F.E. Rushford

PRNC 48

PUERTO RICO NUCLEAR CENTER

An Examination of Program Objectives

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-F O R E W O R D-

The special report which is here submitted is the result of a discussion at AEC Headquarters in which it appeared desirable that I should undertake a review of the objectives of PRNC with an analysis of the present status. In the main text and appendices, I have brought together what seem to me the most illuminating materials for the purpose.

Inevitably the document reflects my personal experience in more than 25 years of work in connection with developing countries in South America, Africa and Asia on behalf of The Rockefeller Foundation. The opinions expressed, however, are strictly my own and the Foundation has not been asked to endorse them. The same is true for the University of Puerto Rico.

My personal involvement with the program in Puerto Rico naturally introduces some degree of bias in judgment. As far as possible, however, a detached position has been maintained.

Since this is not a scholarly treatise, a complete listing of sources is not attempted. However, I wish to note four excellent sources from which material has been taken:

Man, Land and Food, by Lester R. Brown. Foreign Agricultural Economic Report No. 11, U. S. Department of Agriculture, 1963.

Resources in America's Future, by Hans H. Landsberg, Leonard L. Fischman, and Joseph L. Fisher. The John's Hopkins Press, 1963.

Civilian Nuclear Power - A Report to the President, U. S. Atomic Energy Commission, 1962.

A Comprehensive Agricultural Program for Puerto Rico, by Nathan Koenig. U. S. Department of Agriculture and the Commonwealth of Puerto Rico, 1953.

Since developmental and educational programs are inherently possessed of a long time scale, they can bring little political reward to any administration. To the extent that the beginning of a new venture becomes politically identified with the administration in power at the time, the ultimate success of the program is likely to be handicapped. Quick results of substance are usually impossible and by the time the real values have emerged, the political issues have changed and frequently the initiators themselves may have long since disappeared from the political scene. There is a long term

continuity to educational and technological development that precludes any marked partisan political benefit. In this respect, technological development, both national and international, resembles the areas of foreign policy and defense in the long lead time between the initiation of projects and the emergence of the practical results.

Notwithstanding this characteristic, it is also possible to blend long term and short term values so that a mix of benefits may be achieved in the time scale. In developing the Puerto Rico Nuclear Center, the effort has been made to secure such short term results and, while so doing, to strengthen the base of the longer range programs.

John C. Bugher

John C. Bugher, M. D.
September 15, 1964

An Examination of the Program Objectives of the Puerto Rico Nuclear Center

by
John C. Bugher, M.D., Director

GENERAL BACKGROUND

Among the various efforts to implement the "Atoms for Peace" program which was initiated in 1953, was a special one directed toward Latin America. Generally, this arose out of the belief that (1) the non-military applications of atomic energy could serve to accelerate greatly the processes of development, and (2) the Latin American countries were facing economic problems of increasing severity which could only be met by more effective technological as well as social development. Generally, the underlying considerations for both of these assumptions had not been clearly stated.

Under the pressure of weapons requirements, the AEC itself had not pursued with conviction its own program of peacetime applications. The ultimate necessity of switching to nuclear power on a wide scale was acknowledged but the generous reserves of fossil fuels tended to alleviate any sense of urgency. At the policy level, the technical problems of nuclear power reactors and the time scale of their solution were generally underrated. The exploitation of radioisotopes in medicine, agriculture and industry did not have the emotional impact to those developing foreign policy that costly and massive atomic power stations possessed. This factor, combined with a widespread misunderstanding of the

With the desire to accelerate atomic energy development in Latin America, it appeared to those in charge of the program that considerable benefit could be obtained if the United States were to establish a modest training center somewhere in Latin America where the work could be pursued in a Latin environment and where Spanish would be the dominant language. By this means, it was considered that the "cultural shock" received by a student would be lessened and that his attention to his studies could be more effective than if he were to be received in one of the Continental centers.

Study of the possibilities rather quickly led to the conclusion that for practical purposes the only location in Hispano-America where the AEC could maintain both supervision and operational control, was in Puerto Rico. Since a reactor was to be the center of activity, operational control for the assurance of safety was indispensable. To follow the usual contractor pattern, the natural choice was the University of Puerto Rico, a young institution that as a consequence of "Operation Bootstrap" had been compelled to grow at a prodigious rate and had at the time (1956) approximately 15,000 students.

Contrary to the pattern previously followed by other universities in their development of AEC programs, the University of Puerto Rico did not begin on a basis of existing post-graduate studies. A few members of the faculty had had personal experience in research in nuclear physics and radiation chemistry, but there was no well established interest in nuclear science in the University. All

available funds and resources had been more than absorbed by the exceedingly rapid growth of the student body at the undergraduate level.

Notwithstanding the problems implicit in this academic situation, conversations were initiated with the authorities of the University as a result of which a contract was signed in 1957 establishing the Puerto Rico Nuclear Center as a training center for Latin Americans. A training course in radioisotope techniques modeled on that given at the Oak Ridge Institute of Nuclear Studies was initiated at once and building plans were formulated.

Because the College of Engineering was located at the Mayaguez Campus at the western end of the island, the decision was made that the reactor and the main components of the Center should be constructed there. Medical activities were being centralized at Río Piedras, near San Juan, in a large Medical Center, so that a second component was constructed as a part of that Center to house radiation therapy and the medical applications of radioisotopes together with the basic radioisotope techniques course.

With the availability of the facilities of the new institution and the widespread publicity given its establishment, the immediate response was good, with most of the students being interested in learning the basic techniques in handling radioisotopes. Interest on the part of students in the University of Puerto Rico was

cultural climate of the University of Puerto Rico was still an advantage in permitting visitors from other countries to concentrate on their studies as a result of the reduced problems of adjustment.

The rapid development of graduate studies in the Nuclear Center accelerated plans in the University, and Master of Science degree programs became established in chemistry, physics, biology, engineering and agriculture. While the number of students from other countries remained fairly constant until the present year, their qualifications and general preparation have steadily increased. During the current year, there has been an upturn in the number of students from other countries, largely as a reflection of the improvement in the level of educational effort.

The impact on the University of Puerto Rico has been striking. The number of graduate students of Puerto Rican origin has increased sharply and gives indication of continuing to increase further. The new graduate program in Nuclear Engineering has been received with enthusiasm. Chemistry and physics attract increasing numbers of graduate students and in the process these disciplines have acquired additional scientists so that special research supplementing that associated with graduate teaching has been a natural result. A vital part in the development of the physical sciences in the Nuclear Center has been the close cooperation with the Departments of Physics and Chemistry of Brookhaven National Laboratory. Through the efforts of several staff members of these two departments it has

been possible to develop fruitful research in a short span of time.

It was evident from the beginning that a project of the dimensions of PRNC, while operating in several disciplines, could not undertake to cover adequately all of their content. Nor would it be desirable that the institution should attempt to pursue programs which would require a large installation for their successful completion. It was the consensus that PRNC should undertake to emphasize work in those areas which are best attacked on an island in the tropics; it would give especial attention to those major problems of importance to the United States whose solution requires a laboratory in a tropical setting. The physical sciences forming the foundation upon which the biological sciences must be erected, a major effort would be made in mathematics, chemistry and physics, but with a focus on research which can be conducted to advantage in a small operation and also which would give the greatest ultimate support to the biological and medical activities.

The evolution of the program along the lines outlined has resulted in an institution whose general orientation is toward Latin America but whose program in great part is directed to significant problems of continental United States. What some of these problems are will be set forth later in this discussion. The essential point is that PRNC is no longer simply a training center for Latin Americans but a teaching and research institution, located in the tropics, which is deeply engaged in scientific problems of major significance to

the United States. There now exists a flexibility of organization and a pedagogical and research competence that make it possible to respond to any one of several program plans.

LATIN AMERICAN DEVELOPMENTAL OPPORTUNITIES

During the past 15 years there has been much play on words in considering assistance to other countries. Terms such as "developing", "emerging", "nations in transition", etc. have tended to obscure certain hard principles. National development is a continual process and is never ended. Trouble arises when economic progress in some areas lags behind the potential implied in the state of political and social development of those areas and in the world at large.

Whatever may be the degree to which outside stimulus may be applied, ultimately the economic and social development of a region must depend upon the efforts of the people of the region themselves. Without a dedication to the appropriate goals on the part of the peoples concerned and without the will to achieve these goals, no important benefit can be expected from outside assistance.

Modern development cannot simply repeat the past experience of the more affluent societies. The acceleration which is part of the spirit of the time requires that modern technology be applied to the problems to be solved, even those of primitive societies. These technologies require an educational sophistication which in many instances does not exist locally. To talk of industrial

development without emphasizing the requirements placed on education is to insure failure of any program so constituted. Education is a laborious process which does not lend itself to great acceleration. The time scale is that of human development. Yet if the improvement of a society is to be achieved, the education and training of the youth are indispensable. Political stability is necessary and to this end programs such as improvement of housing and the development of desirable services may do much, but the absolutely vital factors lie in the educational system both at the elementary and advanced levels.

Although in the present context we are concerned with scientific and technological development, it is essential to bear in mind that the educational effort must embrace many and diverse disciplines. Technological development must necessarily proceed from a reasonably stable economic and political base. Technology which does not contribute to economic improvement and an increase in productivity is self defeating and will be of only passing importance. Furthermore, even diverse technologies must be integrated and maintained in an overall balance. Electrical power production implies an industrial structure to absorb it and employ it creatively. Transportation and communications are vital. Despite industrialization, an expanding and efficient agriculture, capable of freeing the country from importing foodstuffs that can well be produced locally, must be achieved if economic and social balance is to be attained.

RAW MATERIALS

Technology involves the bringing of scientific knowledge and practical skills to operate upon the raw materials of a region to carefully chosen and defined ends. The availability of the raw materials of a modern society then becomes of substantial importance. Primitive societies are limited to the use of raw materials which occur in easily processed form. Thus, metals such as copper, tin, gold and silver were early used in place of stone implements because of the ease of separating them from other substances and their occurrence in nature in high concentration. Later, iron became of utility and as technological resources increased in sophistication, aluminum and numerous other metals difficult of extraction and fabrication came into common use.

Although hydroelectric plants have been of substantial importance in industrial power development, the industrial strength of modern nations has depended chiefly upon power derived from abundant supplies of fossil fuels. Far more is known about the reserves of coal and petroleum in Europe and North America than in South America, giving the impression that the latter continent is seriously deficient in these materials. This may well be true, but it is also obvious that with vast regions which have either been explored very superficially or not at all, any comparative estimates are almost certain to be pessimistic with respect to fossil fuels in South America. Notwithstanding this, it does appear that in most countries

of the southern continent, fossil fuels are either scarce, difficult of recovery, or remote from any prospective market.

On the other hand, large deposits of minerals are known in Brazil and the Andean countries and it is almost certain that vast ore deposits exist whose presence is not now suspected. Large deposits of copper, tin, platinum and gold have long been known in the Andes but in recent years great resources in iron, aluminum, thorium, uranium and zirconium have been uncovered. It appears that although Latin American countries are generally energy poor, this need only be a temporary state. The potentials for energy from fossil fuels and especially from nuclear materials are impressive and probably more than sufficient for any foreseeable demand. It may well be that much of the fossil fuel may be found to be uneconomic for energy purposes in comparison with nuclear energy by 1980.

Agriculture in Latin America in its technology is at least a generation behind that of North America. Large areas of the equatorial portion of the South American continent have relatively low fertility and much of the western portion of the continent is mountainous. However, there are vast areas of high fertility in the great span of latitudes and there is probably no crop of agricultural importance that cannot be produced to advantage in Latin America.

Portions of Latin America are arid, especially along the Pacific borders of South America. Notwithstanding this, rainfall

in its totality is abundant and vast quantities of water rush to the sea in the river systems, the greatest of which is the Amazon. Watershed redistribution is possible on an increasingly substantial scale so that huge areas exist which may be opened to agriculture through irrigation. One of the first of such projects is being pushed to completion in Perú east of Lima where a tunnel 10 miles long penetrates the continental divide at high altitude to bring water from the wet eastern slope of the Andes to the arid west, also producing a large amount of electrical power in its descent to the lower levels. It may eventually be economic to move great quantities of water over mountain ranges by a combination of pumping followed by hydroelectric power generation on the descending side, using nuclear power to achieve energy balance.

In summary, Latin America possesses all the raw materials needed for the future and has them in abundance and of types especially well suited to a nuclear power economy. Critical raw materials, in amount and availability, are more than adequate for the immediate future and modest exploration will undoubtedly bring to light additional resources as time progresses.

SOCIAL FACTORS

The Spanish and Portuguese heritage in the New World was a society essentially feudal in outlook. Those in a favored position of wealth and political power could enjoy the best that Europe could afford in culture and education. The great mass of the people,

however, could anticipate little in the way of education save through the ministrations of the Catholic church. There resulted a gap between the cultured and educated aristocracy on the one hand and the mass of unlettered peasantry on the other. There was little tendency to develop a creative and effective middle class; even with the introduction of modern industrial technology, there was a striking lack of the "foreman" category of worker, one who could translate advanced technology into practical accomplishment and act both as leader and teacher in developing craft skills. For many years this gap was filled in some degree from Europe but in the main continued to exist as it does, with some exceptions, to the present day.

The onset of World War II brought a profound change in the orientation of Latin America. Culturally linked to Spain and France and commercially to Germany and England, the countries comprising the Spanish and Portuguese portions of the New World turned, by necessity rather than by choice, to the United States. Long suspicious of the "Colossus of the North", an attitude not discouraged by the influential European elements, the rapidly elaborated links with the United States were viewed with considerable apprehension, especially by the older and governing generation. There was great concern that the drawing together of the countries of this hemisphere, enforced by the sweep of world events, would result in the economic, political and cultural control of the entire

region by the United States and the loss of national and cultural identities. While this concern may have lessened with time, it is a potent factor in determining the manner in which Latin American countries associate themselves with the United States and with each other.

Because of the European orientation of Latin America, the educational system that developed in the various countries followed the pattern then prevailing in Spain and France. Mass education at the elementary level was not the objective so that the scholastic interest touched only a fraction of the children. Here and there, forward looking leaders attempted to achieve a more adequate access to education, at least at the elementary level. Generally, however, the educational base remained wholly inadequate with the situation in the universities even worse.

With respect to higher education, one must recall that there were universities in Spanish America long before any such educational centers were established in what is now the United States. There is an unresolved debate as to whether the National University of Mexico or San Marcos University of Lima, Perú is the oldest institution in the New World. San Marcos University was operating over a century before Harvard University was established in the Massachusetts Colony.

To a marked extent the universities of Latin America have followed

the pattern of organization of San Marcos which in turn was modeled on the structure of the University of Bologna, a format that was so unsatisfactory that it was finally abandoned in Europe. To an unhappy degree this pattern of isolated special colleges, serving as active political centers, of faculty subservience to student domination, and the lack of continuity of strong leadership has remained with the national universities throughout Latin America. Only in the last decade has effective movement toward the reform of higher education made any headway.

The strong dissimilarities between the universities of the United States and those of Latin America in administrative structure, intellectual objectives and approach to national issues and problems have made effective cooperation difficult. As mutual understanding advances, the obstacles to productive intercommunication will become less formidable; but extensive readjustments in the structure of higher education are necessary throughout Latin America if these countries are to achieve full use of the scientific and technological advances of the present era.

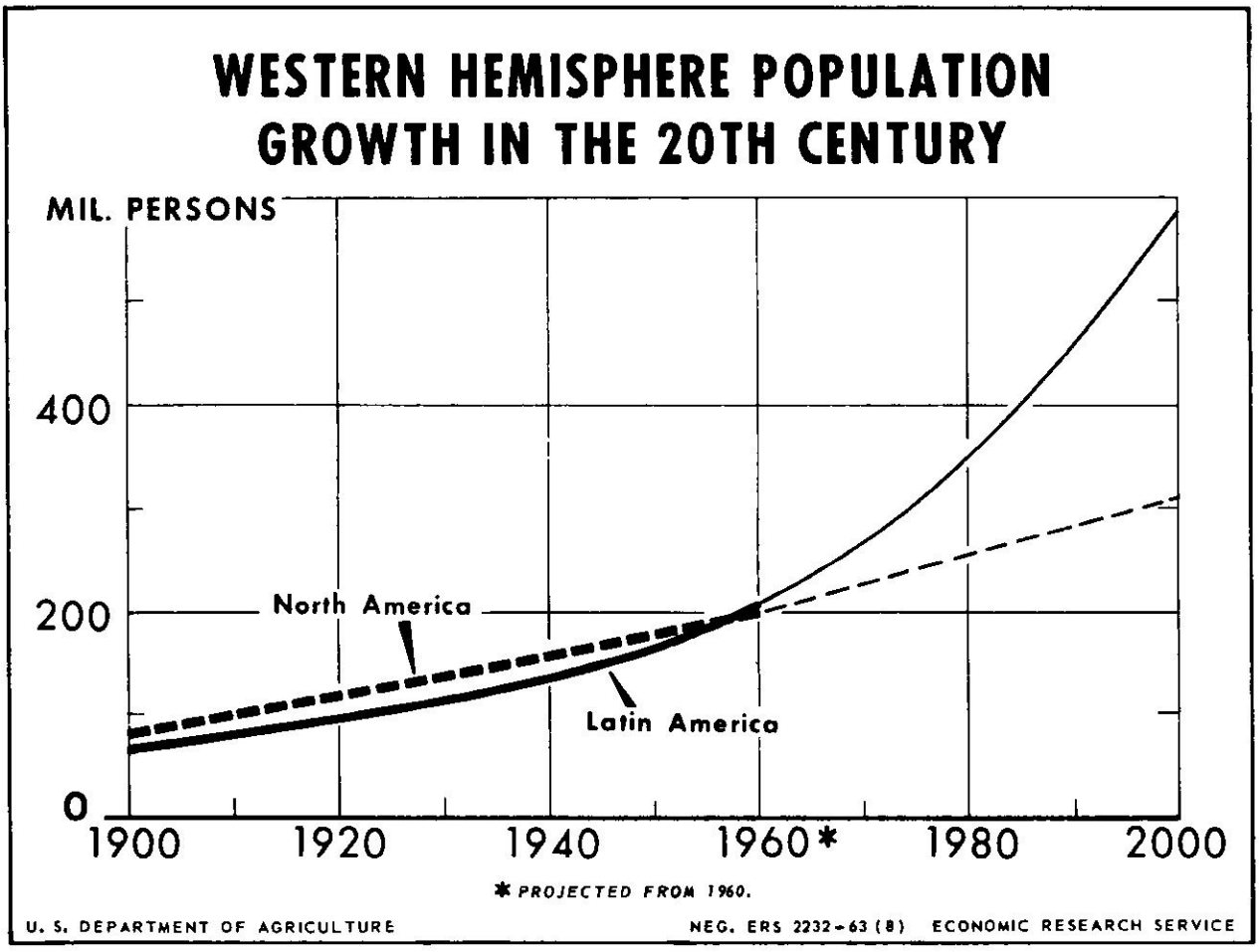
It is frequently assumed that the facile solution of such difficulties is the sending of large numbers of students to the United States or to other countries to study in the universities. There are several reasons why this solution would be futile, not the least of which is the fact that there is no room in existing American institutions for the large number of students that would be necessary. Of almost equal weight is the consideration that the academic structure of Latin

America must be reformed at the same time and that this must be a growth from within.

