REPORT ON THE ORGANIZATION AND SCIENTIFIC PROGRAM OF THE NUCLEAR RESEARCH CENTER "DEMOCRITUS"

by

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INTRODUCTION

At the invitation of Prime Minister Dovas' Cabinet, I visited Athens, Greece from October 7, 1961 until October 16, 1961, to assist and evaluate the organization and scientific program of the nuclear research center "Democritus".

During this period of time, I had the opportunity to have long discussions with most of the members of the Greek Atomic Energy Commission, namely: Dr. Pantazis, Dr. Kawassiades, Dr. Malamos, Dr. Petropoulos, Mr. Kefalas and Dr. Kanellopoulos and was informed by them on matters of general policy of the Commission, methods of implementation of the policy, the scientific and educational program of the research center "Democritus", the anticipated building and equipment expansion and growth of the scientific personnel force.

I did not talk with the Chairman of the Commission, Admiral Spanides, because he was out of the Country.

I also had the opportunity to interview individually practically every scientist employed at the Center (approximately seventy people) and visit their laboratories. This allowed me to form a fairly good opinion on the scientific qualifications of the staff, its methods of operation, its achievements to date, and its long range aspirations.

I spent several hours with the key administrative personnel in an effort to understand the mechanics of operation of the administrative services and their interaction with the scientific objectives of the Center.

Finally, I tried to gather information from the engineering personnel of the Department of Technical Works (YTE) regarding the design and construction of new laboratory facilities as well as the degree of planning that is devoted to the same.

I approached my task from two general standpoints: the managerial and the scientific. From the managerial point of view, I was primarily interested in determining what lines of authority and responsibility exist throughout the organizational structure of the Commission and the Center. From the scientific point of view, I was particularly concerned with the importance that the Commission and its scientific staff give to scientific methodology and scientific excellence.

I was impressed by the magnitude of funds that the Greek Government is allocating to nuclear research and by the genuine desire of the members of the Commission and of the scientific personnel at the Center to advance and exploit the nuclear field for the benefit of the Greek people.

However, both from the managerial and the scientific points of view, the present state of nuclear activities at the Center leaves much to be desired.

What follows is a detailed exposition of my impressions and a series of recommendations. For expediency of presentation, the report evolves around five interrelated topics that preoccupied my mind at the various stages and levels of my discussions and interviews.

1. Policy and strategy of the Greek Government toward nuclear research in Greece.

2. Organization and administration of nuclear research in Greece.

3. Scientific programs.

4. Education of scientific staff.

5. Priority of projects.

Before I expound on these topics, I would like to emphasize two points which are very important to the understanding of the report.

First, the proposed recommendations are not based entirely on information that I gathered during my recent visit to Athens. They also represent my personal views on how research should be planned, organized and implemented in our Country. I have been following the nuclear developments in Greece as a private individual since their birth and have devoted considerable time to the questions of organization and research planning. The reason for this is that I was intrigued by the efficiency of methods and procedures used in other Countries and longed to see them modified and applied in my own.

Second, all proposed recommendations are set forth with full sincerity of intention for the achievement of a noble goal. They are meant to be positive contributions and should not be misinterpreted as sterile criticisms.

1. POLICY AND STRATEGY OF GREEK GOVERNMENT TOWARD NUCLEAR RESEARCH

General Remarks

The ultimate sponsor of capital investments and running expenses of the research center "Democritus" is the Greek people through its Government. In view of the limited resources and the tremendous problems that the Government faces in all sectors of economic development, it is imperative to examine very carefully what kind of economic burden the Greek people should be expected to tolerate in sponsoring nuclear research or for that matter, any type of scientific research in Greece.

It is my considered opinion that this basic question of policy has not been faced either at the Government level or at the level of the Atomic Energy Commission, which is currently the primary advisory committee to the Greek Government on matters of nuclear development. This question is very important and any further postponement of a clear and well studied decision on the matter will undoubtedly result in a sizable waste of money and human effort.

Furthermore, even if such a policy decision existed, I believe that there is no realistic strategy for its implementation at any executive level. The immediate need for an effective strategy cannot be overemphasized.

Admittedly the formulation of the governmental policy and strategy toward investments and running expenses of a nuclear research center is a multisided problem and cannot be examined alone. It is a strong function of the Government objectives in the other Institutions of higher education in Greece, of the funds that are allocated to those Institutions for research, the needs of our Country for research workers in fields other than nuclear, the percentage of the national budget that the implementation of all these

items represents, etc. However, in what follows it is appropriate to consider some simplified estimates in order to have some quantitative reference.

Governmental Policy

In order to analyze the question of governmental policy, consider a research team as a basic unit and estimate its running expenses. For the purpose of this discussion, a research team consists of a senior scientist with a Doctor's degree, two junior engineers or physicists with the equivalent of a Master's degree and one technician. The annual costs of such a team may be estimated as follows:

Senior scientist (1)	$300/month	$3600
Junior scientists	2x$200/month	$4800
Technician	$100/month	$1200
	Total salaries	$9600
Overhead (2)	100% of salaries	$9600
Materials (average)		$5800
Total annual costs per team		$25,000

The question at this point is: How many times $25,000 per year is the Greek Government willing to spend to sponsor nuclear research?

This is a policy decision that the Greek Authorities must make in the context of the rest of their responsibilities. Whatever the decision is, it must necessarily take into account that nuclear research should not be overemphasized at the expense of other fields important to the Greek Economy and that nuclear education should not be promoted at the expense of other equally significant scientific endeavors.

Another factor that must be considered in answering the previously raised question is the matter of capital investments that are necessary in order to accommodate the

(1) The salaries are approximate.
(2) The overhead, covering administrative and technical assistance as well as building depreciation and maintenance is of the order of 100% of salaries for a well organized and administered establishment. If this is not the case, the overhead may very easily run up to 200-300%.

anticipated research teams. In this respect it is essential to realize that the yearly running expenses of a productive research establishment are usually more than 50% of the invested capital and consequently investments and running expenses must be decided upon simultaneously.

Needless to say, all policy decisions concerning capital investments and running expenses must be based on dynamic rather than static considerations.

Governmental Strategy

The next important problem is the strategy that the Greek Government should use to implement its policy toward nuclear research and education. There are several interrelated questions about this problem which need a well defined answer if nuclear energy is to be of value to the Greek people.

a) The first question is: How does the Greek Government decide on the magnitude of capital investments in nuclear research during, say, the next ten years? My recommendation is that such a decision must be based on a well studied architectural plan of the whole Center as a unit and not on momentary qualitative estimates. The study must be made by a qualified and responsible organization.

b) The second question is: Suppose that such a plan is formed, does the Greek Government start immediately the erection of large buildings without any substantial guarantees that the anticipated returns will materialize?

My recommendation is a strong "no". The reason is very simple. The essence of a research installation is not its architectural structures but the scientific activity of its staff. Scientifically productive activity necessitates

competent scientists who are very hard to find throughout the world. Consequently, a planned expansion should follow the availability of qualified scientists and the needs of well thought out and programmed scientific projects rather than the other way around.

