you going to submit to us for the record some support for the low energy physics, mathematical and computer research chemistry, and metallurgical—

Dr. McDANIEL. I had not included any information in my opening statement.

Representative Hosmer. You are going to give us something for our records so that we will have it?

Dr. McDANIEL. We will be happy to submit it for the record; yes, sir.

¹ By letter dated April 1, 1970, the AEC was informed by Dr. Howard W. Johnson, President, Massachusetts Institute of Technology, that the Executive Committee of M.I.T. had authorized the naming of the accelerator after the late Congressman William H. Bates. The Chairman of the AEC subsequently advised Dr. Johnson of the Commission's agreement and

standing and long time confinement have justified this decision. Stellarator plasmas are more complex principally because of the nature of their magnetic fields. In recent years confinement in stellarators has been improved beyond the anomalous or Bohm level, but the improvements have not been as great as achieved in multipoles and tokamaks.

As you know, the Soviet tokamak systems have recently demonstrated attractively long confinement at near-thermonuclear conditions. This achievement has received world-wide attention and establishes the tokamak as an especially attractive confinement device because of its reactor potential. The intense interest in tokamaks within the U.S. program is based primarily upon the following belief: it is easier to understand the important elements of plasma confinement by studying and perturbing a good confinement experiment rather than trying to unravel the problems associated with—and possibly inherent to—a system which has demonstrated poorer confinement properties. This philosophy was recently adopted at Princeton where a limited budget did not allow the laboratory to operate a meaningful stellarator experiment, the forthcoming large spherator experiment (FM-1), and a meaningful tokamak experiment in parallel. Their decision does not imply that stellarators may not eventually make attractive reactors. Rather, it expresses the laboratory (and program) decision that tokamak research is a more efficient line of pursuit at the present time in terms of understanding confinement.

It should be noted that the situation with respect to tokamaks was not clarified until late last summer when, as we reported to you, a visiting team of English physicists performed a critical laser diagnostic experiment on the T-3 tokamak. This experiment definitively established the true thermonuclear nature of the tokamak plasma. Prior to this experiment the possibility of an anomalous explanation of the tokamak performance clouded the desirability of pursuing this area of research. Because of this uncertainty we chose simply to study tokamak physics and consider experimentation, but generally we treated the subject conservatively. Even before the confirmation the U.S. program reviewed its priorities and initiated two major new tokamak experiments (ORMAK at ORNL and Model ST at PPPL). After the confirmation the program recommended two other supporting experiments (Alcator at MIT and Doublet II at GGA). Currently it is reviewing yet a fifth proposal (University of Texas). The decision to proceed in this manner evolved after considerable study and review over the past nine month period.

Each of these devices concentrates on a different aspect of tokamak research, and the total effort represents a massing of varied expertise to attack the tokamak problem (and therefore the toroidal problem) on a broad front. Briefly the unique features of these experiments are as follows:

(1) ORMAK models the Soviet TM-3 experiment but provides significantly improved magnetic field design. The importance of this variable must be evaluated before the program embarks on larger tokamak experiments, since field design requirements can strongly effect both performance and costs. The uniquely flexible design of ORMAK permits easy alteration. Therefore, a relatively inexpensive second coil will allow the exploration of geometrical scaling without necessitating a completely new system.

(2) The conversion of the Model C stellarator to a tokamak (called Model ST for "Symmetric Tokamak") will provide the quickest means of obtaining an operating tokamak system in the U.S. This conversion at PPPL brings to tokamak research the tools and expertise of one of the world's best toroidal research teams and is expected to significantly advance our knowledge of basic tokamak operation.

(3) The Alcator experiment at MIT incorporates a unique technology developed at the National Magnet Laboratory in the design of what would be the world's highest field CTR experiment. Opening this new regime of high magnetic fields is considered extremely desirable from both the theoretical and experimental points of view. In addition, the Alcator brings to bear the knowledge and background of a number of accomplished basic plasma physicists and usefully concentrates a formerly diverse university program.

(4) Doublet II is the logical extension of the first U.S. experiment in tokamak research (late 1968). By combining the best features of multipoles and tokamaks, it holds the promise of an order of magnitude increase in relative plasma pressure (over that achievable in the simpler tokamak geometry).

(5) Texas Tokamak is intended to study the turbulent heating of tokamaks. The University of Texas has specialized in turbulent heating for a number of years and has received AEC support for part of its studies. (Note that the de-

The FY 1971 Presidential budget briefly describes these systems and also refers to a combination system, the so-called Stellarator-Tokamak at Princeton. At the time that this budget was being prepared, it was strongly believed that a major new toroidal system would be required in the FY 1971-FY 1973 period, although the exact nature of this system was not specified in detail. Recent developments have clarified this situation to the point that a somewhat modified concept is now in design. This system has been named the "Proto LT" for "Prototype Large Tokamak" and will replace the previously designated "Stellarator-Tokamak". Proto LT is intended to meaningfully test the content of plasma compression by reduction of both the major and minor plasma radius as a means of further heating the confined plasma. If successful, this concept would lead to the LT or "Large Tokamak", which would be aimed at the demonstration of the scientific feasibility of CTR, i.e. an n value of greater than 10^4 . The cost of Proto LT is estimated to be \$3.1M (as opposed to \$6M for Stellarator-Tokamak) and completion is projected for December, 1972. The machine would utilize existing technology and available motor generator sets for the first phase of operation. At a later time an additional generator may be required for advanced experimentation.

These shifts have virtually eliminated stellarator research in the U.S. program for the time being. However, this area of research is being pursued in the United Kingdom, Germany, and the Soviet Union, and future developments in stellarator research can be expected to be communicated to the United States. In the meantime, we feel that the above referenced program will provide the background which is necessary for a toroidal feasibility demonstration in the mid-1970's.

I hope that this explanation clarifies the recent actual and proposed changes in the toroidal research portion of the CTR program. We would be happy to provide further details should you so desire.
Sincerely,

S. G. English,

Assistant General Manager for Research and Development.

Chairman HOLIFIELD. Would you briefly tell us the similarities and differences between these devices and state the reasons for going to five devices simultaneously?

Dr. McDANIEL. May I call upon my technical expert in that field, Dr. Robert Hirsch, who is acting director until Dr. Gould comes in.

Dr. Hirsch, can you give a short answer to the question? And I emphasize the "short."

Chairman HOLIFIELD. You understood the question?

STATEMENT OF DR. ROBERT HIRSCH, ACTING ASSISTANT DIRECTOR FOR CONTROLLED THERMONUCLEAR RESEARCH

Dr. HIRSCH. Yes.

Chairman HOLIFIELD. We want to know the similarities and differences between these devices, why you are going to five devices simultaneously. Is this a new romance of these laboratories, or is it something new that they are all interested in? Is there a duplication involved in this in the way of capital investment? Are you making five of the same kind of devices or close to the same kind? What is going on here?

BACKGROUND ON TOKAMAK RESEARCH

Dr. HIRSCH. We are not making five of the same device, sir. Allow me to provide you background. In the CTR program we feel that the Soviet tokamak results represent a major step forward in low beta toroidal research. We have been somewhat hesitant in the past to become involved in this area of research for scientific reasons as well as the fact that we were committed to other lines of research.

Dr. HIRSCH. It is called the conversion of the Model C Stellarator or Model ST—standing for “symmetric tokamak.”

Representative HOSMER. This was a quick and dirty job to start work fast and cheap on this?

Dr. HIRSCH. That is right.

Representative HOSMER. What was it designed to get for you?

Dr. HIRSCH. This will provide us a duplication of the T-3 plasma—the plasma which was so successfully established to be a true thermonuclear plasma by the English team. It puts us right with the Soviets.

Representative HOSMER. To reproduce the T-3?

Dr. HIRSCH. That is right.

Representative HOSMER. The English established the temperature, the Soviets established the density. The holding time was irrelevant, because there wasn't any effort to make it any length of time; is that right for the T-3?

Dr. HIRSCH. The T-3 device contains the plasma for about 25 milliseconds, which is the highest value of the product of τ (density times confinement time) of any toroidal machine in the world. It is a very successful containment device.

Representative HOSMER. What is one element that the T-3 did not seek to get?

Dr. HIRSCH. It is ion temperature. You recall the temperature of the ions is the most important temperature in a fusion system.

Representative HOSMER. Is that what the British confirmed, the temperature?

Dr. HIRSCH. I misunderstood what you were asking. The question about which we were concerned was the nature of the electron distribution in the T-3 plasma. Was it indeed a Maxwellian or equilibrium distribution? We felt that the Soviet experiments were such as to admit another possibility, and this other possibility was that there was a cold group of electrons superimposed upon a very hot group of electrons orbiting around the axis of the device.

If that was indeed the case, it would have been an “anomalous” plasma. It would not be of thermonuclear interest, because it would not be an equilibrium situation.

Representative HOSMER. That did not turn out to be the case?

Dr. HIRSCH. No.

Representative HOSMER. Therefore, what was the \$200,000 for the ST supposed to buy?

Dr. HIRSCH. This would buy us two things. It would provide a duplication of Soviet plasma at a very early date. It would provide us experience in tokamak plasma—experience which we do not have up to this point in time—and it would permit us to move ahead using one of our very best diagnostic teams to further understand the operation of the T-3 plasma.

The tokamak plasmas are not as easy to understand as some of the other plasmas that we are currently investigating. It is often difficult to understand these plasmas, but proper understanding is a prerequisite to determining the true potential of the tokamak.

Representative HOSMER. Will you take up the other models now and tell us what additional you are getting out of each one in order, and for how much?

Now that the British have confirmed beyond any doubt that the tokamak is truly a thermonuclear plasma, it is clear that the Soviets have made a major step forward in this area of research. We feel that we cannot and should not ignore tokamak research any longer; we would be irresponsible to do so. In addition, we feel that many of the questions which we must answer in toroidal research can best be answered in a truly effective confinement device, such as the tokamak.

There has been a great deal of enthusiasm in this country to move ahead in this area. We have not reached this conclusion overnight. Our interest in the tokamak actually began to increase after the Novosibirsk Conference in 1968, when the first encouraging results were presented. We did not move ahead with formal plans for tokamak experiments at that time, however, because there were still scientific questions about the true nature of the plasma.

After the Novosibirsk Conference, Academician Artsimovich visited this country and informed us of still further improvements in tokamak performance. This was in the early spring of last year. At that point we felt that in spite of our scientific questions, we had to initiate tokamak research in this country. These questions, sir, were such that we felt that there was a possibility that the plasma in the tokamak was not a true thermonuclear plasma; that is, we recognized that it could be an anomalous plasma and, therefore, not of interest to us.

Representative HOSMER. This was last summer?

Dr. HIRSCH. Last spring.

Representative HOSMER. 1969?

Dr. HIRSCH. That is right.

THE U.S. TOKAMAK PROGRAM

At that point the CTR Standing Committee reviewed a number of proposals—five to be specific—to begin tokamak research in this country. In spite of our uncertainties about the scientific nature of the plasma, we strongly felt that we must understand and move forward in this area. After considerable deliberation the CTR Standing Committee recommended—and the Division of Research subsequently initiated—the two tokamaks at Princeton and at Oak Ridge. The reason for selecting these two was our belief that those two laboratories were best able to marshal the forces that were necessary to move forward quickly and effectively.

Briefly, those two machines are characterized as follows: The machine at Princeton is a relatively low cost (\$200,000) and rapid conversion of the model C stellarator. It brings to tokamak research one of the world's best teams of toroidal physicists.

Representative HOSMER. What are they calling that one?

Dr. HIRSCH. They call this the model ST.

Representative HOSMER. Is that listed in those that the chairman mentioned?

Dr. HIRSCH. This is listed as conversion of the Model C Stellarator, or alternately as the Model ST or the Tokamak. We have informed you of the nature of this device in two recent letters.

Representative HOSMER. There is some problem of semantics. I am just trying to straighten out which is which.

Dr. HIRSCH. To recapitulate for a moment, the Princeton device—the duplication of the T-3—provides us an opportunity to touch base and gain experience on a plasma which we know is thermonuclear from their experience.

I would now like to turn to the ORMAK system at Oak Ridge National Laboratory. In its first configuration this machine is similar to the Soviet TM-3 device, with two very important differences. First, the magnetic design in the ORMAK device is as nearly perfect as is possible. The device uses a simple one turn coil. There are in effect no "lumps" in the magnetic field, whereas in the Soviet system this is not the case.

We have in the ORMAK almost perfect magnetic symmetry and with this device we can determine how important symmetry is to the operation of tokamaks. Magnetic symmetry will be important in the design of future experiments, because it has major effect on cost. In addition, the magnetic field in the ORMAK I is a factor of two higher than the field in the Soviet TM-3 device. Therefore the ORMAK I provides us an opportunity to test magnetic field scaling in the tokamak. One of the questions in tokamak research is how these devices scale with the various external parameters, such as the symmetry of the magnetic field, the size of the field, etc. The ORMAK I would provide some insight to this question.

Representative HOSMER. You did skip ORMAK 0?

Dr. HIRSCH. ORMAK 0 was an attempt to take an old quadrupole device and modify it at low cost to make a quick and dirty small tokamak for tabletop experimentation—something to use "to get one's feet wet." As it turned out, the device did not operate in what Oak Ridge considered to be a reasonable fashion and the device has been dropped; it does not exist.

Chairman HOLIFIELD. What about the ALCATOR?

Dr. HIRSCH. May I finish on the Oak Ridge device for just a moment? There is another unique feature of the Oak Ridge device which I think is very noteworthy. The coil is a one-turn coil design unlike the many-turn coil configurations used in other devices. This permits us—at relatively low cost at a later time—to replace the first coil with a different coil to check the importance of aspect ratio scaling. In other words, we can remove this small coil and install a larger coil—one that has a larger opening but yet a smaller major diameter. This will give us an important point in terms of aspect ratio scaling of tokamak systems. Beyond that, we can envision other changes that can be relatively straightforwardly made on this machine that otherwise would require completely new machines.

The ALCATOR device was conceived at the Massachusetts Institute of Technology and has been reviewed by us. Its important feature—its single most important feature—is the fact that it will permit a much higher magnetic field than has heretofore been possible in any CTR device. As a matter of fact, it has the capabilities of going to 130 kilogauss—which is a factor of about 4 higher than the Soviets have utilized in their tokamak experiments and is considerably higher than we have utilized in experiments in this country. This high field opens a whole new regime of plasma operation. We know from the Soviet data that the performance characteristics of the tokamak

improve with increasing magnetic field. So, by going to a much higher magnetic field, we definitely expect a significantly more interesting plasma—higher energy, longer containment time, and so forth.

Representative HOSMER. Does this include the improvements that ORMAK I incorporated relative to the symmetry of the magnetic field, and so on?

Dr. HIRSCH. No, this will not. We are going forward in parallel in this case, as with all of these systems, rather than in series. ALCATOR will have a very good magnetic field design. It will have some ripple associated with the fact that a discrete coil configuration is utilized. I would say that the design of this device is in excellent hands, because it is being designed by the National Magnet Laboratory, which is funded by the Air Force, as I think you probably know. These people have many years of experience in the design of these particular magnets as well as many other magnetic configurations. We expect that the ALCATOR will get us into a new range of plasma operation—one that has not been investigated before. It will also, of course, provide us more data on magnetic field scaling in tokamak systems. It brings to bear an experienced faculty at the Massachusetts Institute of Technology—one that has been engaged in plasma physics both at MIT and, during summers and sabbatical years, at the various national laboratories for well over 10 years. These people have a great deal of experience; a number of them have operated big machines in the past, and they have done a great deal of basic plasma physics work under the AEC. They have the diagnostic capability to study these plasmas in detail. As a matter of fact, the English experiment on Thompson scattering was pioneered at MIT a number of years ago.

The next device is the Doublet II at Gulf General Atomic. This machine is the successor to the first tokamak system that we had in this country. The Doublet I was an attempt by the scientists at Gulf General Atomic to extrapolate beyond multipoles to a reactor. It utilizes the good features of multipoles and eliminates the bad feature of internal conductors to move toward fusion reactors from multipole research. They originally called this device the "Plasma Current Multipole." What they did in effect was to remove the internal conductors and replace them by currents in the plasma.

They came up with a configuration which they feel is very attractive, one which would allow higher relative pressure—higher beta if you would like—than is possible in tokamak. (One of the disadvantages of the tokamak is that it currently seems to be limited in beta to the order of a few percent.) Theoretical studies of the Doublet indicate it can achieve a beta of 10 to 20 percent—a value well within the reactor regime. Doublet I achieved a beta of 1 percent, which is a factor of ten higher than the tokamaks have thus far displayed.

(Related correspondence follows:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., February 11, 1970.

Mr. EDWARD J. BAUSER,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR Mr. BAUSER: The Controlled Thermonuclear Research program has recently completed a review of a proposal from Gulf General Atomic on an improved tokamak concept—the so-called Doublet II. We hope to initiate fabrica-

tion of this experiment in FY 1970 and wish to inform you of the background on this matter. The staff will be prepared to provide more details to you at the time of the authorization hearings on the Physical Research Program.

The Doublet concept was conceived by Dr. Tshiro Ohkawa in late 1967 as an outgrowth of their work on toroidal multipoles. A prototype of this system (Doublet I, a device fabricated at GGA expense) was operated in early 1968 and demonstrated the stability of the system. Although the experiment was limited in its operating parameters, it achieved a beta value (the ratio of plasma to magnetic pressure) of 1%, which is about a factor of ten higher than the largest value so far achieved in the Soviet tokamaks. The Doublet I represented the first U.S. tokamak-type experiment and occurred before the recent interest in tokamaks.

The Doublet II system is much larger than its predecessor and is designed to create and confine a collisionless plasma as opposed to the collisional plasma in Doublet I. If successful, this experiment would demonstrate stable, long-time plasma confinement of a plasma whose beta would be of the order of 10-20%, i.e., considerably higher than achievable in tokamaks. The total cost of the machine to AEC is estimated to be \$350,000 of Major Device Fabrication funds and \$230,000 of Capital Equipment funds. The remainder of the estimated \$810,000 total cost will be borne by GGA. We hope to provide \$140,000 of Operating funds and \$76,000 of Equipment funds in FY 1970; the remaining funds would be provided in FY 1971. When the device comes into operation in July, 1971, it will replace the D.C. Octupole experiment and thereby not significantly affect the operating level at GGA. In addition to partial financial support, Gulf General Atomic has agreed to grant the Government full rights to the Doublet concept.

If the Joint Committee would like additional information on this experiment, we would be most happy to provide it.

Sincerely,

R. E. HOLLINGSWORTH,
General Manager.

Dr. Hirsch. The last tokamak which I would like to mention is the device at the University of Texas. Its purpose is to test turbulent heating as a means of raising the ion temperature in tokamak well into the thermonuclear regime. The physicists at the University of Texas have been involved in turbulent heating for many years and have an acknowledged expertise in this area. We are still in the process of reviewing this proposal. Therefore, I think that other than to say that it attacks yet another portion of the tokamak problem, I would suspect I ought not to say anything more.

We now are ready to move ahead on both the ALCATOR and Doublet II.

Representative Hosmer. As distinguished from what it might appear to be to a casual observer, there is some relationship among these various tokamak-type investigations you are now carrying on, and it is not a helter-skelter race by various geographical locations to get into the business.

Dr. Hirsch. No, sir; it very definitely is not.

Chairman HOLIFIELD. What is the total cost of this tokamak program, Dr. Hirsch?

Dr. Hirsch. The total cost we project for Fiscal Year 1971 for tokamak research is about \$5.5 million. That would represent about one-third of our expenditures in the area of "Confinement Systems."

Chairman HOLIFIELD. What was it last year?

Dr. Hirsch. During this present fiscal year?

Chairman HOLIFIELD. Yes.

Dr. Hirsch. I don't believe I have those figures with me, sir. It would be less.

Chairman HOLIFIELD. It would be less?

Dr. Hirsch. Yes, because of course we are just getting underway

THE OUTLOOK FOR CTR

Representative Hosmer. Would you care to speculate how far along we are on the road to the Eldorado of limitless, almost free electric energy of the controlled nuclear fusion process?

Dr. Hirsch. As you recall, Dr. Bishop had been projecting for years that he expected the scientific feasibility of CTR to be demonstrated by the year 1978. With the way things are developing at the present time, it could be much sooner. I say "could be much sooner" because we have now in our hands a number of very important developments which demonstrate that plasma confinement is not limited by some of the anomalous effects which we had previously observed and which we had to wrestle with for so long in the past. Nature is not against us in this work. As a matter of fact, it appears that all we have to do is be careful enough and do the right things. Indeed it appears we can go all the way to classical confinement in a number of plasma systems. If we can do this, in my opinion, we certainly can develop controlled fusion.

Representative Hosmer. At that point, 1978 or earlier, we could think of getting into the practical aspects of it?

Dr. Hirsch. Yes, sir. What I was about to say was that at this point in time the people in the CTR community feel for the first time we are in a position to progress forward at a rate which is determined by the funding which is allocated to the program. We could not say this in the past.

Representative Hosmer. Do you believe that with proper funding this could progress and move ahead of the fast breeder development?

Dr. Hirsch. I would say with proper funding we could move forward very rapidly.

Representative Hosmer. That was not exactly a responsive answer. We will leave it there.

Chairman HOLIFIELD. Mr. Young?

Representative Young. Mr. Chairman, I am glad to hear Dr. Hirsch say what he did about the advantage of studying turbulent heating at the University of Texas. I am familiar in general with their efforts down there. They are most enthusiastic about the opportunity that they have there. Actually, they are providing the facilities and AEC is going to provide the operation; is that correct?

Dr. Hirsch. Yes, sir, that is their proposal. We understand that it is expected that this Friday the Board of Regents at the University of Texas will allocate \$350,000 for the fabrication of the device which they expect to begin immediately. We also understand that the Texas scientists have obtained approximately \$200,000 for 2 years from the Edison Electric Institute to help instrument this device.

Representative Young. Thank you very much. Thank you, Mr. Chairman.

