DR13

DR13

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS RESEARCH LABORATORIES

STUDY OF MAJOR NEW RESEARCH FACILITIES

PRELIMINARY REPORT

by

R.C. CAIRNS

NOVEMBER 1982

AUSTRALIAN ATOMIC ENERGY COMMISSION
RESEARCH ESTABLISHMENT
LUCAS HEIGHTS RESEARCH LABORATORIES

STUDY OF MAJOR NEW RESEARCH FACILITIES

PRELIMINARY REPORT

by

R.C. CAIRNS

November 1982

SUMMARY

This paper reviews proposals and ideas on major new facilities which have been put forward in the past by AINSE and the AAEC for possible installation at Lucas Heights. Both research facilities and developmental projects have been included.

The purpose of this preliminary report is to assemble in one document those proposals and ideas so that discussion by those responsible for new programs can proceed with a knowledge of past proposals.

It is concluded that formal input should be sought on the proposals mentioned in this report (not all of which are now options) and any others by drawing together those competent in the fields from the AAEC and AINSE.

CONTENTS

1. INTRODUCTION

The Directorate has asked that a study be carried out of possible new major research facilities. This study is to include a review of the facilities themselves, their uses, their implications for future programs within the AAEC and Australia, and an indication of their costs, together with recommendations.

This preliminary report reviews what has been proposed in the past by the AAEC and AINSE and collects together views expressed during discussions with senior staff at Lucas Heights and information collated from relevant documents including those provided by the AAEC and AINSE staff.

The next step, as given in the conclusion, is to seek formal detailed input on existing and any other new options available by drawing together those experts in the AAEC and AINSE with a contribution to make. It is most important also to seek early input and exchange of opinion from universities, Departments, including Finance, and ASTEC whose support would be needed for any new major facility at Lucas Heights.

In considering what major facility could be built at Lucas Heights to replace HIFAR in its previous role as a focus for nuclear science and technology in Australia, the first question to resolve is whether another major facility is necessary.

The decision to build HIFAR at Lucas Heights was made around the mid 1950s at the time when no nuclear research program had been defined by the AAEC. At that time initial Australian staff were at Harwell in UK for training and more were being recruited. Several DIDO reactors were under design or construction for location at Harwell and Dounreay in the UK, Riso in Denmark and Julich in the Federal Republic of Germany (FRG). These reactors are essentially materials testing reactors, and in those days it was considered that a major problem in relation to the commercialisation of nuclear energy was the development of suitable materials.

Subsequently, and before HIFAR was completed in 1959, the AAEC research program concentrated on a liquid metal fuel reactor concept and a high temperature gas-cooled reactor concept, both of which were abandoned by the late 1960s.

Since its start-up in 1959, HIFAR's role has gradually changed from materials testing to isotope production and provision of neutron beams for university workers through AINSE.

Throughout the twenty-three year operating history of HIFAR, it is probably true that the facilities available in HIFAR have never been fully utilised. Nevertheless, the HIFAR reactor has served in the past as a focus for a coherent site program and has resulted in the collection of experience in fields such as materials research, neutron beam research, nuclear plant operation, and waste management, none of which could otherwise have been gained in Australia. There can be no doubt also that without HIFAR, AAEC staff could never have embarked on a large isotope production program and radiopharmaceutical application program.

Today, HIFAR no longer serves as the focus for a site program and it can be argued that programs in Divisions are becoming less connected and more diverse, leading to fragmentation of effort. It can also be argued that unless some new major facility is planned, this fragmentation will become more evident within a few years, leading perhaps to a break up of Australian research and development in nuclear science and technology. There could also be an apparent loss of nuclear competence in Australia as seen by our neighbours in SE Asia who are at present expanding their nuclear activities.

The opposite view is that nuclear science in Australia can survive without a new major nuclear research facility and that expertise can be maintained within the AAEC with the current program philosophy and awareness through the literature. The present research and development effort at Lucas Heights is no longer coordinated around a main theme and a centralised program is no longer essential. It is not necessary to have a large facility to act as a focus of activity. The present research work is primarily short-term with defined objectives and programs are measured in a few years. If industry and State governments require information, they can obtain it from countries with the nuclear experience of interest.