In the context of this recommendation, it is of value to note that the laboratory space now available at the center "Democritus" is more than adequate to accommodate any reasonable expansion rate in the next few years, provided, of course, that the Center is staffed with people who know what they want to do. The office and laboratory space now available is larger than that of other similar establishments in the United States where the scientific activity is several orders of magnitude higher. In fact, I can go even further and postulate that even the teaching facilities of the Center are more than adequate in the sense that the scientific personnel of "Democritus" could very well be using classrooms either at the University of Athens or the Technical University of Athens where the classroom load factor is very low. The use of classroom facilities of the Universities is recommended not only on the grounds of economy but also because it represents part of the absolutely necessary cooperation between the research center "Democritus" and the Universities, a necessity that will be further illustrated later in this report.

c) The third question related to the problem of strategy is: If a certain amount of money is to be allocated to the Greek Atomic Energy Commission for running expenses, how does the Greek Government decide its amount and how should this money be spent?

The first recommendation is that under no circumstances should money be allotted or spent for a project which is not supported by a scientifically and financially analyzed proposal. This point will be elaborated further in another section.

The second recommendation is that money should not be spent merely because it is included in the national budget for nuclear activities but because it serves a useful purpose. More specifically, suppose that it is planned to hire an expert on Biophysics and a certain amount of money is allotted for his first year's expenses. Then suppose that no suitable man has been found for this job. The question then is: should this money be spent anyway? My recommendation is no. Money is budgeted to fulfill a definite purpose within the context of certain requirements and specifications of quality. If these requirements and specifications cannot be met, it is better to use the money in other sectors of the Economy rather than buy purposeless instruments or hire unqualified personnel. The idea of spending money because it is available is purposeless and wasteful. Nuclear instruments and installations are not only very expensive but they are also useless unless someone needs them for a specific program. Instruments should be purchased only for specific programs and not for exhibits because they become obsolete very fast due to the rapid development of science in this field.

d) Finally, the fourth question of strategy is related to the speed of execution of different decisions.

My recommendation is that all legal and administrative steps be taken to speed up the handling of all paper work related to nuclear research.

Research in general and nuclear research in particular are highly competitive fields. Therefore, an experiment

which is very important today may be altogether useless in a year's time because someone else has done it. In view of this simple fact, it is inconsistent to spend large amounts of money to support original or applied research and at the same time have the research establishment operate within a bureaucratic and slow moving legal and administrative framework. The "Greek Reality" has no place in research and development work and should in no way affect strategy decisions of the Greek Government pertaining to research. The only way that the Greek people can enjoy the benefits of their comparatively heavy investment in nuclear research is by realizing the problem not within but without the "Greek Reality" and moving toward its solution swiftly, with courage, imagination and ingenuity.

2. ORGANIZATION AND ADMINISTRATION OF NUCLEAR RESEARCH

General Remarks

Viewed from the management standpoint, authority and responsibility are the two major attributes of any large Institution, Establishment, or Enterprise which involves more than one person. These two important attributes when properly delineated and applied allow any organization to be productively administered and prevent it from reaching stages of conflict, confusion and stagnation.

In my judgment both attributes are practically absent in the organization and administration of the nuclear research center "Democritus". The major excuse for the lack of delineation of authority and responsibility is the "Greek Reality". Personally, however, I have no respect for this notion and refuse to accept it as an unsurmountable obstacle. It is an enemy, yes, but not one that we should not fight against with all legal and administrative means that we can find.

How authority and responsibility are delineated depends on the organizational and administrative structure of the establishment in question. The latter in turn is a strong function of the type of available personnel, the number of persons involved, the objectives, etc. In a growing concern all these considerations are dynamic and therefore the administrative structure should be flexible enough to swiftly accommodate new developments.

The present organizational and administrative structure of nuclear research in Greece leaves much to be desired because it does not enhance the high returns that are expected from the costly investments already incurred or anticipated.

In view of these remarks I recommend that the entire structure be completely reorganized. The objectives of the reorganization must be the establishment of mobility of action, encouragement and stimulation of scientific initiative and definite delineation of true authority and responsibility.

Admittedly all these objectives are universally accepted. However, in order to determine who should be encouraged to develop his initiative and who should be given the necessary authority to responsibly carry on his duties, it is essential to ask at this point: "Why is the Greek Government interested in sponsoring nuclear research in Greece?" In my estimation the principal and noble motives of the Greek Government are two: the first and justifiably most prominent motive is the genuine desire to assist present and future outstanding Greek scientists to fully realize their scientific potentialities in Greece; the second motive is the conscious desire of the Greek Government to enhance the exploitation of new technologies in our Country for the cultural and economical advancement of the Greek people.

The nobility and significance of these two motives imply far reaching consequences, so well known that they

need no further analysis. However, if my estimate of motives is correct then I believe that the reorganizational objectives that were previously postulated are best served by the organizational scheme indicated in Figure 1. This organizational scheme appears almost identical to the one existing today. However, its mode of operation is completely different. The major changes recommended are:

a) The Atomic Energy Commission is replaced by an Atomic Energy Directorate. The Directorate consists of one individual in charge, the Deputy Director, and an executive staff of specialists.

b) The entire nuclear research center "Democritus" is under the true and powerful directorship of only one individual, the Director of the Center. All scientific, technical, administrative and clerical personnel at the Center are under his absolute jurisdiction. In short, he is the boss of his home, as his title implies.

c) The scientific research at the Center is performed by the Research Leaders and their teams. The Research Leaders have freedom to develop their initiative and work independently.

d) The scientific programs originate from the Research Leaders.

e) The management of funds allocated to research projects at the Center is the responsibility of each of the Research Leaders to whom the funds have been allotted.

The detailed functions of each department of the new organization are described in the subsequent sections.