Chairman HOLIFIELD. Dr. McDaniel, we are going to put the rest of your statement in the record.

Dr. McDaniel. I think Dr. Hirsch has testified more eloquently than my written statement would have done.

Chairman HOLIFIELD. He is a very competent witness.

Representative Hosmer. He is quite a capable forensic physicist.

(The statement of Dr. McDaniel follows.)

CONTROLLED THERMONUCLEAR RESEARCH

The goals of the controlled thermonuclear research program are to establish the basic laws of physics relevant to the confinement of thermonuclear plasma; and to experimentally demonstrate the creation, heating and containment of a gaseous plasma suitable for the economic production of electric power. We estimate that the U.S. program represents approximately 1/4 of the total world wide fusion effort. A recently completed "World Survey of Major Facilities in the Field of Controlled Fusion" describes 187 plasma devices of which 38 are in the United States.

The achievement of useful controlled fusion energy requires that we (a) heat a dilute gas of fusion fuel to temperatures of hundreds of millions of degrees, and (b) contain it long enough (and at sufficient purity) for an appreciable fraction of the fuel to react. Plasmas above the ideal ignition temperature at densities needed for controlled fusion have been routinely produced for a number of years. The world research effort has been concentrating on how to adequately contain the hot plasmas. During the past year, plasma confinement has been obtained which is close to or above the minimum conditions needed for a fusion reactor in both open and closed confinement experiments.

The next step is to combine the necessary density, temperature, and confinement time into a single experiment to demonstrate the scientific feasibility of fusion power. The recent results in the Tokamak T-3 reported by the Soviet Union are a major achievement in this direction. The Tokamak T-3 has a 4,000,000° C. plasma with a density of 5×10^{18} particles per cubic centimeter contained for 1/60 of a second. These results have been confirmed by a laser diagnostic team sent from the United Kingdom to the Soviet Union. In the area of open systems research in the United States the 2X experiment at LRL has achieved equally remarkable conditions. Its temperature is 80,000,000° C.; its peak density is 5×10^{18} particles per cubic centimeter and its confinement is very close to the classical upper limit.

Our September 4, 1969, letter to Mr. Bausier advised you of plans concerning initiation of tokamak research involving fabrication of a tokamak system at Oak Ridge National Laboratory and conversion of the Model-C Stellarator at Princeton Plasma Physics Laboratory into a Tokamak. Since that time technical reviews of two additional proposals have been completed although no work has been initiated. These proposals involve (1) fabrication of an experimental device named ALCATOR which will be housed in the National Magnet Laboratory at MIT and (2) fabrication of an experimental device named Doublet II by scientists at Gulf General Atomic Corporation. A fifth proposal submitted by the University of Texas is currently under review. Each of these devices focuses on a different aspect of tokamak research. At Oak Ridge, a unique and flexible one-turn coil design is incorporated in a device called ORMAK. This is basically a model of the Soviet TM-3 experiment but provides significantly improved magnetic field design. The relatively inexpensive addition of a second coil will allow the exploration of low aspect ratio scaling without necessitating fabrication of a completely new device. Conversion of the Model C Stellarator, located at the Princeton Plasma Physics Laboratory, to a tokamak will provide the quickest means of obtaining an operating tokamak system in this country. We expect to significantly advance our knowledge of basic tokamak operations from this device. The MIT ALCATOR system has the capability of exploring a wholly new and interesting range of high magnetic fields i.e., to 150 kilogauss, a level about three times higher than achieved in the Soviet experiments. Opening this new regime of high magnetic fields is considered extremely important from both the experimental and theoretical points of view. The Doublet II offers a potential means of increasing the relative plasma pressure over ten times higher than that achieved in the Soviet experiments.

Research with tokamak devices represents but one facet of our low-beta toroidal research effort. In addition to tokamaks, multipole and stellarator systems are also under study. The simplicity, relatively low cost and flexibility of multipoles are such as to make them very attractive from both an experimental and theoretical point of view. For this reason we have emphasized work on multipoles and recent successes in understanding and long-time confinement have justified this choice. Moreover, confinement of plasmas in stellarators in recent years has been improved beyond the anomalous or bohm level.

The initiation of research on tokamak systems represents an attempt on our part to bring balance to our low beta toroidal research effort and to exploit, if possible, what appears to be a quite fruitful line of pursuit at the present

We are requesting \$29.61 million for the Controlled Thermonuclear Program in FY 1971 which is an increase of \$1,930,000 over the FY 1970 level. Included in the request is an increase of \$2,204,000 for normal, or base program, operating expenses, and a decrease of \$364,000 in the major device fabrication activity. The increase in normal operating expenses will permit a strengthening of our efforts in confinement systems research providing support for the experimental devices which are used to check theory and progress toward the goal of a fusion reactor. The major device fabrication activity will be decreased \$364,000 to a level of \$2,470,000. Details pertaining to the nature and funding status of our various devices are contained on pages Res 31 and 32 of our budget document.

If I might cast an eye toward the future for a moment it is apparent that an intense program of research aimed at proving scientific feasibility lies ahead. To obtain the plasma conditions necessary for a fusion power reactor in a single experiment may require several years. Simultaneously, technological studies oriented toward design of fusion reactors should be intensified—various fusion fuel cycles should be studied and new energy conversion technologies uniquely applicable to fusion power should be investigated. In all these endeavors environmental considerations will be continually assessed to achieve the maximum compatibility of fusion power with the future needs of our society.

As you know, Mr. Chairman, Dr. Amasa S. Bishop, who has served as the Assistant Director in charge of the Controlled Thermonuclear Program for the past four years, is leaving the federal service. He has done an outstanding job in shaping the direction and tenor of the program. Professor Roy Gould of the California Institute of Technology will replace Dr. Bishop for a two year period. Professor Gould has considerable experience in plasma physics and CTR and is familiar with both the research effort and the present laboratory management. We are confident there will be a smooth transition and continuation of the encouraging momentum characterizing the program.

This concludes my remarks Mr. Chairman, I will be pleased to respond to any questions you and other members of the committee may have.

LASERS FOR CTR

Chairman HOLIFIELD. Before we close, could I ask you one question, and we are going to supply you with a number of questions which we may ask you to answer for the record. This one I thought we might bring up.

We have noted quite a few articles recently about laser research being conducted, laser-induced fusion research being conducted in the United States and elsewhere. Is there real possibility that lasers can substantially shorten the time to a practical fusion reactor?

Dr. MCDANIEL. Dr. Hirsch is my expert on lasers too.

Chairman HOLIFIELD. Dr. Hirsch.

Dr. Hirsch. In the CTR program we have been involved in laser plasma research for a number of years, recognizing the possibilities since the advent of lasers back in the early 1960's. Right now we are primarily involved in utilizing lasers to create plasma by the irradiation of a small pellet within some of our standard magnetic field configurations. This research has worked out quite well in recent years, and it is progressing forward.

Another possibility involves irradiating some kind of suitable fusion material with a very high power laser to produce a microexplosion. This microexplosion could conceivably be adapted to make a fusion reactor—one in which the operation is similar to that of an automobile engine, where a series of explosions would be produced by continually dropping these pellets into a reacting volume, irradiating them, thereby producing microexplosions. The explosive energy would be externally converted into electrical power. We recently took a hard look at this possibility. It is our feeling that it will be some time in the future before this particular scheme could be made into a thermonuclear reactor contender.

Chairman HOLIFIELD. Thank you, sir.
 Dr. McDaniel. Mr. Chairman, Dr. Bishop, as you know, who has been heading this program has accepted a position in Europe and this particular day he had to go to Europe and asked me to express his admiration of this committee and hopefully that he would be able to see you personally before he takes his new job sometime around the first of April.

He is prepared to give you any prognosis, Mr. Hosmer, on the future of controlled thermonuclear and other things, and I would be willing to prepare a case for you.

Chairman HOLIFIELD. We are going to recess until 2 o'clock. We will have Dr. Totter on the biology and medicine part of the program.

Thank you, gentlemen.
 (JCAE questions on the physical research program and AEC responses follow:)

U.S. ATOMIC ENERGY COMMISSION,
 Washington, D.C., March 24, 1970.

Mr. EDWARD J. BAUSER,
 Executive Director, Joint Committee on Atomic Energy,
 Congress of the United States.

DEAR MR. BAUSER: Your letter of March 10, 1970, provided a number of questions pertaining to the physical research and the civilian applications of nuclear explosions programs. I am pleased to forward our responses to your questions which I understand will be included in the hearing record of the FY 1971 authorization hearings.
 Cordially,

W. E. JOHNSON, Acting Chairman.

DIVISION OF RESEARCH REPLIES TO SUPPLEMENTAL QUESTIONS ON PHYSICAL RESEARCH PROGRAM PROVIDED BY THE AEC

(in millions of dollars)

	Fiscal year—			Fiscal year 1971, President's budget
	1966 actual	1967 actual	1968 actual	
Operating expenses:				
Atomic Energy Commission	\$97.4	\$107.7	\$113.3	\$118.6
National Science Foundation	5.8	6.5	9.1	11.4
Department of Defense	4.7	6.1	2.3	13.6
National Aeronautics and Space Administration	1.5	1.4	1.8	1.6
Total operating expenses	109.4	121.7	128.5	137.2
Capital equipment (obs.):				
Atomic Energy Commission	21.3	21.4	15.7	13.7
National Science Foundation	1.4	.8	.9	.9
Department of Defense	0	0	0	0
National Aeronautics and Space Administration	0	0	0	0
Total capital equipment	22.7	22.3	16.7	14.7
Subtotal	132.1	144.0	145.2	151.9
Construction (obs.):				
Atomic Energy Commission	30.1	31.1	23.9	34.2
National Science Foundation	3.6	4.7	2.8	4.7
Department of Defense	0	0	4.4	0
National Aeronautics and Space Administration	0	0	0	0
Total construction	33.7	35.8	31.1	39.2
Grand total	165.8	179.8	176.3	191.1

The JCAE questions and AEC responses on the civilian applications of nuclear explosive program appear on p. 642.

2. The Committee understands that the AEC management information system currently under development contains several subsystems pertaining to the management of various AEC activities. Is there a subsystem pertaining to research activities? If so, briefly describe it, and, if not, explain why.

AEC does not have a single automated subsystem for research. There are currently available, however, systems for financial information, contracts information and personnel information that the Division of Research may draw upon for their purposes. Current plans include exploration into a research-oriented special system in the future.

3. Does AEC attempt to influence the laboratories' level of effort in each of the three budget categories—design and development of devices, research and operations? If so, please explain how this is accomplished.

AEC influences the laboratories' level of effort in the three sub-categories by indicating funding levels for each sub-category in the financial plans issued to the contractor. These financial plans are normally reviewed and revised several times during the course of the year. In addition, correspondence transmitted periodically to the contractor contains specific guidance regarding selected special items or activities. This type of guidance is also carried out more or less informally throughout the year through numerous meetings and discussions. The laboratory has the responsibility to determine the final allocation of funds among the sub-categories to achieve the best balance and most productive program within the funds available.

4. In connection with AEC's determination of the amount of operating funds to be allocated to each accelerator, what consideration is given to the laboratories' backlog of experiments to be run?

The size of the backlog of experiments to be run at each accelerator is not a direct consideration in determining the allocation of HEP funds since it is not considered a particularly good quantitative indicator of accelerator priority. There are heavy demands and significant backlogs of high-quality experiments on all of the accelerators in the high energy physics program. Any significant indication of loss of interest in the experimental utilization of a particular accelerator as evidenced by a reduction in backlog (or a deterioration of the quality of proposed experiments) however would certainly lead to a re-analysis of its operation and reassessment of its funding level.

5. When allocating funds to these facilities, does AEC consider the average operating costs per accelerator beam hour and experimental hour at each laboratory? If so, please provide this type of information for the major high energy accelerators or general statements regarding the relative differences in such costs among the laboratories.

The cost per beam hour is not a major direct consideration in allocating funds since each accelerator has a unique set of characteristics, and experiments are generally done at the accelerator at which they can be most effectively handled. It is recognized that some types of machines are intrinsically more expensive to operate than others. For example, an electron Linac is more expensive to operate than an equivalent energy proton synchrotron, however, experiments requiring high energy electrons cannot be done at all at the proton facilities. The concept of cost per beam hour can be very deceptive since during each running period there are one to three high priority experiments which dictate the principal operating parameters. Other experiments are then run simultaneously in a non-interfering manner. A major consideration is that accelerator is usually most "cost effective" when operated at maximum capacity within budgetary constraints.

6. To what extent does AEC allocate funds on the basis of the relative priorities of the various classifications or categories of research? Please list these various categories of research and the relative priority that has been assigned to each. No attempt is made to define fixed classes of research for the purpose of assigning definite priorities to each. Areas of greatest research interest are in a continuing state of evolution and change since each phase of investigation is determined to a large extent by the results of previous investigations. Progress in one area often brings greater understanding in another and thereby leads to even further progress in both areas. Priorities are assigned on a current basis by the laboratories to individual experiments with regard to their promise of shedding light upon the most pressing current questions. Priorities can shift on short notice on the basis of results from U.S. or foreign laboratories. A general consideration involved in allocating resources is the necessity to maintain a broad-based set of capabilities so that the program is in position to respond rapidly to the need for investigations in new directions which appear to be most promising.

2. Theorists in both physics and nuclear chemistry are undertaking the analysis of more complicated theoretical models, and are employing more sophisticated numerical techniques. For example, very sophisticated nuclear structure models are currently being analyzed on the CDC-6600. Each of these programs uses the entire 128,000 word memory, and running time is on the order of one to two hours. Availability of richer and more detailed experimental data now will allow refinement and extension of the models; but the computations required are beyond the capacity of the 6600.

3. Investigation of magnetic fields in superconducting magnets is currently hampered, because the enormous volumes of calculations needed for 3-dimensional magnets is beyond the capacity of the 6600.

4. Data concerning results of treatment of leukemia and acromegaly patients have been digitized, and an interactive program has been written which allows the testing of various hypotheses concerning the efficacy of treatments. The result is a marked increase in computational requirements of the Donner Laboratory.

5. The use of data collection facilities on-line to small computers has greatly increased the data output of many experiments. In the next few years an increasing number of these small computers will be run on-line to a major computer system. The increasing use of digital read-out spark chambers, which allow the scanning and measuring steps of an experiment to be by-passed, results in a very significant increase in the amount of data to be analyzed. Also, new techniques in large bubble chambers, such as fish-eye optics, will place heavy demands on the central computing facility as the film becomes available.

Failure to obtain an additional large-scale computer will therefore severely handicap many experimental and theoretical programs. It would not be possible to analyze more than a subset of data from most experiments and no more than partial results would be available for long periods, and publication of final results would be delayed.

6. In addition to satisfying in-house LRL needs, this system would also serve as a central facility for university high energy physics groups. Such a facility was recommended as a strong need for these university groups by the HEP-AP subpanel on Computer Usage.

10. Will any one of the AEC proposed controlled thermonuclear research devices equal or surpass the achievements of the Soviet Tokamak-3 in temperature, density and confinement? If so, which device?

Although there exists some uncertainty in tokamak scaling laws, the following machines have a high probability of equaling or bettering the plasma parameters of the Soviet T-3 system:

(1) The ORMAK I may achieve both higher temperature and confinement time, but the ORMAK II is expected to achieve significant improvements in all parameters.

(2) The Model ST models the Soviet T-3 and therefore should achieve similar temperature, density, and confinement.

(3) The Alcator is expected to achieve longer confinement, higher temperature, and higher density.

(4) The Doublet II is a test of a uniquely new approach to tokamak systems which may achieve longer confinement time, although its value is best viewed in terms of plasma β . If successful, a $\beta \approx 10-20\%$ would be demonstrated—values of more than a factor of ten better than demonstrated in T-3.

(5) The purpose of Texas Tokamak is to determine if turbulent heating can be utilized in tokamak systems. Its success would provide higher temperatures than here-to-fore achieved by the Soviets.

11. On several occasions in the recent past, this Committee has been told that the Stellarator-C at the Princeton Plasma Physics Laboratory was an unequalled device in the U.S. controlled thermonuclear research program. Now AEC is proposing to spend several more years and much money to turn this device into a tokamak of unspecified vintage.

a. Would not the Model C Stellarator be lost for all research while it is being modified and for stellarator research thereafter?

b. How does AEC justify this action?

c. If AEC dropped some of its 38 device support projects, could the funds be used effectively in a more concentrated stellarator and tokamak-type program?

7. What other criteria are considered in determining the funds to be allocated to each accelerator and what relative weights are assigned to these criteria?

The two major overall factors considered in determining the allocation of funds are the scientific importance of the experiments which require the capabilities of the accelerator facility and the need to support each facility at a level necessary to maintain an effective program. However, a multitude of complex considerations enter into the decision-making in the process of evaluating these two major factors. A detailed knowledge and understanding of the status and many needs of the program and their relative importances and urgencies is required. In general, determinants affecting the level of funding include such things as whether or not new laboratory facilities are coming into operation at one or more of the labs; whether use of some facilities may be terminated; the necessity for major new items such as bubble chambers or other detection devices, lab space, experimental area, computers and so on; the relative operating levels of the various accelerators; and the need for beam-time by experimentalists. Allocation of funds within the high energy physics program requires constant review in that the needs and methods of reaching program goals shift in time so that the picture is never static. In establishing funding levels each year (and modifying them during the course of each year) a great deal of effort is expended in keeping up to date in assessing and understanding the various requirements at the different labs. A large part of this effort takes the form of studying budget documents, having conversations with lab officials, lab staff, and users, conducting program reviews, meeting with High Energy Physics Advisory Panel and studying the periodic reports from the labs. Each year, and indeed, during the course of any particular year, fiscal requirements must be weighed in terms of conditions and programmatic needs prevailing at the time. Proper evaluation of these many factors depends critically on the scientific and technical competence of AEC staff.

8. Is there a report of the High Energy Physics Advisory Panel discussions on the FY 1971 budgetary problems? If so, please provide it for the Committee.

No specific report on the FY 1971 budgetary problems has been issued by the Panel. However, AEC has received letters from the Chairman of HEPAP regarding the shutdown of PPA and the importance of the SLAC electron-positron colliding beam program. (Copies of these letters are on p. 577). The major source of advice from HEPAP ensues from direct participation by AEC representatives in the HEPAP discussions. In addition, the Panel's June 1969 "Report on High Energy Physics" which is an excellent and detailed overall report on the high energy physics field, includes discussion of the FY 1971 budgetary needs as well as hopes and aspirations for the future. (See p. 706.)

9. The AEC FY 1971 Budget includes \$8.7 million for a CDC-7600 type computer at the Lawrence Radiation Laboratory. Briefly, what will be the capabilities of this machine and what other computers will also be available at LRL? On the basis of what criteria was it decided to purchase this \$8.7 million computer?

Acquisition of a major computer system at the Lawrence Radiation Laboratory is required to avoid a restriction of research productivity at the laboratory. At the present time, four major scientific computer systems are available; an IBM 7094 Model II, an IBM 7044, and two CDC-6600's.

These computers are being fully utilized, and the laboratory's requirements are expected to increase significantly over the next several years. In order to maintain computation capabilities in balance with requirements of the research program, an additional major system having three to four times the throughput of a CDC-6600 on the laboratory's problem mix should be acquired. At a minimum, the system should have the following technical capabilities: a) 250,000 words of addressable central memory, b) hardware commands for floating point arithmetic operation of 48 bit accuracy, c) an effective execution speed of 12 million instructions per second, and d) at least three data channels capable of simultaneously transmitting one million characters per second.

The requirement for additional major computing capacity is based on the following programmatic criteria:

1. In order to undertake the analysis of much more complicated experiments, and to seek results which have increased statistical significance, a more powerful computer is required. Historically, small digital computers made it possible to analyze experiments containing a few thousand events. Typical experiments today contain several hundred thousand events, and each of those events may be ten to twenty times more complicated to analyze than an event of ten years ago.

(Note: The time and money required to modify the Model C Stellarator are rather modest. The conversion will take about four months and cost about \$200,000. This relative ease of modification is possible because tokamak devices and stellarator devices are quite similar.)

a. The Model C Stellarator has not been available for experimental research since December 22, 1969—the date when the experiment was shut down to begin modification to a tokamak. During this "down-time" physicists are planning detailed experiments and preparing the necessary diagnostic equipment. After the tokamak experiments are completed in the next 2-3 years, the machine could easily be converted back to the stellarator mode if that were desirable. The present conviction is that the key questions in toroidal research can best be answered utilizing the excellent containment properties of the tokamak and also that it is highly probable that the knowledge gained in tokamak research will be useful in future stellarator research.

b. The decision to modify the Model C Stellarator experiment was made after a great deal of study and evaluation by both the Princeton group and the CTR Standing Committee. This decision reflects a responsible response to a major achievement by the Soviets as well as a change in priorities within the U.S. CTR program. The Princeton Plasma Physics Laboratory, the CTR Standing Committee, and the CTR Program Office all would have preferred moving forward with stellarator and tokamak research in parallel, however, within projected levels of funding, higher priority has been assigned to tokamak research.

c. The alternative of dropping other projects within the CTR program was considered in depth. It was decided to eliminate the DCX-2 and ORNL Quadrupole experiments in order to provide funds for tokamak research. Beyond these two terminations it was deemed highly undesirable to eliminate any other experiments. The CTR program at its present stage is a broadly based research program wherein information from a variety of sources is utilized to understand and improve all plasma confinement systems. To further upset the present balance would not be in the program's best interests in the opinions of the majority of the CTR community, the CTR Standing Committee, and the CTR Program Office.

12. The letter of February 18, 1970, stated that the modified Model C Stellarator would be named the "Proto LT" for "Prototype Large Tokamak" and that, if successful, this concept would lead to the LT or "Large Tokamak".

a. When would this so-called "Large Tokamak" be built? What will it cost? machine?