Ultimately, we arrive at the conclusion that the production of the large number of teachers required must be accomplished in the countries concerned. The key to the academic reform would seem to be the selection of a much smaller number of outstandingly competent and dedicated persons for advanced education in the crucial disciplines with the expectation that they will become the university leaders for the training of a new generation of teachers and educators.

At the same time this is going on, there must be a massive effort to widen the coverage of elementary education, to create the necessary physical facilities, and to emphasize the training of good elementary teachers contemporaneous with vigorous university reform and the drive toward academic stability. All of this must spring from the conviction of the leaders; external assistance cannot be a substitute for the national dedication of a people to the improvement of their own country.

In every country of Latin America there now exists a high rate of population increase. The accomplishments in health and sanitation have lowered death rates but birth rates have continued high with the result that South America shows the world's highest rates of population increase. (Fig. 1) At the same time, there is a shift in age distribution as adults live to greater ages as a rule and share in the


WESTERN HEMISPHERE POPULATION
GROWTH IN THE 20TH CENTURY
MIL. PERSONS
400
200
0
North America
Latin America
1900
1920
1940
1960*
1980
2000
* PROJECTED FROM 1960.
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NEG. ERS 2232-63 (8) ECONOMIC RESEARCH SERVICE

Figure 1

general increase of life expectancy.

The population increase is usually viewed with alarm. The fact is that the continent is grossly underpopulated and will continue to be so for many years to come. Sound economic development requires some reasonable level of population density if satisfactory progress is to be made. The disturbing character of the current South American population growth is in the tendency for the people to concentrate in a few large urban centers and neglect the utilization of the great resources of the region. It becomes as much a problem of distribution as of numbers.

Education, as is all development, must be preoccupied with the nature of the society to be served in the ensuing decades. As an example, medical education must be formulated in terms of the social structure and health problems the mature physician will serve, not those of periods already past. This, of course, is not a dilemma unique to Latin America, but becomes critically important in any society which is undergoing rapid change. The exceedingly high rate of population increase of Latin America adumbrates a host of social problems upon whose acceptable solution future political and economic stability will depend.

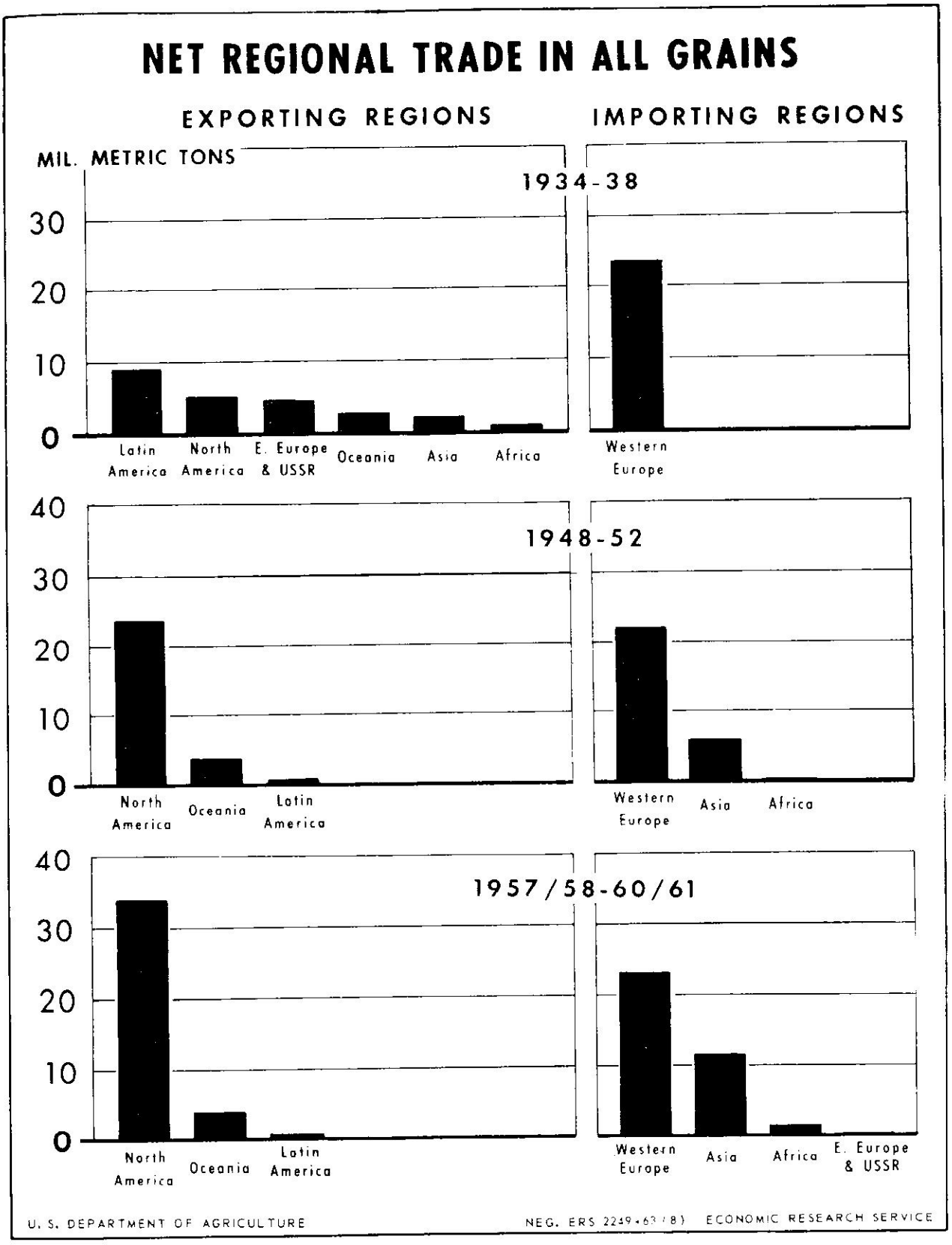
INDUSTRY AND AGRICULTURE

Purely agricultural countries are generally economically handicapped and from this arises the common belief that the remedy

is to achieve a rapid conversion to an industrial economy. Too often this results in the neglect of agriculture with the creation of new problems which may be even more difficult than the original set. Food is an absolute necessity and reliance on external supplies creates a situation of inherent instability.

Traditionally, Latin America has been self sufficient in food and has been able to export significant amounts. In recent years, however, Latin America has become a net food importing area, thus joining the Communist Block, Asia, Africa and Europe in accepting either chronic and widespread malnutrition or, as in the case of Europe, dependence on overseas food supplies. The Unites States and Canada have become, according to recent studies of the U. S. Department of Agriculture, the breadbasket of the modern world. (Fig. 2) Upon the great increase in agricultural productivity of the North American area, the minimal nutrition of a large part of the world now depends. The agricultural surpluses of which we complain would be rapidly eliminated if the needs of the free (or semifree) world were to be met in significant degree. There is no net overproduction of agricultural products; in fact, the contrary is the case and the substantial increase in total and man-year agricultural productivity is one of the greatest of world needs.

With over one half of man's calory intake along derived from the direct consumption of grains and most of the remainder indirectly


NET REGIONAL TRADE IN ALL GRAINS
EXPORTING REGIONS
IMPORTING REGIONS
MIL. METRIC TONS
1934-38
30
20
10
0
Latin America
North America
E. Europe & USSR
Oceania
Asia
Africa
Western Europe
1948-52
40
30
20
10
0
North America
Oceania
Latin America
Western Europe
Asia
Africa
1957/58-60/61
40
30
20
10
0
North America
Oceania
Latin America
Western Europe
Asia
Africa
E. Europe & USSR
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NEG. ERS 2249-63 (8)
ECONOMIC RESEARCH SERVICE

Figure 2

from grains through meat, milk, eggs, etc., the production of grains is the best single indicator of the general state of agriculture of a region. A succinct description of the relative deterioration of Latin America in grain production is quoted from the U.S. Department of Agriculture study: Man, Land and Food.

"Latin America: Surplus to Deficit

"No other geographic region has experienced a deterioration in its standing in world grain trade comparable to that of Latin America. During the late 1930's the region dominated the world grain market as a supplier. It exported more grain than North America and Oceania combined; it was an important supplier of wheat and its net corn exports accounted for almost three-fourths of those of all regions. By 1960/61 Latin America had relinquished its impressive advantage and, in spite of its vast natural resources, emerged as a net deficit region.

"A not inconsiderable effort was made in Latin America, especially during the 1950's, to raise output by expanding the area used for grain production. This effort resulted in an expansion of the grain producing area by nearly one-third over that of the prewar period, but population increased two-thirds and efforts to push up yields met with little success.

"Total production gains of some 42 percent during

the period did not compare unfavorably with many other regions but population grew 66 percent, much more than in any other region. Latin America's population was growing at a rate easily in excess of 20 percent per decade from 1930 to 1960. This stage of rapid population growth, with all its attendant problems is only now being approached in Africa and Asia.

"In spite of the decline in per capita grain production from 254 kilograms in 1934-38 to 214 in 1960/61, availability has risen from 180 to 216 kilograms per person. This has been achieved by sacrificing net exports, which amounted to 74 kilograms per person in 1934-38, and becoming a net importer to the extent of 2 kilograms per person in 1960/61. Of this 76-kilogram change in the per capita trade position, 40 kilograms were required to offset the decline in output per person. The remaining 36 kilograms represent an improvement in per capita consumption. Thus while per capita output was declining 16 percent, per capita consumption was rising 20 percent, but at the expense of exports and the foreign exchange so vitally needed for industrialization."

Part of the solution to the agricultural problem in Latin America lies in the traditional methods of plant breeding and crop improvement along with the diminution of the losses from plant

diseases and insect pests. Another large and highly important area is in the application of power to the agricultural process. As in industry, the worker must guide and control the application of power to his operations; he cannot be the prime mover himself in a prosperous economy. Even animal power is no longer economic save in the most unusual circumstances. Rural electrification and the application of electrical power to farm operations, especially those with fixed machines, and the use of liquid fuels for mobile machine operations are now part of agricultural development. All these imply a well developed system of roads, communication and electric power distribution.

A third essential element in the advancement of agriculture is an imaginative and balanced chemical industry. In nearly every country and certainly in every region, all of the raw materials for the manufacture of fertilizer on a large scale exist. If power can be produced where it is needed, then fertilizer manufacture may profitably proceed close to the areas to be served. The utilization of nitrogen from the air for conversion to ammonia can yield large amounts of oxygen together with significant amounts of noble gases, all of which find their market in a balanced industrial society.

Approached in this manner, agriculture is essentially a chemical industry in which solar energy is converted to chemical energy in a great complex of synthesized products. The feed materials for this chemical operation are the minerals of the soil together with

the trace elements, water, and fertilizers, themselves the products of other chemical operations. For the crucial step of solar energy conversion we have no prospect of any system even remotely approaching the efficiency of the enzymes associated with chorophyll.

In a balanced economy, therefore, agriculture is not so much a way of life as it is a part of industry, drawing upon mechanical and chemical manufacturing for its equipment and part of its raw materials; and in turn delivering to the society a series of elaborately synthesized products, some of which can be consumed immediately while the remainder become the prime material for other manufacturing processes.

The generation of power where needed makes it possible to disperse industrial manufacturing in the same sense that agriculture may be dispersed without loss of efficiency. The growth of industrial slums becomes no longer inevitable nor even profitable, and a far more harmonious distribution of population and resources becomes possible.

It is not suggested that each Latin American country should be self sufficient in all things. There is every reason, however, for each country to develop a balanced industrial-agricultural complex that will produce locally most of the items consumed in large volume, leaving to international trade those products which require extremely elaborate technology or very large capital investment in order to be profitable. The pattern of the industrial-agricultural complex will

differ from country to country, depending upon local resources and needs.

It should be at once reasonably obvious that the key to the development of the balanced economy is the availability of low cost power at the sites where it is needed. In the long run, nuclear power is the only form which can meet all of the criteria. Although the time scale is a protracted one, it appears that electricity and process heat will be produced in Latin America from nuclear reactions far sooner than could have been anticipated only a few years ago.

The radioactive and fissioning atom is not of interest solely because of the liberation of energy as heat for power. Nuclear radiations constitute the most powerful tools known for modifying biological systems, especially in the genetic sense. The radiation geneticist uses nuclear reactions as a means of greatly compressing the genetic time scale by which he can bring together within a few years specific genetic changes that in the natural course of events might well have required a century. The application of nuclear energy to agriculture is still about as embryonic in terms of its ultimate possibilities as in the case of generation of electrical power. We have scarcely taken the first steps.

NUCLEAR ENERGY IN LATIN AMERICAN DEVELOPMENT

In the foregoing sections it should be apparent that nuclear energy has an important and at some points a key role to play in the

future development of Latin American countries in much the same sense as in the United States. Cultural and socio-economic differences will modify the patterns but the fundamental principles hold good for all. The benefits to be achieved in accelerated national development will require the investment of huge amounts of capital but the prospects are dismal indeed unless there is brought to a high level of competence at the proper time the large numbers of well trained engineers, scientists and managers that will be required. A greatly increased emphasis on education at all levels is necessary, together with a series of reforms in the academic structure and functioning of universities throughout Hispano-America.

It should be further apparent that while nuclear energy has a vital part to play in the future of the Americas, it is not a panacea for all of the problems of society. In the utilization of nuclear reactions, man has made available to himself one more way of adapting the forces of nature to his own well being.

THE PRNC IN LATIN AMERICAN SCIENTIFIC DEVELOPMENT

If one accepts the needs for socio-economic development of Latin America that have been sketched in this paper, then one may inquire as to what role, if any, should be assigned to Puerto Rico and especially to the Puerto Rico Nuclear Center. What advantages are attached to the location in Puerto Rico? To what extent are developmental programs and methods pertaining to Puerto Rico

applicable to the problems of geographically huge countries such as Brazil?

The main thesis of the entire discussion is that the great imperative in Latin American development is education,-- education that is pushed to a high level of excellence and competence in all phases of intellectual life, but especially in science and technology. The main job must be done by the citizens of the countries involved but the first seed must come from without. There should be an opportunity for advanced students to observe at the operating level the advanced technology which they are studying; and the circumstances of that demonstration should be as closely related to those of their own countries as is possible. There is little doubt but that the recent history of Puerto Rico, after allowing for the important differences, exhibits many of the same perplexities that now are becoming crucial in South America. With its mixed racial origins, its Hispanic derived culture, its original reliance upon primitive agriculture, its insular character and its tropical location, it is a microcosm which contains many of the most difficult problems that Latin countries have to face. In addition, it possesses political stability, a population of sufficient size to be significant yet small enough to be adaptable to new programs, a society receptive to new concepts of development and an imaginative generation of public officials of high standards of public service and personal integrity.

While the solutions to problems of Puerto Rico may not be directly applicable to those of other regions, the situations are sufficiently similar to arouse expectations that the manner of solving the problems in Puerto Rico might suggest the appropriate approaches in other countries. Stated in more direct terms, the Puerto Rico Nuclear Center will best serve its mission in aiding Latin American development through the utilization of nuclear energy by attacking fundamental problems of Puerto Rico and the general region, including the southern part of the United States. The dimensions of the project and the economic and cultural climate in which it operates tend to give confidence that the manner of solving Puerto Rican problems in Puerto Rico may bear closely on practical solutions to similar situations in the continent to the south of us.

It was with this general philosophy in mind that the University of Puerto Rico began a series of academic "sight liftings" in the Nuclear Center, pointing the program to graduate and post-doctoral studies of a caliber to attract outstanding young scientists from the faculties of South American universities with the objective that they would return to help build up the departments with which they might be associated. The emphasis was placed on quality and scientific advancement rather than on numbers. A significant and vigorous research program was obligatory and this has been progressing rapidly in development with the research projects being pointed

at problems of direct concern to the United States and especially to Puerto Rico. The graduate student or visiting scientist who comes to the Puerto Rico Nuclear Center works on problems whose nature and dimensions he can study at first hand and where the results of his research may be put into perspective together with all of the other factors that compose the problem. Thus he learns about reactors, their design and operation and the economic and engineering problems that must be solved if practical power production is to be gained. He conducts his studies in an environment where he can observe a power system which exploits at a high level of efficiency hydroelectric, fossil fuel and nuclear power plants all subject to the same bases of economic analysis and all feeding into the same power grid. He can observe, if he wishes, the interrelations of rural electrification, small industries and agriculture, all with unsolved problems and in some instances essentially with the same dilemmas that he finds in his own country.

The Nuclear Center thus does not attempt to tell the visitor what the solutions to his country's developmental problems are; rather he participates in a Puerto Rican effort to solve what are fundamentally U. S. problems. In special cases and where the circumstances are favorable, the visiting scientist may work on a scientific problem of primary importance to his own country, but this is the exception rather than the rule.