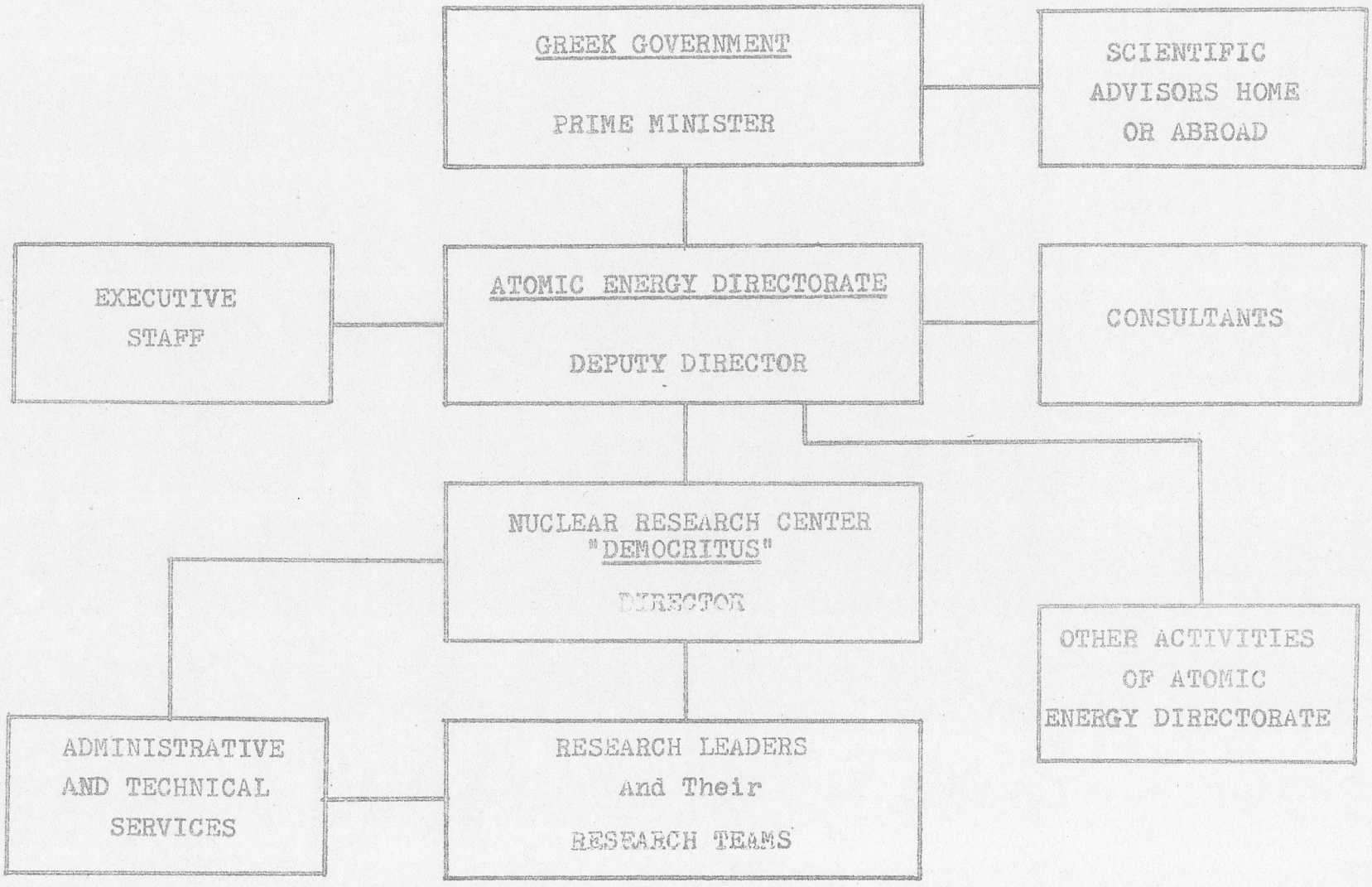

FIGURE 1. ORGANIZATIONAL CHART OF NUCLEAR RESEARCH CENTER "DEMOCRITUS"

Greek Government - Prime Minister

According to the Royal Decree 4115/9-10-1960, nuclear research and education in Greece are under the immediate jurisdiction of the Prime Minister. I would like then, if I may, to discuss how I visualize the interactions between the Prime Minister and the Atomic Energy Directorate.

The Prime Minister has the ultimate responsibility for the basic decisions of policy and strategy toward nuclear research and development. These decisions are based on several general governmental policy considerations, as already discussed. In addition they should be influenced by the following factors:

a) The overall educational and research program of our Country. This point is re-emphasized here because it would be a serious mistake to assume that nuclear education and research are the only scientific contributors to the economical and cultural advancement of the Greek people.

b) The advice of the Deputy Director. This advice should be supported by well documented programs and not momentary qualitative estimates.

c) The advice of scientific advisors, not connected with the Directorate, on the value of the proposed programs. This advice may be sought home or abroad.

Once the policy decisions have been reached by the Prime Minister and expressed in terms of total sums of money, their implementation should be delegated to the Atomic Energy Directorate, for a specific period of time. The mode of operation of the Directorate is subsequently described. However, at this point it is important to emphasize some basic aspects of the delegation of implementation of policy.

Suppose that the Prime Minister has budgeted $1,000,000 for the Directorate to achieve specifically studied objectives, during the next fiscal year. My explicit recommendation is that all legal steps be taken to allow the Directorate to use this amount of money, within the context of the aforementioned objectives, without any interference whatsoever from any governmental agency. The Greek Government must audit the Directorate only at the end of the period during which the allotted funds were to be consumed. There is no need for the governmental departments to check and approve over and over again how every $100 should or should not be spent. The Directorate should be completely entrusted with the details because the Prime Minister made his original decisions on the basis of well documented evidence and because the Deputy Director has a responsible position.

I believe that the delegation of policy execution by the Prime Minister to the Directorate is absolutely necessary for several reasons. First, nuclear research and development is a fast moving field and any delays due to bureaucratic procedures are extremely harmful. Second, the delegation of Policy execution emphasizes the responsibility bestowed on the Deputy Director so that no promises are made without enough guarantees that they can be accomplished, and finally, it gives the Deputy Director the authority to act swiftly in the fulfillment of his duties.

Before leaving the subject, it is of value to emphasize the important role played by written and well documented proposed programs of the Directorate to the Prime Minister and also the use of scientific advisors by the Prime Minister. At a first glance the scheme may appear as bureaucratic. However, it is my considered opinion that nothing is further from the truth.

I am deeply convinced that if one cannot plan one's work this means that one does not know what one wants. One can never find something if one does not realize what one is looking for. This is the essence of planning and it should not be mistaken as a means for increased bureaucracy.

I am also convinced that the use of scientific advisors is of great value to the Prime Minister. Today is a period of a rapidly expanding technology, a technology that has an immediate impact on everybody's life. Therefore, technical subjects should not be revieved at the top executive level only by statesmen but also by technically trained individuals without vested interests in the program under review. Well documented programs can be technically evaluated very fast by an expert so that the gains from the avoidance of a technical error outweigh the cost of the advice and the minute time delay relative to a long range program.

The Atomic Energy Directorate

The Royal Decree 4115/9-10-1960 defines how the Atomic Energy Commission is appointed and how it functions. I believe that this concept of the Commission is inadequate and unwieldy and I recommend that it be reorganized along the lines of a Directorate with only one individual in charge, the Deputy Director.

To make this new concept more clear I would like to restrict my comments only on the role of the Directorate in regard to the educational and research objectives of the nuclear research center "Democritus".

In this context, the primary function of the Directorate is to act as the executive link between the policy of the Greek Government and the Center and to provide an exemplary leadership for nuclear research and development in Greece.

The relationship of the Greek Government and the Directorate has already been briefly outlined in the preceding section. Consider now the question of leadership. This question has several aspects that need special attention

The most important responsibility of the Directorate with regard to the center "Democritus" can be visualized in either of two Ways. The first is that the Directorate consists of people who are prominent scientists in the nuclear field and have the necessary broad and specialized knowledge to stimulate and guide nuclear research in directions of their own judgment. The second is that the members of the Directorate have general scientific background and administrative qualifications which allow them to appreciate the proposed programs of younger specialists and organize the necessary functional environment in which the initiative, imagination and love for creative work of these specialists can flourish.

The first alternative is the best but is unrealistic for our Country as well as many Countries throughout the world. The nuclear field is brand new and the majority of scientists who are at the top level of the academic or professional hierarchy have been educated by a system of entirely different content and during a period of different scientific objectives.

