FINAL REPORT

OF THE EVALUATION COMMITTEE SUBMITTED TO THE GENERAL SECRETARIAT OF RESEARCH AND TECHNOLOGY IN THE GREEK MINISTRY OF DEVELOPMENT

ON

THE EVALUATION OF THE INSTITUTE OF NUCLEAR TECHNOLOGY AND RADIATION PROTECTION WITHIN THE NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"

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Date: **September 2, 2005**

Place: **Athens, Greece**

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EXECUTIVE SUMMARY

The Evaluation Committee convened at the National Center for Scientific Research “Demokritos” (NCSR “Demokritos”) on September 1 and 2, 2005 to evaluate the Institute of Nuclear Technology and Radiation Protection (INTRP). The evaluation was based on the written material provided to the Committee, including the 2004 INTRP Annual Report, and a one-day visit to the Institute. During that visit an extensive oral report was presented by Prof. M. Antonopoulos-Domis, Director of INTRP, each of the Institute’s Laboratories was visited and discussions were held with key scientific personnel. During the second day, after completing their evaluation, the Committee produced this report.

The Committee agrees that Nuclear Technology and Radiation Protection are fields in which Greece must continue to maintain expertise (to preserve independence in the development of environmentally-friendly energy resources, controlling and limiting environmental pollution, attending to matters concerned with the safety and reliability of sensitive plant, etc.). In order for this to be accomplished the Government needs to develop a long-term policy and an associated strategy concerning Nuclear Technology which will ensure that proper provision is made for the support of basic and applied research, the transfer of advanced technology to the public and private sectors and the training of young scientists. Adequate funding to achieve these goals must be provided by the Government, within an administrative framework which allows the NCSR and the INTRP sufficient flexibility in the development of their short and long-term research strategies and in their personnel management and planning.

In evaluating the INTRP, the Committee found that it continues to carry out excellent research and to develop new technologies, whilst maintaining high levels of international collaboration, giving good training to students and young scientists and providing valuable services to both the public and private sectors. Over the past five years, the Institute has succeeded in obtaining considerable financial support for its research and development (particularly from the EU), publishing large numbers of good quality papers in peer-reviewed journals and conferences and also providing high-technology services to the nation (some free of charge). Furthermore, the Institute has self-financed significant improvements to its buildings and its equipment infrastructure. It has the potentials to continue and even increase such self-financed improvements, given more flexibility in the hiring and training of young Scientists and Technicians and the freedom to provide its Functional Scientific Personnel (FSP) with adequate financial incentives.

It should be pointed out that the number of Researchers and FSPs in the Institute has reduced from 30 in 1996 to 22 in 2004 (mostly due to retirements). In the same period, the number of Technicians has reduced from 31 to 27 and the number of Administrative Staff from 6 to 2.

The constraints on the Institute in connection with the hiring young scientists and skilled reactor technicians, and also the problems which is faces due to shortage of space, limit its ability to maintain adequate expertise, develop new research areas, and to increase the self-financing of its activities through carrying out additional research and providing commercial services. They also limit the Institute's ability to maintain a high international visibility and extensive outside collaboration.

The existing resource in terms of Researchers, FSPs and Reactor Technicians are stretched very thinly throughout the laboratories and cover a very broad range of research activity. In spite of this, several groups (notably in the areas of, Solar Energy, Environmental Research and Systems Reliability) still manage to provide excellent services and significant transfer of advanced technology to the private sector, but only by means of recruiting many staff on short term contracts (the numbers of which are sometimes in excess of those employed on a permanent bases). Furthermore, the Health Physics group continues to provide a significant service to hospitals, free of charge, whilst pursuing forefront research into cytogenetics and related exciting activities.

As the sole facility of its kind in Greece the Research Reactor is strategically very important. It provides unique services covering a range of applications. Over the past several years it underwent considerable refurbishment. The reactor control system was improved and the security arrangements were upgraded. It increased its activities and brought in significant funds to the Institute. However, it is still far from being fully utilized and needs additional highly-skilled technicians in order that it can be used more effectively and is able to operate on a full time basis.