(Note: The February 13, 1970 letter identifies the modified Model C Stellarator as "Model ST". The Proto LT replaces the previously projected "Stellarator—Tokamak", which was scheduled for initial design in FY 1971.)

a. The fabrication of the LT or "Large Tokamak" could begin approximately six months after the successful operation of the Proto LT at design conditions. While initial operation of Proto LT is tentatively projected for early calendar 1973, operation at design conditions will probably require another 18 months. Therefore, fabrication of LT probably would not begin before calendar 1975 and would require between 2-3 years. Its cost is very roughly projected at \$10-20 million.

(Note that plans for Proto LT are in a preliminary stage at the present time and LT is by no means well defined as yet. Scoping studies are progressing on these systems, which will be subject to detailed technical and administrative review before they can be formally recommended. These plans and schedules are based upon current funding projections. Should there be a desire and the means to do so, this schedule could be markedly shortened.)

b. Yes, the Proto LT represents an interim step toward the LT.

13. What are the current plans for obtaining a bubble chamber for the National Accelerator Laboratory at Batavia, Illinois? Please state size, proposed source of funds, and other pertinent items of information.

Present plans for NAL call for fabrication of a liquid hydrogen bubble chamber having a viable volume of about 25,000 liters. The design of this chamber will be based to a large extent on the technology developed at BNL with the 7' Bubble Chamber test facility. A total of \$4.5 million equipment funds is to be provided in FY 1971 and 1972 for the project. The experimental area where the chamber will be located is being built as part of the base construction project. It is particularly important to have such a chamber available at NAL, when first beam is available for experiments in order to carry out beam survey and other exploratory experiments.

There remains a strong need for the very large (~ 25' diameter) chamber which has been discussed frequently in prior years. This chamber is crucial for an effective neutrino physics program and will also be important for strong interaction experiments. Present plans for NAL contemplate requesting authorization for this project as a line item for about \$25 million in FY 1974.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
DEPARTMENT OF PHYSICS,
Cambridge, Mass., October 15, 1969.

DR. PAUL MODANILE,
Director, Division of Research,
U.S. Atomic Energy Commission,
Washington, D.C.

DEAR PAUL: I would like to report to you the reaction of the High Energy Physics Advisory Panel (HEPAP) to the present FY 1971 budget figures. Up to now the response to increasingly tight budgets has been a more or less uniform sharing of the burden among the different institutions. This has been a wise policy but the cumulative effect of several years of reduced budgets and the unlikelihood of an early improvement of the situation now brings this policy into question. The cuts have caused serious damage to all centers of research and this is why selective cutting is necessary in order to allow the more vital centers to survive without the gravest damage.

Under these unfortunate circumstances we come to the conclusion that, because of the low beam energy and because many—but not all—of PPA's capabilities can be matched elsewhere, it is logical to reduce the PPA program. We regret to be forced to such a step because we consider the work at PPA to be of scientific and educational importance. We therefore believe that such selective reduction of support should not be equivalent to a shutdown. We quote from our Report (page 39): "At this time (1969) *eff* of the high energy accelerators in the United States are performing important work (within funding limitations) and are of great educational value with programs of considerable scientific interest and significance. None should be shut down in the immediate future."

The decrease of support for PPA is suggested in order to support the most urgent programs at other institutions, and we recommend that this decrease be limited so that the program will not be eliminated but will continue at a reduced rate. It is still an important part of the high energy effort in the U.S. and should remain so for a long time.

Sincerely yours,

VICTOR F. WEISKOPF,
Chairman, High Energy Physics Advisory Panel.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
DEPARTMENT OF PHYSICS,
Cambridge, Mass., October 23, 1969.

DR. GLENN T. SEABORG,
Chairman, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR GLENN: At our last meeting, the High Energy Physics Advisory Panel again discussed the question of electron-positron storage rings to be added to the SLAC facilities. We continue to be firmly of the opinion that these storage rings are of utmost importance. The continued absence within the U.S. of such an instrument would be a major blow to American high energy physics.

Let me briefly outline the reasons for this conclusion. The technique of colliding electron beams was developed in this country. The first colliding beam facility was made in Stanford with an energy of a few hundred Mev. In the meantime, the idea was taken up with great enthusiasm all over the world. Hamburg (DESY) is building a storage ring for 3.5 Gev; Frascati (Italy) has one for 1 1/2 Gev that is already working well; Novosibirsk will have one for 8 Gev in the near future.

The technique of colliding beams is certainly one of the most promising methods of getting at the problems of elementary particles. A colliding beam of particles and antiparticles—as it is planned in these machines—is the purest form of energy available. Its transformation into particles is the most direct process and the cleanest way of investigating the properties of those particles. It is highly probable that decisive insight into the nature of elementary particles

of Dr. Evans' project are as follows: The New Jersey field station, employing three people was placed under Argonne control as of December 1, 1969. The Connecticut field station, also the responsibility of Argonne, is being maintained on a stand-by basis with one part-time employee. Dr. Robert Rowland, Director of the Radiological Physics Division of Argonne, has made offers to nine professional and technical employees of the MIT project. Of these, one individual joined the Argonne staff as of January 1, 1970; a second will join as of March 1, 1970, and a third on June 1, 1970. One offer is still open and five individuals have declined the offer and will remain in Boston. The two remaining individuals will sever connections with the project. The satellite facility at MIT under the direction of Argonne will officially start operating September 1, 1970, employing four scientific people. In addition those physicians now connected with the MIT project will remain attached to the MIT satellite facility as consultants. Dr. Robley Evans and his assistant, Miss Mary Margaret Shanan, will be located in Phoenix, Ariz., but it has not been determined whether their activities will be funded through Argonne to MIT or directly through MIT after the MIT project becomes a satellite laboratory. Dr. Evans and Miss Shanahan will maintain operational contact with both the MIT installation and with Argonne.

Progress has also been made in the transfer of materials, equipment, and records. All records at MIT are being duplicated and one set is being sent to Argonne. At this time, patient records falling alphabetically under A-D as well as more than 50 percent of all X-ray films have already been received at Argonne. Transfer of computer records has been completed, which includes the card file and computer tapes.

One piece of equipment, a large walk-in refrigerator, has been received at Argonne. Only one other major piece of equipment is expected to be transferred to Argonne. This is a recently purchased 4,000 channel analyzer, bought with the agreement of MIT that it would be transferred to Argonne. There has been a steady transfer of bone samples to Argonne, but since the exact amount to be transferred is not known the fraction already moved cannot be accurately estimated.

Plans for ANL provide for the addition of a combination office-laboratory wing to the existing physics building to house the program. This will provide a centralization of studies in the United States on the toxicity of radium and mesothorium in human beings. Eventually Argonne may also have the responsibility for studies of humans contaminated with other bone-seeking radioisotopes. Based upon a preliminary conceptual design, the facility will consist of two full floors, a service floor and fan loft, and will provide approximately 26,500 gross square feet. It is now estimated in the fiscal year 1972 budget. The hoped that it will be included in the fiscal year 1972 budget. The Division of Radiological Physics is now utilizing temporary buildings and warehouse-type facilities, which is considered inadequate. In addition the new facility will be used in part to house the concurrent expansion of the environmental programs of the Division of Radiological Physics.

have been made with electron storage rings abroad have been of unusual interest. Mesons could be produced in an environment undisturbed by strong interaction, which has made it possible to determine their properties in an unambiguous way. Such facilities also were used to test the validity (or the breakdown) of electro-dynamics to a high degree of accuracy.

Further development of these techniques, also in the direction of proton-anti-proton storage rings, will, in all likelihood, be the way to get at the fine structure of nucleons. If quarks or similar fundamental constituents do exist, this may be the only method in which we could make more accurate experiments to find out and to measure their properties. For example: If the recent Australian experiments are correct, and quarks are produced by cosmic rays of 100,000 Bev in the laboratory system, which corresponds to a center-of-mass energy of 400 Bev, a storage ring added to NAL would just be capable of producing these particles artificially.

These are the thoughts which have brought us to the conclusion that the U.S. must go ahead with constructing storage rings. We simply cannot let this way of doing fundamental physics grow stale in our country. The most obvious place to proceed is SLAC, which is the ideal place to experiment with electron-positron storage rings.

It seems that an electron-positron storage ring could be set up at SLAC with an incremental cost of roughly two to three million dollars in 1971, and a smaller amount needed in 1972. These figures are so low because SLAC is ready to sacrifice other important activities for this purpose. In view of this situation we feel that such an instrument should be fitted within the national high energy physics program even at the expense of other items.

I would very much like to discuss this problem with you and Commissioner Thompson at your earliest convenience.

With best regards,

Sincerely yours,

VICTOR F. WEISSKOPF,

Chairman, High Energy Physics, Advisory Panel.

AFTERNOON SESSION

Representative PRICE (presiding). The committee will be in order. This afternoon the committee will continue its hearings on the AEC authorization bill for fiscal year 1971.

The witness this afternoon will be Dr. John Totter, the Director of the AEC's Division of Biology and Medicine.
Dr. Totter.

STATEMENT OF DR. JOHN B. TOTTER, DIRECTOR, DIVISION OF BIOLOGY AND MEDICINE, ATOMIC ENERGY COMMISSION

Dr. TOTTER. Thank you, Mr. Chairman.

It is a pleasure to appear before the committee and report on the status of the radium toxicity studies at the Argonne National Laboratory.

The coordination of the human radium toxicity studies at Argonne National Laboratory is proceeding according to schedule except that construction of the new facilities is now planned for fiscal year 1972. As of this date, the transfer of personnel, records, tissue samples and equipment from Dr. Robley Evans' project at MIT to Argonne is progressing smoothly. It is expected that the MIT project will become a satellite laboratory to ANL by early fall of 1970. The MIT facility, along with the two field stations in the Eastern United States will then be under the financial and scientific supervision of the Division of Radiological Physics of Argonne National Laboratory. Details of the progress of the transfer and utilization of personnel

Clinical studies on patients are being continued through cooperation with Argonne Cancer Research Hospital and with Dr. Herta Spencer at Hines Veteran's Hospital in Chicago.

I would like to add something about the questions that arose last year concerning the Illinois area subjects.

You will recall that Dr. Asher Finkel had difficulty in reconciling his medical responsibilities toward these subjects with the administrative requirement of the centralized operation. These problems have now been resolved in a manner which will assure that the operation will have the benefit of all data gained so far and in the future from this group.

At the same time, Dr. Finkel will continue to make his valuable contributions to the study without compromising the doctor-patient relationship about which he was worried. Doctors Duffield and Rowland from Argonne Laboratory and Mr. Cannon from the University of Chicago are present, and if you desire more detail about the arrangements, they will be glad to answer questions.

Representative PRICE. Dr. Totter, the Division request for authorization and funding for the addition to the physics building at the Argonne National Laboratory to take care of this particular program was \$1,830,000. That is for the requested authorization and requested funding?

Mr. ABRADSSA. That is correct, Mr. Chairman.

Representative PRICE. The Commission then submitted these requests in the exact amount to the Bureau of the Budget?

Mr. ABRADSSA. That is correct, Mr. Chairman.

Representative PRICE. What action did you get from the Bureau of the Budget?

Mr. ABRADSSA. The funding was not allowed.

Representative PRICE. There were no funds for authorization and, of course, if there is no authorization there is no appropriated fund for that amount.

Mr. ABRADSSA. That is correct, Mr. Chairman. The action I think can best be characterized in the context of budget stringency, however, rather than programmatic need. In other words, there was no negative policy decision on the part of the Bureau—

Representative PRICE. It was an arbitrary budget matter?

Dr. TOTTER. That seems to be the case.

Representative PRICE. Not any reflection on the need or value of the program?

Mr. ABRADSSA. That is correct, sir. Without subscribing too much to the word "arbitrary," that is correct, sir.

Representative PRICE. I don't know what else you would call it. We are having the same problem in the Armed Services Committee right now. Projects are regarded by the Department of Defense as being essential but not by the Bureau of the Budget, at least not at the present time.

Now what priority does the Commission, particularly the Division of Biology and Medicine, place upon this program?

Dr. TOTTER. We have listed this project as our first priority. I would like to add however that from this morning's statement by Dr. Rosen, the committee learned that there may be less of a problem in delay with respect to the LAMPF facility for medical care.

I don't think we want to use what he has been able to do as an excuse to put off that facility. I have assigned both of these projects a very high priority.

Representative PRICE. Where is this other project you are talking about?

Dr. TOTTER. The Radiobiology and Therapy Research Facility at Los Alamos.

Representative PRICE. Last year in our authorization hearings we discussed with you and Dr. Rowland, and I think you have made some reference to it, the plan for the Center for Human Radiobiology and we believe we were assured that the case studies in the Human Radium Toxicity program would be made available to the center for continuing study. I think you mentioned that.

Dr. TOTTER. Yes, sir, I did.

Representative PRICE. Will you elaborate on the situation there?

Dr. TOTTER. Perhaps I could ask either Dr. Rowland or Mr. Cannon to address detail to what I have already said, Mr. Price.

STATEMENT OF DR. ROBERT ROWLAND, DIRECTOR, RADIOLOGICAL PHYSICS DIVISION, ARGONNE NATIONAL LABORATORY

Dr. ROWLAND. I will be glad to speak to that, Mr. Price.

In regard to the transfer of this program to our laboratory we have received as rapidly as one could expect the case histories of all those people studied at MIT under Professor Evans. This transfer of material is still underway, but I think this is primarily due to the fact that there is a large amount of material to be transferred, and prudent management requires that it should be copied first so that the records exist in two different locations.

About 2,090 names of people exposed or potentially exposed to radium have been transferred to our files from MIT. These will have to be carefully studied and filed. It is our responsibility, as I see it, to tackle this job as quickly as possible.

In the Illinois area, under Professor Hasterlik and Dr. Finkel, an additional 485 names are known, and some 293 of these cases have been studied and reported on. Due to a doctor-patient relationship, we have experienced some uncertainty as to the timing and method of transfer of the records of these individuals to our center. We have now reached an agreement so that in the very near future the records will begin to be transferred to our possession from Dr. Finkel.

Does that answer your question, sir?

Representative PRICE. Tell me what is the need for additional facilities at Argonne to continue with this program. Why do you need the additional facilities?

Dr. TOTTER. There is a large patient load or subject load, I guess one should say, a large number of body radium and mesothorium measurements to be made. This requires specially designed space and equipment as well as time, because low level whole body counts must be made and analyzed. A large number of histological sections from biopsy and autopsy materials must also be made. Autopsies must be performed when the subjects die and when permission for an autopsy can be secured. This is a very significant and important part of the whole study.

So, one then is forced to have quite a lot of space. Obviously, the operation can proceed much more smoothly and be much better coordinated if the space is contiguous and not scattered all over quite an acreage at Argonne, as it is now.

Representative PRICE. Have you made an effort to get contiguous space at Argonne, tried to get the facilities you need without new facilities being built?

Dr. TORRER. I would like to ask Dr. Rowland to speak to that.

Dr. ROWLAND. I will be glad to speak to that.

Yes, we have made efforts, sir. We have been somewhat successful in the temporary loan of space, but we have not been able to get nearly the space that will be required to carry on this project.

If I may be allowed to state a few words, I think it is well known that the proper subject for the study of mankind is man himself. If we are concerned about the effect of radiation on people, we have no better group to look at than those who were unfortunately internally contaminated with radioactivity many years ago. They are not going to live forever. One of the reasons we need manpower and we need space is, in other words, we would like to get started in an expanded fashion as soon as possible. We have received a good deal of support from the Division of Biology and Medicine in our endeavor but, as you are aware, we are very much space limited; and this precludes our bringing into the study all of the people and applying all of the techniques we would like to use for the study.

Representative PRICE. So that, if you don't have the space to accommodate them, both the patients and the people working in your program, the program is very definitely adversely affected. Is that right? Dr. TORRER. It certainly is.

Representative PRICE. I think we probably have it in the record already, the types of cases you have under consideration, where the people come from, and so forth. But if we don't, and if you could bring us up to date on that, I think the committee should have it.

Dr. TORRER. We will submit for the record all the material we have on this. There is quite a variety of sources of contamination and origin of the people contaminated. But we will provide that for you; yes, sir. (The information referred to follows:)

SUMMARY OF CASES IN RADIUM PROJECT (AS OF DEC. 31, 1968)

	MIT-NJ ¹		ANL-ACRH ²	
	Names known	Cases studied	Names known	Cases studied
(a) Dial painters.....	360	208
(b) Inorganic.....	66	81
(c) Chemists ³	145	4
(d) Others.....	34
Total.....	2,090	605	485	293

¹ Of cases studied, 50 percent radium, 50 percent Radium-Mesothorium mixtures.

² Essentially all cases studied are radium cases.

³ Industrial exposures other than radium-dial industry

Representative PRICE. It has been recently reported that member agencies of the Federal Radiation Council, including AEC, have responded to the Senate Public Works Committee request for com-

ments on the Gofman-Tamplin testimony presented to that committee in November of last year.

Will you bring us up to date on this situation?

Dr. TORRER. Yes, sir. We were asked by Senator Muskie for comments on the Gofman testimony, and we responded with a review which was the one submitted to this committee in its Phase I hearings on the environmental effects of producing electric power. We have not submitted for the Senate Public Works Committee any other comments than those, but the FRC has been asked by the Secretary of Health, Education, and Welfare to look into the Gofman-Tamplin testimony and assess it. (See p. 965 for related correspondence.)

And in doing so, of course, to assess whether there needs to be any change in the FRC method of arriving at suitable standards for radioactivity exposure. They are in fact meeting today, the working committee of the FRC is meeting today on this problem.

Representative PRICE. Could this committee have a copy of any response you have made?

Dr. TORRER. Yes, it already has. We submitted the same material which we submitted to this committee.

Representative PRICE. Do you have any later information on the subject of exposure of uranium miners? We have discussed it at various times in the past.

Dr. TORRER. A little more than a year ago, I believe, there were arrangements made to restudy the record of the miners and restudy the pathological material which is available. This was not in our hands, but in the hands of another agency. My understanding is that that has not been so successful yet. That is, the study is not completed. So that we cannot at this time suggest any changes in the original epidemiologic findings.

Representative PRICE. I notice in your statement referring to the fiscal 1972 request for funds for the facility, you increase that from the \$1,830,000 estimate for fiscal year 1971 to \$2 million. What is the difference there?

Dr. TORRER. I would like to ask Dr. Rowland also to speak to that.

Dr. ROWLAND. I assume, Mr. Price, that the change in cost from \$1,830,000 to \$2 million represents engineering analysis of the effect of the cost of living, and increased cost of construction materials resulting from a 1-year's delay.

Dr. TORRER. If you would like to, Mr. Price, I have a little bit more on the uranium miners.

Representative PRICE. Yes, I would like to have it.

Dr. TORRER. We have established an epidemiological study. It was started in 1968 with Dr. Eugene Saccomanno, at Grand Junction, Colo., who was primarily concerned with the studies of development of lung cancer in working miners. This study continues to address itself to: (1) Identifying and following the clinical course of exposed uranium miners by means of a registry; (2) seeking a reliable and practical biological indicator, such as sputum cell changes, which would predict serious diseases at a time when applied countermeasures would be reasonably expected to be effective; and (3) evaluating the influence of other mine pollutants and smoking on the incidence of lung cancer in uranium miners.

That study is underway.

Representative PRICE. Thank you very much, Dr. Totter.

The committee would like to express its appreciation to Dr. Cannon, vice president of the University of Chicago, for his effort to improve the organization of the laboratory to do reactor work.

We have been very much interested in that. We hope that you can continue your efforts to get adequate staff, a good staff, particularly by bringing more people into the laboratory who are highly qualified in the area of reactor work.

**STATEMENT OF DR. WILLIAM B. CANNON, VICE PRESIDENT,
UNIVERSITY OF CHICAGO, CHICAGO, ILL.**

Dr. CANNON. Thank you very much, Mr. Chairman.

I should point out that the work has really been done by the director of the laboratory, Robert Duffield.

Representative PRICE. The appreciation also goes to him, because we are very much interested in building up the reactor work at the laboratory.

I would like to say that the chairman of the committee, Mr. Hollifield, is tied up in another conference at the present time. He was hoping to be here for your testimony, Dr. Totter. I think we have elicited the replies to the questions the committee was interested in. We are very appreciative of your cooperation.

Dr. TOTTER. Thank you, sir.

Representative PRICE. We have a number of other questions on the biology and medicine program which we will submit to you in writing. The committee will recess until Thursday afternoon, when we will consider the Plowshare program, at 2 o'clock.
(Statement of Dr. Totter follows:)

**STATEMENT OF DR. JOHN R. TOTTER, DIRECTOR, DIVISION OF BIOLOGY AND MEDICINE,
TO THE JOINT COMMITTEE ON ATOMIC ENERGY IN SUPPORT OF THE FISCAL YEAR
1971 AUTHORIZATION REQUEST**

The proposed budget for the biology and medicine program reflects the emphasis that is being placed upon problems relating to the effects of radiation on man and his environment, thus contributing to the accomplishment of important national objectives such as the achievement of nuclear power production at the lowest possible cost with the minimum adverse effect on the environment, the use of radiation and radiotopes for medical research which will improve human health, and the maintenance of national security.

Because the operating budget of \$88,300,000 is less than either FY 1970 or FY 1969, reductions in many important research areas will be necessary, but the AEC and its laboratories are constantly reviewing priorities and expect to maintain the most urgent programs at appropriate levels of support. Among the priority areas are: (1) the late effects of low exposures to radiation, particularly as they relate to dose rate; (2) the hazard to man from inhalation of plutonium and other alpha emitters; (3) the program of the Atomic Bomb Casualty Commission in Japan, from which increasingly important information about human exposures will develop; (4) thermal alteration of lakes, streams, estuaries and the atmosphere which might result from nuclear power plant operations; and (5) special uses of radiotopes in nuclear medicine.

To support the research programs, a budget of \$5,500,000 for capital equipment not related to construction is proposed, along with general plant projects of \$1,000,000. The details of these budgets have already been provided to the Congress.