The second alternative is not only feasible in Greece but if properly conceived and implemented can yield excellent returns in the interim period until a top quality nuclear scientific tradition is established and the need for more than one research establishment arises. This is the alternative that I strongly recommend and would like to present in some detail.

As already repeatedly emphasized the Directorate has only one key member, the Deputy Director, who is the man

who has the ultimate responsibility for the effective implementation of governmental decisions.

The Deputy Director has broad general scientific knowledge and, most important, managerial qualifications of the highest caliber.

The Deputy Director is assisted in his duties by a small number of scientific and administrative executives but he is the only one responsible to the Prime Minister and is entrusted with the execution of the governmental nuclear policy. The executives assist the Deputy Director in his scientific, administrative, and non-scientific obligations in an advisory and/or executive capacity and are responsible to him for successfully carrying on their assignments.

The Deputy Director's proposed programs to the Prime Minister stem from two sources of information. First, the proposals that are submitted to the Directorate by the Research Leaders of the Center, through the Director of the Center. Second, the advice of the executive staff and if this is inadequate in specific cases, the advice of consultants outside the entire organization, who may be working in Greece or abroad.

The recommendation for the formation of an Atomic Energy Directorate with one Deputy Director and an executive staff may sound completely out of the ordinary and indeed it is. However, the scarcest commodities in our Country are authority, responsibility and mobility of action. In my opinion the delegation of nuclear policy execution to one Deputy Director will be very effective in instituting these three badly needed attributes in the nuclear endeavor in Greece and should be seriously considered even if it is beyond the bounds of the ordinary.

Also the use of outside consultants should be seriously considered. I have noticed that in our Country only a few people are willing to admit the universally accepted notion that nobody can be an expert on everything. In my judgment the best quality of a leader is not his competence in solving a specific problem but his capability to recognize the problem and ask the advice of the appropriate specialist.

Regarding specific goals that the Atomic Energy Directorate should be pursuing I have the following recommendations:

a) The Deputy Director and his executives should continuously worry about the long range objectives of nuclear research in Greece. In this respect they can be greatly assisted by the advice of consultants, the constant surveillance of the national and international developments in the nuclear field, the conscious consideration of the economic growth of our Country and the cooperation with the Director of the center "Democritus" and the Universities of Greece. The long range objectives should be regarded as open-ended projections and not as inflexible and irrevocable decisions. The Directorate should be constantly in an up-to-date state of preparedness but act only during opportune times. This is very important because well studied long range plans should be executed only as they are needed and become feasible and not because they have been preconceived.

b) The Deputy Director should use his power and authority to establish an organizational structure for the Directorate and the Center with clear cut lines of action. He should also be given the freedom to arrange the organizational structure as he sees fit to the short and long range objectives of the nuclear endeavor. Atomic Energy in any

Country is an expensive undertaking. Consequently, positions should be created strictly on the basis of needs to be fulfilled and appointments should be made strictly on the basis of excellence. No compromise should be tolerated in this respect.

c) The Deputy Director and his executives should pursue the scientific cooperation of all Institutions of higher education in Greece, the financial assistance of the Greek Industry, and the scientific attention of all other professional groups which might benefit or contribute to the development of nuclear energy and radiations. Thus the research center "Democritus" will be promoted to a truly national laboratory, available to anyone with progressive research and development ideas.

d) The Directorate should persistently seek the cooperation and exchange of technical information with other similar outstanding organizations abroad. This can be achieved by inviting world renowned lecturers to lecture at the Center, by organizing symposia, by undertaking complementary projects with other laboratories etc.

e) The Directorate should make a serious and continuous effort to convince everybody inside or outside the sphere of activities of the Directorate that the funds that are budgeted for nuclear research belong to all the Greek people and therefore that they should be spent with caution and purposefulness and not because they are available.

Unfortunately, many Countries have misinterpreted their participation in the Atoms for Peace program as a way to establish scientific status through construction of large and expensive installations and employment of a numberous but inactive personnel. Nothing could be a more costly and ineffective misconception. The Atoms for Peace program can

indeed establish a scientific status for a Country provided that it is clearly understood by all concerned that status is the result of hard, imaginative, and productive scientific work and not of impressive buildings. These comments are particularly applicable to our Country where funds are very difficult to raise.

f) The Deputy Director should exercise his best judgment in appointing the Director of the Center. This is absolutely necessary because the concept of the Director in this report places him in the number one position of the entire nuclear research effort at the Center. The Director's role and responsibilities are described in the next section.

The Nuclear Research Center "Democritus"

It is evident that the nuclear research center "Democritus" is the unique vehicle for the accomplishment of the research objectives of the Greek Government and the Atomic Energy Directorate. When the nuclear reactor becomes operational in six months to a year from now, it will constitute a unique tool for experimental research by qualified scientists.

Consequently, the staffing, organization and programming of activities of the Center are subjects of primary significance whose impact on the future development of nuclear energy in Greece cannot be overemphasized. Unfortunately, these subjects have not been given adequate attention and the present status of staffing, organization and programming of activities of the Center is well below the subsatisfactory level. The reasons for this are: First, the Center does have a Scientific Director, but he is completely powerless. The actual direction of the Center originates from 4-5 miles away and it is exercised by several people. Second,

the majority of the scientific staff has had no extensive post-graduate training and has no particular appreciation for scientific methodology. Third, the majority of the administrative, technical and clerical assistance personnel has a very low sense of duty. Fourth, apart from a few exceptions, there are hardly any well studied programs for the use of the experimental facilities.

These remarks lead me to the following set of recommendations:

Director of the Center: The directorship of the Center as a unit should be delegated to only one individual with outstanding scientific and leadership qualifications. This is the Director of the Center whose position should be viewed as one of the most important in the entire organizational structure.

The Director should play as prominent a role in connecting the research center with the Directorate as the Deputy Director does in linking the Atomic Energy Directorate with the Government.

Admittedly, the Director acts within the framework of authority that has been delegated to him by the Directorate. However, he should be entrusted to use this authority to the fullest degree and to the best of his judgment. To put it differently, the Director should have the true authority that goes along with the directorship of any establishment so that he can be held responsible for his actions.

The responsibilities of the Director are many but the scope of the report is not to enumerate all of them. Nonetheless, there are several directions of action and initiative that must be particularly stressed.

a. The Director should inspire his associates with a strong devotion to duty, an unquestionable respect for scientific methodology, and a high spirit of enthusiasm for the execution

of the common goal, namely, the promotion of nuclear research in Greece. This can be achieved only by one man who follows a righteous and conscientious managerial practice and who has accomplished outstanding achievements in the realm of scientific endeavor. Only one individual with the required scientific and leadership qualifications can create the necessary spirit of cooperation among his associates and preserve it by ingeniously overcoming the unavoidable human obstacles that often arise.

Today, scientific research in general and nuclear research in particular, rely on many skills. It is a major responsibility of the Director to establish a high esprit de corps among all his co-workers, in spite of the fact that he must emphasize and encourage individual initiative, ambition and imagination.

b. The Director must have under his jurisdiction a staff of scientists, engineers and technicians for the safe and continuous operation and maintenance of the laboratories. Reactor operators, health physicists, physical plant technicians, administrative personnel, technical services, security force, purchasing, finance, etc. fall under this category and can be called the supporting services.