Whilst the Institute has been able to attract substantial support for research from the European Union, and this is undoubtably of considerable importance in connection with its successful operation, it must be borne in mind that over-reliance on such outside support could, in the long term, negatively affect the ability of Greece to maintain its independence in both basic and applied research on Reactor Technology and Radiation Protection.

PART 1 GENERAL OVERVIEW

1.1 General description of the field

Nuclear Technology is a broad field covering both basic and applied research. It is concerned with the development of a wide variety of plant and equipment involving nuclear radiation (including reactors and radioisotopes), energy/electricity production, application of radiation and radioactive sources in industry (for example non-destructive testing), medicine (nuclear medicine, cancer therapy), biology (radio-biology, radiation effects on DNA and cells), effects of radiation on materials, radioactive waste management, radiation protection and health physics, etc. It should not be confused with nuclear and particle physics which is mostly concerned with fundamental studies of the structure of matter, production of elementary particles production and interactions between them and, also astrophysics.

1.2 State of the art in Greece compared with Europe and the rest of the world

Nuclear technology in general and nuclear energy in particular has suffered from lack of the support in many parts of the world over the last 20-30 years. Many nuclear research institutes were forced to either modify or even completely change their research activities, many research reactors were shut down, and educational programs in nuclear engineering were canceled or merged with other programs. Some European countries even decided to freeze or cancel their nuclear energy/technology programs. However, other (notably France) have continued to support nuclear technology as their strategy to maintain energy independence and security. At the same time, in other parts of the world there has been a growing interest in nuclear technology and particularly nuclear power plant (Korea, Taiwan, China, India and Pakistan are notable examples).

It must be pointed out that there has been a clear indication of a revival over the past several years (particularly in nuclear energy). Many factors have contribuited to this revival: the price of fossil fuels, instability of supplies of gas and oil, evident increase in the effect greenhouse gases and further increases in energy demands. China is planning to build 40 to 50 new nuclear power plants in the next 20 years. There is a high probability that construction of new nuclear power plant will commence in the USA within the next 3-4 years after more of 30 years of stagnation. Also, it seems quite likely that there will be an interest in new nuclear reactors in the UK as well. This will cause the other countries to rethink their policies with regard to the development of nuclear technology. Many countries (including the USA and the UK) have lost expertise in this field due to retirement, lack of support for research and development, and lack of long term training planning.

Greece should be commended for supporting its Institute of Nuclear Technology and Radiation Protection and not shutting down the research reactor. As a consequence of this, it will be relatively easy for Greece to maintain expertise and know-how in the field and even increase its research and development.

Furthermore, it is critically important to retain top-level scientists and their commitment to the development of knowledge for the benefit of the country. However, the relevance of the subject and performance of the practitioners should be critically evaluated in terms of priorities, discussed and stated within a clear long-term scientific policy at the national level.

Greece, although officially designated as a "Developing Country", with a GDP must lower that the EU average, operates with the highly competitive arena of the European community. This has placed special demands on its future programs related to nuclear technology. It is not easy to optimize and justify the commitments needed in terms of manpower, skills and budget. Although Greece increased its expenditure on R&D to ~0.7% of GDP from a figure ~0.5 a few years ago, it is still low when compared with the other E.U. countries.

The Committee agrees that nuclear technology and radiation protection belongs to the fields in which Greece must continue to maintain expertise. In order for this goal to be accomplished the Government needs to develop a long-term policy and strategy regarding nuclear technology: covering support for basic and applied research, transfer of the advanced technology to the public and private sectors, and training for young scientists. The necessary financial support must be provided by the Government with effective budgetary control that allows enough flexibility to NCSR and INTRP in the development of short and long-term research strategies and personnel planning.

The Institute of Nuclear Technology and Radiation Protection has a broad mandate and operates six main laboratories with a permanent staff of 72. In addition, there are 38 temporary staff funded mostly by European Union contributions. While this is an indication of success in a very competitive climate, it also represents a tremendous vulnerability in terms of the stability of research funding. This is especially so since substantial amounts of funding from this source are seemingly used for funding maintenance and operational costs as well as consumables and equipment. The policy of limiting state financing mainly to providing salaries and basic support services with a lesser contribution to operational expenses is a matter of some concern. However, the success in obtaining a large amount of funding from contracts, where expertise is deployed in the market, demonstrates both the relevance and the value of research performed and an impressive ability to complete effectively.