Resolution of these opposing viewpoints is a policy matter with important political considerations. In this study, it has been assumed that a program involving a properly selected major facility has more chance of holding a group of competent people together in Australia in specialities such as nuclear science and technology, if that is the objective, than one without it. However, the siting of a new research reactor at Lucas Heights is unlikely and it may well prove difficult to locate any other new major research facility at Lucas Heights unless it is obviously tied to an easily understandable objective and/or university activity.

2. STATEMENT OF THE PROBLEM

By the year 2000, HIFAR, the major facility at the AAEC Research Establishment will more than likely be either dismantled or a museum piece, even if it is refurbished. There are no current definite plans for its replacement and, if there were, it would be difficult in present circumstances to locate a new reactor at Lucas Heights because of the lack of public acceptance and reduction in the restrictions on land use around Lucas Heights. By 2000, the present Commissioners, AAEC Research Establishment Management, all Division Chiefs and present senior research and operating staff will either be retired or no longer here.

The new program of the AAEC Research Establishment has recently been announced with the intention of retaining a first class nuclear research establishment at Lucas Heights. The research program covers nuclear energy research and development, and nuclear science, including a small program on nuclear fusion. The new program is aimed also at retaining sufficient competence in nuclear technology to support the operation of HIFAR; such operation is intended to ensure the supply of radioisotopes for medicine and research and the opportunity for Australian scientists to undertake research with the source of neutrons available from HIFAR.

Apart from isotope production in Isotope Division, about four people in Applied Physics Division are engaged on neutron diffraction studies which rely on the availability of HIFAR. Of the remaining five research Divisions at Lucas Heights, Materials Division is partly dependent on HIFAR and the others not at all. Except for Isotope and Applied Physics Divisions, it can be said that the new program depends little on the availability of HIFAR which, as commented earlier, will more than likely be not in operation by the year 2000.

There are about 80 researchers in universities whose work involves the use of HIFAR through AINSE. Four full-time AINSE staff members are based at HIFAR to assist these workers, of which an average of about four are attached at any one time.

HIFAR may become unavailable if it becomes obsolete or there is an accident, or breakdown. Unavailability could also result where the expense of full refurbishing, or repair of a major component, e.g. the aluminium tank housing the core, is too great. Over the years it has been demonstrated that there is a continuing need to repair or modify HIFAR and eventually the cost will become prohibitive.

The need for a new research reactor to replace HIFAR has been well documented in the past and considered by the Commission. The basic concept has been to provide another facility which would do what HIFAR does now and more, as well as to provide a focus for nuclear research in Australia.

In the past the arguments for replacing HIFAR have been accepted by the AAEC but the funds required to establish a new site with a new research reactor are unquestionably not available from the Government in the short-term and unlikely to be available in the long-term. If funds were ever made available it would seem more economical to purchase an existing research reactor type or design rather than specify an Australian design. Also the effort and competence to produce an Australian design is not available.

The cost of establishing a new site with a new research reactor can only be a guess in the absence of a specific location and specific reactor type, but it is of interest to note that the depreciated value as at 30 June 1981 of land, buildings, plant and equipment, HIFAR, library and films at Lucas Heights was $32.5 million. A new site and new reactor with research facilities would cost considerably more. The total direct costs of operating HIFAR has been estimated at about $2.5 million per year and the equivalent running cost of a replacement would presumably not be less.

When HIFAR ceases to operate, it can be expected that funds would not be provided by the Government for establishing and operating a replacement on a new site to carry out all the functions at present performed by HIFAR.

If no new research reactor is available as a major facility for retention of nuclear science and technology competence in Australia then what other facilities could serve this purpose at Lucas Heights?

In the following review, AINSE proposals and AAEC proposals and ideas, which have been put forward in the past, are described including their status reached. Some of the AAEC proposals and ideas are development projects, rather than research facilities, which would presumably terminate on completion or lead to expansion of the project at Lucas Heights or somewhere else. They have been included for completeness since they involve the building of a major new development or demonstration facility.