At this point it is essential to emphasize that the scientific and engineering personnel, involved in the operation and maintenance of the laboratories, should also be encouraged and stimulated by the Director to contribute creatively to research. This is necessary because the criterion of employment at the Center must be scientific and creative excellence. The criterion stems from the fact that the basic objective of the Greek Government is sponsor-

ing nuclear research is neither the operation of the nuclear reactor and the laboratory facilities as such nor the scientific death of the employed scientists. On the contrary, the objective is the creative use of the former and the scientific advancement of the latter.

In order for the Director to be effective in this respect, he must be given the authority to judge his associates and have the right to hire or dismiss any member employed at the Center. Of course, the rules and procedures used in this process should be established by the Directorate in cooperation with the Director. However, since the Director is the individual under whose immediate supervision this personnel functions, he should be given the responsibility and authority to exercise his judgment.

There is no need for the research center to become another governmental agency. Greece has enough of those. What is needed is a free Government sponsored enterprise with flexibility of action and emphasis on scientific excellence and essential qualifications. No other criteria are of any practical use.

c. The Director must be given the authority and responsibility to hire top quality scientists and engineers whose sole preoccupation is original nuclear research and development. These are the Research Leaders who constitute the heart of the structure that is the subject of this report and who are directly responsible to the Director.

The Director must exercise his best judgment in the selection and continuous evaluation of the Leaders and take all the necessary administrative and technical measures to assist, encourage, and channel their aspirations. The details of the functions performed by the Leaders are given below. However, suffice it to add here that the Director

must cooperate with and coordinate the efforts of the Leaders. He must also make absolutely sure that all supporting services at the Center are at the disposal of the Leaders instead of the other way around.

d. The Director must see to it that a set of rules and regulations are established for all the functions and safety aspects of the Center. The primary objective here is not simply the establishment and publication of the rules but mostly the conviction of all employees at the Center, scientists and non-scientists, that rules are to be respected and applied and not to be shelved in book-cases. This is particularly true in the case of health and accident hazards where disrespect of well thought procedures by thoughtless and inexperienced individuals can lead to harmful and costly consequences, even when seemingly there is no danger whatsoever.

Research Leaders and Research Teams. The research activities at the Center, in various sectors of nuclear science, must be directed by Research Leaders and performed by small research teams. The Research Leaders are directly responsible to the Director of the Center as already indicated.

The Research Leaders should preferentially have doctor's degrees, must have worked in a scientific environment at home or abroad, and must have excelled in the realm of science. The reason why the Research Leaders are required to have these qualifications is very simple. A nuclear research center cannot be formed by hiring 50 or 100 or 2000 graduates, building large installations and buying a lot of instruments. A diploma from a Greek or foreign University is not a positive indication that its holder is capable of doing original research, particularly

if the research is to be done in a traditionless environment, regardless of the magnitude of available facilities. What is needed to get things started is a core of qualified scientists who through their achievements inspire their co-workers, who through their experience guide other less experienced junior scientists into the frontiers of the wonderful world of research, and who through their ideas create a tradition for the Institute under the auspices of which they are working. Hence the recommendation that the Director of the Center must seek and hire top quality Research Leaders as they have been defined above.

As a matter of fact, the stringent requirements on the Research Leaders stem also from the responsibilities that are bestowed on them and which may be summarized as follows: First, in a reasonable length of time, each Research Leader must formulate and propose in writing a specific research program. Second, he must organize one or more research teams, depending on the size of the proposed and approved program, to carry out the anticipated research work. For the purposes of this discussion, a research team consists of a Research Leader and his immediate co-workers, namely: one or two junior scientists or engineers and possibly one technician. In essence then the Research Leader is the director of his own project and consequently he must be hired and treated as such.

The details of programming are deferred until the appropriate section. However, suffice it to emphasize here that the written programs must include both a scientific and a financial analysis of the proposed project.

Regarding the organization and function of a research team there are several points that need special emphasis if

the organizational scheme proposed in this report were to achieve its objectives.

a) Each Research Leader must be given the initiative to select and possibly even hire his own co-workers. The reason behind this suggestion is that each Research Leader knows exactly what kind of people he needs for his project and consequently he is in a better position to judge and select. Furthermore, since the Research Leader is the only individual responsible for the successful completion of a project, he must be given the opportunity to organize his team according to his own best judgment.

b) Each Research Leader must be the manager of the funds allotted to his project. More specifically, assume that a research program has been proposed and approved, a research team has been formed and a certain amount of money has been allotted to the team for the next two years. My recommendation is that the Research Leader must be given the responsibility of spending this money within the context of the proposed program and without any requirements for further approvals. For example, if he needs to buy an instrument, he places the order with the purchasing department and the latter executes it after checking only whether there is any money left in the account under consideration.

Of course, there will be occasions during which the need may arise for an expensive instrument which is of more general use than a single project requires. Then the matter should be considered with the Director and the other interested Leaders. However, even in this case the decision must be reached within the Center and not outside.

c) The immediate co-workers of a Research Leader are directly responsible to him and they should perform according to his instructions. However, the Leader has the responsi-

bility of stimulating and scientifically promoting his co-workers in the same way as the Director assists and encourages the Leaders. This point is very important to the long range growth objectives of the Center.

d) Even though each team is concentrating on a specific research project, a high spirit of cooperation and exchange of information must be developed between the teams in spite of the fact that they are seemingly working in entirely different sectors of nuclear science. It is a well recognized fact that the sectorization of a field is only a matter of expediency and not of objectively compelling requirements. Consequently, it is a serious mistake to erect impenetrable departmental walls where there should be none and when the funds and the available scientific talent are limited.

Supporting Services: The kinds of supporting services required for a research center are well known and need not be enumerated here. However, I would like to make some recommendations about their mode of operation.

a) All supporting services connected with the operation of the Center must be on the premises. For example, there is no reason why the purchasing or finance departments should be in Athens if the Laboratories are in Ayia Paraskevi and there is no reason why the Department of Reactor Technology should be in Athens if the nuclear reactor is in Ayia Paraskevi etc.

b) All supporting services must be at the disposal of the researchers. Their function is to assist research and not to check or decide what must be done. Decisions are taken only by the Research Leaders and the Director.

c) An internal accounting system must be developed at the Center for all supporting services that are contributing direct labor to projects. More specifically, suppose that project A requests the construction of an amplifier from the Electronics Shop. Then the Electronics Shop should account

for all the labor and materials devoted to this amplifier and charge project A accordingly. The same comment is applicable to the use of the facilities at the nuclear reacfor, the use of the workshop, etc. Internal accounting is valuable in establishing the exact cost of all projects and also in emphasizing to the researchers that all services are costing money.

This concludes my remarks and recommendations about the organization of the nuclear research center "Democritus". Many aspects have not even been mentioned. However, one thing must be clear and re-emphasized. Whatever organization is adopted, the key personnel must have the authority to execute their duties swiftly and be held responsible for their actions.