(i) Environmental Radioactivity Laboratory

This Laboratory does extensive measurements and focuses on sampling and monitoring to detect enhanced natural radioactivity (including indoor and outdoor measurements of radon), radioactive contamination due to accidents, marine and lake radioactivity and radioecology, and aerosol studies. The laboratory also continuously measures the environmental background radioactivity in air, eater and soil. It is reasonably well equipped in terms of equipment and infrastructure and deploys its resources systematically and in a well oriented manner. The laboratory activities are of considerable importance to the country. Although some of the facilities and equipment need to be modernized, the performance of the Laboratory is in line with that of many other similar ones around the world.

(ii) Health Physics and Environmental Hygiene Laboratory

This is a very active and productive group that studies molecular genetics and radiation cytogenetics and their use in biological dosimetry to provide estimates of absorbed doses and cancer risks. In addition, it studies genetic predisposition to radiation sensitivity and radiation-induced carcinogenesis. It also provides health physics and waste management services to NCSR "Demokritos". It is well-equipped with modern equipment and has a satisfactory infrastructure within which it can carry out its activities. The work of the Laboratory is recognized internationally and it belongs to the European network of excellence in studying leukemia.

(iii) Research Reactor Laboratory

The 5 MW, pool type reactor is the only research reactor in Greece. Over the last several years the Research Reactor underwent considerable refurbishment, the control system was improved, and physical security was upgraded. The reactor safety was evaluated by the IAEA, and positive marks were obtained. With these upgrades and improvements, the reactor utilization has increase significantly, but there is still an opportunity to increase it further if the reactor were to operate on a 24-hour basis (three shifts). The present operational time is limited to a few days per week and a maximum of two shifts per day. This does not represent a baseline of operation and usage for effective exploitation. The activities of the Research Reactor Laboratory include: neutron activation analysis, neutron diffraction for research and materials studies, radiation sterilization, neutronics, reactor operations and maintenance, and aspects of reactor safety. The available supply of fresh fuel remains sufficient for several years of operation. Bearing in mind that a large number of research reactors around the world have been shut down and that the availability of the services which such reactors provide is becoming increasingly limited it is clear that Greece should continue to maintain and support this unique facility.

(iv) Laboratory of Systems Reliability and Industrial Safety

The technology developed by the Laboratory is mainly applied to aid the understanding in Greece of potential large-scale accidents in the chemical industry. The Laboratory provides integrated safety/reliability/maintainability programs and the staff have completed evaluations of 45 chemical installations. It would seem that this laboratory is well-focused on serving needs of the public and industry. It has excellent international visibility.

(v) Environmental Research Laboratory

The Laboratory develops scientific expertise and innovative tools for research and services in the areas of environment protection, pollution measurement and assessment and its reduction, and in the technological development of an efficient, environment-friendly energy source (hydrogen). In particular, it develops simulation tools for studies of atmospheric pollutant dispersion, meteorological modeling, the factors and activities contributing to global worming, and the characterization of nano-porous materials in the environment. The Laboratory has expertise in software development and their software package ADRIA-HF has been accepted for use by the EU for safety assessment of hydrogen applications.

(vi) Solar and Other Energy Systems Laboratory

This Laboratory develops technologies related to solar energy systems: solar heating applications, desalination, air-conditioning, space/water heating and drying systems. The Laboratory enjoys a good collaboration with commercial companies, does relevant work on current commercial products and is capable of generating a major component of its expenses.

1.2.1 Human Capital

The opportunity to work with skilled, highly motivated persons in a collaborative the environment is a special feature of research centres and of paramount importance for their development and success. The INTRP is no exception. The following comments rely heavily on data presented in Tables 1a, 1b, 2a, 2b, 4a, in the early 2004 INTRP Annual Report which was made available to the Committee by the Head of Institute and, of course, the laboratory visits made by the Committee and the discussions with staff in the course of those visits.