3. AINSE PROPOSALS

In 1973, AINSE Council agreed that it should consider developing special submissions relating to the establishment and operation of additional centralised scientific facilities at Lucas Heights, the financing of which would be outside the Institute's normal financial arrangements. Subsequently, three separate working groups were established by AINSE to examine proposals for installation at Lucas Heights of a cyclotron, a one million volt electron microscope and a cold neutron source in HIFAR. Each of these proposals foundered for one reason or another although a modified proposal was submitted to AAEC early in 1982 requesting provision for basic improvements in neutron diffraction facilities in HIFAR (including a cold source). At present there is no examination being made by AINSE Council of other major research facilities which would be of interest to or use by academics at Lucas Heights in the next decade and beyond. The status reached by each of the AINSE proposals follows.

(a) Cyclotron

The 'AINSE Working Group on the Cyclotron Proposal' in 1974 produced a proposal for a variable energy, high intensity, high resolution, isochronous cyclotron. The facility was envisaged to comprise the cyclotron installation itself, fully operated and maintained on a seven-day week basis, a seven-position beam switching magnet passing beams into experimental areas, including one for neutron therapy and one for radioisotope production, complete with all beam transport systems.

Customers for machine time were seen by the working group to include all members of AINSE-AAEC (isotope production, neutron physics, materials testing) and the universities (medical, biological, materials, solid state, geophysical, radiation chemistry, nuclear and other interests). The machine was to be under the control of AINSE Council and operated through a small sub-committee responsible for allocating machine time among the users.

Estimates of probable capital costs and operating costs, made in 1974 by the working group, were $1 million, and $60 000 per annum, respectively.

The working group recommended that the Institute should take action toward the future provision of a multi-purpose cyclotron, and associated facilities, but AINSE Council decided after lengthy discussion that the Institute should take no further action at that time.

(b) One Million Volt Electron Microscope

The 'AINSE Working Group on the Ultra High Voltage Electron Microscope Proposal' noted that a high voltage electron microscope would be used in many fields of application, among them biology, mineralogy, solid state physics, solid state chemistry, metallurgy and radiation damage. The working group declared it evident that Australian scientists from a wide range of disciplines then needed access in Australia to a high voltage electron microscope and recommended that a one million volt electron microscope should be established as a national facility.

Probable capital and operating costs were estimated by the working group in 1974 as $1.05 million, and $120 000 per annum, respectively.

AINSE Council supported the recommendation, AAEC agreed that the proposal should be submitted through the Commission and, in 1975, it was submitted to the Minister for Minerals and Energy, but was not successful.

(c) Cold Source in HIFAR

The 'AINSE Working Group on Major Neutron Diffraction Developments (1974)' considered future provision at Lucas Heights of major items of equipment related to neutron diffraction activities, including a cold neutron source, a time-of-flight neutron spectrometer and a high pressure scattering system.

Research with the low temperature, long wavelength neutrons available from the cold source was foreshadowed in the disciplines of biology, chemistry, geology, and materials science and physics. The working party produced probable cost estimates of $1.938 million capital cost and $55 800 per annum operating costs for the major neutron diffraction facilities.

Consideration by AINSE Council of the proposal was deferred in 1974 as the AAEC at that time was reviewing possible plans relating to the future of HIFAR and could not enter any undertaking concerning its long-term availability for major neutron diffraction development of the type proposed.

Subsequently, the AAEC commenced a study for a new research reactor, the preliminary work for which began about 1975. Following the recommendations made by the NERDDC Review Committee in 1979, the new reactor study was terminated and replaced by a HIFAR refurbishing study. In 1980, AINSE advised the AAEC of its decision to support, as an integral part of the refurbishment of HIFAR, the upgrading of the neutron beam facilities, including improved collimators and shielding, a cold source to provide long wavelength neutrons, neutron beam guides and an annex to the HIFAR sealed building. Preliminary AAEC estimate of the cost of this upgrading was $3.1 million which later became $5.5 million.

Following discussions between representatives of ASTEC, AAEC and AINSE early in 1981, the Commission agreed to forward to the Government, as a new policy proposal, a submission requesting funds totalling approximately $5.5 million to permit the inclusion in the program for refurbishing HIFAR of plans for upgrading the neutron beam facilities, including a cold source. However, the Federal Budget for 1981-82 did not provide any part of the $5.5 million requested.

Early in 1982, AINSE strongly recommended that the Commission give favourable consideration to taking action towards obtaining, in its 1982-83 budget, authority for expenditure during that year and the succeeding three years of an amount totalling $2 million for the provision of improved neutron beam facilities (including a cold source) as an integral part of plans for refurbishing HIFAR. The Commission forwarded this recommendation to the Minister as a new policy proposal for funding commencing 1982-83 but it was not approved.