The concept of "training" has been extended to a much higher

level of performance than is usually meant by the term. Graduate education and its associated research become in themselves training at a mature level. In the process the student is stimulated to think of his national problems and to project possible practical ways of attacking them. The scientific output of his work becomes available to all and, with time, some of this work may have an appreciable economic impact in the area. A good example of values obtained in this way is in the studies of retardation of spoilage of tropical fruits through moderate doses of radiation. The arrest of ripening of bananas, mangoes, etc. can permit a marked reduction of losses in shipping and of the requirements for refrigeration. All of this work has been done by graduate students and can continue for a considerable period of time into the future.

At the same time that the level of performance in training and education was raised, a major effort was undertaken to develop research which could be supported by the program divisions of AEC. Here the objective is the research itself, rather than training; but these activities have had a profound effect on the vigor and content of the training programs.

The present status is that slightly more than one half of the total program of PRNC is devoted to training and education with the other portion being concerned with advanced research. A condensed program description is given in Appendix D. All of the

research is directed to matters of concern to the United States and to the immediate Caribbean region. Among these activities are those devoted to developing knowledge concerning the long-term effects of radiation and fission products on marine life and similar questions pertaining to the cycling of radioactive elements in tropical forests, questions which are intimately linked with the feasibility of constructing a new canal through Central America or the Isthmus of Panamá using nuclear explosives for the earth removal.

Also, the present dynamic program of PRNC in training radiotherapists for the treatment of cancer opens up unusual opportunities for significant research in this area. Puerto Rico, for reasons unknown, has a very high death rate from carcinoma of the esophagus and the cervix uteri, with a strikingly low rate of malignancy of the testis. The organization of medical and health services permits ready access to the entire population for studies which, while important to Puerto Rico, would be relevant to the situation in other countries, especially the United States. (See Appendix C).

As the result of these program developments, the Nuclear Center is now in such a state of balance that it can readily respond to a change of emphasis as desired; that is, it can intensify its graduate education activities, or it can exert more drive in the area of primary research. The point is made here

that policy choices need not be forced by the limitations of circumstances but rather should be made in terms of national and international needs and policies.

PROGRESS OF PRNC IN RELATION TO THE FIVE YEAR PLAN

In February 1961, an analysis of the Latin American needs for training and education was made the basis of a five year plan for PRNC. The text of this is attached as Appendix B. Program development has rather closely followed the plan and most of the specific projections have already been implemented and, in some instances, have already advanced beyond the level contemplated at the four year point.

The scientific program has generally advanced well save in agriculture. There have been serious handicaps resulting from the inability to expand the physical plant in phase with the program plans. The lack of space has been partially offset by the generosity of the University of Puerto Rico in making available a number of laboratories on the several campuses.

As graduate programs have come into operation there has been a sharp upturn in PRNC students from Puerto Rico. (Fig. 3. Table 1) Participation from Latin America has been slow in development as far as numbers are concerned. In FY-1964, of the 35 foreign students, 19 (or over one half), were in medicine and public health programs at the professional level.

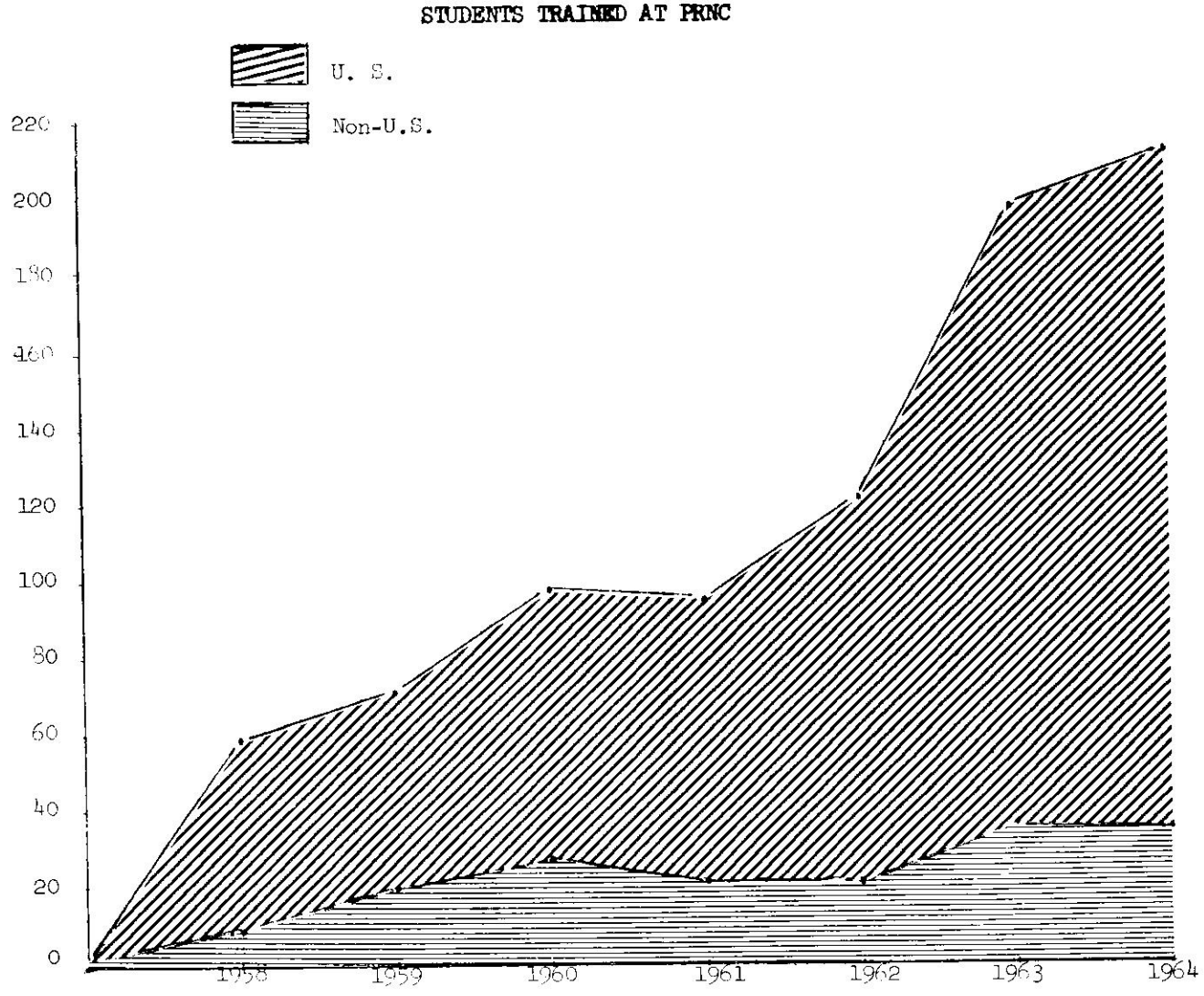

STUDENTS TRAINED AT PRNC
U. S.
Non-U.S.
220
200
180
160
140
120
100
80
60
40
20
0
1958
1959
1960
1961
1962
1963
1964

Figure 3

Latin American interest in PRNC will develop as the institution develops a reputation for scientific excellence and as it becomes better known to the universities of the various countries. Personal visits by staff members to heads of departments of leading universities in Latin America are indispensable for developing mutual understanding and cooperative interchange.

A revision of the Five Year Plan would result in some relatively minor changes. As events have moved, we would probably now give more weight to the early development of nuclear power in Latin America. In the fourth year of the plan, we are already much farther along in nuclear power activities in Latin America than we had anticipated.

Marine Biology and Terrestrial Ecology have progressed at a rapid pace as has the University's program in Marine Biology. The Solid State Physics program is about on the anticipated schedule.

We now are moving toward a joint NIH-AEC cancer program which will be much more broadly based than that outlined in our original plan. Puerto Rico should become one of the major United States centers for cancer research.

Although the Five Year Plan stressed the development of research, it was essentially a program for Education and Training. Table II shows the operations and equipment cost projections with which can be compared the actual costs for the respective fiscal years. It

TABLE II

Comparison of PRNC Costs with Five Year Plan Projections
Program 07 Training and Education

	FY-1958		FY-1959		FY-1960	
	Proj.	Actual	Proj.	Actual	Proj.	Actual
Oper.	-	119,068	-	283,180	-	450,263
Equip.	-	40,552	-	226,193	-	222,606
Total	-	159,620	-	509,373	-	672,869

	FY-1961		FY-1962		FY-1963	
	Proj.	Actual	Proj.	Actual	Proj.	Actual
Oper.	859,000	753,764	1,203,500	1,208,593	1,450,000	1,181,042
Equip.	272,000	188,683	228,000	97,405	250,000	225,395
Total	1,131,000	942,447	1,431,500	1,305,998	1,700,000	1,406,437

	FY-1964		FY-1965		FY-1966	
	Proj.	Actual	Proj.	Actual	Proj.	Actual
Oper.	1,650,000	1,105,997	1,790,000	1,146,000	1,920,000	1,456,000
Equip.	100,000	70,000	100,000	82,000	100,000	100,000
Total	1,750,000	1,175,997	1,890,000	1,228,000	2,020,000	1,556,000

TABLE III

Comparison of PRNC Total Costs with Five Year Plan Projections
All Programs: 05, 06, and 07
Operations and Equipment

Fiscal Year	Projection	Actual	% Prog. 07 of Total
1958	-	$ 159,620	100
1959	-	509,373	100
1960	-	672,869	100
1961	$1,131,000	942,447	100
1962	1,431,500	1,404,647	93
1963	1,700,000	1,938,994	73
1964	1,750,000	1,941,657	60
1965	1,890,000	2,117,000	58
1966	2,020,000	2,594,000 (Est.)	60 (Est.)

is evident that if Program 07 alone is considered, there has been a persistent underfinancing in terms of the job to be done. The result is that Program 07 is about where it could have been and should have been at the end of FY-1962.

On the other hand, special research has been developed rapidly with the introduction of Programs 05 and 06. Programmatic research, although not primarily designed to serve the research needs of graduate education, does offer a substantial opportunity for a limited number of graduate students. In Table III, therefore, the total costs of all programs are compared with the projections of the Five Year Plan. From this it is evident that the total expenditures in PRNC by AEC are now appreciably more than projected in the Five Year Plan.

As noted, special research aids a program in graduate education, but the one does not substitute for the other. At the level of funding now available for Program 07, it is not possible to operate adequately in all of the disciplines involved. Considering all factors, it would appear that a fully effective program in Training and Education will require approximately $1,500,000 yearly in operations and $100,000 for equipment, or $1,600,000 total. This level should permit a productive effort in agriculture and medicine, with parallel emphasis on reactor applications and physical sciences.

It is suggested that Program 07 should hold at approximately this level until further experience has indicated a definite need for additional expansion.

CONCLUSIONS AND RECOMMENDATIONS

1. The utilization of nuclear energy is an essential and, in some instances, critical factor in Latin American development. To the extent that the United States participates in this development as a matter of national policy, the nuclear energy activities should be pursued at an appropriate level.

2. The necessary base for technological development in Latin America is a great acceleration in education at all levels with a rapid strengthening of the sciences in the universities together with the necessary reforms of university structure and function.

3. Puerto Rico is highly suitable for advanced training in the application of nuclear energy to developmental problems since in this microcosm the student may explore, not only the theoretical approaches, but also may observe at first hand the applications to the practical problems of a small society in rapid development.

4. Agriculture, for the purposes of this discussion, forms a complex with industry and both may be greatly benefited through the introduction of nuclear energy.

5. The Training and Education Program of the Nuclear Center

should be further developed along lines similar to those now in operation. For the foreseeable future, it should level off in costs at about 25% more than the current level. Research, which is essential to graduate education, should continue to be directed to problems of primary importance to the United States, or to its foreign policy, so that direct benefit to the nation may be forthcoming from this operation in the tropics.

6. Programmatic research should continue its orderly development to the extent dictated by the national interest. The investigations should be those unique to a tropical environment or those whose nature indicates that the tropical location of PRNC can confer a definite scientific advantage.

7. The primary mission of the Puerto Rico Nuclear Center should continue to be in relation to Latin American development, but the doors should be opened to a greater extent to advanced students from the United States. To the extent that it is AEC policy, the same consideration should be extended to a small number of nationals of other countries.

8. In conformity with the policy decisions, the physical plant should be amplified to achieve greater efficiency and coordination. The University of Puerto Rico should continue to serve as the operating contractor and encouraged to maintain the pace of university development in the sciences that it has recently demonstrated.

9. The integrated medical services of Puerto Rico and the unusual frequencies of some forms of cancer, establish an attractive opportunity for cancer research in cooperation with NIH.

10. The Five Year Plan, written in 1961, still constitutes a reasonable statement of program objectives. The Training and Education activities have not reached the full level projected in the plan but generally now stand in reasonable harmony with that plan when special research is considered.

APPENDIX A

ADVISORY COMMITTEE FOR BIOLOGY AND MEDICINE
to the
UNITED STATES ATOMIC ENERGY COMMISSION
Washington 25, D.C.

Box 1823-U.P.R. Station
Río Piedras, Puerto Rico

October 26, 1960

Memorandum

To : Mr. John McCone, Chairman AEC

From : The Advisory Committee for Biology and Medicine

Subject: The Role of Nuclear Energy in Inter-American Development

The renewed crisis in Latin America demands reappraisal of the position, policy, and procedures of the United States.

In simple terms, the great need of Latin America is a substantial increase in productivity -- an increase not only in absolute quantity but above all in human terms. Without a substantial augmentation in man-year output, there can be no real improvement in the general standard of living.

Our policy of aid has been: (a) to send technicians to Latin America who know how to increase food production or improve public health, (b) to keep our hands on the purse strings. These two policies carry their own built-in weaknesses.

With respect to (a), we do not encourage our youth to take up foreign service as a career and we have few schools to train foreign technicians. Often the technicians we send abroad have never been out of their home environment before and they cannot wait to get back. They seldom can speak the local language and they want to escape the fleas and the flies and get home as soon as possible.

In regard to (b), to give people money and then to tell them that it must be spent according to the gospel of the G.A.O. is stultifying and self defeating.

We of the Committee suggest that a new approach is needed. Clearly, the AEC cannot revise American foreign policy but it can

"leaven the loaf" by setting up a pilot plant, possibly through the Inter-American Nuclear Energy Commission or the Puerto Rico Nuclear Center.

Of concern to us is the application of modern technology in a reasonably sophisticated and informed society. This is equivalent to saying that one of the essential requirements is a radical and rapid elevation in the quality of education, particularly in the scientific fields. The education program in science must be directed to the establishment of a broadly based scientific competence from which can emerge the specialists upon whom the pace of development must ultimately depend. This is the seed corn for the great crop of technological progress.

Nuclear science can play a definite part in accelerating the pace of development to a degree commensurate with the development of the educational system of each country. Here one finds the uniquely powerful tools which in the hands of the expert may dramatically compress the time scale of human progress. In the short time that nuclear energy has been available for peaceful development, only the most superficial application of these remarkable tools has been attempted, especially in agriculture where Latin American needs are among the most crucial.

The contribution of nuclear energy is thus seen to be a very broad one in a general upgrading of science and technology. Taking Latin America as a whole, the areas of top priority for nuclear activities are agriculture and medicine with nuclear power development coming at a much more deliberate pace except in special areas where it can contribute economically to the prompt utilization of proven resources.

What approaches are feasible and also most productive? The most important ones in the long run are in the field of education. Here, as in other areas of development, programs of immediate benefit must be combined with those of long term values. An underprivileged populace will not be content with rewards in the indefinite future. Some results must be obvious in a short span of time and these are likely to show at different levels of education in the various countries.

1. Education

The pace of development in education is that of human growth. The expansion of good education depends upon the development of capable and dedicated teachers. Ultimately, this is a university responsibility. In the meantime, however, certain

substantial improvements may be made in the quality and effectiveness of existing educational systems.

a. Institutes for teachers of science

There has been sufficient experience in the U.S. to show that special training of high school science teachers can be made highly successful through cooperation with university science faculties. Such a program, with emphasis on nuclear science, could be inaugurated during the summer recess throughout Latin America. The course content and the pattern of organization have been established and but little alteration to fit the various national systems of education would be necessary.

b. Local fellowships

At the university level especially, much can be accomplished by providing fellowships for study within the students' own country. Under such a program, a young instructor in a university could have one or two years of special study in an outstanding department of another institution in his own country. A program of this type has been under trial in Brazil for five years with outstanding success.

c. Fellowships for overseas study

Provisions for advanced study at the post-graduate university level are needed for those who have taken advantage of the resources in their own countries. This would be an expansion of existing programs with a broadening of their terms of reference. The program should be reciprocal; that is, there should be provision for fellowships for outstanding U.S. students to study in Latin American universities at the graduate level.

d. University organization

The foregoing activities should bring about a progressive improvement in University science faculties including medicine. This improvement will not take place, however, unless certain changes take place in the university structure. Adequate salaries to permit full time teaching and research, stability of tenure,

and a climate in which scientific research may progress are essential. Implied are standards of student selection and limitation of enrollment in the universities and a strong administrative authority in mature and responsible hands. Most of the Latin American universities require some degree of reorganization to provide the cultural and scientific basis for professional education and to establish the structure of post-graduate studies.

The encouragement of national research and educational councils could facilitate the organizational changes which are necessary.

2. Research

Both the tradition of scholarship in the sciences and the physical means for its activity must be encouraged and assisted. Equipment for research can be provided from external sources but the intellectual climate is the responsibility of the institution.

A few major research centers are needed. These generally should be associated either with a single university or a group of universities. Group associations of this kind are still very new and experimental in the U.S.; they are unknown in Latin America, but the prospects are reasonably good in some countries.

Again, all fields of science are included but special emphasis should be upon the physical and biological sciences that bear upon basic agricultural, medical, public health, and engineering problems.

3. Program emphasis

For the generalities to have meaning, the program must be expressed in terms of specific goals and priorities. These need to be stated as a result of consultation among experts who have special knowledge of the problems and resources of the various countries. Tentatively, the primary emphasis in nuclear science might be upon agriculture and medicine in terms of human nutrition and the secondary one upon the development of new power sources.

a. Agriculture: In the agricultural field, neither the production of calories nor contemporary market value is an adequate goal. The complete nutritional requirements of man should determine the direction of agricultural development. A program giving special attention to research and development in the following fields could be exceptionally rewarding:

Plant Breeding. Generally, the work of the plant breeder is directed to achieving the most satisfactory reassortment of existing genes and the pace is determined by the growth characteristics of the plants concerned. Entirely new characters, or mutations, occur relatively infrequently. However, the adaptation of important food plants to different environments may require the presence of mutant characters in order to succeed. The various forms of nuclear radiation, and especially neutrons, may be the means of achieving this objective through their capacity of increasing the frequency of mutations.