- All but one of the laboratories have experimental facilities, hence they need technical staff to help carrying out the research activities and fulfilling contracts. Furthermore, to operate the research reactor efficiently, productively and at the high levels of safety, which meet those recognised by IAEA, a suitable number of highly-trained and skilled technical personnel is mandatory. Is is for these reasons that at INTRP there are 27 permanent Technicians and 11 Scientists in addition to the 22 permanent researchers and Functional Scientific Personnel. In some cases, as for the development of research reactor activities, the laboratories are under-staffed.
- The problem of renewing staff and maintaining the knowledge and expertise available within the Institute has been addressed mainly by hiring the temporary personnel under 30 years of age (Table 1a). Moreover, by analyzing the trend of personnel structure over the past decade, it is apparent that the decrease in the permanent staff since 1996 by 8 Researchers and FSP's, by 4 Technicians and by 4 Administrative Staff, has been covered mainly by personnel hired on temporary contracts (+10) and to lesser extent by other entry level scientists (+6). This clearly

demonstrates the ability of the Institute to obtain the funding by means of research and industrial contracts. Its ability to attract and motivate young people is also demonstrated by the number of students (BSc, MSc, PhD) that collaborate in research and other activities within the laboratories. Over the past three years, 35 final year projects and 11 PhD projects have been completed. Work is currently in progress on a further 21 PhD projects.

- The productivity of the Institute is good, both in terms of producing scientific publications and obtaining funding. In the year 2004, the average number of publications in refereed international journals per scientist was 5.1. Over the past five years, this performance indicator has risen significantly (in 2001 it was 3.2) in spite of the fact that the number of Researchers and FSP's decreased. There has been a significant improvement in the funding raised over the past five years; in 2004 it was 120 K€ per scientist (R+FSP+CR). As a whole, the Institute increased its capability of obtaining research funds and commercial and industrial contracts. From national projects and studies income increased by 46% since 2000 (Table 2a). From R&D contracted by firms and other private legal entities it increased by 500%, and from sales of products, services, etc. by 145%. The global income of the Institute, apart from the regular state budget funding, increased by 22%. The average externally-raised budget of the Institute is larger than the average value for the Center as a whole (Table 2b). The INTRP obtains more than one fifth of the Centre's funds from national projects and studies, more than one quarter of the income obtained from the sales of products and services, and more than two thirds of the revenues from R&D contracted by firms and other private legal entities.

The good reputation of the Institute and its international visibility in the scientific community clearly is demonstrated by the fact that it is currently actively involved in 6 Integrated Projects within FP VI.

1.2.2 Research Accomplishments

The following research activities have been carried out in the laboratories of the Institute:

- Research Reactor Laboratory (RRL): This is one of the major contributors to scientific publications and funding within the Institute. It is also the largest laboratory since it operates the research reactor. Besides the heavily burden of operating and maintaining such a reactor successfully and at a the high levels of safety required, as recognised by an IAEA commission of experts, the laboratory is active producing results in a number of fields such as: neutron activation analysis; the study of material properties by means of neutron scattering techniques (including materials for fusion technology applications); the study of aerosols and multiphase flows; the application of nuclear technology to biology. Scientific results have also been produced in fields such as thermal hydraulics and neutronics related to nuclear reactor performance. A significant effort is being expended to enhance the availability of neutron beams. The laboratory participates in several EU-funded programs and it also cooperates with other laboratories within the Institute and within the Centre. Its scientific collaboration and services could be improved further in areas such as in the radiopharmaceutical studies, if support for additional personnel was available.

- Health Physics and Environmental Hygiene Laboratory (HPEH): This is an important laboratory and it is internationally renowned. It develops both services and scientific knowledge in the field of biological dosimetry and the evaluation of absorbed doses and their effects at molecular, chromosomal and cellular level. It is the reference laboratory for the Greek Atomic Energy Commission and the International Atomic Energy Agency (IAEA). It belongs to the "European Network of Excellence for Leukemia" supported by FP VI and it is the National Reference Laboratory for cytogenetic characterisation of myelodysplastic syndromes. It developed new cytogenetic methodologies and it contributed to identifying the mechanisms underlying biological effects of ionizing radiation. It serves all the hospitals in the country by means of its laboratory capabilities.