4. AAEC PROPOSALS AND IDEAS

Over the years there have been several AAEC proposals for constructing a major facility at Lucas Heights which did not eventuate. Probably the first was the proposal in the 1960s for building a fuel reprocessing plant for processing HIFAR fuel elements. This project, which was not a research facility, did not proceed primarily because at that time it was not seen as the AAEC's role to design and build a plant to process HIFAR fuel elements and because of the expenditure and effort involved.

Another project which did not proceed was the Aborigine pebble bed project. Here the intention was to produce a transportable reactor of output of the order of 1 MW(e) for remote areas. Although initial installation at Lucas Heights was not likely it was not excluded. The project was a survival from the work done at Lucas Heights for the large scale high temperature gas-cooled reactor concept which had been abandoned. The Aborigine idea was also abandoned because of the decline in interest in small transportable reactors for Australia.

(a) Reprocessing Facility for Nuclear Fuel

Because of Australia's comparative remoteness from countries that have plants for reprocessing reactor fuel elements, the AAEC was interested in studying, in the 1960s, the prospects of establishing such a plant. Also, because of our interest, in this period, in reactor systems involving reclamation and eventual re-use of unused or generated fissile material, we were examining fuel reprocessing costs as an essential part of fuel cycle costs and the cost of nuclear power.

In mid-1960, the opportunity was taken to study a design philosophy which might result in lower costs, and a preliminary design of a low throughput facility to reprocess fuel from the reactor HIFAR at Lucas Heights was attempted. The plant was of pilot scale compared to reprocessing plants existing at that time. A preliminary capital costs of $892 000 and direct operating cost of $128 000 per annum were deduced for location of the plant at Lucas Heights, with maximum use of existing facilities, services and plant.

As mentioned previously this project did not proceed.

(b) Cyclotron

Basically there are two forms of isotopes for use in nuclear medicine - reactor-produced isotopes and accelerator-produced isotopes. Without a cyclotron there is no access to about half of the spectrum of radioisotopes in existence. The isotopes of choice in advanced diagnostic nuclear medicine are the neutron-deficient radionuclides. For example, iodine-123, which cannot be made in a nuclear reactor but can be made in a cyclotron, promises to be as useful a universal diagnostic radioisotope as has been technetium-99m because of its half-life, chemistry and radiation characteristics. It is not available in Australia and all neutron-deficient isotopes for radiopharmaceutical use are imported into Australia.

Cyclotrons produce neutron-deficient nuclides whose radiation characteristics are ideally suited for nuclear medicine, in particular positron emitters which can be used for tomography studies that cannot be done using reactor-produced nuclides.

Experience has shown, however, that essential isotopes for the manufacture of radiopharmaceuticals for diagnostic purposes can be imported into Australia when HIFAR is not available. During the extended HIFAR major shutdown between 17 September 1979 and 3 June 1980, importation of essential isotopes cost about $720 000 which is equivalent to an annual cost of about $1.1 million.

The use of a cyclotron for radioisotope production is not considered to be a suitable substitute for a nuclear reactor because diagnostic techniques and instrumentation in Australia have been primarily based on reactor-produced technetium-99m. Sharing of a machine for both nuclear physics research and routine isotope production is not considered practical. The use of a cyclotron located at Lucas Heights for radiation therapy in the absence of a hospital would create significant logistic problems in the transport and treatment of patients.

Over the years there have been several proposals for the installation of a cyclotron at Lucas Heights. These included an AAEC proposal in the late 1960s to purchase a cyclotron for producing fluorine-18 and gallium-67 and later for nuclear physics; consideration of the purchase from ANU by AAEC of a cyclotron; and an AAEC proposal in 1978 for a cyclotron facility at Lucas Heights for radioisotope production. The last proposal, which followed rejection of the suggestion to purchase the ANU cyclotron, was for a cyclotron for the production of isotopes, such as thallium-201 for use in a radiopharmaceutical as it is a most valuable agent for non-invasive diagnosis of coronary artery disease. The machine envisaged was a high energy machine which would open the possibility of having a neutron therapy unit for cancer patients at Lucas Heights.