It would be desirable to direct primary attention to improving the quality, productivity, and resistance to disease of food plants already established in the various climatic zones, but especially in the tropics. On the basis of new knowledge thus gained the second step could be the adaptation of plants of desirable features from other parts of the world and from different climatic zones.

In many tropical regions, the effective development of a dairy industry is hampered by the lack of nutritious forage capable of growing on poor land and upon hillsides. For example, in Puerto Rico, the trailing indigo meets these needs excellently save that it is toxic for cattle. The development of a mutant variety lacking the toxic factor could make possible the profitable use of marginal land in a highly desirable nutritional shift involving the expanding consumption of dairy products.

Soil Fertility. Throughout Latin America, with its great range of soil types and conditions, far more must be known concerning the availability of essential elements if productivity is to be increased substantially. Particularly with respect to the trace elements is there need for a large amount of work for upon these elements not only does the vigor of the plants themselves depend, but also much of human malnutrition is the result of their deficiency. Radioisotopes are indispensable for these studies and may be the only means by which some of the problems may be resolved.

Of outstanding utility in this field is activation analysis which enables the rapid estimation of extremely minute amounts of many elements. The technique requires a source of neutrons so that the procedure must be carried out in those centers possessing nuclear reactors.

Water Resources. The study of the water resources of a country including underground storage and movement may be greatly facilitated by nuclear technology. The measurement of natural tritium is of the greatest value and may directly indicate the degree of dependence of underground supplies upon local rainfall. Radioisotopes such as tritium may be added in small amounts at critical points to determine the speed and volume of underground flow. Nuclear technology thus becomes an adjunct to other procedures in the full delineation of the water resources of a country, a study that is essential for intelligent planning of agricultural, industrial and urban development.

b. Medicine: The greatest single contribution of nuclear energy to clinical medicine and public health in the next decade will probably lie in the broad area of diagnosis. While many of the health problems of Latin America result from infectious disease, complex and little understood metabolic disturbances are frequent and also often intermingled. Some of these disturbances are nutritional in origin while the basis of others is completely obscure. Procedures involving the use of C-14 and H-3 tagged organic compounds must be moved from the research laboratories to clinical practice as rapidly as possible. This requires the closest of association between the nuclear centers and those of medical education and clinical research.

In the field of public health, there are important areas of insect biology to which nuclear science may make significant contributions. For example, radioisotopic tagging of mosquitoes in their natural environment to determine their flight range, life span and other population characteristics has been very little employed; yet there is no other way by which essential information concerning vectors of many important infectious diseases may be obtained.

c. Nuclear Power: We have stated that the development of nuclear power in Latin America must inherently proceed at a slower pace than the nuclear applications in agriculture and medicine. Partly this is due to the state of the art, but largely it is related to the rate of growth of the power market in any given country which in turn is linked with other economic factors of industrial and urban development.

While one must be prepared to accept delayed returns in this field, we feel that the most serious consideration should be given to the establishment of a few nuclear power stations in regions of critical power shortage. In this connection, we feel that the choice of Puerto Rico for a developmental plant was a particularly happy one as a first step of a sound Latin American program.

4. Method of operation

A developmental program for Latin America should presuppose the active financial participation of all the associated countries. Inevitably, it would fall to the U.S. to carry a large share of the financial burden. It then becomes tempting to some to insist that the U.S. should directly control the expenditure of its contribution. Experience indicates, however, that operation through an international organization such as the Organization of the American States in the long run leads to the greatest degree of real cooperative endeavor and the preservation of national dignity. In the recently established Division of Scientific Development of OAS, with the associated Inter-American Nuclear Energy Commission, there appears to be at hand the necessary organizational structure for the purpose.

Long experience in cooperative undertakings has shown that the best results are obtained when there is only a small minority of foreign nationals of high competence engaged in a project. Further, for each foreign national, there should be a counterpart from the host country. These pairs should work together in complete unity. The termination of service of the foreign national will then always leave a well trained and competent local person to carry on.

We stress our conviction that AEC should not develop its international program in isolation but rather that it should take the lead in achieving close integration with all other agencies of government which have responsibilities for scientific development and for the improvement of education. The program operations of

these agencies should be based upon a common philosophy and should generally move along lines that are mutually reinforcing.

Finally, we recognize that the scientific development of a country must take place within a sound sociologic and economic structure. Forward planning must take cognizance not only of the aspirations of people but also of the resources which nature has provided. With the studies of resources for the future must be associated those of population trends. The achievement of a favorable distribution of population is vital to intelligent planning. Human health and happiness may be vitiated by excessive population densities on the one hand and gross underpopulation on the other. We are confident that the various lines of inter-American development may be directed within the broad perspectives of foreseeable social needs.

Recommendations:

To advance the purposes of Inter-American development, we recommend to the Commission that it:

1. Recognize the potential contribution of nuclear energy to Latin American development in scientific fields vital to economic progress and human health;

2. Urge the sponsoring by the U. S. Government of a strong developmental program along lines set forth in this memorandum;

3. Invite the consultation of experts under the aegist of the Inter-American Nuclear Energy Commission to determine the specific objectives of a program of economic and scientific development and their order of priority; and

4. Consider the desirability of assigning the operating responsibility to the Organization of American States.

Respectfully submitted,

John C. Bugher, Chairman
H. Bentley Glass
Fred J. Hodges
James H. Horsfall
Robert Loeb
Leonidas D. Marinelli
Carl V. Moore
James H. Sterner
Harland G. Wood

APPENDIX B
FIVE YEAR PLAN

I. INTRODUCTION

The Puerto Rico Nuclear Center, operated by the University of Puerto Rico under a contract with the U. S. Atomic Energy Commission, was established in October, 1957, as part of the Atoms-for-peace program. It grew out of the proposal made by President Eisenhower on July 22, 1956, at the Panamá Conference, that work be initiated to "hasten the beneficial uses of nuclear forces throughout the hemisphere - both in industry and in combating disease". The main objective of this Center is to serve as an effective teaching and research organization in the principal applications of nuclear energy. The University of Puerto Rico gives graduate credit for the majority of courses offered by the Nuclear Center and its principal teaching staff are members of the Faculty of the University.

The Nuclear Center is bilingual with the teaching predominantly in Spanish. Knowledge of English is not required for admission to the courses given. However, a reading knowledge of English as well as Spanish is to be encouraged and, in fact, the great majority of graduate students in the universities of Latin America today not only read English well but also possess reasonable skill in speaking the language.

The Center operates on the three campuses of the University: Mayaguez, Río Piedras and San Juan. At Mayaguez, near the campus of the College of Agriculture and Mechanic Arts, are located the reactors and associated facilities for instruction at the Master of Science level in Nuclear Science and Technology, Health Physics, and Agricul-

tural Bio-Sciences. The emphasis in radiobiology is chiefly on plant physiology and radiation genetics.

At the Río Piedras and San Juan campuses, the program is medically oriented in great part. However, training in radioisotope technology is also given here with increasing attention to radiochemistry and physical chemistry. In the medical field, the primary emphasis is upon new methods of diagnosis of disease and in improving the applications of radiation in the treatment of cancer.

II. SCIENTIFIC DEVELOPMENT IN LATIN AMERICA

Since World War II, there has been a great acceleration in scientific progress throughout Latin America. The exent to which there is a constant improvement in the quality of education in science and in research in the leading universities has not been generally appreciated in the U. S. Traditionally, Latin America has been culturally oriented towards Europe, and in literature and the arts this is still true. In the sciences, however, the association with the U. S. has been much more close, especially in recent years.

The progressive increase in quality of education in Latin American universities has a special implication for those scientific centers and institutes that are intended to function in an inter-American sense. Their programs cannot be static. If they are to presume to leadership, they must be constantly upgrading the level of their educational and research programs in phase with the

improvement in preparation of those who may wish to avail themselves of their offerings. As time passes, the special centers must leave to the universities the more elementary educational efforts in science and devote themselves increasingly to graduate education and research. This is an evolutionary process and not one to be encompassed in a single reformation. As the special centers and institutes relinquish the more elementary activities, they must in turn replace these with more advanced studies and research.

Scientific leadership has been developing in Latin America in a number of fields. Perhaps the most outstanding is genetics, where in Brazil and Chile there is today a remarkable group of young geneticists of high competence. Physiology has acquired substantial strength in several countries. It should be remembered that some of the greatest advances in public health in recent decades have been achieved in South America. The worldwide campaign to eradicate malaria is largely based on technology developed in Brazil. Substantial competence already exists in physics and radiochemistry in Brazil, Argentina, and Chile.

Certain characteristics of Latin American universities operate to retard scientific development, especially those phases which are fundamentally multidisciplinary in their content. Professional schools usually have some provision for post-graduate education but it is the general rule that there is little or no university oriented program of graduate studies.

In order for full progress in science to be achieved, certain changes must take place in the structure of most Latin American universities. Adequate conditions to permit full time teaching and research are essential. There must be firm standards of student selection and limitation of enrollment, with strong administrative authority in mature and responsible hands rather than in those of an adolescent student body. Most of the Latin American universities require some degree of reorganization to provide the cultural and scientific basis for professional education and to establish the structure of post-graduate studies.

III. INTER-AMERICAN COOPERATION IN ADVANCING THE USES OF NUCLEAR ENERGY

A single center such as the Puerto Rico Nuclear Center cannot function properly without reference to the needs and resources of Latin America and without close cooperation with other scientific centers in the various countries. Nuclear science must find its proper place in the perspectives of science if it is to make its full contribution to the general welfare.

In a recent report to the U. S. Atomic Energy Commission, its Advisory Committee for Biology and Medicine said:

> "Nuclear science can play a definite part in accelerating the pace of development to a degree commensurate with the development of the educational system of each country. Here one finds the uniquely powerful tools which in the hands of the expert may dramatically compress

> the time scale of human progress. In the short time that nuclear energy has been available for peaceful development, only the most superficial application of these remarkable tools has been attempted, especially in agriculture where Latin American needs are among the most crucial.
>
> "The contribution of nuclear energy is thus seen to be a very broad one in a general upgrading of science and technology. Taking Latin America as a whole, the areas of top priority for nuclear activities are agriculture and medicine with nuclear power development coming at a much more deliberate pace except in special areas where it can contribute economically to the prompt utilization of proven resources.
>
> "What approaches are feasible and also most productive? The most important ones in the long run are in the field of education. Here, as in other areas of development, programs of immediate benefit must be combined with those of long term values. An underprivileged populace will not be content with rewards in the indefinite future. Some results must be obvious in a short span of time and these are likely to show at different levels of education in the various countries."

Not only are there a number of strong scientific centers in Latin America; several centers or institutes of nuclear studies already exist. Outstanding among the latter are the Institute at the University of Sao Paulo, Brazil, and the somewhat smaller program at the University of Minas Gerais. The Argentinian Atomic Energy Commission, in association with the University at Buenos Aires and the Instituto de Física at Bariloche, is supporting a substantial program along the lines of a national laboratory. A small reactor is functioning and two more are being developed. At Sao Paulo, there is a one megawatt pool reactor with associated research divisions of chemistry, physics, engineering, and biology. Minas Gerais has a

pool reactor of 100 kilowatts and is developing a graduate program around it with participation by the medical school. Venezuela has now in operation in its research center a three megawatt pool reactor which constitutes one unit of a multidisciplinary research center of about four times the magnitude of PRNC. Radioisotopes (often from Harwell) are used in large quantities in practically all of the universities south of the Río Grande. A variety of accelerators are in use in Mexico, Brazil, Argentina, and Chile.

As the first effort of its kind on the part of the U. S. outside its continental borders, the Puerto Rico Nuclear Center is neither the first nor the largest of such institutions in Latin America. What, then, should be its long range mission? Clearly, a vast expansion to make it another national laboratory would be unwise in a governmental unit as small as that of Puerto Rico. Neither would it enhance the position of the U. S. for the center in Puerto Rico to engage in non-productive competition with similar centers already in existence in the various countries.

One must look for features wherein the PRNC may be distinctive and where it may add substantially to the total scientific resources of the Americas. One aspect comes to mind at once. Puerto Rico is located in the tropics, the climatic zone where so many of the difficult developmental problems are to be found. With the exception of the small reactor at Université Lovanium in the Congo, PRNC, the Indian Center at Bombay, and the Institute in Venezuela are the only research centers in the tropics where neutrons are available in quantity.

Second, Puerto Rico is not only in the tropics, it is an island in the tropics, and thus presents sharp ecological boundaries which greatly facilitate many phases of agricultural and medical research. Its variety of environment makes it possible to approximate the climatic conditions of most of tropical America.

Third, Puerto Rico is itself a model of rapid Latin American development. Health services and sanitation actually exceed in quality those of most of the states. The so-called "diseases of the tropics" are here either now eradicated or rapidly approaching termination. Social and industrial development on a planned basis are world famous. The standard of living excells by far that of any Latin American country. Yet conditions are still sufficiently representative of those found in other Latin American areas that experimental results in many fields have direct application in other countries.

From these considerations, it would appear that PRNC should function cooperatively rather than competitively with the other centers of Latin America. It should be an institution preoccupied with the problems of the tropics which, by their nature, must be solved in the tropics. Here is a field which in the Western Hemisphere it shares only with the Venezuelan Institute and possesses an enormous advantage over the latter in that it can look to the national laboratories and the universities of the U. S. for support. PRNC enjoys a depth of support matched by no other university or national center in Latin America.

In the cooperative framework, the Puerto Rico Nuclear Center

may be regarded as a unit of a Pan American system of scientific development and research which should take as its primary interest those major problems which have special tropical reference. Similarly, the other centers and institutes should be expected to give their most active attention to issues distinctive of their regions. No one of these should undertake programs that are better executed elsewhere.

To achieve the full benefits of the cooperative endeavor, reasonably frequent conferences should be held and a considerable amount of consultation should be encouraged. Program planning and execution should be benefitted and a climate of cooperative scientific undertaking gradually established.

The composition of the program of PRNC must be determined by the needs and resources of Latin America. Until the present year, the Center has been directed almost exclusively to the teaching of techniques in the application of nuclear energy and to the teaching of courses substantially at an undergraduate or elementary level. A few years ago, this was the type of education for which students generally in Latin America were qualified and which was primarily needed. This is now no longer the case. The rapid progress of higher education in Latin America and the flow of graduate students to scientific centers of the U. S. over the past decade have now made it possible for all or nearly all of the leading universities to offer satisfactory courses of elementary and technical character.

A PRNC program devoted to the level of purely technical

education is not needed in the Pan American sense; it would also tend increasingly to attract less well prepared and competent students. Gradually the position of PRNC would be established as one of inferior quality, incapable of meeting the needs of students from the better universities, particularly those from South America.

To maintain its effectiveness as a regional center, PRNC must achieve scientific and academic distinction in the fields in which it can operate to the greatest advantage. This inevitably means a shift of emphasis from purely technical instruction to a post-graduate curriculum associated with a strong research program. The areas in which PRNC should be most active are those in which there is also the greatest need for the advancement of knowledge. Medicine and agriculture, oriented to the tropics, are obviously major areas of program activity. However, graduate education and research in these fields cannot be productive without strong resources in the physical sciences. Nuclear physics and radiochemistry are indispensable to the effective development of the bio-medical sciences. Consequently, an upgrading of PRNC activities on a broad front is imperative if the mission of the institution is to be achieved.

Although the University of Puerto Rico is now a large institution, its scientific strength is relatively weak; certainly it is inadequate to the objectives of the PRNC as they have been set forth. The greatest research activity has been in the Medical School. Very little has been undertaken in the physical sciences. The reasons for this situation need not be considered here; but the fact is basic

to the forward planning of the PRNC program. The UPR faculty cannot supply all of the scientists with the advanced academic qualifications which are needed. The development of strength through the training of young Puerto Ricans in U. S. institutions would require several years, a delay which would be fatal to the objectives of PRNC. The path to follow by necessity appears to be that of strengthening the scientific staff by recruitment from outside Puerto Rico, chiefly from the U. S. universities but also from other countries when suitable candidates may be so encountered. At the same time advanced training of young Puerto Rican scientists is essential for the future.

Most of the scientists recruited from outside Puerto Rico will probably be temporary but some should be willing to identify themselves permanently with PRNC. Obviously, such individuals must be acceptable to the University as tenure faculty members if they are to be considered permanent members of the academic community. In any case, service on a leave of absence basis of less than two years would not be generally productive and there should be a reasonable prospect that the visiting scientist will continue his association as part of his activity in his own university.

These remarks in the university framework apply equally to those whose normal posts are in the national laboratories or other special research institutions. There should be a special claim on the national laboratories because of their complete identification with the atomic energy program.

IV. PHYSICAL FACILITIES

On the Mayaguez campus, there is a building with approximately 39,000 square feet of floor area which houses the research reactor and the laboratories. A greenhouse of 2,000 square feet floor area has been constructed and equipped with the necessary features for work in the tropics. An auxiliary building of low cost construction to house the training reactor and teaching activities for which there is inadequate space elsewhere is planned for termination in FY-61 or early FY-62.

The largest piece of equipment is the research reactor. A pool type, this reactor is presently operating at one megawatt, but it is planned to raise the power later to five megawatts. It is designed for maximum flexibility and meets all foreseeable reactor requirements. The second reactor is a 10-watt aqueous homogeneous type and has proved invaluable for training reactor operators and for teaching the principles of reactor design and operation. A graphite-natural uranium subcritical assembly and a nuclear reactor simulator complete the reactor physics complex of major equipment.

The laboratories are well equipped for work with materials of both low and high levels of radioactivity. There are fully equipped laboratories for metallurgy, radiochemistry and physics. A gamma irradiation facility is being provided for the study of radiation effects and for research in food preservation.