Emphasis in this statement will be given to several program areas which are of particular interest at the present time and which for the most part are not expected to be the subject of oral testimony.

SCOPE, OBJECTIVES AND FUNDING OF ECOLOGICAL STUDIES

The DBM program in ecology encompasses the land and fresh water, marine, and atmospheric sciences. The overall funding for this program in FY 1971 is in excess of \$18 million. These vital research areas predate the current popular interest in environmental problems, and include studies dealing with interrelations of organisms and populations with their environment, with particular emphasis on the fate and effects of radioactivity within these living systems. Most of the support is for research on pathways, rates of movement, and distribution of radioactive substances in the natural environment and man's food chain, but many studies on effects of radiation on natural populations have also been supported. Some of the effort is necessarily devoted to baseline studies which establish the norm on which prediction may be made about fate and effect. Along with goals of understanding radioactivity in the biosphere, these programs contribute much to basic knowledge about ecology, man's food chains, and other broad aspects of environmental science.

The research has included studies of radiation in all of the major habitat areas from the tundra to the tropics, in lakes, rivers, oceans, estuaries and the atmosphere. Since it is impossible, however, to investigate every environmental niche for every radionuclide, it is necessary to generalize from the results of the studies supported. For example, the principles discovered concerning the biospheric behavior of fallout have later proven invaluable for assessment of radioactive activity from other sources, such as reactors, space nuclear applications, nuclear excavation, and other peacetime applications of nuclear energy.

Because of the urgency for an early understanding of the effects of fallout, the largest share of past ecological studies has been on transport, deposition, and transfer of radioactivity to man.

Anticipating the increasing demands that will be made of our lakes, streams, and estuaries, DBM began an expansion of thermal effect studies from about \$0.4 million in FY 1969 to \$1.2 million in FY 1971. It is planned that this program be expanded to \$3.0 million in 1976.

The current broad objective of the research program concerning radioactive and thermal emissions is designed to insure that the orderly development of nuclear energy is not limited by lack of understanding of ecological effects. We are particularly aware of the need to accelerate the program in the areas relevant to nuclear power reactors, specifically studies of radionuclides and thermal releases in aquatic systems.

In addition to the ecological studies which are summarized in this statement, the biology and medicine program includes many projects directed to the genetic and somatic effects of radiation. The research program in radiation biology supplies important information needed to support other AEC activities.

Land and Fresh Water Environmental Sciences—Research in the land and fresh water environmental sciences category is expected to cost approximately \$9.6 million in FY 1971. Within this category, we have recently expanded studies in several of the AEC laboratories in the area of thermal effects on biological systems at the community level of organization. For instance, increases proposed in FY 1971 at Savannah River, Oak Ridge, and Richland are for new studies of thermal effects in aquatic systems initiated in FY 1970. Other studies are being initiated on tritium in terrestrial and fresh-water ecosystems.

The ecological program at Oak Ridge National Laboratory will be supported at just over \$1.2 million in FY 1971. Studies at this laboratory are on the responses of plants and animal populations to ionizing radiation, radionuclide cycling in terrestrial and aquatic ecosystems, thermal effects, waterfahed aquatic habitat interactions, and systems ecology.

At Pacific Northwest Laboratory the program is concerned with thermal and radioecological aspects of the Columbia River, fallout cesium 137 and iron 55 in Alaskan food chains, and the arid land ecosystem. The total operational funding is nearly \$1.0 million in FY 1971.

The AEC is also sponsoring the University of California at Los Angeles for ecological research on the Nevada Test Site, addressed largely to the effects of radiation on desert animal and plant populations, with a proposed funding of \$0.8 million. Dynamics of mineral cycling and responses of the radionuclides in the tropical oceans and forests are the focus of current ecological research at the Puerto Rico Nuclear Center, with a much smaller budget (\$0.2 million). The Savannah River Ecology Laboratory now has important programs on thermal effects and the cycling of tritium, with a proposed budget of \$0.8 million. At Brookhaven National Laboratory, funded at \$0.3 million, current research is on the effects of chronic radiation on a forest ecosystem.

The Argonne National Laboratory is presently developing a program on the pollution of Lake Michigan, and is now involved in the initiation of studies adjacent to existing and proposed nuclear plant sites. This program is an excellent example of ways in which AEC scientists contribute to several kinds of environmental problems. The Laboratory will be measuring the distribution, transport, and fate of selected non-radioactive chemical species as well as radionuclides. Studies of stable element behavior provide information about the behavior of radioactivity, just as our earlier studies on radioactivity have provided a bulk of information on non-radioactive pollutants. The cost of these studies is expected to be \$0.3 million in FY 1971.

Radionuclide transport studies are continuing at Lawrence Radiation Laboratory, Livermore, and the Health and Safety Laboratory. At Livermore, new field studies on radionuclides from Plovershare gas stimulation experiments and continued analysis of the ecological and bio-medical aspects of environmental radioactivity are anticipated. That part of the Livermore program which is considered ecological research in the terrestrial and fresh water environmental sciences will be funded at approximately \$2.6 million.

At the HASL, studies of strontium 90, stable alkaline earths and natural radioactivity in diet and man are continuing. These studies, supported at \$0.5 million, are contributing to a model which relates environmental levels of artificial and natural radioactivity to their appearance in man through the diet. Here, again, studies of non-radioactive pollutants contribute knowledge to radioactivity behavior.

Marine Sciences.—The program in marine sciences is proposed for funding at approximately \$3.9 million. The objectives of this activity are to provide a basis to predict the fate and possible effects of radioactivity introduced into the marine environment as a result of nuclear energy operations. Research is conducted in biological, chemical, geological and physical oceanography and is directed toward learning the effects of biological activity, sedimentation and physical-chemical processes on the dispersion and accumulation of radionuclides. Further studies on the effects of thermal alteration of the marine environment will be initiated in FY 1971.

Most of our marine work is carried out by university oceanographic groups and other institutions, rather than at the National Laboratories. An example is the study of the fate of radioactive effluent from the Columbia River in the estuary and at sea off Oregon and Washington. Cooperating in the project are the University of Washington, Oregon State University, U.S. Bureau of Commercial Fisheries, U.S. Geological Survey, and Battelle-Northwest Laboratories. The radioactivity is being followed in the water, in sediments, and in the biota, and mechanisms of transport and concentration are being defined.

A group at the University of Miami, Florida, is studying the ecology of Biscayne Bay prior to the operation of the first power reactor (scheduled for 1971). Their study will provide a baseline to which future changes can be related.

Atmospheric Sciences.—The AEC also supports studies of those atmospheric processes which link pollutant and thermal sources to biological receptors. The proposed budget for these studies in FY 1971 is approximately \$4.9 million. These include programs in the transfer of radionuclides from the atmosphere to vegetation and to water bodies, and a variety of studies dealing with fluxes of heat and water between the surface and the atmosphere. The Laboratories are further engaged in program-oriented studies of air pollution meteorology. Proposed programs dealing with air-lake interchange of waste heat, the problems of injections of massive quantities of moisture directly into the atmosphere, and the behavior of the atmospheric environment of a major city are currently being evaluated.

It is fortunate that the history and location of AEC Laboratories, and their particular areas of expertise allow for unique programs at each. Communication is encouraged among them and with universities so that an ecological generalization derived for a particular habitat can be checked for validity in another ecosystem.

The off-site program in terrestrial, fresh water, marine and atmospheric ecology currently involves contacts with universities, research laboratories, and other Government agencies. These studies are under continual review, and undergo changes in direction dictated by past findings and current needs. Research on possible ecological effects of chronic low-level radiation, thermal effects, and mission-oriented environmental quality problems is being encouraged.

CHRONIC EXPOSURE OF HUMANS TO RADIATION

Studies in humans on the long-term radiobiological effects resulting from chronic low-level exposure to ionizing radiations are being conducted primarily through four investigations. While differing in their specific goals, they form closely related and essential components leading to achievement of the overall objective of these studies.

Lifetime Health and Mortality Studies.—The study of lifetime health and mortality experience of AEC and AEC contractor employees, being conducted by Dr. Thomas Mancuso, University of Pittsburgh, was started in 1965 to test its feasibility. The feasibility of this investigation has now been established. It will be maintained as a critical study and after the completion of analysis of past years, current data will be added to the study on a continuing basis. Presently the primary emphasis concerns the study of the populations of Pacific Northwest Laboratory, Richland, and at Oak Ridge (Oak Ridge Gas Diffusion Plant, Oak Ridge National Laboratory and Plant Y-12), where radiation occupational records go back over 20 years. The conversion of the record data from both exposed and control populations to IBM cards and magnetic tape is nearing completion at Hanford. Another year will be required for the process at Oak Ridge. Additional pertinent information such as identification of deceased, from Social Security and State records, the place, and cause of death are being actively sought. To permit statistical comparison of radiation exposure, all data will be periodically reviewed and, to the extent possible, standardized in those installations currently under study and for use by those facilities in which a similar analysis is planned. Steps are being taken to insure the retention and accessibility of all health records permitting their conversion to automatic data processing format. All data will, therefore, be available for further information retrieval, and accumulation and analysis of data can be periodically accomplished.

It is planned that this study will be extended to other AEC facilities such as Rocky Flats, Mound, and Los Alamos Laboratories. Once the system is established and working at a given installation the conversion of information to automatic data processing will be made part of the normal operational cost of the respective facility. It is also anticipated that as funds become available from completion of the relatively expensive retrospective studies at any given site, these funds will be redirected into retrospective studies at the other aforementioned installations for inclusion into this study.

Plutonium Registry.—The National Plutonium Registry was formally established in 1968 under the direction of Drs. W. D. Norwood and P. A. Fuqua of the Hanford Environmental Health Foundation, a contractor of the AEC. Its purpose is to accumulate and evaluate data on human uptake, distribution and retention of plutonium and other radioactive transuranic elements, and to determine their effects on persons exposed during the course of their employment.

A classification system, based upon type and extent of exposure, of both active and terminated plutonium workers has been established. It is also planned to study transferred and retired employees. Autopsies will continue to be carried out, when permitted, on deceased plutonium workers and the radioactivity of organs and tissues measured. These findings will then be compared with the most recent estimates of the individual's organ burden determined prior to death by urinary excretion, metabolic models, and/or whole-body counting.

As of December 1969, 300 employees at Hanford have been interviewed of whom 298 have subscribed to the program. It is hoped that a total of 2000 employees will eventually be included in this group when this project is completed. Seventy have already signed autopsy releases. Exploration of methods for extending the Plutonium Registry to such facilities as the Savannah River, Rocky Flats and Oak Ridge plants, are in progress. These arrangements are aimed at assuring a high-rate of voluntary post-mortem examination, and an accessible and reliable laboratory back-up system mandatory for the multidisciplinary analysis of the obtained specimens. These would contribute information essential to validating current, or uncovering additional predictive biomedical endpoints, thus permitting a more accurate assessment of an occupational plutonium hazard.

Uranium Miners Epidemiological Study.—The uranium miners epidemiological study was established in 1948 under the leadership of Dr. G. Saccomanno at Grand Junction, Colorado. It is primarily concerned with the problem of the

for the construction of the new facilities at Argonne, and the continuing effort to obtain data from radium recipients studied in the Chicago area.

Incorporation of the MIT Project into the ANL Operation.—As of this date the transfer of personnel, records, tissue samples and equipment from Dr. Robley Evans' project at MIT to Argonne is progressing smoothly. After September 1, 1970, the MIT facility will function as a satellite laboratory under the financial and scientific supervision of the Division of Radiological Physics of ANL. Three scientific associates, all holders of Ph.D. degrees, will move to Argonne from MIT by July 1970; two of these have already moved. A fourth member of the MIT group has been offered a position at Argonne but has not as yet accepted. Dr. Robley Evans and his assistant, Miss Mary Margaret Shanan, will be located in Phoenix, Arizona, after September 1, 1970, and will maintain operational contact with both the MIT installation and with ANL.

The MIT satellite laboratory will retain a staff for efficient monitoring of radium recipients in the eastern U.S. This staff will include four scientific personnel for whole-body counting and radon breath analysis, three consulting physicians to give physical examinations and arrange for autopsies, and supporting personnel as needed.

Two small field offices will also be maintained on the east coast. The New Jersey field office with a staff of two nurses and a secretary will continue to maintain contact with the 200-300 radium cases in that area and arrange for referrals to the MIT Laboratory. The Connecticut field office is only manned by a part-time employee and is maintained on a standby basis.

Progress has also been made in the transfer of materials, equipment and records. All records at MIT are being duplicated and one set is being sent to ANL. At this time, patient records ranked alphabetically from A-D as well as more than 50% of all x-ray films have already been received at ANL. Transfer of computer records including the card file and computer tapes has been completed. One piece of laboratory equipment, a large walk-in refrigerator has been received at ANL. Only one other major piece of equipment is planned to be transferred to ANL. This is a recently purchased 4000 channel analyzer, purchased with the agreement of MIT that it would be transferred to ANL. There has been a steady transfer of bone samples to ANL, but because the exact amount involved is not known the fraction already moved cannot be accurately estimated.

Plans for Construction of New Facilities at ANL.—Plans at ANL for the addition of a combination office-laboratory wing to the existing physics building to house the program have been made. This will provide for a centralization of studies in the U.S. on the toxicity of radium and mesothorium in human beings. Eventually ANL may also have the responsibility for studies of human beings contaminated with other bone-seeking radioisotopes. Based upon a preliminary conceptual design, the facility will consist of two full floors, a service floor and fan loft, and will provide approximately 26,500 gross square feet. It is now estimated to cost \$2,000,000. The Division of Radiological Physics is now utilizing several temporary quarters, such as an abandoned Nike site, temporary buildings and warehouse-type facilities, which are considered to be inadequate. In addition, the new facility will be used in part to house the current expansion of the environmental programs of the Division of Radiological Physics.

Medical Records of Radium Recipients in the Chicago Area.—Negotiations are being completed for access to all past and future patient records of radium cases in the area. Clinical studies on patients are being continued through cooperation with Argonne Cancer Research Hospital and with Dr. Herta Spencer at Hines Veteran's Hospital in Chicago.

Recruitment of staff for the human radium toxicity studies at ANL is nearing completion. It is planned that the following additional personnel will be added to the staff as soon as practicable: a physician to act as medical director of the project, a medical anatomist to prepare tissues obtained at autopsy for study, and a radiation chemist.

In summary, it is expected that by September 1, 1970, the fiscal and scientific responsibility for AEC's ongoing studies of human radium toxicity will be centralized and coordinated through the Division of Radiological Physics of ANL, under the supervision of Dr. Robert Rowland, Director of that Division.

development of lung cancer in men working in uranium mines. This study continues to address itself to: (1) identifying and following the clinical course of exposed uranium miners via a registry; (2) seeking a reliable and practical biological indicator, such as sputum cell changes, which would predict potential serious disease at a time when applied countermeasures may be expected to be reasonably effective; and (3) evaluating the influence of other mine pollutants and smoking on the incidence of lung cancer in uranium miners.

The Registry to date includes all death records of uranium miners on the Colorado Plateau who have died since 1955. Data from 142 individuals, obtained by surgery or autopsy specimens, have been evaluated.

As part of the search for a biological indicator, 163 ex-miners whose sputum samples included significant numbers of atypical cells are cooperating in the study in which their sputum samples will be examined bi-annually over a period of five years. Additional patients are being added to this series as they emerge clinically. An equal number of individuals who are still active in the mines and/or who smoke will also be examined. The course of cell changes, either their progression or regression to normalcy, will be correlated with the development and type of lung cancers. Dr. Saccomanno has inaugurated a "double-blind" and "repetitive" review system for his group of consulting pathologists in order to minimize bias and enhance quality control in the reading and interpretation of the cell preparations. Additionally, colored photographs of representative specimens of these different stages of sputum cell changes are being collected and collated for eventual publication as a technical reference manual.

The influence on the lung cancer in these miners vis-a-vis smokers and non-smokers and other known occupational environmental agents is being observed on a continuing basis.

Radium Toxicity Studies.—Radium and mesothorium studies which have been conducted by Dr. Robley D. Evans at MIT in Boston are being consolidated under Dr. R. Rowland at the Argonne National Laboratory, as described in more detail below. These studies will continue to add to the published body of information on these chronically exposed individuals. In addition, Dr. Rowland also plans to incorporate into his program past and future similar radium studies conducted by other investigators from the Argonne National Laboratory and the Argonne Cancer Research Hospital, Chicago, Illinois.

It is noted that the aforementioned four projects deal with late effects of chronic low-level exposures in man, and thus impose obvious moral and temporal limits on data acquisition. To remedy in part these limitations, animal experiments have been actively carried out under conditions approximating those which occur in man, and are being expanded in the more pertinent areas. These long-term animal experiments are being conducted at various laboratories such as Lovelace Foundation, University of California, Davis, Pacific Northwest Laboratory (PNL), University of Utah, and University of Rochester. During the past year investigations with plutonium (alpha program) as an inhalant hazard have been expanded at the Lovelace and PNL laboratories. To integrate further the animal experiments and human clinical studies to their mutual benefit, cooperative work has been initiated between staff members of Lovelace and PNL, to provide sputum samples (lung washings) from dogs exposed to selected radionuclides to Dr. Saccomanno for cytological evaluation and for comparison with his findings in man. In turn, Dr. Saccomanno has visited each of these laboratories.

Information derived from the internal emitters program contributes its part to the overall AEC interest in radiation effects. This information is appraised in context with the contributions to our knowledge on the long-term radiation effects from acute exposures obtained by the studies of the Atomic Bomb Casualty Commission in Japan, from fallout exposure to the Marshallese correlated through studies at Brookhaven National Laboratory, and from the many relevant AEC programmatic experimental studies at all levels of life.

STATUS OF THE RADIUM TOXICITY STUDIES AT ARGONNE NATIONAL LABORATORY

The development of the human radium toxicity studies at Argonne National Laboratory is proceeding according to schedule, and the construction of the new facilities is now planned for FY 1972. To be described briefly here are the status of plans for incorporating the MIT project into the ANL operation, the plans

MODIFICATION OF THE JANUS REACTOR AND THE CONDUCT OF NEUTRON EXPOSURE EXPERIMENTS

The engineering deficiencies in the high flux room of the JANUS reactor at the Argonne National Laboratory, that interfered with its usefulness for biological experimentation, have now been corrected. Specifically, the walls, ceiling and floors have been lined with borated material and/or lead to reduce the induced radioactivity, while the shutters and converter plate have been redesigned and are functioning properly. These modifications should correct the safety hazard to the operators and scientific personnel. Improvements have also been made in the control system and attenuator plate which will improve the technical features of the facility. At the present time, all modifications have been made and the facility is awaiting final safety approval and licensing. These modifications will result in a considerably improved radiation spectrum having an average neutron energy of 9-1.2 Mev within the exposure room, compared to a 2-4 Mev prior to the modifications. This is a predicted spectrum based upon crude measurements and calculations; detailed spectral measurements will be conducted in late March. Although the radiation intensity remain about the same, the gamma contribution could well be lower than the 8% previously found. The high level exposure room is now ready for biological experimentation. It is not planned to modify the low flux room at this time. Technically, certain studies could be conducted although the neutron to gamma ratio is not satisfactory for the late effects experiments.

Biological and dosimetric studies will be initiated upon final safety approval which is expected soon. Biological dosimetry studies, using animal and cell culture experiments, will be initiated first to determine the biological effect of the improved neutron spectrum. Simultaneously, physical dosimetry studies will define the radiation levels of the entire exposure room with and without animal loading. Personnel from ORNL will be involved in these studies as an inter-laboratory check.

Initial short-term animal experiments will begin upon completion of the pertinent dosimetry. These studies will provide data on organ damage, exposure time, dose accumulation and recovery factors after single and fractionated exposure which will define the basic phenomenology necessary for planning the late effects experiments. Data are expected within two months from this date. The first late effects experiments, the major objective of the JANUS program, are expected to begin by June 1970.

A meeting was held between DBM and Argonne scientists at Germantown on February 10, 1970, to review progress on the modifications and discuss the biological experiments that are being planned. The DBM scientific staff was satisfied with the proposal and approved initiation of the experimental program. Interest is high at both Argonne and AEC Headquarters in seeing the neutron hazard experiments begin. The JANUS program will be under continuing review by DBM as the program progresses.

UCLA PERSONNEL SITUATION SUMMARY

The GAO report of about a year ago on the management and administration of the DBM program noted certain management and personnel matters related to the research program supported by AEC contract at the Laboratory of Nuclear Medicine and Radiobiology, UCLA. These have previously been the subject of extensive discussions between the University, the AEC, and the JCAE. In March 1969, agreement was reached on a number of contract amendments designed to improve and strengthen this laboratory's operation. By letter dated April 8, 1969, the Chairman, JCAE, was notified by the Commission that the contract with this laboratory had been extended by modification through September 30, 1972, which included a number of significant amendments. These amendments are basically as follows:

1. Organizational changes which provide administrative responsibility for the laboratory to be placed at the level of the Chancellor's office at UCLA
2. Provision for award under the contract of five FTE (full-time equivalent) regular faculty positions in the laboratory
3. Provided for a major review of the research program to be conducted in either late 1969 or 1970 to assure that the activities of the laboratory comport with the contract objectives and contribute significantly to the Commission's overall program

4. Establishment of improved review procedures for the advancement of individuals in the Professional Research series

5. Continuing and serious consideration to be given by the University for the improvement of employees grievance procedures, with particular reference to the interests of the non-senate academic employees.

Since the date of the contract extension, continuing review by DBM staff of the research program at this laboratory and recommendations made have resulted in the strengthening of a number of its activities, and they include the following: Drs. J. F. Mead and G. V. Taplin have been appointed assistant directors of the laboratory to assist Dr. O. R. Lunt, Director, in planning and policy matters. This administrative change has had a salutary effect on the laboratory's staff and program. The director and assistant directors have recently made plans for or actually inaugurated changes in research responsibilities that should strengthen the laboratory's research effort, especially in the biochemistry and nuclear medicine programs. These changes relate to the advancement of promising young scientists to independent research status and the more effective utilization of the talents of other investigators. In addition, it should be noted that one young investigator received a special FTE appointment with the university on July 1, 1969, and two others have been recommended for similar appointments. Recently completed plans for the purchase and installation of a cyclotron for the production of clinically useful radionuclides should significantly advance the laboratory's effort in nuclear medicine. The University is making a substantial financial contribution toward this important program development by providing space and supporting facilities for the cyclotron.