This proposal was to purchase a modern machine of higher energy than the ANU machine for installation at Lucas Heights for a total commitment of $3-4 million. The proposal was referred by AAEC to the NERDDC Review Committee. The NERDDC Review Committee concluded in 1979 that the proposal of an Australian Institute of Nuclear and Radiation Medicine, a major aspect of which would be the establishment of a cyclotron facility at Lucas Heights, was a matter for consideration by the National Health and Medical Research Council. The Department of Health supported the proposal and agreed to cooperate in preparing a joint Cabinet submission setting up an autonomous radioisotope production organisation at Lucas Heights including the provision of a cyclotron. Subsequent Government decisions covering the co-location of CSIRO and AAEC at Lucas Heights, with consequent reduction of AAEC staff numbers, has caused this proposal to be set aside for the time being.

(c) <u>New Research Reactor</u>

Most work for a major facility has been done on the new research reactor proposal. This work, spearheaded by the operators of HIFAR (not the scientists at Lucas Heights), commenced in the late 1970s as it was realised that HIFAR had a limited life and, if a new research reactor was to materialise, then work for a new reactor had to commence using the existing experienced operating and research staff. The reactor type chosen for detailed study was an enriched fuel swimming pool type reactor based on the French OSIRIS (70 MW upflow pool reactor at Saclay) or SILOE (35 MW downflow pool reactor at Grenoble).

It was initially proposed that the reactor, by providing a large volume, high flux neutron source, would be used for radioisotope production, neutron beam facilities, neutron activation analysis and materials and fuel irradiation. National awareness and prestige were also seen as additional reasons for building a new research reactor. The implication for future programs within the Commission was that the new reactor would provide increased opportunity to continue similar work to that done with HIFAR.

A final report on the new reactor design study was completed and submitted to the Commission. Because of reductions in the scope of the study, particularly in relation to development of a particular design concept related to specific site and safety criteria, no capital cost information was included. Comparative operating costs for upflow and downflow reactor concepts, based on CEA experience with OSIRIS (70 MW) and SILOE (35 MW), were provided under the Technicatome study contracts, and showed the former to be approximately 40 per cent higher overall.

A preliminary global cost estimate made before the study suggested that a SILOE system with comprehensive experimental facilities constructed at Lucas Heights could be expected to cost between $30.6 million and $42.2 million (December 1976). Capital costs of the alternative upflow system have been predicted in the final report as being substantially higher.

The Commission agreed in March this year to review the New Reactor Design Study in twelve months' time in the light of the HIFAR Refurbishing Program results at that time.

It can be argued that few new research reactors will be built in industrialised countries because existing facilities have served their major purpose. Thermal nuclear power reactors have been developed in several countries and are now available commercially, and breeder reactors are being developed to augment and/or replace them. It can be argued also that future major nuclear science and technology developments will be in fusion energy, not fission energy, although a research reactor could be used for some aspects of fusion research technology.

(d) Alternative Neutron Sources and Ion Beams

Alternatives to a fission reactor as a neutron source were examined in 1979 by the Steering Committee established by the Director to prepare a clear and accurate statement of the case for the new research reactor. In discussing alternative neutron sources the Steering Committee reported in their July 1979 report that:

> "A facility to replace HIFAR need not necessarily be a fission reactor; intense neutron fluxes can be generated by other means. Further, radioisotopes of commercial and medical interest can be produced by bombardment of targets with particles other than neutrons. These possibilities have been discussed by Gemmell [Neutron Sources: Alternatives to Fission Reactors, W. Gemmell, unpublished report, January 1979].
>
> "At least for the production of neutron beams for scattering experiments, the most promising device is the

spallation source. This offers the potential of neutron beam conditions which, for a wide range of scattering experiments, are superior even to those produced by the very expensive high-flux beam reactors. Such a source could possibly be used for radioisotope production although accelerators producing charged particle beams might be a better method if fission reactors are to be avoided.

"There would be a number of advantages arising from the adoption of the non-fission reactor approach to HIFAR replacement. Firstly, the device could be at the forefront of world facilities whereas a reactor could only duplicate what has been available elsewhere for some years. Secondly, because it does not involve a critical mass of fissile material, it would probably be more environmentally acceptable to the public for location at Lucas Heights than is a reactor. Finally, its design and construction would form the basis for a major and coordinated research and development program for the Research Establishment.