3. SCIENTIFIC PROGRAMS

General Remarks

Sponsorship of research must always be based on well studied written proposals. A written proposal serves a host of extremely useful purposes. First, it stimulates its author to think about the problem at hand for a substantial length of time and clarify in his own mind the essential from the trivial and the purposeful from the repetitious. Second, it provides the sponsor with a document which permits an objective evaluation of the soundedness and feasibility of the proposed program and allows a realistic estimation of whether the proposed project falls within the general aims of the sponsorship or not. Third, if the program is approved and sponsored, it supplies the sponsor with an unprejudiced means to intermittently check whether the work proceeds according to promises and whether satisfactory progress is accomplished.

The advantages of written proposals are appreciated throughout the world and all sponsorships of research and development work, that I know of, are based on such proposals, regardless of whether the sponsorship originates from governmental agencies, industrial concerns, national Foundations or private individuals. As a matter of fact, our Country has a precedent of the effectiveness of such a mode of operation in the excellent work being done by the Royal Institute of Research in Greece.

Unfortunately, there are hardly any real proposals or programs at the center "Democritus", in spite of the fact that many of its employees have been on the payroll for several years. This is an extremely disturbing situation and it makes me wonder how decisions have been or are being taken about expenditures, instruments, personnel requirements etc. In fact, what is even more disturbing is that most of the employed scientists have not the slightest appreciation for scientifically methodical programming.

In my opinion this state of affairs must be remedied immediately and only those individuals be employed and sponsored who are capable of formulating specific, well organized and sound research programs for a period of one or two years. The exact content of proposed programs and the procedure for their use are the subjects of discussion of the following sections.

Proposals of Research Leaders

As already indicated, proposed programs for nuclear research originate from the Research Leaders. More specifically, each Research Leader should be given a reasonable credit of time to formulate and submit to the Director of the Center a specific research proposal which,

if approved, constitutes the program for the research work of the Leader and his team.

There are four important items that such a proposal must contain.

The first part of the proposal must be devoted to a concise statement of the proposed type of scientific research. The choice of the topic is the responsibility of the Research Leader. Included in this part of the proposal must be a review of the published literature and a series of well documented arguments about the scientific need for the proposed work, its importance to Science, its value to the Greek Economy or Greek educational aims, its contribution to the long range objectives of the Center etc.

The second part must deal with the anticipated procedures to be followed in the implementation of the investigation. More specifically, the theoretical approach to the problem should be outlined, the experimental methods and techniques should be described and the necessary instrumentation and materials should be delineated. The instrumentation should be broken down to instruments already available at the Center and others that must be constructed or purchased.

The third part of the proposal must describe the personnel requirements and the time schedule of the project. In particular, the number of members of the team to be formed should be indicated, the time required from various supporting services (such as nuclear reactor facility, electronics shop, machine shop, etc.) should be estimated and a detailed time schedule of the entire program should be included.

Finally, the fourth part of the proposal must delve into the finances of the project. The finances of the project should include salaries, wages, materials, instrumentation, supporting services and overhead. Special attention must be paid to making financial estimates so that as many factors

are considered as possible. This is necessary in order to avoid having to cope with situations where a project is estimated to cost X dollars and ends up by costing ten times as much.

All proposals of the Research Leaders are submitted to the Director of the Center for further processing.

Program of the Center

The scientific and financial program of the Center is deduced from the proposals of the Research Leaders. The man who is responsible for this task is the Director of the Center.

To this effect the Director must process the proposals and combine them into a single scientific and financial program for the entire Center.

The processing of the proposals involves several important steps. First, the Director must evaluate all the proposals with a critical eye and establish whether what is proposed fits within the overall aims of the Center and the overall capabilities of the organization. Second, in cooperation with the Research Leaders, the Director must try to interject his personal suggestions wherever he feels competent to do so. Third, the Director must try to eliminate unnecessary duplication of effort and expenses.

The combination of the processed proposals leads to the formulation of the overall written program of the Center for a period of time, a program that includes specific topics to be investigated, anticipated personnel, materials, instruments, and facilities requirements, overall time schedule and the budget.

This is the program that the Director submits and presents to the Deputy Director and the executive staff of the Atomic Energy Directorate. How the program is used from then on up to the Prime Minister has already been discussed

and need not be repeated here. However, one point which should be emphasized is that throughout the process of formulation of the proposals and the program of the Center there must necessarily be a continuous exchange of information and views between the Research Leaders, the Director of the Center, and the Atomic Energy Directorate in order to arrive at an overall plan which is more or less consistent with the anticipated policy of the Government and represents the optimum use of existing facilities and the proposed expenditures. The effective use of the invested capital at the Center, of the available scientific personnel and of the running funds allotted to nuclear research are hard facts that must not be overlooked either by the Director of the Center or by the Directorate.

4. EDUCATION OF SCIENTIFIC STAFF

General Remarks

Scientific research has two prerequisites: well educated and trained personnel and well organized administrative and service departments. Consequently, the question of education and training of the scientific staff at the Center is of the utmost import to the short and long range objectives of the leadership of nuclear research in Greece.

For the time being, the education of nuclear scientists cannot and should not be attempted in Greece for several essential reasons. First, there are not adequate facilities for the complete education of nuclear scientists. Second, the needs of Greece in nuclear scientists and engineers do not justify the establishment of an independent and integrated school to accomplish this purpose. Third, there are not enough qualified scientists to undertake the teaching responsibilities implied by an integrated school of nuclear physics and engineering.

In view of these remarks I would like to recommend an alternative approach to the serious question of education which, in my opinion, will best serve both the short and the long range educational objectives of the Greek Government in the field of nuclear science. This approach is based on a program of scholarships, a program of self-education and, after five to six years, the establishment of an International School of Nuclear Science and Engineering.

Scholarships Program

As already indicated it is neither realistic nor justifiable to create a School of Nuclear Science and Engineering in Greece at this stage of development. Therefore, the question of nuclear education of the scientific staff of the Center must be answered by sponsoring qualified graduates to be trained abroad, particularly in the United States.

By training abroad I do not mean to send graduates to the United States or European Countries for a few months, even if this is done several times. On the contrary, I strongly recommend that qualified youngsters be given scholarships to attend a graduate school, with the explicit obligation to acquire a Master's or a Doctor's degree.

So far, most of the graduates that were sent abroad by the Atomic Energy Commission followed review type lectures which have only an introductory character and do not serve either the short or the long range objectives of the Greek Government.

If the recommendation for scholarships is adopted, the next question is: What organization should award them? My recommendation is that this responsibility be delegated to the National Scholarships Foundation (IKY) and not to the Atomic Energy Directorate. The reason for this recommendation is twofold. First, the time of the Directorate is too

valuable to be devoted to decisions for scholarship grants. Second, IKY operates under excellent principles and is very successful in its aims. All the recipients of scholarships from IKY that I have met, and I have met a large number of them, are top rate scientists and consequently I believe that the services of IKY will be of great value to the Directorate.