We are also pleased to report that with the adoption of this contract modification and the extension of the contract period, the University has essentially met all of the additional conditions to the satisfaction of the AEC. For example, forward strides have been made in the award of FTE positions and in a program for the establishment of tenure positions. In addition, through a series of reviews, a number of the laboratory's well-qualified scientific employees have been awarded commensurate salary advancements. Also, the University by Regents action last July added the In-Residence staff to the Academic Senate, which effectively tripled the number of laboratory staff members entitled to these rights and privileges.

During the past month, a committee appointed by the Director, Division of Biology and Medicine, consisting of members of the Advisory Committee for Biology and Medicine and outside consultants, conducted a thorough review of the research program at this laboratory as required by the contract amendment. The report of this committee has not yet been received, but we are confident it will provide important information relative to the present strength of the laboratory and useful guidance for its future programming and direction.

(JCAE questions on the biology and medicine program and AEC's answers follow:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., April 7, 1970.

Mr. Edward J. Bauser,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States.

Dear Mr. Bauser: This is in response to your letter of March 26, 1970, requesting additional information related to the Biology and Medicine Program. Enclosed are answers to the questions which are to be published in the record of the fiscal year 1971 authorization hearings.

Cordially,

(Signed) GLENN T. SEABORG,
Chairman.

RESPONSES TO SUPPLEMENTAL QUESTIONS FOR THE BIOLOGY AND MEDICINE PROGRAM REQUESTED IN THE ENCLOSURE TO MR. BAUSER'S LETTER OF MARCH 27, 1970

1. Question. A principal justification for building the Janus reactor facility at Argonne National Laboratory was the need to conduct long-term, low-level radiation studies referred to as "late effects experiments." The Division of Biology and Medicine's statement for the record comments that "the neutron to gamma ratio (in the low flux room) is not satisfactory for the late effects

experiments." Please elaborate upon this remark including cost and time scheduled for any modifications which may be contemplated for the purpose of improving the neutron to the gamma ratio. When, if at all, will these modifications be made?

1. Answer. The original concept of the Janus program was to compare systematic high and low dose-rates of fission-spectrum neutrons for relative biological effectiveness (RBE) in mammals. The reactor was designed to allow this comparison with sufficient numbers of experimental animals to detect any significant difference.

Inherent in the whole concept was and is the necessity that relative neutron flux, therefore dose rate, should be the only variable in the experiment. As a consequence the neutron energy spectrum and neutron to gamma-ray dose ratio must be the same in both the high and low flux rooms.

The high-flux room had so many problems associated with it that it could not be used. Moreover, the neutron energy spectrum and neutron to gamma-ray dose ratio was not the same in both rooms.

A study indicated that the high-flux room could be modified to provide ideal exposure conditions for high dose-rate studies. Moreover, low dose rates could be obtained by merely reducing the power of the reactor; thus, the planned experiments could be done under conditions where the neutron energy spectrum and neutron to gamma ray dose rate would be identical. It was thus decided to abandon the low-flux room and modify only the high flux room. These modifications are essentially finished and satisfactory from a safety point of view and the neutron spectrometry and dosimetry from a safety point of view and

The present thinking about the future of the low-flux room is as follows: It is not known whether the RBE for mice and other mammals changes over the neutron energy range of 1.2 to 0.2 Mev. A determination of any RBE change with energy over this range can be made by systematically degrading the neutron beam in the high-flux room. Such a determination cannot be made elsewhere. In fact, it could not have been made in the low-flux room even if it had been modified. This will comprise an important and early experiment in the Janus program. Should no change in RBE be found over this energy range, it is possible to modify the low-flux room to reduce the gamma-ray to neutron dose ratio to approximately that of the high-flux room. This can be accomplished by adding an additional 4 inches of lead either inside or outside of the concrete face of the reactor shield in the room. Further reduction of the gamma-ray component can be made by applying a coat of gadolinium paint to the internal wall surfaces of the room. Such modifications are estimated to the less than \$30,000 and will entail no appreciable shut-down time.

No modification of the low-flux room will be made until such time as the biological experiment indicates the plausibility of doing so, possibly in two or three years.

2. Question. The DBM statement makes the point that "all modifications (to Janus) have been made and the facility is awaiting final safety approval (to licensing)." It will be recalled that inadequate safety review priority was cited as a principal reason for serious delay in the early life of this project. Please provide further detail on the present status of the safety review and the procedures steps that lie ahead prior to granting final operating approval.

2. Answer. The Janus Reactor has been operational for over two months and has been approved and licensed for full-power operation since March 8, 1970. The physical measurements are on schedule and it is expected that the first late effects experiments can begin in June 1970.

3. Question. The DBM statement mentions briefly plans to extend studies under the University of Pittsburgh contract of lifetime health and mortality experience of AEC and AEC contractor employees to include possibly Rocky Flats, Mound, and Los Alamos Laboratories. This study concerns effects on humans from low-level chronic exposure to ionizing radiation. As such, it is a possible source of highly relevant information bearing on the question of permissible exposure levels. Is this study being extended to larger populations as rapidly as would be scientifically justified or is it hampered in any manner by budgetary limitations?

3. Answer. The "Study of Lifetime Health and Mortality Experience of AEC and AEC Contractor Employees" is being conducted by Dr. T. Mancuso, University of Pittsburgh, on the populations at Oak Ridge and Richland. It is expected that it will take another year to complete this phase of the study at which

time a determination will be made as to the extent and character of the subsequent work. For accomplishing the above immediate objectives, current funds are adequate.

It is considered prudent to await the results of the above scientific appraisal prior to effectuating the extension. As the results warrant, it is planned to extend initially the study to Rocky Flats, Mound Laboratory and Los Alamos Laboratory in an orderly fashion. A tentative estimate to start this extended work is \$900,000 for fiscal year 1972.

Attention is invited to the fact that related studies such as the uranium and plutonium registries, and the follow up on individuals exposed to radium and mesothorium are continuing.

(Subsequent to the receipt of the AEC responses to the JCAE inquiry on matters discussed in the fiscal year 1970 authorization report, the committees requested certain followup information on the biology and medicine program. Correspondence on this matter follows:)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., March 26, 1970.

Mr. ROBERT E. HOLLINGSWORTH,
General Manager, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR MR. HOLLINGSWORTH: Your letter of February 18, 1970, discussed the actions taken by AEC on the recommendations included in the General Accounting Office's April 16, 1969, report to the Joint Committee on administration and management of the biology and medicine research program.

In general, the actions taken appear to represent a commendable response to the GAO recommendations. The Committee has a question, however, concerning one of the matters discussed in your letter.

In commenting on the GAO recommendation that the laboratories periodically report actual costs to the Division of Biology and Medicine at the research area level, you stated in your letter that even though most laboratories maintain cost information on this basis at present, additional staff may be required to provide this information to DBM in a number of instances. During the 1970 House Appropriations Committee hearings (p. 668), a reference was made to the question of whether the benefits that would accrue to AEC in its day-to-day management activities would warrant the burden of that additional accounting.

The GAO report stated that DBM had advised GAO that, with the exception of Brookhaven, each of the 27 laboratories performing biomedical research for AEC accumulates costs by research area. The GAO recommendation, therefore, appears to have been predicated upon the premise that the needed information was already available and that significant additional costs would not be involved in merely communicating it to DBM.

Please advise the Committee as to (1) the laboratories at which additional staff would be needed to comply with the GAO recommendation, (2) the nature of the staffing needs, and (3) the reasons that additional staff would be required in those cases where cost data is already being accumulated by research area.

The Committee would appreciate receiving your response by April 7, 1970, so that it can be included in the hearing record.

Sincerely yours,

EDWARD J. BAUSER, Executive Director.

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., April 7, 1970.

Mr. EDWARD J. BAUSER,
Executive Director, Joint Committee on Atomic Energy, Congress of the United States.

DEAR MR. BAUSER: This is in response to your letter of March 26, 1970, in which you requested further information relative to the General Accounting Office's report to the Joint Committee on administration and management of the biology and medicine research program, with particular reference to the

periodic reporting of actual costs at the research area level by the laboratories to the Division of Biology and Medicine. Response to the three questions specifically raised by you necessitated referral directly to the laboratories involved, which we are now doing. We do not foresee that this information will be available by your deadline date of April 7, 1970, but will transmit it to you promptly after receipt.

Upon reflection, it is currently our considered judgment that the trial plan for semiannual cost reporting at the research area level, as outlined in our letter to you of February 12, 1970, would have a minimal impact on staffing, if any at all.

It is hoped that the information provided above will serve your purpose pending the receipt of the laboratories' reports.

Sincerely,

R. E. HOLLINGSWORTH, *General Manager.*

(Whereupon, at 2:25 p.m., Tuesday, March 3, 1970, the committee recessed, to reconvene at 2 p.m., on Thursday, March 5, 1970.)

APPENDIX 5

PROGRAM STATEMENT AND JUSTIFICATION DATA FOR BIOLOGY AND MEDICINE PROGRAM

U. S. ATOMIC ENERGY COMMISSION
 FY 1971 Budget Estimates
 Appropriation - Operating Expenses

BIOLOGY AND MEDICINE PROGRAM - OPERATING COSTS

PROGRAM STATEMENT

Estimate FY 1971.....	\$ 88,300,000
Estimate FY 1970.....	89,450,000
Decrease.....	\$ - 1,150,000

Research in biology and medicine is an integral part of the overall AEC program contributing to the national security and the general welfare. Along with the continuing studies of the interaction of radiation with biological systems, a substantial effort will be devoted to assess, evaluate and control radiation exposure to man and his environment. Applications of radioisotopes and radiation in medicine and biology are also being developed.

Major problems of prime importance to the AEC and the nation which need resolution will receive increased attention. Among these are: (1) thermal alteration of environments as a result of nuclear power plant operations and the effects of this on local ecosystems; (2) the hazard to man from pulmonary exposure to aerosols of plutonium and other alpha emitters; and (3) maintaining the scientific and fiscal stability of the program of the Atomic Bomb Casualty Commission in Japan at a time when the importance of these studies is increasingly apparent. With an operating budget of \$88,300,000 substantial reductions in other important research areas will be necessary in order to meet the commitments to immediately critical programs.

During the past year a number of significant advances in the biomedical research program have been reported which should be exploited, and the underlying research which lead to these advances must be strengthened to assure future contributions. Among these advances is the observation that gallium 67 has an unusual affinity for certain soft tissue tumors and thus is promising in tumor detection by radioisotope scanning. Significant advances have been made in studying the effects of radiation on man by showing that persons with a measurable body burden of radium have characteristic defects and destructive changes in skeletal structure. New techniques are now available for measuring DNA, which is the critical component of living cells.

In conducting its biomedical research program the AEC must go to the scientists and laboratories having the qualifications and the facilities necessary for the work. In many instances, the combination of unique interdisciplinary teams and specialized equipment is available only in the AEC national laboratories. In addition, many of the nation's best scientists are located in the universities. For these reasons, every effort will be made to assure that the most productive research programs are supported. Nevertheless, some reduction in mission-oriented research at universities and at AEC laboratories will be necessary.

BIOLOGY AND MEDICINE PROGRAM - continued

The total biomedical research program has been realigned to identify problem areas. A number of the most significant research areas for which increases or decreases are proposed are highlighted below:

	<u>Estimate</u> <u>FY 1970</u>	<u>Estimate</u> <u>FY 1971</u>	<u>Increase</u> <u>or</u> <u>Decrease</u>
1. <u>Interaction of Radiation with Biological Systems</u>			
a. Evaluation of the relative biological effectiveness of gamma rays and fast neutrons for low doses administered daily for the lifespan of the experimental animals, at Argonne National Laboratory.....	\$ 463	\$ 535	\$ + 72
b. Research on the late effects on mammals of single low exposures to gamma radiation, at Oak Ridge National Laboratory.....	1,083	1,123	+ 40
c. Investigation of metabolic alterations in irradiated farm animals, studies of trace elements of interest in nutrition, soil chemistry research and studies of ion exchange in soil systems, at the University of Tennessee.....	410	280	- 130
d. Research on the responses of plants to light duration and unidirectional force of gravity, at Argonne National Laboratory.....	260	190	- 70
e. Development of techniques for the analysis of human tissues and body fluids in the molecular anatomy program, at Oak Ridge National Laboratory.....	247	277	+ 30
f. Studies on the genetics of root development, physiological and cytochemical effects of radiation in plant cells, at the University of Tennessee.....	171	98	- 73
2. <u>Assessment, Evaluation and Control of Radiation Exposure to Man and His Environment</u>			
a. Continuation of the program of the Atomic Bomb Casualty Commission to collect uniquely valuable data on late radiation effects in the survivors of the bombings of Hiroshima and Nagasaki.....	4,000	4,200	+ 200

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BIOLOGY AND MEDICINE PROGRAM - continued

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
b. Studies of the pulmonary toxicology of plutonium and other alpha emitters at the Pacific Northwest Laboratory, Lovelace Foundation and Los Alamos Scientific Laboratory.....	\$ 2,113	\$ 2,269	\$ + 156
c. Human radium toxicity studies, at Argonne National Laboratory and other locations.....	543	580	+ 37
d. Evaluation of the effects of the discharge of heated effluents from nuclear power plants on the fresh-water and marine environments and in the atmosphere at selected representative locations.....	688	1,211	+ 523
e. Documentation of radionuclide distribution following Flowshare cratering events, at Lawrence Radiation Laboratory, Livermore.....	3,450	3,070	- 380
f. Terrestrial ecology studies at the University of California, Los Angeles.....	923	835	- 88
g. Extension of the Airstream monitoring project to continue the inventory of debris from French tests, and continuation of the overall upper altitude sampling program to measure the world inventory of strontium 90, plutonium 238 and other radionuclides.....	1,200	1,300	+ 100
3. Beneficial Applications of Radiation			
a. Clinical research using the newly available short-lived isotopes at the Argonne Cancer Research Hospital, University of California at Los Angeles, and other medical centers.....	356	393	+ 37
b. Studies of the effectiveness of total-body irradiation in cancer therapy, at Oak Ridge Associated Universities.....	457	500	+ 43

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BIOLOGY AND MEDICINE PROGRAM - continued

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
c. Studies of experimental hypertension and the effects of hormones on the metabolism of carbohydrates and lipids, at Brookhaven National Laboratory.....	\$ 600	\$ 513	\$ - 87
d. Research on human physiology and experimental medicine, at Lawrence Radiation Laboratory, Berkeley.....	295	231	- 64
e. Studies of lipids in cells and organelles of normal neoplastic and irradiated tissue, at Oak Ridge Associated Universities.....	243	153	- 90
f. Continuation of microbiological aspects of radiation preservation of foods program.....	170	130	- 40

The increases identified relate to approximately twelve percent of the program. In all other important scientific areas there will be a reduction.

Coordination of this program with related programs of other Federal agencies is being achieved through (1) liaison at the working level with program administrators in other agencies, such as the study sections of the National Institutes of Health and panels of the National Science Foundation and other formal and informal relationships; (2) representation on interagency committees established by the Federal Council for Science and Technology, the National Academy of Sciences, and other governmental and non-governmental organizations; (3) jointly sponsored research programs in areas of mutual interest; and (4) exchange of scientific information through publication in journals, attendance at scientific meetings, and the use of information pools such as the Science Information Exchange.

There are a number of program changes, both expansions and reductions, and these program areas are described in more detail in the justification which follows:

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SUMMARY OF ESTIMATES BY CATEGORY

Page No.		Actual FY 1969	Estimate FY 1970	Estimate FY 1971
B&M 6	1. <u>Interaction of Radiation with Biological Systems</u>			
	a. Effects of Radiation on Living Organisms.....	\$11,983,487	\$12,150,000	\$11,945,000
	b. Molecular and Cellular Radiobiology.....	16,476,733	16,242,000	15,855,000
	c. Radiation Genetics.....	7,658,624	7,487,000	7,280,000
	Sub-total.....	\$36,118,844	\$35,879,000	\$35,080,000
B&M 12	2. <u>Assessment, Evaluation and Control of Radiation Exposure to Man and His Environment</u>			
	a. Exposure to External and Internal Radiation.....	13,297,486	13,517,000	13,765,000
	b. Combating Detrimental Effects of Radiation.....	1,861,013	1,842,000	1,815,000
	c. Chemical Toxicity.....	596,398	615,000	610,000
	d. Land and Fresh Water Environmental Sciences.....	9,613,774	9,653,000	9,570,000
	e. Marine Sciences.....	3,899,199	3,950,000	3,895,000
	f. Atmospheric Sciences.....	4,473,197	4,967,000	4,900,000
	g. Nuclear Energy Civil Effects.....	1,153,209	1,180,000	1,190,000
	h. Radiological and Health Physics and Instrumentation.....	7,373,157	7,299,000	7,210,000
	Sub-total.....	\$42,267,433	\$43,023,000	\$42,955,000
B&M 24	3. <u>Beneficial Applications of Radiation</u>			
	a. Cancer and Other Clinical Research.....	\$ 7,273,980	\$ 7,548,000	\$ 7,390,000
	b. Biological and Agricultural Research.....	2,789,257	2,830,000	2,745,000
	c. Radiation Preservation of Foods.....	329,556	170,000	130,000
	Sub-total.....	\$10,392,793	\$10,548,000	\$10,265,000
	Total - Biology and Medicine Program.....	\$88,779,070	\$89,450,000	\$88,300,000

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BIOLOGY AND MEDICINE PROGRAM - continued

Since partial recovery of radiation damage seems to be a general phenomenon, it is important to understand how dose-rate influences the expression of radiation damage. It is obvious now that there are species differences among experimental animals in regard to capability for recovery from radiation damage. Preliminary studies at Los Alamos Scientific Laboratory suggest that the monkey shows much slower recovery kinetics than rodents or dogs. Recent radiotherapy results suggest that man's recovery rate may be similar to that of the monkey. An expansion of this program at Los Alamos is important and some meaningful data should be available in FY 1971. The overall cost will be significantly reduced by eliminating some rodent studies.

During the first third of gestation the developing embryo or fetus is quite susceptible to teratogenic effects resulting from exposure to radiation or chemical agents. A program at the University of Tennessee Agricultural Research Laboratory will study the early physiological development of the fetus in farm animals and determine the mechanisms responsible for the abnormalities. The decrease in the metabolic program at the University of Tennessee primarily reflects an internal re-orientation with a reduction in studies of metabolism of calcium and strontium in poultry. Sufficient practical information has been realized and the basic studies of transport mechanisms and cellular interactions, although of interest, are not of sufficient priority for continuation at the present level.

Response of Organ Systems and Tissues

To understand the effects observed in the whole animal, a knowledge of the interaction of radiation at the tissue or cellular level is required. Detailed supporting investigations of the effects of radiation on important organs and tissues as well as single cells comprising them are required. In addition, investigations at the cell level using model in vitro cell systems contribute to the knowledge of radiation damage at this level of organization.

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A new program has been initiated at Brookhaven National Laboratory, which will involve the largest single group of mammalian cell biologists in the AEC program devoted exclusively to the investigation of repair of ionizing radiation damage in mammalian cells in vitro. This research will involve investigation of the mechanisms involved in the production of radiation damage at the cellular and molecular level as well as the macromolecular aspects of repair of the damage which leads to increased survival. An important aspect of this work will be an attempt to correlate the increased relative biological effectiveness (RBE) of neutrons with ability of the cells to repair the damage produced.

Research at the Laboratory of Radiobiology at the University of California Medical Center will be specifically oriented to the biochemical and genetic aspects of mammalian cell and tissue differentiation. Although it is known that all cell renewal systems in mammals are under homeostatic control we have little or no knowledge about the mechanisms of the control or regulatory processes of these systems.

At the Oak Ridge National Laboratory a complementary program is underway to investigate the biochemical aspects of regulation of differentiation in a model tissue tumor system in rat liver. The transformation from normal to tumor cells seems to involve changes in the amount of certain enzymes present in the cell. These studies are important from the point of view of understanding normal differentiation and abnormal differentiation involved in carcinogenesis.

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JUSTIFICATION OF CATEGORIES

1. Interaction of Radiation with Biological Systems..... \$ 35,080,000
 a. Effects of Radiation on Living Organisms FY 1969: \$11,983,487 FY 1970: \$12,150,000 FY 1971: \$11,945,000

The objective of this research is to understand the immediate and delayed effects of exposure to radiation of various types and intensities. Only by studies of the whole organism and at the organ and cellular level with experimental animals and other organisms, e.g., plants, bacteria, etc., can the effects of radiation injury be adequately assessed. The animal experiments provide data on which to predict hazards to domestic animals and, integrated with the limited information obtained from actual human exposures, such as radiation accidents and radiotherapy provide a more reliable basis for predicting the hazard to man as well.

Program Highlights

Changes are proposed for the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Evaluation of the relative biological effectiveness of gamma rays and fast neutrons, at Argonne National Laboratory.....	\$ 463	\$ 535	\$ + 72
(2) Research on the late effects on mammals of single low exposures to gamma radiation, at Oak Ridge National Laboratory.....	1,083	1,123	+ 40
(3) Investigation of metabolic alterations in irradiated farm animals and of trace elements of interest in nutrition, soil chemistry research and studies of ion exchange in soil systems, at the University of Tennessee.....	410	280	- 130
(4) Study of the repair of ionizing radiation damage in mammalian cells, at Brookhaven National Laboratory.....	191	212	+ 21

Effects on Whole Organisms

The emphasis in whole organism studies has shifted from assessment of immediate effects of large radiation doses to the effects of low doses or a low dose-rate continuous exposure of large populations of animals and man. These sub-lethal exposures can produce injury that will be expressed only after a long delay in time, and at a relatively low frequency of occurrence. Two such large, long-term experiments are in progress. One at Oak Ridge National Laboratory will evaluate the long-term effects in mice of a single low exposure to gamma radiation while the other at Argonne National Laboratory will evaluate the relative biological effectiveness of gamma rays and fast neutrons for low doses administered daily for the life-span of the animals.