"However, the pioneering nature of the non-fission approach makes it difficult to estimate the capacity of novel devices to satisfy future requirements, particularly for radioisotope production. More importantly, the cost and timescale necessary to develop such devices are uncertain. Cost estimates are available for some relevant overseas ventures, although these assume a depth of expertise and experience already existing in these establishments. In the Australian context, it is likely that a spallation source would be considerably more costly and involve more effort than a reactor replacement for HIFAR.

"The advantage of the fission reactor approach to replacement is that is uses established technology and can be purchased on a firm contract basis from an experienced constructor. The direct effort required from AAEC staff would be relatively small. A non-fission device would require a heavy commitment of staff effort, would involve considerable research and development, and could not be built to a firm budget and timescale. While work related to such a device might be justified as a research and development project at the Research Establishment, at this time it would not appear to provide the basis for a viable contingency plan for the replacement of HIFAR, where national needs such as radioisotope production and access to neutron beams are paramount. However, the situation may change and, if the decision to replace HIFAR is sufficiently delayed, the feasibility of a non-fission reactor could be reassessed."

Intense neutron sources are still custom built and are not available off the shelf. Two are operating in the USA, one at Argonne National Laboratory and one at Los Alamos Scientific Laboratories, and one is constructed at the Rutherford Laboratory in the UK. Notional costs of these facilities are probably available in the literature.

An intense neutron source could produce isotopes but the quantity produced may be greater or less than that produced by HIFAR depending on the intensity achieved for the costs involved. The source could provide neutron beams for materials irradiation damage, research in the fission and fusion fields, and charged particle beam research. It is considered that competence remains on the site to specify a design for contract and construction.

An alternative neutron source is a dense plasma focus neutron source. This would also be custom built and could be used primarily for beam work and irradiation damage studies. There are probably more than fifteen of these in the world and notional costs are probably available. A small laboratory device has already been built at Lucas Heights.

Staff in Applied Physics Division and Nuclear Technology Division at Lucas Heights are giving some thought to building and using a 14 MeV neutron generator at Lucas Heights. The machine, which could probably be designed and built at Lucas Heights, would be used for neutron data collection, neutron therapy, materials research and/or fusion blanket technology. The target design would be the main engineering problem. Off the shelf 14 MeV neutron generators would not be suitable because it is thought they may not be commercially available at the high currents intended. Mention has been made of using a neutron generator to study the elimination of long half-life nuclides from high level waste emerging from reprocessing plants by fission or transmutation into short half-life or non-radioactive nuclides.

New ideas are available for the production of very intense ion beams (100 mA or greater) and for ultra-intense pulsed ion beams (1 kA peak current). Production, acceleration and application of such beams involve considerable problems in electrical, thermal and nuclear engineering, the solution of which could pave the way for construction of some unique facilities. Uses of such beams could include neutron generation as mentioned above, materials modification (doping, annealing, etc.) and isotope production (including those from multiple interactions).

Ion beam analysis techniques have reached a stage of sophistication which makes them attractive in many fields (minerals, environment, archaeology, etc.). A dedicated accelerator for such work would be much more efficient than part-use as at present. It would be feasible to design a facility which could be transported to sites such as mines, processing plants, factories or museums for scheduled applications or demonstrations. Costs could be $0.5-2 million, depending on specifications.

(e) Synchrotron

Proposals have been floated in Chemical Physics Division, CSIRO, for an Australian high-energy accelerator, to produce synchrotron radiation, as a new generator multi-purpose facility for atomic, molecular, crystallographic and other studies in physics, chemistry, biology, etc. Such a facility would be very expensive (tens of millions of dollars, or even more) but it has been suggested that it is the type of field which Australia needs, to support progress in science. Notional costs are probably available in the literature. Lucas Heights would be an obvious place to operate such a facility.

(f) Fusion

(i) Fusion facility

A proposal was put to the Commission in December 1977 for a national nuclear fusion research program. The Commission agreed to the principle of the design and construction of a medium-size fusion physics facility, based on magnetically confined plasma, at an indicative budget cost of about $9 million to be operative by mid-1983. However, the NERDDC review of the AAEC Research Establishment in November 1979, when considering fusion research, concluded that Lucas Heights should not establish a major national facility for fusion research.