- Environmental Radioactivity Laboratory (ERL): This laboratory provides an important basic service for the nation, since it operates a key part (40 stations) of the Greek network for environmental radioactivity (soil, indoor, marine, aerosol radioactivity) and represents Greece on several national and international committees. It is active in radioecology, in evaluation of contamination scenarios, in providing effective countermeasures and studying the effects of protracted low-level irradiation, in studying the physical-chemical properties of atmospheric contaminated aerosols, and in the development of novel sampling and measurement techniques. A significant effort has been devoted to developing theoretical and experimental knowledge in this last field. It has participated in EU funded projects and gained access to large-scale facilities in Europe.

- Environmental Research Laboratory (EREL): This laboratory is one of the major contributors to the output of scientific publications from the Institute and, at the same time, one of its major contributors in terms of funding. The average age of its personnel is low and is mainly made up of young and highly motivated people (6 PhDs have been hired as permanent staff in recent years). It successfully carries out both theoretical and experimental research and also provides services for industry and the private sector. It was born as a "scientific spin-off" of nuclear technology and now develops research in the important fields of energy and the environment. The high level of visibility and credibility of the laboratory at international level is demonstrated that its leader is acting as the coordinator of five EU projects and consortia involving research organizations and industries. The topics range from the development of state-of-the-art modeling and related software for atmospheric dispersion of pollutants, which leads also to the commercial exploitation of the CFD tools produced in the course the research, to the study of porous media for hydrogen storage (including nanoporous materials) and the structural and dynamic characterisation of biological systems. It has a fully equipped laboratory for pollution measurements. The dynamism of the group is demonstrated by the wide spectrum of topics it covers in its publications.

- Systems Reliability and Industrial Safety Laboratory (SRISL): The laboratory is very active both at national and international level. Besides being the technical advisor to the Greek government and competent authority for the SEVESO directive, it has developed an integrated methodology and new tools for the safety analysis and the quantification of uncertainties. This has been applied to more than 45 Greek installations. Moreover, a methodology for emergency response optimization and a decision support system has been developed. The laboratory has good visibility within the EU. It is part of European research programmes, devoted to the consideration and evaluation of human factors in safety (the VIRTHUALIS project) and it has been involved in a pioneering campaign of the Dutch Ministry of Labour and Social Affairs for the development of methodologies and models to quantify the risk from accidents at work. The laboratory is mainly engaged in activities involving "software". It is not responsible for any experimental equipment or test facilities.
- Solar and Other Energy Systems Laboratory (SESL): This is the key laboratory in Greece for the development of solar thermal technologies and provides outside services in this important sector. In connection with solar collectors and systems, promising work is being done in applying heat pipes. The researchers are also active in the field of solar cooling. The importance of the topics covered by the Laboratory and it external visibility allowed it to be selected for involvement in an international research programme with the Chinese Academy of Science in Beijing to study and build a test facility for solar thermal products. Other results have been obtained in the field of solar desalination and energy storage. The laboratory collaborated with the RRL during the refurbishment of the reactor and the safety report preparation.

1.2.3 Opportunities and threats in relation to the national and regional economy

OPPORTUNITIES

- The possibility exists of the reactor producing radio-pharmaceuticals and radio-tracers for hospitals in Greece and also for neighbouring countries, provided that full time operation of the reactor is possible.
- The Institute could have closer collaboration with the Institute of Radioisotopes and Radiodiagnostics Producs, with a view to providing a complete set of services for the nation.
- The Institute could enhance the exploitation of multidisciplinarity, by identifying common, wide-ranging projects on which several laboratories within the Institute could be involved. By joining efforts and competencies, value could be added due to the enhanced critical mass. For example, Building Architecture, studied as a complex system, requires expertise and

competencies in the areas of: energy, heat transfer, CFD, human comfort and health, safety, etc.

- Similarly, added value could also be achieved by the Institute becoming involved in research and development in conjunction with other institutes in the Centre (possible areas could be energy and the environment, life science, etc.).
- Utilising the specialised expertise in nuclear technology available, the Institute could expand into the important, developing area of detection of illicit trafficking of radioactive elements, fissile materials and pollutants.
- The Institute could develop activities concerned with the important matter of developing techniques for monitoring the coastal environment, to detect pollution and possibly control it.
- Finally, it could increase its links with research organizations and universities abroad and do more to attract researchers from other countries.

THREATS

- Uncertainties in obtaining funding for research from the EU as its policies and priorities in connection with Nuclear Technology change could possible pose a threat.