At the Río Piedras location, the various programs are to be housed in a building of approximately 22,000 square feet floor area which is now nearing completion. The new structure is part of the Puerto Rico Medical Center now under development and is close to the new Cancer Hospital and also convenient to the University Hospital and other units of the growing Medical Center. A small amount of space will still be held at the Medical School in San Juan and in the school of Natural Sciences on the main campus.

Major AEC equipment available to the San Juan-Río Piedras programs consist of a complete radioisotope training laboratory, an 8,000 curies fixed-field Cobalt-60 teletherapy unit, Cobalt-60 needles and capsules of various sizes totalling about 800 radium milligram equivalent and other items of counting and radiation measurement equipment. In addition, the Radiotherapy and Cancer program utilizes the following equipment which is owned by the Dr. I. González Oncological Hospital:

a. Rotational Teletherapy Cobalt-60 unit of approximately 400 curies

b. Two deep therapy X-ray units

c. One superficial therapy X-ray unit

d. Approximately 700 milligrams of radium in the form of needles and cells of various sizes and activities.

The use of the above equipment by the Radiotherapy and Cancer Division is strictly dependent on the work load of these units as scheduled by the Dr. I. González Martínez Oncological Hospital.

V. ORGANIZATION OF PRNC

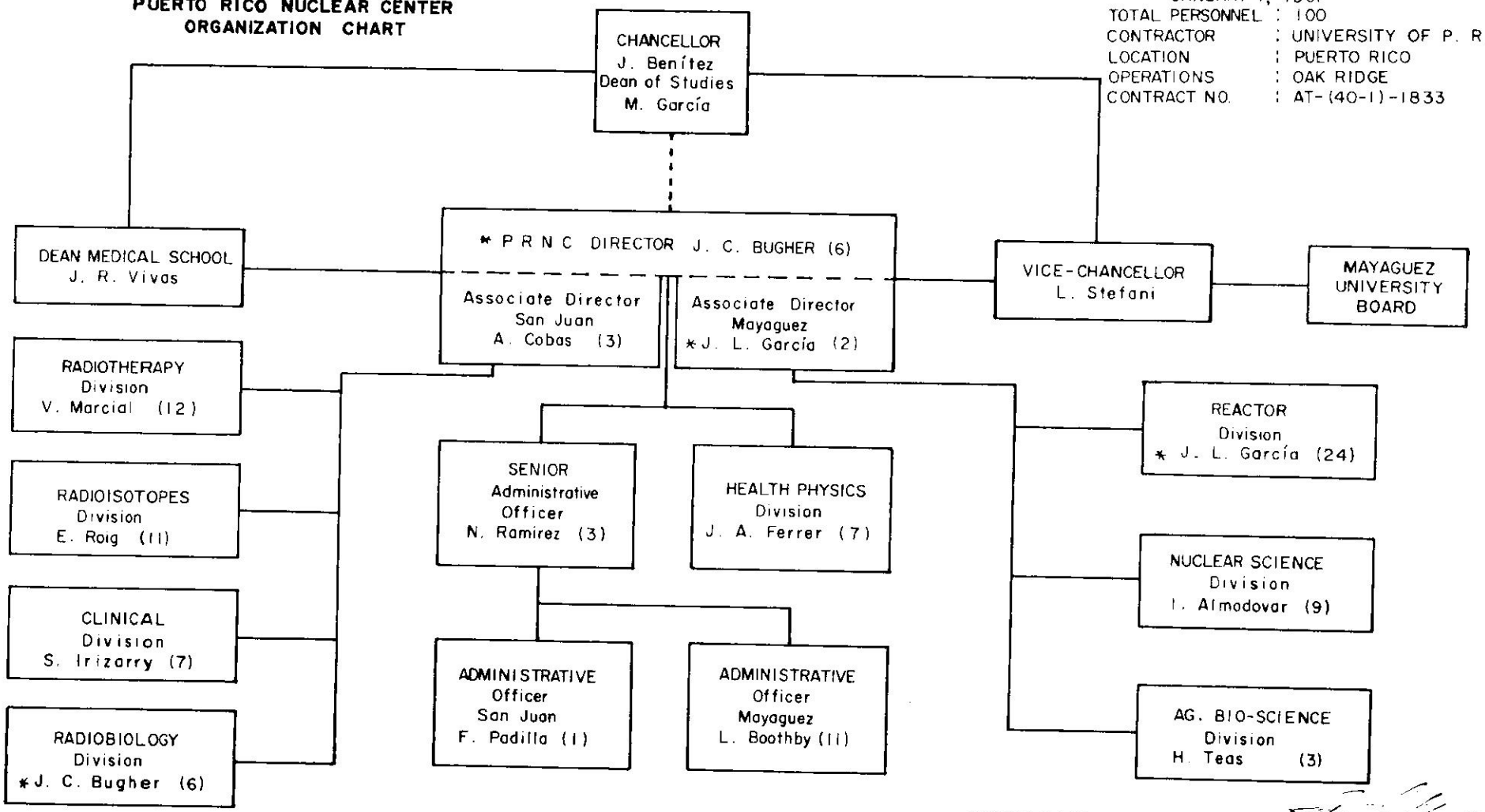
The general organization is shown in the accompanying chart. The program functions under a Director and two Associate Directors, each of the latter being primarily responsible for one of the geographic subdivisions of the Center. The Director reports to the Chancellor of the University through the Dean of Medicine in matters pertaining to the Río Piedras-San Juan campuses and through the Vice-Chancellor in matters concerning the Mayaguez area.

The major program areas are represented by Divisions, each with its respective Head, who is responsible for the operations in his program area.

To an increasing extent the programs will tend to involve the entire Center and measures must be taken to offset the handicaps imposed by the separation of 100 miles between the two halves of the organization. Modern communications are imperative and plans are under way to solve this part of the problem. The existing telephone service is entirely inadequate. Part of the communications lack can be remedied by a microwave beam installation carrying telephone, teletype, and television channels with further provision for data transfer between the two sections of the Center so that full advantage may be taken of a large computing facility which the University is planning for the near future.

PUERTO RICO NUCLEAR CENTER
ORGANIZATION CHART

JANUARY 1, 1961
TOTAL PERSONNEL : 100
CONTRACTOR : UNIVERSITY OF P. R.
LOCATION : PUERTO RICO
OPERATIONS : OAK RIDGE
CONTRACT NO. : AT-(40-1)-1833



* DUAL FUNCTION

APPROVED FOR CONTRACTOR

APPROVED FOR AEC

VI. PRESENT PROGRAM

The present programs of the Nuclear Center at Mayaguez comprise a series of courses of instruction which lead to a Master of Science degree:-

1. The Nuclear Science and Engineering Program: The PRNC offers a full curriculum leading to the degree of Master of Science in Nuclear Technology. The course of study starts with the summer session and requires one full academic year of 11 months. The curriculum follows the outline required for the USAEC nuclear science and engineering fellowships and has been approved by the Commission for attendance by these fellowship holders. The curriculum was first given in FY-1958 and is designed to give the students an understanding of the theory and operation of nuclear reactors and the associated chemical and metallurgical processes.

2. Radiation Physics and Health Physics: This is a one-year program first given in 1959-60 and leading to the degree of Master of Science in Radiological Physics. The curriculum is designed to provide the fundamental knowledge in radiation physics and biophysics, interaction of radiation with matter and living systems, dosimetry, instrumentation, and the principles of permissible exposure and preventation of undesirable exposure. The student is also introduced to some of the legal and public relation aspects of radiation protection.

3. Agricultural Biosciences: This new Division was established in late 1960 and is presently developing three Master of Science programs which have much in common but differ in their emphasis. The prospectuses of these programs are given in Appendix C. They have been formulated in close consultation with the College of Agriculture and will, it is expected, be an important channel by which the agricultural applications of nuclear energy will be accelerated.

Research activities of the Division have already been initiated with the equipment currently available. A preliminary study of the effects of neutrons and gamma radiation on a number of tropical plants, both as seeds and in the vegetative form, are under way, irradiated fuel assemlies being utilized as high intensity gamma sources. Other studies in plant physiology are being conducted in cooperation with the Federal Experiment Station and the University of Puerto Rico Experiment Station.

At San Juan-Rio Piedras the programs are directed mainly toward radioisotope utilization and training, and medical and biological uses of nuclear energy. These programs are as follows:

1. Radioisotope Techniques Training Program: This is the full time four-week course patterned after a similar course offered by the Oak Ridge Institute of Nuclear Studies. This course permits scientific and technical personnel to obtain training in the use of radioisotopes as tracers, to utilize them efficiently in testing and research.

2. Clinical Radioisotope Applications Program: This is a full time program in training and research in the clinical applications of radioisotopes for diagnostic and therapeutic purposes. Two kinds of programs are offered: a short term program which may last one or two months and another long term program which may last from three months to a year. In the short course the more common diagnostic procedures are stressed. In the long course therapeutic and research aspects of radioisotopes in clinical medicine as well as the diagnostic procedures are stressed. After the basic radioisotope techniques course has been successfully completed, two months are spent at the Clinical Radioisotope Laboratory in a formal program of lectures, seminars, and practical work.

3. Radiotheraphy and Cancer Training Program: The main purpose of this program is to teach physicians the safe use of ionizing radiations in the treatment of cancer. Two types of

trainees are accepted. Short term trainees are accepted for a minimum period of one month or longer for specialized training in a particular technique or to carry on a particular research activity. Long term trainees are accepted for a year or longer. Some may stay for as long as three years which is the minimum training time required by the American Board of Radiology. Trainees are taught to diagnose cancer, determine the extent of the disease, determine the radiosensitivity of the particular tumor, plan the treatment using radiation alone or in combination with other methods, carry out the treatment, and follow-up to determine response. In addition they are taught to solve various clinical problems associated with this form of treatment and also become familiar with roentgentherapy of different voltage levels, cobalt teletherapy of the rotational and stationary types, radium and cobalt for interstitial and intercavitary therapy, radiological physics, and radiobiology.

4. Radiobiology Program. The objective of this program is the teaching and training of physicians and advanced biologists in the utilization of radioisotopes and radiation in the preclinical or basic sciences of the medical field, including particularly biochemistry, pharmacology, physiology, anatomy and microbiology. The one-month radioisotope techniques course is a prerequisite. The program starts with an introductory laboratory and lecture course in nuclear biology. For those desiring more thorough training the program will be extended a second semester with seminars and a formal research problem in their own field of interest.

Since the inception of the program as outlined, a total of approximately 296 individuals have received training. (Details are shown in Appendix B.) Of the total, 61 are from 16 countries in Latin America, 189 are from Puerto Rico and the United States, and 5 are from Spain, India and the Philippine Islands.

Training in the Radiobiology Division has been limited to the use of facilities by nine (9) medical school students to do specialized experiments in biosynthesis of radioactive sulfur components by yeast and the incorporation of radioactive phosphorus into the phospholipids of different tissues of albino rats. These experiments were perfomed under PRNC supervision. Training by this division has been limited by the illness and eventual resignation of the division head.

VII. FUTURE DEVELOPMENT AND EXPANSION

The future development and expansion of PRNC programs should be determined by the needs of Latin America and Puerto Rico and the availability of qualified staff for the programs. The discussion of future development is primarily on organizational lines for clarity and presentation.

The contract for the Center provides that it will be a training and research institution. To date, however, emphasis has been placed on training with little attention being given to research. Experience indicates that the measure of competence of an institution offering graduate programs lies in the quality, vigor, and support of its research. The development of research is a prerequisite to the offering of sound graduate level training. Indeed, graduate education and research in a university may properly be considered as high level training.

A. Mayaguez Programs

1. Reactor Division: The Reactor Division is basically a service division in charge of the physical plant, running the reactors, hot cells, gamma sources and irradiators according to the needs of the other divisions. Also it is a technical division and the reactor supervisors must know how a reactor works, how its performance can be maintained and improved, how utmost safety can be achieved consistent with efficiency.

These are precisely the aspects that many Latin Americans will wish to learn, so training courses are planned for them. But to maintain the vitality of the staff and to contribute to knowledge of reactor design and operation, the staff members must have the opportunity to engage in research and development work along these lines. This work will be done jointly with the Nuclear Science and Technology Division for maximum effectiveness.

It is evident that there are many possibilities for suitable research, development, and testing programs in reactor operations, and these aspects should be encouraged, both for the sake of the staff and that of potential trainees.

The research reactor has been operating since October, 1960. It has been checked under the manufacturer's supervision, and the tests have subsequently been repeated. No significant difficulties have been encountered.

Procedures have been written for the principal training and research operations, such as start-up, rod calibration, neutron

irradiation, etc., and operator training courses will be established. It is planned that all graduates of the Nuclear Science and Technology Program will be eligible to obtain a reactor operator's license. Neutron irradiation techniques will also be established for the routine irradiation of samples for research and instruction in PRNC, and for any other approved organization.

As they develop, all services by the research reactor will be put under regular procedures. A number of instructional experiments, such as control circuit characteristics and operation, approach to criticality, control rod calibration, pile oscillation, void reactivity, etc. will be developed for student use.

A six-month to a one-year program for reactor supervisors will also be initiated. A study of reactor operation will be carried out, in cooperation with the Meteorological Station, to determine conditions under which higher power operation of the reactor might be permissible. These procedures may merely require suitable weather conditions, or may involve installing and testing a semi-enclosed coolant circuit within the pool.

Other appropriate services and activities, such as neutron activation analysis, gross radiation exposures, public inspection tours etc. will be established.

2. Nuclear Science and Technology Division: The present activity and recognized obligation of this division is the teaching of the courses that make up the curricula in Nuclear Science and Technology; the responsibility for scheduling faculty, students and

facilities for these curricula; and the development of research programs.

The nuclear sciences and nuclear engineering are presently associated in one division. Such a grouping becomes awkward as the division expands into the various activities with which it is charged, although this is an acceptable expendient during the initial establishment of the Center.

3. Health Physics Division: Until recently a section under Nuclear Science and Technology, Health Physics has now been given divisional status. In its surveillance functions, it reports to the Director and is responsible for health and safety in all of the operations of the Center. Experimental programs are reviewed for proper safeguards before initiation and consultation and direct assistance in operations are forthcoming from the staff of the new Division. The previous practice of contracting out some of the health physics operations is being discontinued so that the Health and Safety function may be completely met within the organization of PRNC itself. Otherwise, it would be impossible to maintain the ability to respond effectively to an emergency radiological situation.

In its teaching and research functions, the Health Physics Division will function as do the other Divisions. It will be based at Mayaguez but will have an operating branch on the Rio Piedras campus. The courses in Health Physics will be reoriented so that part of the training of Health Physicists will be given at the Medical Center where the students will become more familiar with the situations wherein patients must be given therapeutic radiation exposures

without endangering the health of those in the vicinity.

Environmental surveys will be, in part, the responsibility of this Division. There is special interest in adequate ecological studies of the Rincón region before operation of the Bonus reactor.

4. Curricula: The Center at Mayaguez has offered two curricula leading to the Master's degree: a Master of Science in Nuclear Science and Technology and a Master of Science in Radiological Physics. Based on the experience of the last three years, it is apparent that these two curricula do not adequately meet the needs of the students seeking to attend the Puerto Rico Nuclear Center. It is proposed to substitute the following degree programs, all of which would require the same total number of semester credits for the master's degree - (at least 30 and not more than 36). Each would carry admission requirements appropriate to the field of specialization. All would require a portion of the total effort to be applied to a special project, thesis, or design problem, as appropriate. Moreover, in a manner similar to that of most present day graduate schools, the curricula would be about one-half specified and the other tailored to the individual needs of the student. This would not jeopardize our authorization to accept AEC special fellows in Nuclear Science and Technology or in Radiological Physics, but is a change in the same direction as recent changes in the requirements for these fellowships. The curricula would start with the fall semester, and would, for the normal student, require full-time work and attendance until the end of the following summer. The summer

preceding the regular fall admission would be available for the fulfillment of unsatisfied admission requirements.

a. Master of Science in Health Physics: This will be quite similar to and will replace the present M.S. in Radiological Physics. The change in title is in line with recent actions of both the Health Physics Society and the AEC Committee on Health Physics fellowships.

b. Master of Science in Nuclear Engineering: This will be quite similar to the offerings in many U. S. University graduate schools. It will acknowledge the particular engineering bias of the candidates for admission, and will allow the students a specialization in an aspect of nuclear engineering related to their undergraduate training. For instance, the applicant with a Bachelor's degree in Chemical Engineering would logically continue specializing in the chemistry and technology of nuclear fuels. The electrical engineer candidate would specialize in reactor instrumentation and control problems.

c. Master of Science in Reactor Physics: This will be designed for the students interested in the problems of the operation and application of research and training reactors. It differs from nuclear engineering in many significant ways. There will be more emphasis on reactor physics, the dynamic behavior of reactors, the electronic aspects of reactor instrumentation, and the instrumentation of problems associated with the use of reactors. Such training is becoming more important as reactors become more numerous and varied in design.

d. Master of Science in Nuclear Science: This is intended for the broad spectrum of students interested in the nuclear aspects of the biological and physical sciences. The degree will carry a specification of a major in some topic, such as Agronomy, Nuclear Physics, Radiation Biology, Radiochemistry, etc. The curriculum will be partly unspecified, but will require those courses common to all of these areas, such as Health Physics. It will be designed to fit with the background and experience of the student. Courses will be accepted by the academic departments of the University as representing graduate level work, and

will include a thesis representing an investigation of some nuclear aspect of the student's specialization.

The above recasting of curricula is based on the presumption that there will be available, either on the Center staff or on the faculty of the University, the variety of professional capacities that are necessary. Although such a diversification of offerings will represent some increase in average effort expended per student, it does not represent by any means a proportional increase in teaching load. Many of the courses will be common to several curricula. By means of thesis research, design problem, or special project, the students will in turn contribute to the research program of the Center.

B. San Juan-Río Piedras Programs

1. Radioisotope Techniques Program: In the Radioisotope Applications, the needs for training in Latin America should increase due to the present trend and emphasis being placed on the use of radioisotopes in medicine, industry, and agriculture. Along with this increase there must be an increase in the number of persons trained in the uses of radioisotopes.