(ii) Fusion physics

As a consequence of the NERDDC review the program planned in fusion physics at Lucas Heights is quite modest. It involves a total of about 11 staff, including those on attachment at Sydney University, and a capital expenditure of around $70 000 per annum. The concept of the Applied Physics Division program in fusion physics is to work closely with the existing Australian effort on RF interaction with plasma by examining, in particular, the use of RF energy for heating and current drive (in collaboration with Sydney University) and the use of RF sources for plasma confinement, as in the Rotamak (in collaboration with Flinders University). No Tokamak development at Lucas Heights is contemplated, the concept being that collaboration in this field with ANU and Sydney University would be adequate if desired. The work being done at ANU with the LT-4 Tokamak would serve as a training ground for AAEC staff on diagnostics.

Following work at Flinders University, supported by staff from AAEC, there has been a joint agreement that the group at Lucas Heights should undertake high-power long duration experiments with Rotamak type devices and equipment and laboratory facilities are under preparation for this project.

No large fusion machine is envisaged or contemplated. The objective of the work planned is to establish credentials in the field by reputation and publication and it is felt that there is no likelihood of establishing a major facility at Lucas Heights in the next few years. In the long-term, a machine of significant size is possible at Lucas Heights if this was Government policy. However, universities are, and will be, competing for funds on fusion research.

(iii) Fusion blanket neutronics

It has been agreed that a program of research into the technology of neutron-absorbing, heat producing blankets for prospective fusion power reactors should be undertaken at Lucas Heights. Action is in hand in the Nuclear Technology Division to carry out neutronic and thermohydraulic analysis of blanket concepts. The objective of this program is to gain sufficient knowledge and expertise to enable the AAEC to participate in an international collaborative enterprise relating to the design and testing of blanket modules in a fusion reactor experiment or one of its precursors, e.g. INTOR or one of the national programs.

Nuclear Technology Division is assembling equipment to measure tritium breeding in assemblies of nuclear materials representative of prospective fusion reactor blanket arrangements using low neutron fluxes. The various experimental findings would then be subjected to theoretical analysis as doubts exist at present whether present theoretical techniques and available nuclear data can adequately predict blanket performance. This experiment is part of the approved program at present under way at Lucas Heights. Initially, small scale experimental equipment is involved using a substantial existing building and available extensive stocks of nuclear materials left over from previous fission-reactor research programs. This work could develop into a major project although present plans involve a capital expenditure of about $50 000 per annum.

(g) Centrifuge Enrichment Demonstration Plant

Some thought has been given to building a centrifuge enrichment demonstration plant at Lucas Heights. The Centrifuge Enrichment Project Division has developed essentially Australian technology for the enrichment of uranium to the point where such a facility could be designed and constructed.

The design and construction of a centrifuge demonstration plant is possible at Lucas Heights. The main objective would be to test operation and predict economics for a commercial plant using the latest Australian technology. Industry would be expected to participate in both manufacture and operation of the plant. The Australian Government encourages the upgrading of indigenous resources and the only way to upgrade uranium significantly is to enrich it.

This facility would permit continued centrifuge technology development in Australia if commercialisation of enrichment by industry is unsuccessful, significantly delayed or abandoned. It would also permit this development to continue in order to retain competence in the event that overseas technology holders placed unacceptable conditions on the supply of technology and market franchise.

In 1979, a notional cost of around $20 million was suggested for the capital cost of this facility. It can be argued that to be actively engaged in a substantial plant operation is the only way to maintain full competence in the field and retain Australian based technology.

(h) Inactive SYNROC Pilot Plant

The AAEC and ANU have been collaborating in the development of SYNROC since March 1979. The AAEC has concentrated upon scale-up of SYNROC fabrication (supported by a continuing NERDDC Grant), leach testing of SYNROC containing simulated radioactive waste and radiation damage testing of SYNROC in HIFAR using fast neutrons. ANU (supported by a NERDDC Grant and an AAEC Research Contract) has studied radiation damage in natural SYNROC-type minerals and has periodically adjusted the SYNROC composition. ANU's main current role is to generate, from laboratory studies of SYNROC powder preparation and fabrication, basic flow sheet data which can be tested at Lucas Heights on a larger scale and then incorporated into a mutually agreed fabrication flow sheet.