The extent to which thyroid-pituitary radiosensitivity serves as an index of residual radiation injury in the dog and the pathologic mechanisms of permanent and delayed radiation effects in rodents will remain a major radiobiological effort in this activity at the University of Rochester. Program emphasis will be directed to elucidating the mechanisms of the regulatory membrane of bone, bone structure and its metabolism. In addition, significant research interest will continue on characterizing the physiological factors controlling pulmonary function and the biophysical properties of aerosols as they influence lung clearance and retention of inhaled dust particles.

At the Brookhaven National Laboratory some interesting results have been obtained with "partial-body" irradiation of growing plants which indicates that irradiation of a small stem section in some plants is almost as effective per unit dose as irradiation of the entire plant. This phenomenon seems to correspond to that observed in mammals.

To parallel the current advances in mammalian radiobiology using cell cultures, investigations using plant cell cultures will be conducted. The plant cell tissue cultures offer the advantage over animal derived cultures of demonstrating controlled differentiation through the use of chemical treatments. Thus it should be possible to study not only damage and repair of cell division but also the potential for normal differentiation into an integrated organism.

In the off-site program, investigations to characterize the radiobiology of fast neutrons, as from californium 252, will be undertaken to determine the normal tissue tolerance with respect to both early and late effects upon such organ systems as skin and hair follicles, corneal epithelium and lens of the eye, intestine, and its vasculature, bladder, and, of course, tumor tissues. Emphasis will be on defining injury, repair, recovery and residual damage at the cellular and cytogenetic level in these and other appropriate test systems under *in vivo* and *in vitro* conditions. Of particular importance will be data quantifying the effects of such modifying factors as dose, dose-rate, exposure schedules, dose distribution and oxygen tension in order to determine Relative Biological Effectiveness (RBE) and Oxygen Enhancement Ratios (OER) values for the eventual application of californium 252 to human radiotherapy.

Greater emphasis will be placed on elucidating the cellular basis for radiosensitivity between and within mammalian species. Data from studies on the dynamics of cell renewal systems will be correlated with the organism's mortality rate from acute or fractionated radiation exposures. Of interest are the basic mechanisms of the immune response in order to control the severity of the response of the acutely irradiated mammalian organism. Interest will center on characterizing the properties, responses and potentialities of the hemopoietic stem cells.

- b. Molecular and Cellular Radiobiology FY 1969: \$16,476,733 FY 1970: \$16,242,000 FY 1971: \$15,855,000

The objective of studies in this activity is to understand the physical and chemical bases of the effects of radiation on cells. The investigations carried out under this activity employ the tools and concepts of biophysics and biochemistry. They range from studies on the absorption of energy, to its transfer among various molecules and to the succeeding chemical and biological consequences.

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BIOLOGY AND MEDICINE PROGRAM - continued

Program Highlights

Changes are proposed for the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
(Costs in thousands)			
(1) Research on the responses of plants to light duration and unidirectional force of gravity, at Argonne National Laboratory.....	\$ 260	\$ 190	\$ - 70
(2) Development of techniques for the clinical analysis of body fluids in the molecular anatomy program, at Oak Ridge National Laboratory.....	247	277	+ 30
(3) Studies of the mechanism and control of sulfate reduction in plants, at Michigan State University.....	25	0	- 25

Biophysics and Photobiology

The biophysics and photobiology portions of this program seek to understand how radiation energy is absorbed and transferred in living matter. Initial excited states and subsequent chemically reactive states of molecules are studied, both in biological systems and in chemical model systems. Studies on proteins and nucleic acids and their derivatives are especially useful for explaining radiation damage and its consequences. Better understanding of the structures, energy states, and interaction of such molecules is an added benefit from these studies. Magnetic resonance methods, both for atomic nuclei and for unpaired electrons, are especially useful in working out the detailed relationships of various structural components of molecules.

Structural studies of macromolecules both by sequence analysis of chemical groups and by X-ray and neutron crystallographic analysis of three-dimensional structure are increasing in extent and in refinement through various technical advances. Automated preparation of pure materials in bulk quantity is one such advance. Important and detailed relationships are being recognized between physical structure, chemical composition, and biological function of macromolecules.

At Oak Ridge National Laboratory studies of the physical properties of synthetic and biological polymers will be added to the present chemical ones to advance the understanding of the changes in nucleic acids brought about by ultraviolet radiation. At the Laboratory of Radiobiology the means by which mammalian and human cells can repair damage brought about by ultraviolet and ionizing radiation will be studied. There will be further effort at Lawrence Radiation Laboratory, Berkeley, using new sophisticated techniques and equipment such as photoelectron spectroscopy and high resolution nuclear magnetic resonance spectroscopy for studying the structure and activity of important biological macromolecules.

Decreases in the plant radiobiology program at Argonne National Laboratory, on the responses of plants to light duration and unidirectional force of gravity, are expected because of deferral of projects which are considered to be of lesser urgency from a programmatic standpoint.

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BIOLOGY AND MEDICINE PROGRAM - continued

Advances in the techniques of pulse radiolysis and flash photolysis now permit more refined studies of the early physical and chemical events leading to radiobiological damage and more work is planned in this area. Studies of the mechanism of the protein-nucleic acid relationships and of the nature of radiation induced alterations in the structure of nucleic acids are also planned.

Biochemistry and Molecular Biology

In the biochemistry and molecular biology portions of this program the emphasis is on describing the biochemical processes of the cell and the effect of radiation on them. The cellular processes most heavily emphasized are those relating to the replication of chromosomes and to the means by which cellular processes are regulated. Studies of the mechanism of synthesis of proteins, ribonucleic acid and deoxyribonucleic acid is a major continuing effort which is basic for understanding the processes above. Many functions of a cell occur only when the appropriate macromolecules are synthesized. For example, mitosis, a particularly radiosensitive process, requires the coordinated synthesis of all three macromolecules. Changes in function are frequently accompanied by structural changes in a cell for which electron microscopy is an increasingly valuable tool.

The means by which cellular processes can be controlled is becoming an increasingly important area of investigation. For this reason the studies on transfer ribonucleic acid are being pursued not only because of the well known role of this material in protein synthesis but also because a regulation occurs of the types and amounts of transfer ribonucleic acid synthesized during growth and development. The nature and consequences of this regulation should be far reaching. For example, the extreme sensitivity of some plants to ionizing radiation makes it necessary to consider how this damage occurs and how it may be ameliorated. Work on plants in this activity is restricted to studies of their basic metabolism, especially the role of hormones in growth and development.

At Argonne National Laboratory emphasis will be placed on studies to correlate the structure of proteins with their biological activity. Chemical studies of amino acid sequence will be combined with the results of X-ray crystallography to determine the three-dimensional structure of proteins and the points of binding of molecules to proteins. Theoretical calculations of nucleic acid conformation and research on energy transfer mechanisms in biomolecules will be undertaken. Other studies on nucleic acid include work relating nucleic acid structure to biological function focussing mainly on transfer RNA's and the activity of synthetic polynucleotides in coding for proteins. Much of this is now made possible by advances in sequencing of nucleic acids carried on at Oak Ridge National Laboratory. Additional support will be given to the molecular anatomy program to support the development of new instruments and new techniques to analyze human tissues and body fluids more completely and more rapidly than has been possible before. At the Los Alamos Scientific Laboratory effort will be placed on studies to analyze the biochemical events occurring during the life cycle of the cell. At Michigan State University studies on the location of plant hormones in cells, their effect on protein synthesis and breakdown, and the isolation and characterization of the DNA synthesized in response to the presence of certain plant hormones will be continued. Studies of the mechanism and control of sulfate reduction in plants will be discontinued.

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In developmental biochemistry it is planned to look further into the effect of radiation on the biochemistry of nucleocytoplasmic interactions. Additional studies will provide an understanding of the properties of DNA as it exists as a complex in

BIOLOGY AND MEDICINE PROGRAM - continued

chromosomes; particularly needed are studies to determine how the proteins and lipids of the chromosome control the structure and regulate the activity of the DNA. Correlated with this will be studies on how the deoxyribonucleic acid of mammalian chromosomes is replicated. Other studies designed to isolate and characterize the protein components of ribosomes are also of considerable interest as are studies of the structure and activity of ribosomes. Also, investigations on how molecules synthesized at one site in the cell are subsequently transported, localized and activated elsewhere in the cell will be pursued; this type of work is needed to improve understanding of how ions and molecules move within and between cells. Finally, the origin, development and duplications of all cell organelles remain pressing problems.

c. Radiation Genetics FY 1969: \$7,658,624 FY 1970: \$7,487,000 FY 1971: \$7,280,000

Major objectives of this research are to determine the different types of genetic damage produced at the level of the chromosome, the gene, and nucleic acids, and to define the sequence of events that take place in production of damage at each of the above levels of genetic organization. From such investigations it is ultimately hoped that one can predict with reasonable accuracy the consequences of specific types of genetic damage in the individual so affected and in individuals of succeeding generations. Of equal importance is the long range objective to understand and predict the impact of specific types of genetic damage on populations and the mode and rate of elimination of the damage from the populations. Research in this activity is primarily designed to obtain an understanding of the genetic effects of radiation on man; however, experimentation with humans has definite limitations; consequently, experiments with animals, plants, and microorganisms must provide much of the basic data.

Program Highlights

Changes are proposed for the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Studies of the effects of radiation and other mutagenic agents in the production of mutant organisms, at Oak Ridge National Laboratory.....	\$ 562	\$ 587	\$ + 25
(2) Research in mammalian genetics and cytogenetics, and in mutation rate analysis, at university laboratories.....	970	1,009	• 39
(3) Studies on the genetics of root development, and the effects of radiation in plant cells, at the University of Tennessee.....	171	98	- 73

Biochemical and Developmental Genetics

Major emphasis will be placed on genetic mechanisms underlying cell division, growth, differentiation, and repair of radiation damage. Biochemical and molecular genetics provide the basis for a full understanding of normal differentiating processes, how these processes are selectively disrupted by radiation, and how the cell repairs otherwise deleterious radiation damage. Increased efforts in molecular genetics will be made for studies in identification of genes that control

BIOLOGY AND MEDICINE PROGRAM - continued

synthesis of the different RNAs and determine the structure and function of ribosomes, and the effects of radiation on genes when observed directly under the electron microscope. Also of interest are the molecular aspects of genetic repair of radiation damage and recombination mechanisms, including naturally occurring and radiation-induced breaks in DNA. Increased emphasis will be given to comparative mutagenesis in several different organisms by radiation, chemicals, and radioisotopes to better understand the mechanism of radiation damage at the chemical and molecular level. From these studies the sequential biochemical steps involved in production of normal cells, tissues, organs and individuals can be understood and the precise effects of radiation and other mutagenic agents in the production of mutant organisms can be ascertained. Major on-site programs will continue at Argonne National Laboratory, Lawrence Radiation Laboratory, Berkeley, and Oak Ridge National Laboratory.

A decrease in effort in plant studies at the University of Tennessee reflects a curtailment of that part of the program, involving studies on the genetics of root development, physiological and cytochemical effects of radiation in plant cells.

Human and Mammalian Genetics and Cytogenetics

Research is oriented to biochemical and genetic studies on the intact animal and on mammalian, human, and plant cells cultivated in vitro. Attention will be directed to programs on human somatic cell genetics, procurement of biochemical mutants of mammalian cells cultivated in vitro for radiation-induced mutation rate studies, and repair of radiation damage to mammalian and human cells. Efforts will be made, primarily in off-site programs, for genetic studies on haploid animals (amphibian) and plants and in organ transplants in embryonic development. Isolation of individual human chromosomes into separate test tubes will be sought to study the chemical properties of chromosomes, their gene products, and to detect alterations that may signal radiation-induced changes related to radiation-induced perturbations in chromosome replication in vivo. Studies to ascertain genetic polymorphism in human populations and to develop models as to how these variations arise and are maintained in the populations will be continued. The on-site programs are conducted primarily at Oak Ridge National Laboratory and the Laboratory of Radiobiology, University of California Medical Center at San Francisco.

Population Genetics and Mutation Rate Analysis

Emphasis will continue on research that provides more accurate estimates of the relationship between radiation dose and mutation rate at low doses and dose rates in mammals. This information is needed for reliable predictions of the rates of mutation induced by ionizing radiations and the mechanisms whereby the mutations become established or eliminated from a population. The effects of chronic doses of radiation and environmental factors on the production of mutations will be continued principally in on-site programs. Effort will also be made to develop critical theoretical and experimental estimates of the rate and maintenance of induced mutations in a population in successive generations. The major on-site programs are at Argonne National Laboratory and at Oak Ridge National Laboratory.

2. Assessment, Evaluation and Control of Radiation Exposure to Man and His Environment..... \$ 42,955,000
 a. Exposure to External and Internal Radiation FY 1969: \$13,297,486 FY 1970: \$13,517,000 FY 1971: \$13,765,000

The objective of this research is to assess the biological consequences of accidental exposure to external radiation sources,

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BIOLOGY AND MEDICINE PROGRAM - continued

as well as occupational exposures to various radionuclides. This research along with that in somatic, genetic and molecular radiobiology provides the basis for establishing operating procedures and exposure limits. Because of the limited number of human exposure cases, studies are conducted utilizing experimental animals with the expectation that a reasonable extrapolation to man may be made.

Program Highlights

Changes are proposed for the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Continuation of the program of the Atomic Bomb Casualty Commission, Japan.....	\$ 4,000	\$ 4,200	\$ + 200
(2) Human radium toxicity studies at Argonne National Laboratory and other locations....	543	580	+ 37
(3) Studies of the pulmonary toxicology of plutonium and other alpha emitters, at several AEC laboratories.....	2,113	2,269	+ 156
(4) Studies of thyroid exposures due to skin absorption of iodine, at Idaho Nuclear Corporation.....	27	0	- 27

Human Exposure to Radiation

The Atomic Bomb Casualty Commission continues to collect uniquely valuable data on late radiation effects in the survivors of the bombings of Hiroshima and Nagasaki. The total sample under study is approximately 120,000 people. After nearly 20 years of largely negative results (except for leukemia induction), positive findings are beginning to emerge. These include the strong suggestion of an elevated death rate among the more heavily exposed and an indication that the incidence of tumors of the breast, lung, thyroid, and stomach may be increased. The U. S. State Department, on behalf of the AEC, has approached the Government of Japan to ascertain whether Japan would be willing to discuss future operations at ABCC. Only preliminary discussions have been held. A strong effort should be made to ensure that no valuable data are being overlooked and to accelerate the evaluation of data at hand. The staff of ABCC is declining; the increase in budget reflects the increased cost of conducting research in Japan.

The research initiated as a feasibility study to determine the effects, if any, of low-level occupational radiation exposure from AEC and AEC contractor employees by the development and formulation of an automatic data processing system is progressing. With this system, retrieval of the complete work history, employment dates, job title, work locations, work changes, and radiation exposures at any point in time or for the cumulative trend for any employee or group of employees can be obtained in a matter of seconds. Once the employee populations and controls have been established, the mechanism of processing consists of matching tapes of the study group and controls against the Social Security master tapes to obtain identification of those deceased. Mortality and cause of death can then be determined for the study and control group. For the "pilot-test" studies the facilities at Richland and Oak Ridge were selected. Data from these facilities are now largely available and analysis of a portion of this information has begun.

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BIOLOGY AND MEDICINE PROGRAM - continued

The study of native populations exposed to radioactive fallout as a result of a thermonuclear test in the Bikini atoll in 1954 will continue in FY 1971. Annual medical surveys have been made to two populations of natives living in the Marshall Islands near Bikini at the time of the 1954 test. With the return of the Bikini inhabitants to their home island, whole body monitoring of each individual is planned, and it will be necessary to follow their body burdens of radionuclides on a regular basis. Brookhaven National Laboratory has been assigned this responsibility.

The studies on the toxicity of radium and mesothorium in human beings represent a valuable segment of the human radiobiology program. Studies of human beings exposed to internal radionuclides should be continued as long as useful scientific data can be developed, and the specific proposal to consolidate the Massachusetts Institute of Technology and Argonne National Laboratory studies on human radium toxicity at ANL is being implemented. There is widespread agreement that these studies have been invaluable in providing a "check-point" for animal studies and in establishing maximum acceptable doses of certain radionuclides.

A fairly constant death rate of 15-20 subjects per year is anticipated. Deaths can be expected until the turn of the century. By the year 1990, more than 100 of the present study group will probably still be alive and perhaps 40 or so will survive until the year 2000. The names and locations of more than 1000 radium-contaminated people are known. Of these, 70 percent are alive. About 85 percent of the living and 20 percent of the deceased individuals have been studied at least once by physicists and physicians at MIT, ANL-ACRD, or the New Jersey State Department of Health.

Additional emphasis has been given to the exposure of humans to plutonium and radon progeny. It is possible that studies which will attempt to develop a lung tumor registry and an atlas of sputum cytology and to establish temporal changes in sputum samples obtained from uranium miners will require expansion or complementary emphasis. Because attempts are being made to relate the human studies to animal experiments now in progress, additional work may be required at this important interface. Also, the recently established plutonium registry will continue to meet the needs for record gathering, data reduction and data analysis increase.

Inhalation Studies

An increase at Pacific Northwest Laboratory is associated with the recently established plutonium pulmonary radiotoxicology studies for both plutonium 238 and plutonium 239 in beagles. This work will be directed towards establishing the dose-response curve for tumor formation and reduction in life span at low exposure levels. The lowest exposure level will be comparable with the human maximum permissible lung burden level. Exposures will begin on 120 animals which were produced by the breeding colony during FY 1970. A second breeding cycle during FY 1971 will produce the second group of experimental animals.

The basic inhalation program and the biological studies of uranium miners will also be continued. In the latter, radon daughter inhalation studies using hamsters and dogs and including one additional mine contaminant such as uranium ore-dust, diesel exhaust fumes or tobacco smoke are of interest. This work is extremely important for several reasons: (1) the relative importance of mine-air contaminants as related to lung tumor development in man has not been resolved, (2) these studies will be integrated with the exfoliative cytology study being conducted on uranium miners.

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BIOLOGY AND MEDICINE PROGRAM - continued

At the Lovelace Foundation an increase is required to develop a capability for inhalation toxicology of alpha emitters. Experiments on plutonium and other transuranics will be added to Lovelace's continuing experiment. Most of the increase will be in the departments of aerosol physics, radiobiology, and veterinary medicine.

A program has been initiated at Los Alamos Scientific Laboratory to assess the tumorigenicity of highly radioactive particles in the lungs of rodents. The experiments are planned in such a way that the most important variables such as effects of dose, dose-rate and number of cells at risk can be evaluated. The results of this work should generate a general model for estimating potential hazard for locally deposited radioactive materials.

Additional information is required on the potential hazards related to inhalation of radon and its progeny by uranium miners. The important parameters include: (1) the nature of the aerosol, (2) the relative importance of the short and long-lived progeny in their free, attached or particulate state, (3) physiological parameters such as deposition, retention, excretion, translocation and biologic effects, and (4) the development and evaluation of various protective measures and devices.

The importance of both size and numbers of radioactive particulates as compared with only a consideration of total activity has been established as regards exposure of humans to radioactive debris arising from reactor accidents, space nuclear systems, plutonium from processing, production or weapons, and nuclear propulsion systems. It may be necessary to augment programs relating to metabolism and toxicity of specific physicochemical forms of radionuclides as problem areas are identified. It is expected that both experimental and theoretical approaches will be employed.

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Other Routes of Exposure

At the University of Utah studies on the chronic toxicity of internally deposited radionuclides will continue with no major change. At the University of California, Davis, the treatment phase of the research has been completed with subsequent transfer of animals to outside kennels. A corollary study using x-rays from a cobalt 60 source to determine the relative effect of whole-body irradiation as compared with bone seeking radionuclides has been initiated.

At Argonne National Laboratory important information has been obtained for assessing recovery kinetics in dogs. This is the first experiment in which external, whole-body exposures have been made on a long-lived species, with medium and low dose radiation given daily over the animal's life span. There is a dramatic decrease in effectiveness of gamma radiation at dose below 17 rads per day. Many of the animals have survived more than a year of this exposure regimen, and show good recovery of hematopoietic function. Similar results have been obtained on rats by the British.

Research at Brookhaven National Laboratory includes work on the toxicity of new radiopharmaceutical agents for diagnostic and investigative purposes. An example is the development of new carbon 11 containing radiopharmaceuticals. This combination of expertise in chemistry and medical science uniquely qualifies BNL to exploit the obviously great potential of carbon 11 in diagnostic nuclear medicine.

Studies at the Lawrence Radiation Laboratory, Berkeley, to characterize the physiological mechanisms of accumulation,

BIOLOGY AND MEDICINE PROGRAM - continued

translocation, retention and elimination of transuranic elements like americium, californium, plutonium, and some other bone-seeking radioisotopes will continue with the hope of initiating complimentary human studies.

Because of the increased use of radionuclides in nuclear medicine, especially the short-lived varieties, research projects will be initiated to establish specific organ and body kinetics for radionuclides to be used in both diagnostic and therapeutic purposes. Studies of the exposure of the thyroid to iodine following skin absorption will be brought to completion.

b. Combating Detrimental Effects of Radiation FY 1969: \$1,861,013 FY 1970: \$1,842,000 FY 1971: \$1,815,000

The objectives of this research are to combat or alleviate radiation damage to the whole organism or the cells that make up their organs or tissues, either by (1) treatment with nontoxic chemical agents before exposure (protection), or (2) replenishment of radiation depleted stem-cell pools (recovery). Such replenishment is accomplished by stimulating normal cell proliferation or by cell transplantation. A small, continuing part of this program is a search for methods that reduce long-term deposition of hazardous radionuclides either by reducing the amount deposited, or by mobilization and excretion of already deposited elements.