Of course, the Directorate should indicate to IKY its specific requirements and needs in the various sectors of nuclear science and what emphasis should be placed on one field over the others. This decision should be taken by the Directorate on the basis of priorities which are discussed later.

From the financial standpoint, I believe that awarding scholarships to qualified graduates and sending them abroad is less expensive than employing them at the Center right after they graduate from one of the Greek Universities. The reason is very simple. In general, right after graduation from a Greek University a physicist, a chemist or an engineer is not adequately prepared, either theoretically or experimentally to do nuclear research. If he is hired at the Center, he receives a minimum of $150/month. This implies that, with a conservative overhead of 100%, he costs the Greek Government approximately $300/month without doing anything productive for several years. On the other hand, a person with $300/month can acquire excellent educational background and research experience over a period of a few years by attending a well established and advanced educational Institution abroad and then be of real service to the Greek Government.

In view of these recommendations, there is another problem that must be faced at this stage: What should be done with an unreasonably large number of young graduates that are currently employed at the Center? My unreserved recommendation is that a large percentage of the scientific personnel presently at the Center be dismissed and be given

the opportunity to qualify for scholarships offered by IKY. The reasons for this recommendation are not only scientific and financial as already indicated, but also factual. The majority of young graduates at the Center expressed to me their sincere desire to further their education abroad, in order to acquire the knowledge necessary in their work.

At this point, it is important to note that there is a large number of qualified Greek scientists abroad who long to return to Greece provided that the conditions of employment are conducive to productive work. What attracts these research scientists to foreign research and educational establishments is not a matter of salary. It is the freedom of creative initiative, the spirit of cooperation, the recognition of scholastic and professional excellence and the punishment of scientific mediocrity. Therefore, if such conditions are established at the center "Democritus", it will have more applications for employment than it can reasonably honor.

Lest I am misinterpreted, I would like to emphasize that the previous remarks do not mean to imply that graduates of foreign Universities are better scientists than those of the Greek Universities. Quite the contrary, all I mean to suggest is that a scientist, who had the opportunity to improve his research abilities in the acquisition of a Master's or a Doctor's degree and who spent some time in an established research laboratory, has a better chance of being of value to the Greek Government than another graduate who has limited and incomplete experience.

Self-Educational Programs

Parallel to the program of scholarships for nuclear studies awarded by IKY, there should be self-educational programs at the Center. The Director of the Center in

cooperation with the Research Leaders should formulate perpetuating self-educational programs for all the scientific and technical personnel.

The self-educational programs should consist of regular weekly or bi-weekly seminars. These seminars should be of three types.

The first type of seminars should be covering special subjects of interest to and attended by specific scientific groups at the Center. The speakers should be individuals among the attendees who are assigned to study a series of related articles from the scientific literature or predetermined textbooks and present the outcome of their study to the group. The speakers should be convinced about the seriousness of this undertaking, do their best to present the material that they digested and be prepared to discuss it with their colleagues.

The second type of seminars should be centered around topics of more general interest and should be attended by all the scientists at the Center. The speakers can be either researchers from the Center who report on their work and findings or outside lecturers who give different points of view and stimulate new interests.

Finally, the third type of seminars should address themselves to the problem of training of the technical and supporting personnel of the Center. For example, reactor operators, electronic technicians, etc. are the individuals that must be trained. The speakers for these seminars are selected among the scientific personnel of the Center who must also be required to prepare appropriate notes for the students.

The objectives of the various seminars are many and very far reaching. First, they serve the endless purpose of self-education which is of great value to any scientist, no matter how well qualified he is. This is particularly

true for the nuclear field where so many disciplines are necessary to understand devices based on nuclear reactions. Third, through seminars the different research teams are informed on each other's work and thus avoid duplication of effort and furthermore they are competitively stimulated. Finally, an educational tradition is established which is of value to the long range objectives of the Center.

It must be noted that the cost of seminars is practically nil because they are, as they should be, taxing only some extra time and effort from the scientists, time and effort, however, which is invested in a most rewarding purpose.

School of Nuclear Science and Engineering

There is no doubt that eventually the Atomic Energy Directorate in cooperation with either the Technical University of Athens or the University of Athens should found a School of Nuclear Science and Engineering. However, this goal must be postponed for a few years for the reasons that have already been given and others that follow. First, nuclear scientific talent is scarce in Greece while large investments have already been incurred in the nuclear field and others are anticipated. Therefore, the limited talent now available should not divide its efforts into many directions with the net effect of having mediocre results in all of them. Instead, all efforts should be concentrated on the effective use of the nuclear reactor and its associated facilities at the Center. Second what makes a school worth attending is the scientific achievements of its instructors and not their teaching ability. Such achievements are not abundant right now in Greece.

Hopefully, however, in a few years from now all the prerequisites for an integrated school will be fulfilled and then an International School of Nuclear Science and Engineering

should be launched.

The school should be international and should adopt the English language as its teaching language. There are several reasons for the international and the English language requirements. First, if the school is projected on the international scene students from neighboring Countries will be able to attend and thus justify the expenses of an integrated school, since Greece will not need many nuclear scientists and engineers for many years to come. Second, the adoption of the English language is attractive both to foreign students and to Greek students who thus have at their disposal the overabundant English scientific literature that Greece can never afford to create. Third, it will be very easy to invite prominent scientists from abroad to lecture for one or two years on specific subjects.

In summary, a School of Nuclear Science and Engineering should be a long range objective for the Atomic Energy Directorate and the Greek Universities but should not be undertaken at this time.

5. PRIORITY OF PROJECTS

In any endeavor where many things are possible but the financial resources are limited, a certain priority of efforts should beestablished. In addition, if heavy investments have already been incurred, no further capital expenditures should be undertaken until it is assured that the original money is yielding its returns.

Unfortunately, these well known facts have not been adequately considered by most of the Countries participating in the Atoms for Peace program. These Countries have built large installations, have bought very expensive equipment and have hired tens or hundreds of graduates without specific and well programmed objectives to the extent that today they

do not know what to do with all the buildings, instruments and personnel. I believe that Greece should not follow the same pattern and to this effect I would like to recommend strongly that research projects at the Center be given priorities and that no further expansion of laboratory space be undertaken until the present facilities are productively occupied.

Admittedly the establishment of priorities depends on several often conflicting criteria and the resolution of the conflict is the responsibility of the Atomic Energy Directorate. However, in my opinion, the criteria of investments already incurred and of value of projects to the Greek Economy should be given foremost consideration.

More specifically, the largest investment at the nuclear research center "Democritus" is the nuclear reactor and its associated laboratories. Therefore, steps should be taken to complete all the existing buildings and to give top priority to projects that require the use of the nuclear reactor. In fact, not only should projects requiring the use of the nuclear reactor be given top priority but also everything possible should be done to stimulate interest in this direction. For example, the limited scientific talent available should be discouraged from suggesting projects which do not need radiations produced by the nuclear reactor, until a substantial program is formulated which relies heavily on the reactor.

The other major consideration is the value of the sponsored projects to the Greek Economy. Unquestionably, nuclear research which is of immediate import to the welfare of the Greek people should be given priority and be encouraged and stimulated. For example, nuclear research related to the improvement of agricultural products and to the preservation of food stuffs should be given serious consideration. Also nuclear research pertinent to medical applications in Greece

and to the betterment of the Greek Industry should be enhanced and supported.