It is evident, therefore, that for the Radioisotope Applications Training Program we should:

a. Continue the basic radioisotope courses at the present level.

b. Discontinue the Radiation Protection Techniques course in favor of an amplified program in Health Physics.

c. Introduce specialized courses in the basic techniques as applied to industry, agriculture, and clinical diagnosis.

d. Include research programs in support of the above training and along the lines of interest of the staff. Such research could very generally encompass the use of radiations for sterilization and chemical processes; the employment of radioisotopes in the teaching of basic principles in chemistry; and the application of particle emitters in pure physical or chemical research.

2. Radiotherapy and Cancer Program: It is felt that the Radiotherapy and Cancer program, more than any other PRNC program at present, has been most generally accepted in Latin America and has had the least difficulty in attracting trainees. The usefulness of this program for Latin America can best be stated by the fact that to date there are no organized training programs in Radiotherapy in Latin America, yet these countries are facing a constant increase in the Cancer problem. The Radiotherapy and Cancer Division will assist materially by training individuals who can continue needed programs in their own countries.

The Radiotherapy and Cancer program depends on the Cancer Hospital for those facilities which are impractical to duplicate. Such facilities include the clinical laboratories, patient beds, the departments of medicine, pathology and surgery, and out-patient facilities. However, therapy units are necessary for training in the PRNC building. Trainees must be given the opportunity to use and judge various types of radiation treatment, either alone or in combination with surgery. Also, specialized equipment such as a betatron or a linear accelerator will be required. These units would be used for the production of X-ray beams of supervoltage and megavoltage levels and for high energy electron beam therapy. Such equipment would enhance the training and research

potential of the Center in radiation therapy, radiobiology and radiological physics. The current research programs in the evaluation of radiation response of tumors to conventional and supervoltage modalities by cytological techniques will continue. New programs to be started include tumor and tissue culture studies, effects of pharmacological agents on radiation responses, and alteration of tumor bed circulation and oxygenation. Training course content will be altered and improved as new equipment and personnel are obtained.

3. Clinical Radioisotopes Program: The increasing use of radioisotopes in clinical medicine also makes the Clinical Radioisotopes Program important to Latin America. As in the case of the training in Radioisotope Techniques there is a demand for personnel qualified to use radioisotopes in Clinical Medicine throughout Latin America. There is every reason to believe that within the next few years this program will have many more legitimate requests for training than can be accommodated.

It is expected that there will be no major change in the training program of the Clinical Radioisotope Division in the near future except to introduce new techniques as they are developed and proven. The research potential is good and the current research projects in vitamin B-12 absorption in tropical sprue, fat absorption in tropical sprue and iron metabolism in various anemias will be continued. The activities will also be expanded to include pediatrics, surgery, ophthalmology, urology and gynecology in addition to medicine.

Additional equipment required for the instruction in new techniques in clinical diagnosis and therapy will be procured as required.

4. Radiobiology Program: The Division of Radiobiology will be activated as rapidly as in consistent with other program demands in order that it may be responsible for the teaching of the principles of radiobiology which are fundamental to all of the other biological and medical programs. The interaction of various modalities of radiation with living systems, both unicellular and multicellular, will be presented in considerable detail. The effects of these interactions as manifested at the various levels of tissue organization will be discussed and will form the basis of a series of laboratory operations. Both the genetic and somatic effects of radiation at various stages of tissue and organ differentiation will be considered.

Since its operations will require a considerable amount of biophysical equipment, this Division will have to be prepared to render a number of service functions to the other Divisions of the Center. Among these are: ultracentrifugation, ultraviolet and infrared spectrography, tissue culture, statistical consultation, microbiological and pathological services.

5. Medical Biosciences Division: This new Division should be activated in the near future to provide the bread coverage in the medical field not now supplied by the existing organizational units. The Clinical Radioisotopes Division is primarily concerned with the problems of clinical application of established procedures. There is need for

the Division of Medical Biosciences to conduct those special studies and do graduate teaching in those areas of medicine for which the nuclear tools are essential to understanding. In this Division should be performed those investigations which may ultimately lead to new diagnostic techniques which can be applied by the Clinical Radioisotopes Division.

The primary activity of this Division will be medical research and post-graduate medical teaching in broad areas of first order concern in the tropics. First among the fields to be considered will be tropical nutrition. As infectious disease is overcome, the more abstruse aspects of malnutrition become progressively more important. Gross malnutrition is generally recognized as an outstanding problem among primitive tropical peoples but the finer structure of nutrition in the tropics is not at all well understood. Herein biochemistry, especially that of enzyme systems, must play a major role and must include an examination of the dynamics of trace elements, a field where present day knowledge in fragmentary in the extreme.

This Division should also concern itself with the tropical parasitic diseases that remain in Puerto Rico, and attempt to devise new attacks upon them with the objective of eradicating them. Foremost in the list is schistosomiasis; which not only persists in Puerto Rico but elsewhere in the tropics has stubbornly refused to yield to the existing public health and sanitation techniques. New approaches are needed in regard to this problem and it is possible that useful answers will be found in the radiobiological approach.

These are examples of problems of high priority which await the activation of the new program. Further study of the medical patterns of Puerto Rico will doubtless disclose numerous other disease entities not now suspected. Among them, one can anticipate, will be a number of genetically determined metabolic deviations or defects which can only be recognized and studied by radiological methods.

VIII. RESEARCH PROGRAMS

In addition to the comments regarding research activities that have been made in connection with the divisional plans, certain general statements are desirable. In the perspective set forth in the introduction, it is clear that PRNC cannot attempt to be competent in all aspects of nuclear science. It must emphasize those fields which are of paramount importance in the tropics and especially in Puerto Rico, and which at the same time are within the capabilities of its equipment and manpower. Its research, therefore, cannot be conducted in all of the fields in which it gives instruction. Instead, the research program must be somewhat restricted in that it should be directed at those problems of the region which are of primary importance and the investigation of which can best be done in Puerto Rico.

In the biological area, there is a great opportunity and need for new lines of exploration in medicine and agriculture. Indeed for the near future, as has been reiterated many times in the past, the greatest returns from nuclear energy will probably be found in these two fields. Further, the two may be profitably linked. The study of nutrition in man should establish lines of prior concern for the developments in agriculture. In the medical domain, PRNC can act as the sparkplug for the activation of medical research of a kind new to Puerto Rico and may contribute both directly and indirectly to the advancement of knowledge.

The medical program, which should be primarily directed to the deficiency diseases and cancer, will enjoy the close cooperation of the new laboratories for clinical research now being established by the Medical School. It may look also to the other units of the Medical Center and especially to the brilliantly conceived Regionalization Program of Medical and Health Services for assistance in conducting its research. The Regionalization Program gives immediate access to most of the population of the Commonwealth and will make available to PRNC its great resources in records and statistics.

The potential is outstanding for a highly productive cancer research program on the part of the Nuclear Center. The new Cancer Hospital, in juxtaposition with the PRNC building at the Medical Center, will have 102 beds together with an additional 50 beds for ambulatory patients in the rehabilitation hospital under construction. This hospital, supported by the Puerto Rican public and operated by the League Against Cancer, is an unusual one in the degree with which it is integrated with the medical activities of the Commonwealth. As part of the Medical Center, the Cancer Hospital will be even more effective. For the past 10 years there has been practically 100% follow-up of all cancer patients, and through the Regionalization Program the quality of this activity may be substantially improved from the standpoint of medical records and investigation.

For all practical purposes, PRNC has available for research purposes over 100 beds for which it does not have to provide the capital costs or the operating expense. Through the Commonwealth Department of Health and the community health centers, essentially all cases of malignant disease on the island can be known, so that the statistics can be practically complete. These features, together with the fact that there are unusual frequencies of some types of cancer, make a program of clinical cancer research especially attractive.

In addition to the research program described in some detail in the prospectus of the Division of Radiotherapy and Cancer, there is the opportunity for an advanced study of chemotherapeutic compounds as adjuncts to radiation therapy and surgery. This would involve the synthesis of such compounds tagged with C-14 and tritium, and in some instances with P-32 and S-35. Tissue distribution and the metabolic pathways of these compounds in human beings would be compared with that in tissue cultures of neoplastic and non-neoplastic human cells and to a limited extent of laboratory animals. If the clinical competence exists in PRNC and the Medical School, then these studies should be extended to the steady flow of leukemia in children which would come to the Medical Center and the Cancer Hospital if there were a little encouragement.

Still another line of investigation which is already incorporated in the program plan is the experimental study of the use of

neutron capture reactions in neoplasms. It is not presently contemplated to use the reactor for human therapy but rather to confine the study to transplanted neoplasms in small laboratory animals. This part of the program would function in close collaboration with the Medical Department of Brookhaven National Laboratory.

Agriculture is an area wherein the Nuclear Center has major contributions to make. During the past 20 years, Puerto Rico has put primary emphasis on social and industrial development, and agriculture has received less attention so that its slower progress has resulted in a relative lag. The nuclear scientist has much to contribute to plant genetics, plant physiology and soil fertility. Agriculture to a large extent involves applied science, but the research which is required is often of the most fundamental character. Photosynthesis, enzymatic conversions, electrolyte and water movements, cell respiration and the physical chemistry of inorganic systems of low solubility are but some of the areas of research that are vital to the development of agriculture. Naturally, there is especial interest in those systems of major economic importance. Fundamental research may be conducted with plant systems of economic consequence just as profitably as with those species of little human interest. The problem of experimental design is one that requires intellectual scope that goes beyond the immediate scientific problem.

It would be the expectation that from the research program of PRNC there would ultimately result a substantial increase in productivity in tropical agriculture relative to Puerto Rico. This would presume cooperative operations with the various experiment stations, the College of Agriculture and the College of Engineering.

Earlier mention was made that one of the advantages possessed by Puerto Rico is that it is an island in the tropics. There exists, therefore, the opportunity to carry nuclear technology into marine biological studies. There are many arguments in favor of having PRNC participate in this general field. One of the most cogent arguments is that our ignorance of the functional biology of marine organisms is abysmal. We cannot predict with any accuracy the ultimate effects of radioactive contamination in any part of the ocean. The practical side of this is that policies of waste disposal in the sea cannot be formulated on a sound basis in the present near-vacuum of accurate scientific information concerning the differential uptake of individual radioisotopes by components of the plankton which in turn become part of the food chain leading to man.

The University of Puerto Rico already possesses a marine biological station located at La Parguera, a situation of rich coral growth. A second station is being discussed for the eastern end of the island where the conditions are quite different.

Because of inadequate staffing and the lack of a competent and dedicated marine biologist, the existing station has had a low order of productivity from its inception. The possibilities inherent in the use of radioisotopic techniques have not been at all appreciated.

The contribution of PRNC to this program should be of minor magnitude in terms of budget. A reasonable participation would be to add to the staff an outstanding marine biologist with a few technicians to lead a program, the major support of which would come from other sources through the University. The other sources would be the National Science Foundation, the Office of Naval Research and the private foundations.

In the physical sciences, again, careful selection of the areas of research activity must be made. While it is difficult in nuclear physics to identify specific problems that can be better executed in Puerto Rico than anywhere else, there are other considerations that assist in making the choices. It would be desirable, for example, for the research at PRNC in physics and chemistry not only to have sound value in its own right, but also to be directed to problems the solution of which might have good prospect of leading to substantial progress in other areas of research activity. For this reason, study of the phenomena of the solid state, particularly those concerned with molecular structure and forces, would, in all probability, lead to similar investigations of substances of primary biological interest.

Additionally, there are sections of nuclear physics where present knowledge is incomplete, but where the equipment of PRNC would be admirably adapted to graduate work. Neutron activation cross sections at precisely known energies is an example of this type of study. The potential exists for carrying such measurements to very low temperatures.

In the nuclear engineering field, again the reactor forms a center about which the research program may concentrate. Studies of radiation damage to materials and components of reactor systems are well adapted to Master of Science thesis work and should yield useful scientific information about materials for which knowledge is now insufficient.

Plans are now being formulated for the study of the thermal emissivity of ceramic surfaces under neutron and gamma irradiation. This program, which should begin in July of the current year, will utilize one of the reactor ports and will begin with studies of thermal emission from graphite at about 2,000°F. Later, it is contemplated that similar studies employing single ceramic fuel elements will be undertaken.

All of the new research programs discussed in this section will utilize the reactor in one way or another. Some of them are wholly reactor centered; in other cases reactor services are necessary for their implementation. The production of radioisotopes of short half life is one important function. Another is the

development of activation analysis, especially in connection with the agricultural and medical programs. The reactor is admirably designed for these irradiations. Much remains to be done, however, in the exploration of the neutron energies to be favored in the activation and in the efficiency of pulse height analysis for the quantitative estimation of elements present in small quantity. This will be essential for the program in nutrition mentioned earlier.

Some of the research program would undoubtedly arise simply because of great personal interest on the part of members of the staff. Research of this kind should be encouraged even though it could be conducted as well elsewhere, as long as such research is related to nuclear energy and would not involve the neglect of higher priority work.

In the last analysis, the case for emphasizing research throughout the PRNC program is very simple: No scientific program devoted solely to technology will long survive. A program of applied technology only in the Latin American scene can neither attract good students nor hold superior teachers. Without a rounded and dynamic academic structure and character, the Puerto Rico Nuclear Center would not only fail to enhance the reputation of the United States; it would fail more profoundly in its inability to meet the changing needs of the region it should serve.

In summary, the advanced research programs which have been discussed in this section may be listed as follows, together with the operating Divisions of PRNC that would be involved:

Program	Divisions of PRNC concerned
Human nutrition	Medical Bio-Sciences Clinical Applications of Radioisotopes Radiobiology Reactor Agricultural Bio-Sciences
Chemotherapy and Radiotherapy of Cancer	Radiotherapy and Cancer Medical Bio-Sciences Radiobiology Clinical Applications of Radioisotopes Reactor
Marine Biology	Agricultural Bio-Sciences Reactor Nuclear Science and Technology Radiobiology
Solid State Physics, Neutron Diffraction Molecular Structure	Nuclear Science and Technology Reactor
Heat Transfer under Irradiation	Reactor Nuclear Science and Technology

IX. BUDGETARY IMPLICATIONS

In Table I (page 36)* are presented the actual costs for operations and equipment through FY-1960. Table II (page 37)* exhibits the previously estimated and now revised costs under these categories through FY-66. In this table, which begins with the date of assumption of duty by the present Director, the total

*Page numbers refer to original text. Tables are on following pages.

TABLE I

PRNC OPERATION COSTS FY-58 THROUGH FY-60

	Fy-1958*	FY-1959	FY-1960
Operations	$119,068	$283,180	$467,500
Equipment	140,552	226,193	225,000
TOTAL	$259,620	$509,373	$692,500
Man Years	21	40	67
Cost/Man Year Operations	$5,670	$7,079	$6,978

* 10/1/57 - 6/30/58

TABLE II

PREVIOUSLY ESTIMATED AND CURRENTLY REVISED ESTIMATES PRNC OPERATIONS
FY-61 THROUGH FY-66

	FY-61		FY-62		FY-63		FY-64		FY-65	FY-66
	Submitted (Financial Plan)	Revised	Submitted	Revised	Estimated	Revised	Estimated	Revised	Estimated	Estimated
Operations	758,000	859,000	859,800	1,203,500	935,000	1,450,000	1,000,000	1,650,000	1,790,000	1,920,000
Equipment	180,000	272,000	124,000	228,000	110,000	250,000	100,000	100,000	100,000	100,000
Total	938,000	1,131,000	983,800	1,431,500	1,045,000	1,700,000	1,100,000	1,750,000	1,890,000	2,020,000
Man-Years										
Scientific	41	33	47	56	-	65	-	70	73	75
Technical	22	42	27	63	-	75	-	85	90	95
Other	41	51	41	60	-	62	-	65	67	70
Total	104	126	115	179	120	202	125	220	230	240
Cost/Man-Year Operations										
Scientific	18,487	26,030	18,294	21,491	-	22,310	-	23,570	24,520	25,600
Total	7,228	6,711	7,476	6,723	7,800	7,200	8,000	7,500	7,800	8,000
Construction						500,000				

man-years are broken down into their components in order to show the shifts in character of the personnel that are now in process.

The activation of research programs requires a much greater proportion of the staff be of a technical or supporting level. It is possible that a greater ratio of technical to scientific personnel should be contemplated than is here shown (scientific personnel is here defined as being composed of persons responsible for planning and directing the actual research and teaching), but it is felt that the proportion is about right when one considers the amount of graduate teaching that will be involved.

The cost figure per scientific man-year during these early years is somewhat unstable as a result of the variable relocation costs for those men who have to be recruited from outside Puerto Rico. As time passes, and as staff members are recruited from among those receiving their training at PRNC, this source of cost should become relatively smaller although it will always remain an appreciable item if the policy of drawing upon the universities and the national laboratories is followed consistently.

The annual cost of operation per total man-year appears to be a somewhat more stable figure at the present time. Because of the shift in the composition of the staff to include a greater portion of technical and assisting personnel, the revised estimates for FY-61 and FY-62 show a decrease in the cost per total man-year. This cost, of approximately $6,700 per total man-year, has been

escalated as shown to allow for the maturation of the program and foreseeable cost of operations. No allowance has been made for possible inflationary or deflationary movements in the economy generally.

The estimates for operations being determined on projected total man-year costs, the cost per scientific man-year has been calculated and is shown in Table II. There is implied a rising cost per scientific man-year from approximately $21,500 in FY-62 to $25,600 in FY-66. This appears reasonably in line with the costs of other programs of similar magnitude. It should be borne in mind, however, that the program in Puerto Rico is actually an overseas one and that costs will tend to be higher than for the continental U. S. if experience in other fields may be taken as a guide.

One major piece of construction is shown to be budgeted in FY-63. This is an addition to the biomedical building at Río Piedras which would approximately double its floor area. The addition would involve extending the present building to nearly twice its present length. The land is available for the purpose and since site development has been largely accomplished in the construction of the present laboratory, the cost of the additions is estimated at somewhat less than for the existing structure.