Program Highlights

The level of scientific effort for this research is being decreased. Important studies in radiation immunology and in pulmonary lavage techniques will be emphasized.

The program at Oak Ridge National Laboratory to assess loss of immunocompetent cells as a factor in aging and diseases of old age is a major project of the radiation immunology group. This important program has as its ultimate aim the development of a therapy against a number of human diseases of old age, by transfusion of highly immunocompetent cells from genetically matched juvenile donors.

In another important area involving protection against radiation damage there are suggestions that some protective chemicals already available may protect one type of tissue more than another. This finding indicates that it might be possible to improve radiotherapy by protecting normal tissues that would ordinarily be in the radiation field, but which the therapist does not want to damage. A small effort is planned, probably at the Oak Ridge National Laboratory, to test this possibility.

It has been known for several years that mice irradiated with lethal and supralethal doses of x-rays can be rescued by transplantation of exogenous bone marrow cells. The number of cells required for maximal survival can be assayed quantitatively. It is also known that radiation of bone marrow *in vitro* will destroy the recovery promoting activity and that chemical agents will protect the cells from such inactivation. This principle is now in use at the Oak Ridge National Laboratory as part of a rapid and inexpensive assay for chemical protectants.

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BIOLOGY AND MEDICINE PROGRAM - continued

A project initiated in FY 1970 at the Lovelace Foundation to develop procedures for reducing the lung and body burden of inhaled radionuclides will be continued. Preliminary studies in this area indicate success in achieving a marked reduction in the lung burden of inhaled radionuclides through the use of a pulmonary lavage technique.

It is anticipated that off-site research will produce usable antilymphocyte sera and methods to induce immune-tolerance in adult animals. An effort is anticipated also in isolating and characterizing lymphocyte cell types in bone marrow and circulating blood. During the past year, several successful bone marrow transplants in humans have indicated the potential of this clinical technique for treatment of immunologically deficient diseases and of life threatening hematological depression in persons exposed to high doses of irradiation, either accidentally or therapeutically. Increased emphasis will be directed toward those studies which will complement the planned on-site program in cancer therapy using bone marrow transplantation. Continuing emphasis will be directed toward studying methods for preservation of human blood platelets and white blood cells.

Emphasis will be given to developing methods for the mobilization, complexing and accelerated excretion of undesired radionuclides.

c. Chemical Toxicity FY 1969: \$596,398 FY 1970: \$615,000 FY 1971: \$610,000

In this activity studies are carried out on the chemical toxicity of a number of non-radioactive elements and compounds as well as some radionuclides for which the chemical toxicity constitutes their greatest hazard. Results of these studies permit anticipation of the toxic effects of suspect materials introduced into the atomic energy industry and provides the basis for therapy of workers accidentally exposed to chemical agents.

Program Highlights

Although this is an important area of research, the level of scientific effort must be decreased.

At the University of Rochester efforts will be continued with emphasis on defining how the cell membrane functions, the biochemistry of heavy metal poisoning and the basis for behavioral changes in animals due to toxicity of various agents.

The increased usage of toxic materials such as beryllium in the AEC program will require continuation of chemical toxicity research.

d. Land and Fresh Water Environmental Sciences ... FY 1969: \$9,613,774 FY 1970: \$9,653,000 FY 1971: \$9,570,000

Objective of this research is to develop understanding of the influences and importance of radiation and other stresses from the nuclear energy industry upon interrelated land and fresh-water environments. The investigations involve biological assemblages such as forests, grasslands, deserts, and the tundra; biological processes such as behavior, food production,

BIOLOGY AND MEDICINE PROGRAM - continued

food webs, succession, migration and reproduction; the phenomena of population structure, fluctuations and periodicities; and the persistence of community organization. Studies include the development and application of procedures for sampling and measuring radioactivity in soil, foods and man for the purpose of improving methods of predicting the fate of radioactive contaminants introduced into the atmosphere and biosphere.

Program Highlights

Changes are proposed in the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Evaluation of the effects of thermal alterations of the fresh-water environment.....	\$ 488	\$ 815	\$ + 327
(2) Terrestrial ecology studies at University of California, Los Angeles.....	923	835	- 88
(3) Reduction of the biomedical documentation program, at Lawrence Radiation Laboratory, Livermore.....	2,910	2,634	- 276

Terrestrial and Fresh-Water Ecology

Considerable development of both continuing programs and those inaugurated in FY 1970 is anticipated, especially in the area of thermal effects on biological systems at the community level of organization. At Argonne National Laboratory new ecological studies are projected at the Dresden and Waukegan plants. An increase is also planned for the studies on the radiological status of Lake Michigan. Increases at Savannah River are associated with new laboratory thermal studies initiated in 1970. At Oak Ridge National Laboratory increases are for radionuclide cycling and biogeochemical research, a strongly programmatic activity. A new thermal study will be continued at Oak Ridge in FY 1971. Increases at the Pacific Northwest Laboratory are associated with studies of Columbia River ecosystems.

A reduction of radiation ecology studies at the University of California, Los Angeles, reflects changes in staff. Ecological research at the Nevada Test Site is being coordinated with related projects of other laboratories.

Proposals for new off-site research are being reviewed at present for projects on Lake Champlain (University of Vermont), Lake Cayuga (Cornell University), Gull Lake (Michigan State), and others.

Radionuclide Transport

The biomedical program of the Lawrence Radiation Laboratory, Livermore, will continue at a level of effort appropriate for documentation of previous Plowshare cratering events. The program has a direct influence on nuclear device development and test planning in both the Weapons and Plowshare programs and has many applications in other areas of nuclear technology. It deals with the prediction of fission product and induced radionuclide production in device and environmental materials, the documentation of the chemical and physical forms of the radionuclides, the effects produced by their uptake, and possible means of reducing human exposure by countermeasures at any step in the above sequence.

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Analysis and study of stable alkaline earths and naturally occurring radionuclides in the diet and in bone will be performed at the Health and Safety Laboratory. Studies to develop new techniques for the analysis of samples will be pursued.

Studies of tritium in the soil, food, and man pathway will be initiated, and an effort will also be conducted to assess the biological problems that may exist in the future from krypton 85.

e. Marine Sciences FY 1969: \$3,899,199 FY 1970: \$3,950,000 FY 1971: \$3,895,000

The objectives of this activity are to provide a basis to predict the fate and possible effects of radioactivity introduced into the marine environment as a result of nuclear energy operations. Research is conducted in biological, chemical, geological and physical oceanography and is directed toward learning the effects of biological activity, sedimentation and physical-chemical processes on the dispersion and accumulation of radionuclides.

Program Highlights

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
An increase is proposed for studies of the effects of thermal alteration of the marine environment.....	\$ 179	\$ 250	\$ + 71

There is little on-site research in this activity but a program initiated in FY 1970 at Pacific Northwest Laboratory on geochemical ocean cycling will be continued. The Marine Biology Program at the Puerto Rico Nuclear Center, having input to the problems of Plowshare experiments and reactor siting, will place greater emphasis on measuring the distribution patterns and movements of trace elements in tropical waters.

Most of the increases in the off-site program are related to the effects of thermal alteration of the marine environment. Expansion of the Biscayne Bay studies by the University of Miami will be minimal but new projects related to reactor siting on coastlines are projected. Negotiations are now going on with the University of Maryland, University of the State of New York (Stoneybrook), and Scripps Institute of Oceanography. Other proposals are anticipated. It is possible that beneficial uses may be found for thermal wastes. For example, upwelling may be induced in the ocean to bring nutrients into surface waters and thus increase productivity.

f. Atmospheric Sciences FY 1969: \$4,473,197 FY 1970: \$4,967,000 FY 1971: \$4,900,000

Objectives of this activity are to obtain information on transport and deposition processes in the atmosphere, research on the nature and behavior of natural and artificial aerosols in the atmosphere, development and application of procedures for sampling and measuring radioactivity in air, dust and precipitation, and development and improvement of methods of

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predicting the radiation dose to man resulting from the release of radioactive contaminants into the atmosphere from past and possible future nuclear explosion or nuclear reactors for power or propulsion.

Program Highlights

Changes are proposed in the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Evaluation of the effects of waste heat disposal on the atmosphere.....	\$ 21	\$ 146	\$ + 125
(2) Studies related to atmospheric distribution of nuclear debris from specific nuclear events, at Lawrence Radiation Laboratory, Livermore.....	540	436	- 104
(3) Extension of the atmospheric monitoring program to continue inventory of strontium 90, plutonium 238 and other radionuclides.....	1,200	1,300	+ 100

Research at Argonne National Laboratory includes the precipitation scavenging field work, wherein tracers are introduced into thunderstorms and recovered in the rain. The data will be used to predict the cleansing of the air of fallout, including that radioactivity from cratering events. This experiment, now conducted in Illinois, in cooperation with the Illinois State Water Survey and the University of Michigan, will be moved to Colorado to take advantage of the measurements on clouds made there as a part of the Northeastern Colorado Hail Experiment, and at the same time contribute to understanding the cloud dynamics and nuclei budgets of hailstorms.

The ANL program also includes a joint HEW-AEC air pollution project, plume rise studies, micrometeorological and turbulence modeling in wind tunnels.

A research program will be initiated in the Northeast on the effects of water added to the atmosphere by waste heat disposal. A slight increase is requested for the Atmospheric Turbulence Diffusion Laboratory at Oak Ridge to continue application of the Light Detection and Ranging (LIDAR) to studies of plumes from stacks, cooling towers, and possible verticle line sources.

The Controlled Environmental Release Test (CERT) facility at the National Reactor Testing Station in Idaho will continue to be used for the study of radionuclide entry from the atmosphere to the food chain, but with attention to tritium and less emphasis on radioiodine. The new recirculating tunnel will allow laboratory studies of deposition on a variety of plants and surfaces. Improved atmospheric tracers will be sought.

The major activities supported in the Health and Safety Laboratory will be continued. These are the collection of environmental samples of fission and activation radioactivity, sample analysis, reporting and interpretation of analytical data. The fallout sampling networks are also used in the study of naturally occurring radioactivity. The Laboratory's high

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altitude test chamber is utilized in evaluating sampling equipment for the upper atmosphere sampling program and for studies of stratospheric aerosols. The development and maintenance of equipment for laboratory measurement and sample collection related to these activities is also supported.

Ongoing work in precipitation scavenging, fallout phenomenology, radiochemistry and aerosol studies at Pacific Northwest Laboratory will remain near the same level of effort. The real time capability of diffusion experiments in the field using krypton 85 as a tracer will be exploited. This tracer will provide instantaneous measurements of air concentrations for correlation with rapid response meteorological equipment, permitting verification of theories on diffusion and new insight into diffusive and deposition processes. This inert gas will be compared to depositing particulate tracers.

The atmospheric sciences program at Lawrence Radiation Laboratory, Livermore, will continue to support the Plowshare events as necessary.

Off-site precipitation studies will be directed to: (1) application of unique AEC-developed sensitive tracer techniques to the national problem of hail suppression. New knowledge of washout processes will be gained at the same time; (2) measurement of the scavenging of the pollution aerosol over cities in anticipation of a need for these data in reactor hazards analysis; and (3) the creation and deposition of extra ice, rain, snow, and fog in the vicinity of waste heat disposal sites, such as cooling towers.

Research in atmospheric transport and diffusion will be supported to: (1) allow the development of global fallout prediction models, used for debris from atmospheric weapons testing and SNAP reentry, which will utilize more recent knowledge of the atmosphere's circulation - only AEC supports such model development; (2) develop airborne turbulence equipment which can provide real time readout of the parameters needed in rapid prediction of cloud concentrations over inaccessible areas in advance of Plowshare events - this will provide inputs to prediction models under current development; (3) conduct theoretical and commence field studies of the diffusion of vertical line cloud sources, such as originate from SNAP accidents and nuclear rockets; (4) commence field studies in cities and building complexes to provide data essential to analysis of hazards of reactor siting in cities - these studies would include diffusion, deposition, reentrainment, and translocation of particles and gases, and would contribute to solution of the national air pollution problem as well; and (5) allow for participation in the planned inter-agency mesometeorological experiment (MESOMEX) by utilizing AEC-developed measurement and tracer techniques in diffusion experiments over the MESOMEX network, while simultaneously using the extensive and costly measurements provided by other agencies. It has not been possible to launch diffusion experiments to such heights in the planetary boundary layer before, but the data on these larger scales are required because potential radioactivity sources are now achieving greater heights in the boundary layer.

An increase in the upper air sampling program is required to purchase balloons as current stock is exhausted. The number of high altitude balloon flights was reduced in FY 1970 to the minimum needed to maintain flight proficiency and to keep launch teams intact - a commitment to the Federal Council for Science and Technology. The budget also provides for semiannual

BIOLOGY AND MEDICINE PROGRAM - continued

Airstream flight extensions to 67° South latitude to continue the inventory as French debris moves southward. This extension consumes much of the savings effected when the high altitude balloon flight frequency was reduced.

g. Nuclear Energy Civil Effects FY 1969: \$1,153,209 FY 1970: \$1,180,000 FY 1971: \$1,190,000

Objectives for this activity are to develop nuclear effects data through laboratory and field experiments and theoretical studies. Results contribute to the meeting of needs for weapons effects and countermeasures information for practical applications to non-military defense, emergency preparedness planning, and for use within the complex of nuclear energy activities.

Program Highlights

Emphasis will be on completion of a revision of the handbook Effects of Nuclear Weapons.

At the Nevada Test Site, support will be provided by REECO and Holmes and Narver consistent with the level of research operations of civil effects test projects by EG&G, Inc., ORNL, and investigators receiving Environmental Sciences Program support. Edgerton, Germeshausen and Grier will conduct field experiments with the neutron source, provide support for environmental sciences field studies, and conduct other nuclear energy research.

Oak Ridge National Laboratory will continue its research and development on radiation dosimetry for human survivors for correlation with the ABCC biomedical program and for other heavy radiation exposure cases. Support for the ORNL Civil Defense Research Project will reflect the implications resulting from progression of the anti-ballistic missile program, and the consequence of decisions arising from a study of civil defense for the United States.

The Lovelace Foundation will conduct nuclear effects studies essential to the completion of a satisfactory revision of the Effects of Nuclear Weapons and the completion of work on a revised Nuclear Bomb Effects Computer compatible with data in the revised ENW. This latter effort is being performed by the editor of the previous editions of ENW, in collaboration with the Stanford Research Institute.

h. Radiological and Health Physics and Instrumentation ... FY 1969: \$7,373,157 FY 1970: \$7,299,000 FY 1971: \$7,210,000

The objectives of this program are to achieve a comprehensive description of fundamental radiation interaction processes and of the spatial and temporal distribution of radiation produced products in order that a more complete understanding of radiation effects may be accomplished; to develop dosimetry techniques and to assess radiation exposure situations in order to develop information requisite to the formulation and establishment of improved radiation protection practices; and to conduct instrumentation research leading to improved radiation detection and measurement techniques, and develop specialized instrumentation systems required in other biomedical research programs.

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Program Highlights

Changes are proposed for the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Research and development for the biomedical synchrotron ring, at Lawrence Radiation Laboratory, Berkeley.....	\$ 25	\$ 50	\$ + 25
(2) Instrumentation for <u>in vivo</u> determination of insoluble plutonium, at Idaho Operations Office.....	25	0	- 25

Radiological Physics

Significant progress has been made at Oak Ridge National Laboratory in developing techniques to study fundamental radiation interaction mechanisms in liquids. It is now important that this study proceed beyond the feasibility level. An increase at ORNL will enable return of a scientist from the University of Kentucky to continue investigations of heavy ion interactions in gases with a specific orientation toward dosimetry, which will be achieved in most part by transfer of funds from the off-site contract. Exceptional progress has been made in the establishment of a strong radiological physics and dosimetry program at Pacific Northwest Laboratory and studies of low energy heavy ion interaction processes will be continued. At Lawrence Radiation Laboratory, Berkeley, there will be an orderly development of the program investigating high energy, heavy ion stopping.

Emphasis in the off-site program will be directed toward theoretical studies of low energy electron interactions. This area is not well understood theoretically, yet low energy electrons have a predominant role in the energy deposition process. In addition, some effort is anticipated in experimental studies of the spatial distribution of energy radially away from heavy ion tracks. These new program directions will be achieved by project reductions in the area of radiation interaction in gases, and completion of a study of electron energy loss distributions in semiconductor detectors. Remaining programs involving theoretical and experimental investigations of radiation interactions in solids, energy degradation and migration in condensed systems, and energy deposition distributions on the microscopic scale will continue at the current level of effort.

Health Physics

The neutron dosimetry effort at Oak Ridge National Laboratory involving dosimeter development, evaluation and intercomparison has established this group as one of the leading neutron dosimetry research centers in the world. This group is now providing a valuable service as an important information source in this area. There will be a decrease in the overall program investigating the neutron component of cosmic radiation. Other programs dealing with accelerator dosimetry and shielding calculational techniques, aerosol research, neutron and gamma dosimetry, and in vivo dose estimation for medical and health physics radionuclides is expected to continue at the current level of effort.

BIOLOGY AND MEDICINE PROGRAM - continued

Instrumentation

In anticipation of continued development of the biomedical synchrotron ring facility at Lawrence Radiation Laboratory, Berkeley, a minimum research and development effort is planned. Design studies will be directed toward beam handling and extraction systems, and beam monitoring equipment of improved sensitivities. Continued effort in biomedical engineering is anticipated at Oak Ridge National Laboratory. The prototype neutron diffraction instrument has been successfully completed and has reduced measurement times by three orders of magnitude. The Laboratory hopes to construct a system suitable for initial trials with biological molecules. In addition, plans are under development for the consolidation and intensification of research activities in overall biomedical engineering areas. This will be accompanied by redirection of the current program in nuclear medicine instrumentation. Efforts are also planned for the development and application of detection systems capable of in vivo localization of internal emitters primarily in the off-site program.

Several programs, in addition to the neutron diffraction effort mentioned above, have produced noteworthy accomplishments during the past year. A phosphor of significantly increased detection efficiency has been developed, and future work will be directed toward the development of an improved phosphor screen and its incorporation into a clinically usable image intensifier tube. A germanium research program investigating methods of making ultrapure material has yielded very promising results. Detectors have been fabricated which no longer require shipping and storage at liquid nitrogen temperatures.

Instrumentation to measure radon daughter concentrations in mine air has been developed and evaluated in the laboratory. Field evaluations are presently underway. Uranium mine personnel dosimeters have been developed and are presently undergoing laboratory evaluation.

Much of the new program effort will be accomplished by redirection and completion of work underway. The development of an in vivo plutonium detection system at Idaho is expected to be completed during FY 1971. A dosimeter research effort at the University of Rochester has proceeded through the development phase and will now become associated with specific radiobiological investigations. In addition, the program in scintillator research will undergo some reduction, and the effort directed toward development of improved methods for complex gamma ray spectra analysis will be successfully completed. Remaining programs in semiconductor detector research, nuclear medicine instrumentation, electron microscopy, dosimetry, low level detection technology, photomultiplier and image intensifier tube research are expected to continue at the present level of effort.

3. Beneficial Applications of Radiation \$10,265,000
 a. Cancer and Other Clinical Research FY 1969: \$7,273,980 FY 1970: \$7,548,000 FY 1971: \$7,390,000

Research objectives are to discover, develop, and perfect new and unique applications of radiation and radioisotopes for the diagnosis and treatment of cancer and other disease states.

BIOLOGY AND MEDICINE PROGRAM - continued

Program Highlights

Changes are proposed for the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
	(Costs in thousands)		
(1) Clinical research using the newly available short-lived isotopes	\$ 356	\$ 393	\$ + 37
(2) Total-body irradiation in cancer therapy, at Oak Ridge Associated Universities.....	457	500	+ 43
(3) Studies of genetic and environmental factors in clinical and experimental hypertension, at Brookhaven National Laboratory.....	330	265	- 65
(4) Research on human physiology and experimental medicine at Lawrence Radiation Laboratory, Berkeley.....	295	231	- 64

The nuclear medicine program at the Argonne Cancer Research Hospital will primarily involve development of the cyclotron project plus increased effort in related activities (e.g., organ scanning with cyclotron-produced radionuclides). In addition, a slight increase in effort is planned for work related to the use of high intensity radiation in cancer therapy. Offsetting decreases in other research efforts at ACRH are planned. A continuing problem in the clinical program is the escalating cost of hospital operation.

At Brookhaven National Laboratory, the study of trace elements in biological systems will continue, including the exploitation of recent findings relative to the usefulness of L-dopa in the clinical management of Parkinsonism and other neurological disorders. Included in the projected program are plans for the use of carbon 11 labeling to study the distribution of L-dopa and dopamine in the human brain. Clinical and laboratory studies with californium 252 are also planned. BNL is one of several laboratories currently evaluating the usefulness of this neutron-emitting isotope in cancer brachytherapy. Small decreases in levels of activity are expected for two projects, namely, those concerned with the study of (1) clinical and experimental hypertension, and (2) clinical aspects of vitamin B₁₂, iron, and pancreatic insufficiency.

Research at the University of California, Los Angeles, is being expanded with the completion of the installation of a bio-medical cyclotron. This accelerator will become operational by the beginning of FY 1971 and is expected to produce a number of short-lived radioisotopes which may have medical clinical applications.

Investigations on the direct and indirect effects of heavy particle irradiation for tumor therapy, pituitary gland ablation in endocrine and metabolic diseases and induction of discrete brain and thalamic lesions for control of kinetic disease will be conducted at the Lawrence Radiation Laboratory, Berkeley, using a new human exposure system. The level of effort will remain the same as at present. Patient care costs account for some increase in budget. Research efforts will revolve around studies on human physiology and experimental medicine, but at a reduced level. Investigations concerning the hematologic and cytologic response to radiation from internally administered radioisotopes, control mechanisms of hematopoiesis and iron metabolism will continue.