6. CONCLUSIONS

In the preceding sections I tried to recommend a series of procedures which, in my opinion, will enhance the genuine and praiseworthy ambition of the Greek Government to promote original nuclear research in Greece. The major recommendations that I made may be summarized as follows:

1) The Greek Government should base its estimates of investments and running expenses of nuclear research on financially and scientifically realistic objectives. These objectives should be derived from well outlined and documented programs and be judged within the context of the overall educational and research goals of the Government.

2) The Greek Government should take all steps necessary to assure itself that funds allotted to nuclear research are consumed creatively and efficiently and not simply because they are included in the national budget.

3) The Atomic Energy Commission should be replaced by an Atomic Energy Directorate with one individual in charge and an executive staff of specialists.

4) The entire nuclear research center "Democritus" must be under the true and powerful directorship of only one individual. All scientific, technical, administrative and clerical personnel at the Center must be under his absolute directorship.

5) The scientific research at the Center must be performed by qualified Research Leaders and their teams. The Research Leaders are the originators of the scientific programs of the Center.

6) The management of funds allocated to research projects at the Center must be the responsibility of each of the

Research Leaders to whom the funds have been allotted.

7) The basic education of the key scientific personnel of the Center should be accomplished by financially supporting graduates to study in outstanding foreign educational Institutions. The selection of these graduates should be done through the National Institute of Scholarships (IKY). The recipients of scholarships should be required to integrate their studies abroad through the acquisition of a Master's or a Doctor's degree.

8) An Institute for Nuclear Studies should be a long range objective and should be founded five to six years from now. An Institute for Nuclear Studies should not be undertaken at this time.

9) Projects which make use of already existing equipment and laboratory facilities must be given priority over others that require new and substantial investments. More specifically, projects which will make use of the nuclear reactor when it is operational should be given priority and be stimulated.

10) No funds should be invested in new laboratories until the space currently available is productively occupied by qualified research workers.

I have purposely omitted the recommendation of specific research projects. The reasons for this omission are as follows. First, it is consistent both with the spirit of the report, to assist qualified Greek Scientists to materalize their own initiative and scientific potentialities, and my conviction that research work must originate from within and not without the primary investigator. Second, it stems also from the fact that I do not feel competent to stimulate research in areas outside my own fields of specialization which do not and should not necessarily coincide with those

of the scientists at the Center. Third, the published literature is full of outstanding problems in the field of nuclear science. As a matter of fact, the U.S. Atomic Energy Commission publishes yearly a length report with literally hundreds of suggested topics for investigation. This report is readily available from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C., U.S.A.

I have also avoided the discussion of many other problems which are important to the main subject of this report. The reasons for this omission are self-imposed limitations of scope and/or lack of adequate information.

In closing, I would like to emphasize that, whatever the advantages and inadequacies of this report, one premise must be clear. The effective promotion of a scientific field, with the explicit objective the cultural and economical advancement of the Greek people, necessitates unreserved use of scientific methodology in the planning, organization and administration of all efforts and unquestionable emphasis on essential qualifications of all employed personnel.

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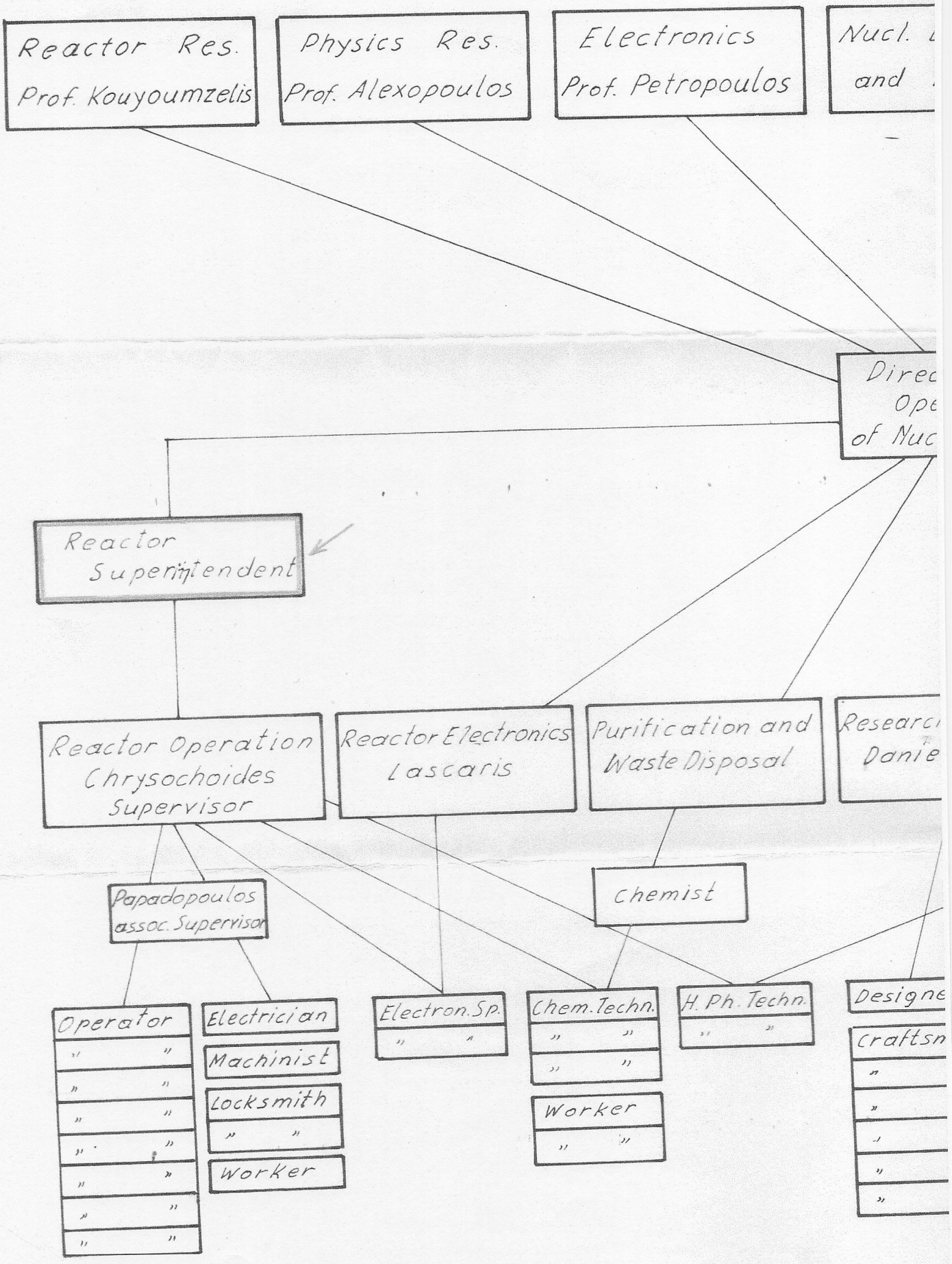

ORGANISATION