Pending the availability of this addition, a temporary animal house is a necessity, there being no animal quarters in the

present Nuclear Center. By sharing the problem with the Medical School, it is probable that the necessary temporary animal space may be constructed within the funds available for minor plant projects.

As to further expansion beyond FY-66, it is difficult to give a clear prediction. If the program will have fulfilled its functions properly, there would probably be a need for further expansion. One can estimate that about 70 scientists is the minimum for effective operation in as many scientific disciplines as PRNC is committed to serve. A very much larger institution would overbalance the University and tend toward isolation from the academic community. It seems reasonable to say, therefore, that growth beyond that projected for FY-66 should depend not only upon the needs in Latin America, but also upon the progress in the sciences that the University of Puerto Rico has itself shown by that time.

APPENDIX C

PUERTO RICO NUCLEAR CENTER
Operated by
University of Puerto Rico
for
U. S. Atomic Energy Commission

August 2, 1963

Gen. Alvin R. Luedecke, General Manager
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Al:

Your letter of July 27 brings to a focus the essential difficulties in defending the financing of this Nuclear Center. Part of the difficulty is historical. The motivation for the original establishment of the program in Puerto Rico was political to an unfortunate extent rather than scientific. It is generally true that political considerations may change with great rapidity while the real scientific problems must be resolved on a different and generally much longer time scale.

Since you bring out the basic question so clearly, I will say that, in my personal opinion, the training of Latin Americans in the applications of atomic energy is a reason but not a sufficient reason for the establishment and operation of a center such as this. I am more concerned with the problems and needs of the U.S.; in this sense, I believe that there is a pretty good case which I will try to state.

With the exception of Brookhaven National Laboratory, our major centers of research in the non-military aspects of atomic energy grew on the structure of the wartime and post-war weapons development operations. This was inevitable for economic and staffing reasons principally, but one result has been that the greatest impact on science and industry of the atomic energy program has been in the northern portion of the United States. The scientific problems of the country, however, have no such geographic emphasis. We have a good number of research centers working on the agricultural, medical and engineering problems of the more wintry portions of the country, but the Center in Puerto Rico is the only center of research which can be directed to primary problems of the tropics. It is in this framework that I feel that PRNC will justify its existence and toward which I have been striving to direct its activities.

A few examples from the present program may serve to illustrate the point:

1. One of the sources of serious loss in sugar production, especially in Alabama, is the cane borer (Diatrea saccharalis). An appreciable portion of the crop is lost each year throughout the cane growing regions, a loss that amounts to many millions of dollars annually. This is basically a tropical problem and is most profitably attacked on an island. It appears from the work we have so far accomplished that there is some prospect of eradicating, through radiation sterilization of the males, this moth whose larvae cause so much damage. This is part of our program of increasing the yield of sugar in proportion to the labor involved. Another phase concerns the genetic structure of sugar cane itself which we are attempting to modify through neutron bombardment of both sugarcane seeds and plants to achieve a more efficient plant.

2. Tropical Marine Biology and Oceanography

PRNC is now conducting highly significant marine research in the tropics. Most of this is related to questions concerning the effects of power reactors and nuclear rocket propulsion on the food cycles of the tropical seas. These cycles are quite different from those of high latitudes and the investigations of one zone do not substitute for those of another.

These operations are also yielding significant new information concerning the geology of Puerto Rico and the adjacent submarine structures. Of substantial, although incidental value, are the measurements being made of the total productivity of the ocean at various depths and areas. These figures, which indicate the ultimate potential of fisheries, etc., can only be obtained by the use of radiochemical techniques and radioisotopes since the basic measurement is of the total photosynthesis per unit volume of the sea. The research reactor has made these measurements possible.

3. Environmental Radiobiology of Tropical Forests

In many ways related to the marine studies, the new program in Terrestrial Ecology is moving rapidly in quantitative evaluation of the effects of nuclear radiation on the growth and survival of forest trees in the tropics when subjected to nuclear radiation. This is the first step of a program the Division of Biology and Medicine plans to extend to forests of higher latitudes. It is a study which is vital to predicting the ultimate damage of nuclear war.

4. Radiobiology of Arthropod Borne Viruses

This second phase of ecology is just becoming established and may produce information of the greatest public health value. While designed to investigate the effects of radiation on naturally occurring virus systems important to man and domestic animals, its operations will yield much information concerning the movement of viruses as yet little known between North and South America by way of the Greater and Lesser Antilles. The recent outbreak of encephalitis in Florida will probably be found to be associated with other centers of virus activity in the Caribbean area and the Department of Health of Puerto Rico has been so advised. Because of the broad interest in this program, both NIH and the Communicable Disease Center of PHS are cooperating with us in this work.

5. Cancer in the Tropics

There are some marked differences in the frequency of certain types of cancer in Puerto Rico as compared with continental United States. These special characteristics plus some unusual resources make Puerto Rico a natural location for major cancer research. A copy of a letter I have written to Dr. Endicott of NIH is attached for further information on this phase of the subject.

It is not generally realized that PRNC in its training and research activities in cancer carries the direct medical responsibility for more cancer patients than all other AEC cancer projects combined. In terms of the number of qualified radiation therapists produced yearly, I believe that PRNC is now second in the United States, the No. 1 training center being Dr. del Regato's service at Penrose Memorial Hospital, Colorado Springs.

6. Solid State Physics

With the timely support of the Division of Research, PRNC is vigorously active in research dealing with molecular organization in the solid state. The program utilizes neutron and X-ray diffraction at Mayaguez; and at Río Piedras, involves studies of photoconductivity as a measure of radiation damage in pure crystals of organic semiconductors. These programs are being developed in close cooperation with Brookhaven National Laboratory and, especially in the case of the neutron diffraction work, the establishment of a good program in a short time was made possible by the active participation of the Department of Physics of BNL.

This research is not related to problems of the tropics but has arisen because the necessary resources and the

scientists who are interested in doing the work are here. Eventually, I anticipate that this fundamental physical research will lead to new concepts and methods in the biological field, thus affecting both medicine and agriculture.

7. Radiation Effects in Schistosoma

This parasitic infestation of man which causes so much misery in tropical Africa and Asia is one of the few public health problems in Puerto Rico which has not been at all relieved by the developments of recent decades. The research going on here is concerned with the possibility of using irradiated parasites to produce immunity. It is actually the only new idea concerning the prevention of this disease that has developed in the last 20 years.

A similar study is being conducted at Walter Reed hospital and there is also interest on the part of the Public Health Service. Cooperation is being developed with both groups. A very important point is that the problem is a serious one in Puerto Rico so that this island is the logical place for such research.

These are a few of the activities which for the most part deal with major issues of the tropics and which are of special concern to the United States. It is a fair statement that a moderate success in any one of several of these projects would repay the total PRNC effort many times over.

The opportunities for participation in advanced research are making the PRNC increasingly attractive to mature scientists in other countries. This is particularly true in organic chemistry, a field in which PRNC, through having attracted some outstanding people, is showing real strength. The educational impact on Latin American countries thus seems to become a valuable by-product of an increasingly strong attack on fundamental problems of this part of the world.

I hope that these remarks may be of some assistance in clarifying the nature of the transformation that has been in process. I am also aware that the delay in getting out an annual report dealing with the program content so far accomplished has been an additional handicap. I have given the issuance of this report the highest priority and we should have it available within a few weeks.

I would be glad to come to Washington at any time that you suggest. Most of our problems arise because the program is moving at a brisk pace on several fronts simultaneously. That is a much

more satisfactory position to discuss than one in which no activity is present.

Although not expressed in specific project terms, the location and the special mission of PRNC has made it possible to improve greatly scientific communication with the Spanish speaking countries. Scientists, who otherwise would not have been available, have been drawn into programs of direct benefit to the United States and for which United States personnel could not have been recruited. In the long run, these activities will strengthen the scientific resources of the respective countries and in the interchange resulting I am confident that the best interests of all will have been served.

Many thanks for your interest and help, and best regards to all of the family.

Sincerely yours,

John C. Bugher, M.D.
Director

Encl.: Letter 8/1/63 to Dr. K. Endicott

PUERTO RICO NUCLEAR CENTER
Operated by
UNIVERSITY OF PUERTO RICO
for
U. S. ATOMIC ENERGY COMMISSION

Bio-Medical Building
Caparra Heights Station
San Juan, Puerto Rico

August 1, 1963

Dr. Kenneth Endicott, Director
National Institute of Cancer
Bethesda, Maryland

Dear Dr. Endicott:

The Puerto Rico Nuclear Center, supported by AEC, under a cost reimbursable contract with the University of Puerto Rico, is a multidisciplinary project operating on the major campuses of the University. It is oriented especially toward Latin American problems in graduate education and research. The medical activities are concentrated at Río Piedras where the Biomedical Building of PRNC forms one unit of the new Medical Center and is adjacent to the new I. G. Martínez Oncologic Hospital.

In the field of cancer, PRNC conducts training in radiation therapy and, under the aegis of the Cancer Hospital, administers all radiation therapy for the Medical Center. It is also developing a research program emphasizing cellular radiobiology and the epidemiology of certain forms of malignant disease which show unusual frequencies in Puerto Rico. In the latter field, the program operates closely with the Cancer Control Service of the Commonwealth Department of Health by which complete patient follow-up has been maintained over the past years.

The Cancer Hospital, physically connected with the Nuclear Center, is another and distinct operating unit of the Medical Center. It has 106 beds exclusively for cancer patients and, in addition, operates a large ambulatory service for which another 50 beds are available in a neighboring convalescent hospital. At the present moment, these beds are primarily devoted to medical care of cancer patients but potentially they are also all research beds. Under the existing agreement between the Cancer Hospital and the Nuclear Center, patients who remain in hospital for special examinations and studies beyond the minimum required for routine care may do so with the additional costs being carried by the Nuclear Center.

Dr. E. Endicott

The close working relationship between the Cancer Hospital, the Commonwealth Department of Health and the Nuclear Center makes possible an unusually effective access to nearly all of the cases of cancer occurring in Puerto Rico and direct contact with the majority of them. It is expected that as the Medical Center organization becomes completely operative, a more intimate association between the Medical School and the Cancer Hospital will develop and that teaching and research activities within the Cancer Hospital will increase.

It seems to me that there is developing an unusual opportunity for advanced research in the field of human cancer. The AEC through the Nuclear Center has already established a substantial operation in the radiological and radiobiological areas. This is a limited effort, however. Such subject as chemotherapy, epidemiology, etc. belong more specifically in the program responsibilities of NIH. The logical result of these considerations might well be a joint or strongly cooperative program in which the available resources would be used to the maximum advantage in advancing knowledge concerning cancer in the tropics.

I would like to invite a site visit on the part of yourself and your staff in order that you might have a first hand knowledge of the advantages as well as the difficulties in the evolution of a program such as I have suggested. I would hope that Dr. Dunham would also join us and that all the factors in this essentially unique situation could be discussed. It is my hope that ultimately a proposal may be developed but it does not seem to me that we have yet arrived at the point of its proper formulation.

The administration of the Cancer Hospital would welcome such a vist as I have suggested as will the Medical School. As to dates, whatever is possible for yourself and Dr. Dunham will be agreeable to us. In many respects, the earlier the conference the better for events are moving quite rapidly here.

For general orientation, I am including some background information concerning the Medical Center, the Cancer Hospital and the Nuclear Center.

Sincerely yours,

John C. Bugher, M.D.
Director

APPENDIX D

THE FOLLOWING NARRATIVE WAS INCLUDED IN THE PRNC FY-1966 BUDGET SUBMISSION:

The budget proposal for FY-1966 for Program 07 is essentially identical with that originally submitted for FY-1965 and which in turn was the level previously planned for FY-1963. In the intervening years, appropriation actions have forced a progressive cutback in educational activities, reaching the break point in the current year resulting in the drastic reduction of operating program in FY-1965. All divisions of the Program 07 are reduced but that devoted to agriculture will be practically suspended. The Division of Agricultural Biosciences has performed very well during the current fiscal year and a very productive program has been in operation, especially in graduate education where it has attracted more advanced degree candidates than any other division. The chief reason for cutting back in this part of the program so drastically is that it is the only division from which the scientific staff can be moved into current special research projects. Since the scientific personnel are also members of the university faculty and are entitled to the same considerations as are those pertaining exclusively to the University of Puerto Rico, the termination of appointment for purely budgetary reasons could well encourage the opponents of the contract between the University and AEC.

These moves inevitably mean a diminution in the effectiveness of PRNC in its Latin American mission of Education and Training and

some reduction in participation must be anticipated, particularly in the category of those who will form the future scientific strength of the Latin American universities.

A substantial change has occurred as the result of the introduction of research support on a project basis by the Divisions of Biology and Medicine and the Division of Research. The financial assistance of course has been of great value but the most important aspect is that research at a high level of competence has been established and that the United States now has a going nuclear research capability located in the tropics in an environment that is entirely propitious for those investigations that pertain to problems either tropical in nature or which may be most favorably attacked in a tropical setting. An example of research which can only be done in the tropics is the program of radioecology of a tropical rain forest which is now fully operative. Among the problems most favorably attacked in the tropics is the genetic work on paramutation in corn where the fact that two crops may be harvested a year doubles the rate of progress over doing the same work in the northern states.

The special research projects are oriented to the interests of the United States and only incidentally to the concerns of Latin American countries. Many of them are entirely concerned with AEC programmatic requirements. The development of this part of the total program thus implies a substantial change of objective. To

a limited extent, the special research programs can absorb a few advanced degree candidates but in general these projects are not designed for graduate thesis research which requires problems of limited time demand and the adjustment of the research to the needs and capabilities of the student. These research programs are essential if the scientific stature of PRNC is to be of consequence; however, they do not substitute for the type of research activity which is vital to Program 07.

Among the outstanding achievements of the current year are:

1. The successful isolation of the virus of dengue fever in the first outbreak in Puerto Rico since 1918. The virus appears to be a new type and one which can be studied only with the most sophisticated of virological techniques. Over 20,000 persons are known to have been affected in this outbreak.

2. A substantial increase in interest in radiological health at the graduate level.

3. By refinement of the techniques of neutron activation analysis and atomic absorption spectrography and their application to the quantitative measurement of stable isotopes of trace elements, new light has been thrown on the geological history of the submarine shelf (analogous to the continental shelf) about Puerto Rico and on the chemical mechanisms of bottom sediment formation.

4. A new class of organic compounds of boron which are resistant to hydrolysis.

5. The participation in a movement sponsored by the Organization of Catholic Universities of Latin America to accelerate the development of science programs at the graduate level in the universities of Latin America with special reference to nuclear science.

6. The establishment by the University of Puerto Rico of a new Department of Nuclear Engineering, the first graduate department in the University. A corresponding Division of Nuclear Engineering was formed in PRNC and Dr. José Luis García de Quevedo resigned his position as Associate Director in order to head both of these new activities. The new Department, although still in the formative stage, is already attracting a gratifying number of graduate students. The new program, while small in financial demands, is the most significant educational development of the year.

7. The colonization in the laboratory of the sugarcane borer (Diatrea saccharalis) and the demonstration that the males may be sterilized by irradiation as adults.

8. The determination of the structure of 4 compounds, copper sulfate, iron orthosilicate, barium nickelate, and copper formate, by the use of neutron and X-ray diffraction.

9. A study of the hazards of losing the pool water in a reactor of the fuel plate type with U_3O_8-Al fuel clad in aluminum at power levels of 1, 2 and 5 megawatts taking into consideration

the risk of the exothermic reaction of the fuel alloy.

The University of Puerto Rico has continued to make available a considerable amount of laboratory space to help relieve the serious overcrowding of facilities. The U.S. Forestry Service has also been very helpful in this and many other respects.

The laboratory space which has been made available by other agencies in many scattered locations is approximately as follows:

University Hospital	950 Sq. Ft.
Cancer Hospital	800
Medical School, San Juan	1,000
Physics Dept., Río Piedras Campus	450
Chemistry Dept., Río Piedras Campus	1,400
Biology Department, Río Piedras Campus	500
Agricultural Experiment Station (U.P.R.)	400
Forestry Dept., (U.S. Forest Service)	2,000
Physics Dept., Mayaguez Campus	1,000
Chemistry Dept., Mayaguez Campus	500
College of Engineering, Mayaguez	2,000
Total	11,000

To this we can add:

Temporary animal quarters, Río Piedras	1,500
Temporary chemistry laboratory, Río Piedras	1,500
Grand Total	14,000

This results in a fragmented and widely scattered operation but without this temporary space it would be necessary to suspend large blocks of program.

Director's Office

The Director's Office operates at both Río Piedras and Mayaguez with most of the staff being at the former location. Accounting and

procurement are based at Mayaguez. The separation of program and administrative activities results in a considerable burden of communication costs. During the FY-1963 a microwave telephone link was established between the two parts of the Nuclear Center at an estimated annual cost of $31,000. Staff travel between the two locations requires $25,000 per year for proper program integration.

Weekly staff seminars have been held at both Río Piedras and Mayaguez as an established activity. These will continue indefinitely and have added substantially to the scientific background of the staff.

Special training for staff members has been emphasized so that an increasingly large fraction of the staff has had basic training in radioisotope techniques, statistical analysis, experimental design, etc.

The staff of the Director's Office, in addition to its administrative duties, participates in the teaching and research of several Divisions, and organizes and directs several special conferences and courses such as the Summer Institute of Radiobiology for science teachers. It is responsible for the production of special reports concerning the activities of the Center and generally serves as the focus of internal communication.

Administration and General Services

As expected, the tempo of the administrative activities as well as the cost of the various services rose in FY-1963 and is expected

to continue at the present level through FY-1965 and FY-1966. Beginning with FY-1964, separate accounting is being kept of what is purely administration and what represents services to the individual divisions and programs.

Reactor

In FY-1964 the Hazards Summary Report for the Research Reactor has been completely revised and updated. Changes have been made where the characteristics of the reactor, as calculated by the fabricator, differed from those experimentally determined by PRNC staff. Written procedures were completed, approved and adopted for all important operations of the Reactor Division.

Two 6 inch beam tubes are occupied by the neutron spectrometry program, and one 8 inch beam tube is occupied by an experiment in thermal emissivity of graphite. Open pool side irradiations are continuously increasing in demand.