1.3 Recommendations and measures to be taken

The Government of Greece needs to develop a long-term policy and strategy on nuclear technology: to support basic and applied research, the transfer of the advanced technology to the public and private sectors and the training for young scientists.

Appropriate financial support must be provided by the Government to achieve these goals, with effective budgetary control that allows enough flexibility to NCSR and INTRP in the development of its short and long-term research strategies and in personnel planning and recruitment.

The Institute of Nuclear Technology and Radiation Protection should be given more flexibility in budget planning, in the hiring/training of young scientists and highly-skilled reactor technicians and in providing the financial incentives for Functional Scientific Personnel.

There is a shortfall in staffing in most laboratories when compared with the number of projects and the wide range of research activities being undertaken. This must be addressed. We recommend that arrangements be implemented to allow overlapping between newly-recruited young researchers and experienced senior staff who are due to for retirement.

The manpower situation should be reviewed in line with the true demand of the scientific and technological skills required to meet the aims and objectives of the

Institute. It is necessary to focus on making arrangements for the re-training of staff, who need to be redeployed.

There is a need for further reinforcement of internal cooperation within the Institute along priority lines. A detailed examination of current programs and activities in relation to staff capabilities should be undertaken.

Measures should be taken to provide 'seed corn' funding for researchers to pursue work on innovative ideas which have a high prospect of success.

It is necessary to be even more aggressive and professional in marketing the capabilities of the Institute to the Government, the public and private sectors companies, and to the international community.

There is a need to ensure that, where capital infrastructure is provided appropriate support for running expenses is available to enable the capabilities to be fully exploited after installation.

The retention of the 5 MW research reactor is considered to be of extreme importance. Every effort should be made to develop a sound business approach to the exploitation of this facility. This ultimately, must involve three-shift operation, if good results are to be obtained.

Environmental radiation background measurements, (in air, water and soil) must continue in order to ensure that well-qualified personnel with the necessary expertise are available in case of an emergency involving radioactive pollution.

Amongst the laboratories which it has visited the Committee wish to recommend rewarding two particularly successful research one, the Environmental Research Laboratory and the Research Reactor Laboratory, bearing in mind that these laboratories were able to increase the funding they receive from competitive programs and increase the scope of services they provide to the public and private sectors, whilst at the same time succeeding in increasing their output of high quality publications and international visibility.

PART 2 Overall Evaluation

In relation to the number of permanently-employed scientists, the Committee found that there is a very broad spectrum of activities within the Institute and an impressive overall output in terms of publications and income generation.

The Institute has developed very positively during the past decade. The motivation of the staff is high and very significant improvements have been made to the infrastructure of the laboratories and the research reactor.

It is noted that the activities of the laboratories depend very much on the particular interests and competences of a rather limited number key members of staff and on their capability of attracting external funding. As a consequence of the number and variety of different projects being undertaken, the numbers of researchers available is inadequate.

There is an acute shortage of space which inhibits the operation of some key areas of activity within the Institute where there is a clear potential to expand. Some re-allocation of space designed to address this matter needs to be given urgent consideration.

The number of doctoral candidates working in the various laboratories is very satisfactory and is indicative of very useful collaboration with educational institutions, both national and international.

The Committee fully agrees with the emphasis put by the Director of the Institute on research and publication, which is in line with the goals of the research environment in Greece. The Institute is trying to respond to societal needs. However, is not really provided with sufficient resource to fulfil them.

The Institute has been successful in obtaining funding from external sources, such as the EU and Industry and other organizations (including some abroad). This testifies to its national and international reputation and has enabled the Institute to finance staff positions, as well as infrastructure and equipment.

The Committee recognizes the dangers of extreme reliance in certain areas on EU program funding and the vulnerability of the Institute's research programs to unpredictable EU policies and priorities. However, even so, efforts to expand EU funded activity must continue.

The staff of the Institute have been very successful in marketing some of its capabilities and know-how for commercial purposes. However, professional help with this activity could undoubtably prove to be beneficial in further enhancing its enterprises.

The Committee are of the view that good progress has been made over the years in the operation of the Institute and wish to emphasise that the remarks made in this evaluation of the Institute reflect very positively on the way that it has been managed.