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BIOLOGY AND MEDICINE PROGRAM - continued

The small project at the Pacific Northwest Laboratory for the development of beta sources for potential application in clinical organ transplantation will be continued.

At the University of Rochester, studies on exploiting tissue specific antigens for cancer therapy may reach the point of application for treating human cancers and possibly be extended for use in diagnosing myocardial infarcts. Until major successes are evident, the level of activity will plateau.

Planning is underway for the development of radioisotopically powered artificial circulatory support systems. Such devices will result in a low-level radiation exposure and thermal heat lead to the patient. Experiments have been initiated at Cornell University to assess the local tissue response and systemic effects in animals that might occur from such a radiation exposure. Further support is anticipated as the program advances to the stage of implantation into large subhuman primates of devices having the heat and radiation characteristics of the proposed engine.

Off-site studies in developing suitable gamma emitting analogs of biologically active compounds for new diagnostic procedures will be encouraged. The characteristics of these radiopharmaceuticals will be responsive to the majority of scanning procedures performed in medical institutions where the use of the short-lived isotopes are not economically feasible. This work would complement the on-site studies dealing with cyclotron and generator produced isotopes.

Other novel diagnostic and forensic procedures will continue to be explored such as fluorescent excitation of *in vivo* stable isotopes and *in vitro* activation analysis, both of which procedures markedly reduce or eliminate the radiation absorbed dose.

Investigations using radionuclides to increase both the understanding of and accessibility to the physiology of lung ventilation and perfusion, and brain tissue blood flow are expected to continue. The lung studies in addition to their broad clinical contributions are also pertinent to the AEC nuclide inhalation studies. In this same general area the use of *in vivo* activation analyses of skeletal tissues in normal, aging, and disease states including cancer in its early developmental stages, shows promise and indicates foreseeable additions to the current studies which are closely related to on-site investigations.

b. Biological and Agricultural Research FY 1969: \$2,789,257 FY 1970: \$2,830,000 FY 1971: \$2,745,000

The objective of this research is to develop and exploit new ideas and techniques involving radiation and radioisotopes to be applied in solving biological and agricultural problems. Examples of such applications are basic studies of organs and systems in health and disease and the use of radiation in the advancement of agriculture to control and eliminate insects and plant diseases and to improve crop and animal productivity.

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BIOLOGY AND MEDICINE PROGRAM - continued

Program Highlights

Changes are proposed in the following program areas:

	Estimate FY 1970	Estimate FY 1971	Increase or Decrease
(Costs in thousands)			
(1) Toxicity of carbon 13 for diagnostic applications, and its use for studies with nuclear resonance spectrometers, at Los Alamos Scientific Laboratory.....	\$ 135	\$ 163	\$ + 28
(2) Reduction of research in lipid metabolism, at Oak Ridge Associated Universities.....	243	153	- 90

Interest in the special biological and medical advantages of carbon 13 is now well demonstrated by support of a significant facility for production of the isotope in highly enriched forms. Carbon 13 will be available in sufficient quantity for study of any possible toxicity in higher organisms, for synthesis into organic compounds important and useful for biology and medicine, and for nuclear magnetic resonance study of carbon-labeled compounds.

Studies of protein synthesis will be emphasized at the Argonne Cancer Research Hospital. This important research underlies much of the clinical work at ACRH. Research in carbohydrate metabolism at Brookhaven National Laboratory and of lipid metabolism at Oak Ridge Associated Universities will also be continued, although the latter work will be substantially reduced.

Radiation and radioisotopes have provided a new dimension in the diagnosis and treatment of human disease. Such an application to agriculture and veterinary medicine has not received a similar emphasis. With the reduced cost of radioisotopes and labeled-compounds, an advancement in veterinary nuclear medicine would now appear feasible. Support is planned for the development of techniques and their application in the treatment of economically-important animal diseases.

Conventional methods for the development of vaccines for use against parasitic infections have been uniformly unsuccessful. A new technique, that of radiation-attenuation of parasites, has proven successful in the development of vaccines against the lungworm of cattle and sheep. Radiation of the parasite induces a loss in virulence without destroying its vitality and ability of elicit an immunological response. Basic studies of host-parasite relationships and the radiobiology of parasites are proposed to make full exploit of this technique possible.

The increased contamination of the environment with insecticides and pesticides is of justifiable concern. It is anticipated that basic studies of the metabolism and degradation of these materials and the mechanisms of insecticide resistance by use of radioisotope techniques will be continued.

The possibilities of using plant tissue cultures derived from irradiated meristems for producing new improved stocks of crop plants will be investigated. Another potential source of new combinations of germ plasma involves the growth of two different plant types in cell culture followed by somatic fusion of the different cell types. The new hybrid species may then be

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induced to form new plants by treatment with appropriate chemicals. These possibilities will be investigated further.

A small program to investigate the reported effects of low radiation doses on seeds and tubers in increasing crop yields is planned.

The further use of radiation for the control of insect pests will be studied with emphasis on development of new techniques and concepts.

c. Radiation Preservation of Foods FY 1969: \$329,556 FY 1970: \$170,000 FY 1971: \$130,000

The objectives of this program are to determine the basic chemical changes, nutritional adequacy, wholesomeness, and microbiological safety of selected perishable foods which have been subjected to low-dose (below 1 Mrad) irradiation for the purpose(s) of storage-life expansion, disinfection and/or control of pathogenic microorganisms (e.g., Salmonellae). Studies in this activity are required, directly or indirectly, to fulfill Food and Drug Administration requirements pertaining to approval of such low-dose irradiated foods for public consumption.

Program Highlights

The program will be directed to the microbiology of irradiated haddock or cod.

The Division of Biology and Medicine's portion of the food irradiation program consists of three general areas, viz., food chemistry, microbiology and wholesomeness.

Food Chemistry includes those studies concerned with the effects of radiation on naturally occurring tissue substrates and with the characterization of the changes (quantitative and qualitative) in terms of chemical, biochemical, and physiological parameters. No new studies are planned in this area for FY 1971.

Microbiology includes those studies concerned with the effect of radiation on the naturally occurring microbiological flora of foods of interest to the program. Microorganisms of interest include both those of public health significance (Clostridia, Salmonellae, Staphylococci, Streptococci, certain viruses, etc.) as well as those which are entirely of economic (spoilage) significance. Studies are also conducted to explore the ecological relationships existing between the two groups and to determine the effect of irradiation on these relationships.

Wholesomeness includes those studies conducted relative to nutritive value, possible carcinogenicity, and possible toxicity of low dose irradiated foods. These studies consist primarily of long-term toxicity studies conducted in accordance with FDA-approved protocols and involving two-year feeding studies on three species of laboratory animals. If the microbiological studies in progress conclude that Clostridium botulinum will not be a hazard during the storage of irradiated fish, long-term animal feeding studies of irradiated haddock may be initiated in FY 1971. Complementary investigations to evaluate mutagenicity may also be started. Data from these studies are necessary to support a petition for FDA clearance of irradiated finfish for human consumption. A companion program to determine radiation processing parameters, storage-life extension, and organoleptic acceptability and to develop suitable radiation source facilities for irradiation of foods is budgeted in the Isotopes Development Program.

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U. S. ATOMIC ENERGY COMMISSION
 FY 1971 Budget Estimates
 Appropriation - Plant and Capital Equipment

BIOLOGY AND MEDICINE PROGRAM - PLANT AND CAPITAL EQUIPMENT OBLIGATIONS

PROGRAM STATEMENT

	Actual FY 1969	Estimate FY 1970	Estimate FY 1971
A - Obligations for Construction Projects	\$ 5,760,735	\$ 990,000	\$1,000,000
B - Obligations for Capital Equipment Not Related to Construction	6,390,738	4,795,000	5,500,000
Total Obligations for Plant and Capital Equipment	<u>\$12,151,473</u>	<u>\$5,785,000</u>	<u>\$6,500,000</u>

Obligations for the Biology and Medicine Program for FY 1971 are estimated at \$6,500,000 of which:

- \$1,000,000 is for the construction projects listed in Section A below, requested for authorization in the proposed FY 1971 Authorization Act.
- \$5,500,000 is for Capital Equipment Not Related to Construction justified in Section B below, requested for authorization in the proposed FY 1971 Authorization Act.

Section A - Obligations for Construction Projects:

The project comprising Section A, which is requested for authorization in FY 1971 is:

Project No.	Title	Total Estimated Cost	Funded Thru FY 1970	Estimated Obligations FY 1971	Funding Required After FY 1971 to Complete Project
71-5	General plant projects	\$1,000,000	\$ 0	\$1,000,000	\$ 0
	Total	<u>\$1,000,000</u>		<u>\$1,000,000</u>	

EXPLANATION OF PROJECTS IN SECTION A

- Project 71-5 General plant projects \$1,000,000
 The purpose of this project is to provide for miscellaneous alterations, improvements and minor additions to research facilities of the biomedical research program necessary to improve efficiency of operation, correct actual or potential operating hazards and facilitate advances in research. The estimate, based on past experience, will cover the necessary improvements at Atomic Energy Commission operated laboratories in the life sciences, as well as minor construction or alterations required by biology and medicine research contracts at universities and other research institutions. A tentative breakdown of the estimate by office is as follows:

BIOLOGY AND MEDICINE PROGRAM - continued

Albuquerque Operations Office..	\$ 152,000
Chicago Operations Office	100,000
New York Operations Office	140,000
Oak Ridge Operations Office ...	270,000
San Francisco Operations Office	175,000
Washington Headquarters	163,000
Total	<u>\$1,000,000</u>

Section B - Obligations for Capital Equipment Not Related to Construction:

	Actual FY 1969	Estimate FY 1970	Estimate FY 1971
Total Biology and Medicine Capital Equipment Not Related to Construction	\$6,390,738	\$4,795,000	\$5,500,000

JUSTIFICATION

This budget of \$5,500,000 for capital equipment not related to construction is considered the minimum amount to support the biomedical research program. Capital equipment continues to be an integral part of a dynamic biomedical research program and must be provided on a current basis to assure that the best possible information will result from scientific investigations.

With the evolution of the program into areas which are more sophisticated and complex, the utilization of advanced automated and unfortunately more expensive equipment is essential. Furthermore, the replacement of equipment items now in use in the laboratories which have reached the obsolescent stage is becoming increasingly expensive.

Examples of costly analytical equipment which are becoming more common to modern biomedical laboratories are spectrometers, electron microscopes of increasing resolution, high speed centrifuges and computer linked equipment. The increasing shortage of manpower is increasing the demand for additional unique equipment.

The FY 1971 capital equipment budget does not contain any single item exceeding a cost of \$500,000, but a representative listing of equipment requirements follows.

Equipment Acquisitions

- Argonne National Laboratory \$550,000
 Equipment requirements at this laboratory are in support of research on the somatic and genetic effects of external radiation including X-ray, gamma rays and neutrons; studies in molecular biophysics and biochemistry; toxicity studies of internal emitters in humans; scanning electron microscope for biological research.

Electron microscope for biological research requiring improvements in photographic and specimen handling capabilities	\$ 60,000
Computer interface scientific equipment	50,000
Equipment for studies of radioelement toxicity, including human radium toxicity studies and studies of calcium transport in bone metabolism	103,000

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BIOLOGY AND MEDICINE PROGRAM - continued

1. Argonne National Laboratory - continued

Plasma arc, irradiation source and other equipment for genetic and molecular biology research \$105,000
 Electron spectrometer for chemical analysis to obtain structural information about complex organic and biological molecules 70,000
 Specialized equipment for radioecology and micrometeorology studies 67,000
 General equipment for biological, environmental and radiological physics research 95,000

2. Brookhaven National Laboratory \$725,000

Equipment requirements at this laboratory are in support of research on the understanding of biological processes in man and effects of ionizing radiation on these processes at molecular, cellular, tissue, organ system and whole body levels; plant radiation biology, including genetics, biochemistry, biophysics, and radiation ecology.

Accessory equipment for the Van de Graaff accelerator 55,000
 Rapid imaging equipment for studies on applications of radionuclides for diagnosis and therapy 55,000
 Spectrophotometer, analytical centrifuge and fluorometric equipment for biochemical research including RNA studies 105,000
 Electron-nuclear double resonance apparatus, optical rotary dispersion apparatus and mass spectrometer-median resolution apparatus for molecular biology studies 108,000
 Coincidence counter and other equipment for metabolic studies and other medical research projects 84,000
 Optico-electronic scanning system for research on the distribution of labeled molecules at the cytological level 100,000
 On-line diffractometer system and computer interface for biological research 85,000
 Growth chamber for research in plant radiobiology 40,000
 General equipment for research in biology, meteorology, dosimetry and health physics ... 93,000

3. Lawrence Radiation Laboratory, Berkeley 530,000

Equipment requirements at this laboratory are for research on a wide range of radiobiological investigations including biophysics, biomedicine, radiobiology, and chemical biodynamics.

Irradiation stereotaxic apparatus for computer control of alignment for the treatment of patients 150,000
 Computer and accessories for on-line experimental use and interface between research instruments and central computer facilities 100,000
 High resolution electron microscope. (An electron microscope, estimated to cost \$400,000, will be designed and built at the Laboratory. It will take about two years and will begin with the purchase of an electron microscope for \$150,000 in FY 1971. The basic microscope, which has a long lead time for procurement, will be improved in FY 1972 and FY 1973 by incorporating superconducting correcting elements cooled by cryogenic inserts) .. 150,000

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BIOLOGY AND MEDICINE PROGRAM - continued

3. Lawrence Radiation Laboratory, Berkeley - continued

Digital computer image dissection equipment to extract information from electron micrographs for further processing \$100,000
 General equipment for medical and biological research 30,000

4. Lawrence Radiation Laboratory, Livermore \$275,000

Equipment requirements at this laboratory relate to the assessment of possible impact of radionuclides released into the biosphere.

Remote controlled particle and gross gamma recording system to study the transport, deposition and redistribution of radionuclides 50,000
 Analog to digital converter to provide quantitative spectroscopic information on individual gamma-emitting radionuclides present in a complex mixture of radionuclides .. 50,000
 Spectropolarimeter with circular dichroism attachment for studies on the binding of radionuclides to small molecules and macromolecules 40,000
 Direct microscope chromosome scanning system, including equipment for computer interface 55,000
 Counting, scanning and general electronic equipment including 2048 channel pulse height analyzer 80,000

5. Los Alamos Scientific Laboratory 180,000

Equipment requirements at this laboratory cover research on studies of somatic effects of radiation including extrapolation of equivalent residual dose concept from laboratory animals to man; studies in molecular and cellular biology.

Low level gamma radiation apparatus for mammalian radiobiology program, and laboratory equipment for genetic, applied aerosol and carbon 13 studies 40,000
 Hot laboratory equipment for the research on the tumorigenicity of high specific activity particle work, and electronic equipment for the human and small animal counters 45,000
 Preparative ultracentrifuge, density gradient fractionator, fluorimeter, data acquisition and analysis equipment and other equipment for research on the molecular biology of information transfer and biochemical events in the cellular life cycle 95,000

6. Oak Ridge National Laboratory 930,000

Equipment requirements at this laboratory cover research on the long term biological effects of radiation including studies in cocarcinogenesis; mammalian genetics; radiation immunology; biophysics and enzymology; terrestrial and fresh water ecology; radiation physics and internal dose estimation; nuclear energy civil effects.

Motor generator sets to supply emergency power for supply and exhaust ventilation, one chilled water pump, and a 15 HP emergency instrument air compressor 150,000
 Containment units to house and provide complete facilities to maintain large animals ... 200,000
 Self cleaning cage rack and isolator units to improve animal care in mouse facility ... 80,000
 Ultracentrifuge with UV optics for measuring molecular weights, cinematographic system for recording morphological changes in cells, and prototype centrifuge for molecular anatomy program 98,000

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BIOLOGY AND MEDICINE PROGRAM - continued

6. Oak Ridge National Laboratory - continued

2 MeV Tandem Van de Graaff machine for radiological physics research	\$165,000
Field irradiation, gamma spectrometer with computer for remote control, and controlled climate facility for radioecological research	95,000
Multidimensional analyzer, electrostatic analyzer, and mass spectrometer for research in radiological physics	84,000
Equipment for biomedical and health physics research	58,000

7. Argonne Cancer Research Hospital \$225,000

Equipment requirements at this laboratory relate to research on the high energy radiation sources for treatment of cancer, radioisotopes for diagnosis and treatment of disease states; research in oncology, hematology and biochemical structure.

Equipment for nucleic acid and protein synthesis studies (sequenator, ultracentrifuge with rotors, automatic UV scanner)	107,000
Positron scintillation camera for the medical physics program	55,000
Medical electronics equipment for nuclear medicine	33,000
General laboratory equipment such as automatic sample injector, low background beta counter and dishwasher	30,000

8. University of California, Los Angeles 135,000

The equipment requirements at this laboratory are in support of research on the effects of ionizing radiation on living organisms and systems of biological significance; dynamic aspects of physiological and biochemical processes in man, animals and plants; assessment of immediate and long term consequences of operation or detonation of nuclear devices on fauna and flora in man's environment; research in beneficial uses of ionizing radiation and radioactive substances in medicine and biology.

Mass spectrometer, refrigerated centrifuge and other equipment for molecular and cellular level studies	53,000
4,000 channel analyzer, anti-coincidence detector system and related equipment for radioecology studies being conducted at the Nevada Test Site	27,000
Multi-channel analyzer for computer analysis of radioisotope scans, target transfer and manipulator system, and other equipment required for studies in nuclear medicine	55,000

9. Health and Safety Laboratory 160,000

This laboratory performs research on studies in radiological and health physics, including nuclear safety hazards; studies of the distribution of radionuclides in the atmosphere and biosphere; development and procedures for predicting, measuring and alleviating radioactive fallout; supporting instrumentation development and requires the following equipment.

Detectors, multi-channel analyzer and other equipment for high resolution measurements of complex radiation spectra and radiation transport in the atmosphere	37,000
Beta spectroscopy system and electronic equipment for radiochemical analysis	79,000
Small general purpose computer, aerosol analyzer and other laboratory equipment	44,000

BIOLOGY AND MEDICINE PROGRAM - continued

10. Lovelace Foundation \$150,000

The equipment needs at this laboratory are in support of research on the biological consequences of inhaling fission products singly and as mixtures so that various levels of exposure can be related to effect.

Remote high-speed line printer, remote card reader and input and display stem for on-line computer capability and graphical output at the field laboratory	\$ 56,000
Recording densitometer for autoradiographic studies in the lung, and physiology recording system for detecting anomalies in cardiac output, pressures in the circulatory system and pulmonary blood volume	48,000
Spectrophotometer, fluorimeter, and other equipment for biochemical, radiochemical, and aerosol physics research	46,000

11. Michigan State University 140,000

This laboratory conducts a comprehensive research program in plant biology, drawing on disciplines such as biochemistry, biophysics, genetics and microbiology, including the influence of radiations upon function and development of plants, and requires the following equipment.

Amino acid analyzer, spectrophotometers, ultracentrifuge and other equipment for biochemical analyses	65,000
Equipment for research in plant growth and development	43,000
Argon laser and other equipment for analysis of biological molecules and processes	32,000

12. Oak Ridge Associated Universities 175,000

Equipment requirements at this laboratory are in support of observation and explanation of biomedical interactions of radiations with living systems, particularly in man; development and application of radioisotopes and radiation in diagnosis and therapy of human diseases.

Mass spectrometer and associated equipment for identification of synthetic or naturally occurring compounds in clinical and hematological studies	50,000
Tomographic laminar scanner for bone, bone marrow and tumor studies	30,000
Instruments for nuclear medicine including physiological monitoring system and computer interface equipment	48,000
Gas chromatograph, autoclave and general laboratory equipment	47,000

13. Pacific Northwest Laboratory 440,000

At this laboratory equipment is needed in support of research efforts affecting toxicity and metabolism of radionuclides; inhalation studies of plutonium and uranium; terrestrial ecology; dynamic balance of radionuclides in Columbia River; micro-meteorology, radiation dosimetry and physics.

Inhalation exposure equipment, whole body counting equipment and other equipment for toxicity studies of plutonium and other alpha emitters	177,000
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BIOLOGY AND MEDICINE PROGRAM - continued

13. Pacific Northwest Laboratory - continued		
ESR spectrometer and other equipment for molecular and cellular level studies, radiological chemistry and radiation instruments for research and development	\$ 56,000	
Environmental chambers, counting equipment, irradiation facility, multidimensional gamma ray spectrometer, equipment for krypton 85 detection and other equipment for studies in the land, fresh water, marine and atmospheric environments	107,000	
14. University of Rochester	\$205,000	
The equipment identified at this laboratory is necessary to pursue the research on the biological effects of radiation and radioactive materials, physicochemical aspects of cellular function and structure, membrane biophysics, physical chemistry of bone and body fluids, new approaches to cancer therapy, and basic problems in aerosol physics, toxicology and respiratory function.		
Scanning electron microscope for molecular and cellular level studies	60,000	
Equipment for toxicity studies of radon, plutonium and other alpha emitters	75,000	
Equipment for long-term studies of effects of external irradiation using dogs and other small animals	45,000	
General purpose equipment	25,000	
15. Other AEC Laboratories	480,000	
New equipment and normal replacement items for laboratory and field investigations at other on-site locations, including:		
Atomic Bomb Casualty Commission	80,000	
University of California, Davis	40,000	
University of California, Laboratory of Radiobiology	50,000	
Idaho Operations Office	10,000	
Nevada Operations Office	50,000	
Oak Ridge Operations Office	30,000	
Puerto Rico Nuclear Center	55,000	
Savannah River Operations Office	60,000	
University of Tennessee	50,000	
University of Utah	55,000	
16. Washington - Off-Site Research	200,000	
Equipment for studies conducted for AEC by off-site contractors and other government agencies.		
Total Capital Equipment	<u>\$5,500,000</u>	

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