The L-77 Homogeneous Reactor has been in frequent operation. Most of its use is for training, but there is substantial use for research not requiring higher flux.

The trend in FY-1965 and FY-1966 will be towards the complete occupancy of the reactor facilities, the increase in operation time from one shift to two shifts and the increase in power from one to two megawatts.

Nuclear Science and Technology

The Division is responsible for graduate teaching and research in the programs for the Masters Degree in Nuclear Technology, Health Physics and Radiochemistry offered through the University. The M.S. degree in Physics has been established by the University authorities and the Division cooperates in this program. Many of the graduate students at present doing research in fields of applied physics within the Nuclear Technology program are now accommodated in this new program in Physics.

An increase in the research activities of the Division is anticipated, while still maintaining the present level of teaching. The principal fields of research will be in Neutron Diffraction (covered in a following section), in Solid State Physics and in Hot-atom Chemistry.

A Solid State Physics program was initiated in FY-1963 dealing with the effect of X-ray, gamma and neutron radiation on ferroelectric crystals. It will include measurements over a range of temperatures to detect transition points, and at frequencies up to the microwave region. Ferroelectric hysteresis measurements afford a sensitive method of detecting crystal damage.

The study of the neutron flux in the thermal column has led to a proposed design for an addition to this facility. The present configuration provides a satisfactory distribution in the vertical access hole, but a badly skewed distribution at the horizontal beam

outlet. A movable extension of the column, about 5 feet long has been designed, which will produce a more uniform flux over a larger volume.

The studies on the ceric dosimeter have lead to the important discovery that the addition of cupric ion stabilizes this system, making it as convenient as the commonly used Fricke (ferrous) system. Further work will investigate the effect of other cations on the ceric dosimeter and the mechanism of the cupric stabilization.

The present studies on Szilard-Chalmers reactions in antimony oxides will be continued to cover the effects of thermal and gamma annealing on the distribution of radioactive antimony between the three and five valence states.

A new program on the hot-atom chemistry of organic sulfur and phosphorus compounds is planned contingent upon outside support. The object of this work is to provide information on the mechanism of hot-atom reactions in large molecules and the nature of the radioactive organic and inorganic products formed will be determined.

The mechanism of reactions following gamma radiation of organic compounds will also be studied in relation to reactions produced photo-chemically. At present the gamma-induced hydroxylation of estrogenic steroids is being investigated and the results will be compared to those found in chemical hydroxylation (Fenton's reagent) and biochemical (in vivo) hydroxylations.

Nuclear Engineering

The youngest of the divisions is the counterpart in the Nuclear Center of the Department of Nuclear Engineering in the University. The latter is the first graduate department of the University and candidates must possess a degree in engineering to qualify for consideration.

This division is concerned with the engineering applications of nuclear energy and research and development that may be related to its objectives. Emphasis is placed on reactor design, effects of radiation upon materials of construction, metallurgy, heat transfer, chemical processing of nuclear materials and power production. Students will take part of their course work on the campus but much of it in the Nuclear Center where all of their thesis work will be conducted.

Some programs, such as that dealing with heat transfer by radiation, are to be shifted from Nuclear Science and Technology to the new Division of Nuclear Engineering.

The latest information is that 15 applicants have been accepted as candidates for the M.S. in Nuclear Engineering in addition to the 4 already enrolled, making a total of 19 for FY-1965 already assured.

Health Physics

The Health Physics Division has continued rendering its services on personnel and area monitoring, environmental surveillance, waste

disposal, instrumental calibration, decontamination and handling of radioactive material. In addition it has continued participating in teaching and training of students in Radiological Physics as well as training of PRNC personnel in general safety. All these services have been extended also to the divisions of PRNC at Río Piedras where we have now a Health Physics Section under the direction of a health physicist.

As a result of the reorientation of PRNC policy, the division is now vested with the responsibility for supervision of all safety; radiation, industrial and fire, while each division is responsible for safe operation of all facilities under its control.

For fiscal year 1965 some increase in services and a moderate increase in supervision is expected. Because of budgetary limitations, the Division has reduced its training activities and is largely concerned with health physics operations.

Agricultural Biosciences

During FY-1964, substantial progress has been made in developing a program devoted to the increase of sucrose production by sugarcane. The use of fast neutrons in producing a maximal variety of chromosomal deletions and recombinations was planned. The initial experiments were conducted with cuttings from the best variety of sugarcane now in use. Lethality occurred at about 2,000 rads (subject to later revision) indicating a high relative biological effect of

the neutrons. Much more irradiation in the vegetative phase will be necessary. The second phase would be to irradiate seeds by the millions and apply mass screening procedures. The two screening measures of most interest are growth in shade and ability to resist drought.

Ultimately the final screening requires a quantitative estimation of sucrose in each plant without significant damage to the plant. The necessary methods have been developed and have been automated so that one technician can perform from 40 to 60 quantitative analysis per hour on microsamples. Both sucrose and invertase are being determined on each sample.

The sugarcane borer (Diatrea saccharalis) has been intensively studied to determine the possibility of control or irradication by radiation sterilization. A laboratory colony has been successfully established and it is felt that a satisfactory method for mass rearing is possible. A fair margin was found between the sterilizing dose of radiation for adult males and that which is lethal. In the larval and pupal stages, the sterilizing dose is also the lethal dose.

Nuclear volumes of many of the tropical plants (including sugarcane) have been determined to test the formulae for prediction of the lethal dose of radiation for each species. At the same time, chromosome volumes have been measured and DNA per chromosome also estimated.

Of eight graduate students at the beginning of the year, one transferred to another university and several will graduate this next June. For these students, work has been very active with courses in advanced genetics, radiobiology, seminars and thesis research.

The progressive reduction of Program 07 support forces the suspension of the Training and Education activities of this Division for FY-1965 after being severely reduced in the current year. Only the teaching required for the existing graduate students is provided. Further applicants will be encouraged to apply to other institutions.

Provision is made in the FY-1966 budget submission for the reactivation of the program. Whether this move is made, however, will be dependent upon the determination of AEC interest in the role of nuclear energy in agriculture in general and in particular in Latin America. The potentials for the improvement of agriculture and human nutrition through atomic energy are almost unlimited but the effort which has been expended has been woefully inadequate, especially in the tropics.

Radioisotope Applications

This Division continues to offer training in the use of radioisotopes in the physical and biological sciences. There will be an indefinitely continuing demand for this training, especially for students of the University of Puerto Rico. The basic course

is offered five times a year and it will probably not be necessary to expand it. With time, a larger proportion of students coming from Latin America will have already had the equivalent in their own universities.

The expansion of graduate work in chemistry related to radiation and nuclear reactions has been well established. The research program, all of which is built around the graduate activity, is being developed under four sections:

1. Organic Chemistry

a. Synthesis of compounds of interest to the nuclear field, especially medicine and radiobiology.

b. Quantitative study of organic reactions utilizing radioisotopes.

2. Radiation Chemistry (sponsored by AEC Division of Biology and Medicine, and National Institutes of Health).

This section has two major fields of activity, which became fully operative in FY-1963.

a. Radiation chemistry and photochemistry of oxyanions. Study of free radicals. The radiation chemistry of water in the alkaline region will be studied.

b. Radiation chemistry and photochemistry of nucleoproteins and the constituent molecules. Emphasis will be laid on the study of cross linking reactions and the role of excited states in the reactions of the heterocyclic bases.

3. Solution Chemistry

Deferred until FY-1966.

4. Solid State Physics of Organic Crystals (Sponsored by AEC Division of Physical Research)

This section studies the effect of neutron and of gamma and X-ray irradiation on the photoconductivity of organic crystals. Measurements have been limited to anthracene crystals; plans are being made to extend the work to other organic crystals.

The indications are that the program of this Division will attract all of the graduate students for which laboratory space can be provided. A temporary structure has been erected outside the Bio-Medical Building which can house 8 graduate students.

Clinical Radioisotope Applications

The Clinical Applications Division is currently offering two types of courses for training physicians at an introductory level; maintains diagnostic services at the Puerto Rico Nuclear Center to support its teaching program; operates the Radioisotope Laboratory at the University Hospital for the Medical Staff of this Hospital; supports with diagnostic supplies the San Juan City Hospital Radioisotope Laboratory on a reciprocal relationship of mutual interest; collaborates in investigative work with other institutions according to the general policies of PRNC and conducts its own research program characterized by work of clinical nature on problems of local and general interest.

Radiotherapy and Cancer

The main purpose of this program is the training of physicians and allied personnel in all aspects of the application of nuclear energy to cancer. Another purpose is the development and carrying out of a program of research activities conducted with the purpose of improving our knowledge in the cancer and radiation fields.

The following functions are carried out to accomplish these purposes:

1. Formal instruction to physicians who want to become qualified radiation therapists. This residency training lasts three years with the addition of a year of supervised practice in the specialty.

2. Formal instruction is also offered to experienced physicians in radiation therapy who have been engaged in this field for a considerable length of time, which permits them to conduct specific research projects in their field and participate in all teaching activities.

3. Training of fourth year medical students to familiarize them with cancer and radiotherapeutic techniques.

4. In-service training for nurses, technicians, and radiological physicists.

Training in exfoliative cytology for technicians and pathologists, offered in the Cytology School and operated in the Nuclear Center as a joint project with the Puerto Rico Department of Health and the University of Puerto Rico Medical School, has been

discontinued in the Nuclear Center due to budget restrictions.

Medical Sciences and Radiobiology

This, the youngest of the Río Piedras Divisions, was formed on July, 1962 by amalgamation of the Division of Medical Sciences with the older Division of Radiobiology. The actual content of the field of radiobiology has been divided in a natural manner between Agricultural Bio-Sciences, Health Physics, Medical Sciences and Radiotherapy and Cancer. It can be said that radiobiology is oriented to plant science in Mayaguez and to medical science in Río Piedras. In the latter location the small program which existed in the Division of Radiobiology is being continued.

I. Tissue Culture Program

The first phase in the program was the development of a central tissue culture facility. It has been evident for some time that several divisional programs have a requirement for the employment of tissue culture techniques. It was also obvious that the size of this project would not permit the successful development of several tissue culture laboratories. The most logical solution to the problem seemed to be the establishment of a single tissue culture laboratory to serve the needs of all programs but in which the various members of the staff might have affiliations with other divisions and be directly interested in their special problems.

Beginning in FY-1964 and extending through FY-1965 several radiobiological studies will be instituted with tissue culture cell

lines. Chief among these will be the studies of the intracellular capture of neutrons by organic compounds containing B-10. The organic chemistry section of the Radioisotope Applications Division has been preparing a series of new boron compounds which are described in the associated Form 189.

II. Indigenous Viruses and their Radiation Induced Genetic Variability

III. The use of gamma radiation to modify Schistosoma Mansoni cercariae so that they induce immunity to attack instead of causing disease.

The procedures outlined in the proposal are, at this stage, directed towards: (1) defining useful parameters for assessing the effects produced and (2) comparing the effectiveness of different approaches to the problem. This program is scheduled over a two year period, by which time it will be possible to decide along what lines any further research might best be pursued, the hoped for end result being a contribution to knowledge which may eventually help in combating the disease.

Technical Services (Mayaguez)

This operation, which originally was part of Reactor Division, is now separated in the new organizational structure of PRNC.

Technical Services carries the responsibility for: buildings and grounds maintenance, machine shop, electronic shop; and the glass

blowing shop. With the exception of buildings and grounds, the Mayaguez Technical Services, through its shops, serve the entire PRNC and must be prepared to meet a considerable variety of demands. The variety of jobs performed by these shops range anywhere from general maintenance and construction work up to the most specialized precision jobs such as: construction of Ionization Chambers, Crystal String Saws, High Frequency Microphones, or X-ray Spectrometers.

Technical Services (Río Piedras)

This section has charge of building maintenance at Río Piedras, the operation of a small electronic shop and general instrumental repair. Shop services in general and engineering supervision are supplied by the Mayaguez branch.

Resonance in Radiation Effects

Experiments utilizing monochromatic X-ray irradiation in the 5-20 Kev range on biological systems have been carried out. This energy region is of considerable importance since it contains the K-absorption edges of the constituent atoms of most living systems. Biological systems chosen for study are those which are composed primarily of light elements with but traces of medium atomic weight elements. Increased inactivation of the metalloenzyme catalase, which contains four atoms of iron per molecule of weight 250,000, was demonstrated near the K-absorption edge of iron. Biological systems under study include the zinc metalloenzyme carboxypeptidase A

and the bacterium E. coli. Biological studies have been supplemented by investigation into the underlying physical phenomena of the radiation effect.

Marine Biology Program

Research in Marine Biology at PRNC was started in January, 1962, and includes the following: Measurements of marine productivity, determination of selected stable elements, measurement of the concentration factors of selected marine organisms for given radioisotopes, measurement of radioactivity and radioisotopes now present in the marine organisms, waters, and bottom sediments off Puerto Rico, and background observations in physical and chemical oceanography for use in the interpretation of the first four programs. Survey work near the new BONUS reactor site was given priority, and has been accomplished. Activation analysis techniques developed in conjunction with this program have reached an advanced state of sophistication. This program is fully operative in all phases.

Radiation Chemistry and Photochemistry

The objective of this program is to investigate the kinetics and mechanisms of (a) radiation induced chemical decomposition and (b) photo-dissociation of oxyanions. It is hoped that this work will quantitatively determine the reactivity of oxyanions to radical attack, will characterize the modes of decomposition of the various excited states of anions, and will uncover evidence indicating the

participation of excited states in the radiation induced decomposition. Work is underway on solutions of nitrate ion. Photochemical decomposition to form nitrite has been demonstrated at wavelengths above 3040 Angstroms. Data are being interpreted in terms of various primary dissociation steps of the excited state and diffusion kinetics.

Paramutation

Genetics regulatory systems which control gene mutation are being investigated with emphasis being given to the paramutation system as it occurs in maize. Radiation treatments of the components of the system have indicated that the type of change which occurs is an inactivation process rather than a true mutational event. Radiosensitivity curves of the regulator responsible for paramutation change are being obtained. The efficiency of densely ionizing radiation from neutrons is being compared with sparsely ionizing gamma rays as an aid in determining the nature of the mechanism of the system.

Terrestrial Ecology Program I: Radioecology of a Tropical Rain Forest

The rain forest irradiation project was started in the Spring, 1963, with the objectives of determining effects of gamma irradiation on the lower montane rainforest near El Yunque and the movement of chemical elements of fall-out in the normal biogeochemical cycles. An area in the Luquillo Forest Reserve provided by the U.S. Forestry

Service has been developed with trails, towers, instrumentation, electric power, and work facilities. A group of 12 participating investigators from other universities began a year of measurements preceding irradiation. The project now involves 65 phases with 15 resident scientists and student assistants. The effect of irradiation will be assayed by measurement of animal noises, vegetation density to light, plant and animal populations, changes in microclimate, localized effects, cytogenetic effects, and changes in chemistry and fallout. A 10,000 curie Cesium 137 source is scheduled to be placed in the study area in December, 1964, and post-irradiation studies will follow the exposure period. Fall-out elements are traceable with existing levels of activity and with tracer experiments. The level of fallout held in the vegetation is relatively high indicating the effect nutrient holding ability of the vegetation.

Terrestrial Ecology Program II: Radiation Induced Variability in Indigenous Arthropod-Borne Animal Viruses of Puerto Rico

In August, 1963 an outbreak of "Dengue-like" illness reaching epidemic proportions occurred in Puerto Rico. The Arbovirus unit joined the local Department of Health and members of the Communicable Disease Center from Atlanta in an attempt to isolate and identify the virus. Successful isolation of a "Dengue-like" agent was accomplished in this laboratory on August 30, 1963. This represented a significant scientific contribution to our knowledge of viruses in the Caribbean area.

Field work on the regular study area continues with successful mosquitoe and rat trapping and bleeding taking place at regular intervals. It is hoped to have a clear picture of the arboviruses present in El Verde before the radiation source is added. No viruses have as yet been encountered in the El Verde material.

The Mechanisms of Antigen-Antibody Reactions Following the Inoculation of Mice with Irradiated and Normal Schistosoma mansoni Cercariae

Approval for this program was received in December, 1963, and the first preliminary experiment designed to determine the number of sexually paired cercariae necessary to induce a standard infection is underway. A modest mouse colony is available and cultivation of host snails for the program has also been started. Previous work indicated an acquired resistance to challenge with virulent Schistosoma mansoni cercariae after infection by cercariae which had been damaged by exposure to gamma irradiation. When the optimal experimental procedures have been established, it is intended to make a detailed study of all detectable reactions occurring between the challenging parasite and the "immune" host.

Neutron Diffraction Program

The first long range research commitment, using the reactor, is in the field of neutron diffraction, in close cooperation with the Brookhaven National Laboratory. Two beam tubes of the PRNC reactor have been assigned to this work, and an advanced design

neutron spectrometer is now in research operation at each of these. One spectrometer was being built by BNL to the same specifications as the newest Brookhaven spectrometers and provides PRNC with a highly accurate and versatile instrument. A spectrometer of somewhat similar design and of comparable quality was donated to the University of Puerto Rico by the Westinghouse Research Laboratories and occupies the second beam tube.

In addition to the PRNC staff members working on this program, there have been three guest scientists who have helped considerably in getting the program off to a fine start. One of these was a senior staff member from Brookhaven, who stayed for one year and continues to give guidance to the program. Another is an excellent X-ray crystallographer who was sent to PRNC by the German Government for two years to gain experience in the planning, installation, and use of neutron diffraction equipment. The third man is a physicist from Kyoto, Japan, who is spending two years at PRNC.

Study of Radiation Damage in Organic Crystals using Electrical Conductivity

Effects of neutron irradiation on the electrical conductivity of anthracene crystals are under study. Initial phases of the study were limited to changes in dark and photoconductivity produced by neutron bombardment which apparently knocks out a hydrogen atom from the crystal. Electrical conductivity was selected because evidence indicates this parameter is most sensitive to the presence of

impurities or defects. Gamma and X-ray irradiation effects will also be studied in the future. Another phase of this investigation will include a more precise and direct technique for determining trap densities and depths by measuring mobility and conductivity as a function of temperature.