The Australian SYNROC development work is justified as an Australian contribution to international studies designed to improve standards for waste disposal, in line with the Prime Minister's 25 August 1977, Statement of Uranium Policy, and Australia's status as a potential major exporter of uranium for use in nuclear power reactors.

Proposals for the building of two small fabrication lines at Lucas Heights, in which radioactive waste elements can be added to SYNROC and the properties of the product studied, have been accepted and funded by NERDDC. This program will help to counter the criticism that no SYNROC containing real radioactive waste has yet been made or tested, although it is not intended that both actinides and fission products be introducted into SYNROC in the one line.

Additional criticisms made of SYNROC are that it is at an early stage of development, and that its fabrication will be complicated and expensive. The proposal to build a non-radioactive fabrication pilot plant at Lucas Heights, will allow semi-continuous cold engineering development work to be done. Although automatic operation of equipment is planned, demonstration of remote operation and maintenance is not intended in this pilot plant. Demonstration of the process in a fully active remotely operated plant at Lucas Heights is also not intended.

The Commission sought Ministerial approval for additional funding for this project. An amount of $1.009 million has been approved for expenditure 1982/83 under capital works and services for this project. The estimated expenditure for the pilot plant over a three year period is $2.75 million.

(i) Electrostatic Accelerator for Isotope Measurements

Accelerator techniques for measuring environmental levels of beryllium-10, carbon-14, silicon-32, chlorine-36, iodine-129 and some others, are being actively developed. The accelerators effectively act as high energy mass spectrometers. Individual atoms are counted rather than radioactive decay events. It is therefore possible to measure much smaller samples than with conventional counting methods. The relative advantage of the accelerator method increases with increasing isotope half-life.

The applications of chlorine-36 and iodine-129 measurements are of direct interest to the AAEC's current program. Chlorine-36 is a cosmogenic isotope with a half-life of 308 000 years, and is potentially useful in the study of:

(i) groundwater dynamics in very large Australian basins; and

(ii) the evolution of groundwater salinity and the development of salt lakes.

In advanced nuclear countries, such as the USA, the experimental demonstration of very old groundwater is important in assessing possible sites for radioactive waste repositories.

Isotope Division is interested in the measurement of environmental levels of iodine-129 which is a product of the natural fission processes occurring within uranium deposits. The data could in principle be used to assess the cumulative effects of migration of this important fission product over millions of years. As a corollary, iodine-129 could possibly be used as a remote geochemical indication of uranium deposits.

There is considerable interest in the accelerator techniques at the ANU and other Australian universities. There is a possibility of obtaining ANU institutional support for any official AAEC proposal to build an accelerator facility at Lucas Heights. ANU's interest is because of their archaeological and Quaternary Era* research.

---

* The era of geological time which includes the Pleistocene and Recent Periods.

An accelerator is to be constructed at CSIRO Division of Mineral Physics. The equipment is to be used principally for mineral studies, although some isotope measurements will eventually be possible.

If an accelerator was built at Lucas Heights, it could be a national facility. The LHRL could become Australia's major centre for environmental isotope measurements, and in collaboration with other research institutes and departments could play an important role in the development of Quaternary Era research in this country.

A world survey of relevant accelerator facilities is to be made by an ANU staff member and the report will be made available to the AAEC. A notional cost for the accelerator has been given as $2-3 million.

5. OPTIONS AND COSTS

Although this preliminary report is not expected to cover detailed studies of the options or of costs, a summary is provided here of the notional capital costs of the projects discussed, not all of which are now options. One option, of course, is that no new research facility be built.

	Notional Capital Costs* $
AINSE Proposals	
(a) Cyclotron	1.0 million (1974)
(b) 1 MV electron microscope	1.05 million (1974)
(c) Cold neutron source	5.5 million (1981)
	2.0 million (1982)
AAEC Proposals and Ideas	
(a) Reprocessing facility for nuclear fuel	0.89 million (1967)
(b) Cyclotron	3-4 million (1978)
(c) New research reactor**	30-42 million (1976)
(d) Alternative neutron sources and ion beams	Data probably available in the literature
(e) Synchrotron	Tens of millions or more (1982)
(f) Fusion	
(i) Fusion facility	9 million (1977)
(ii) Fusion physics	70 000 per annum (1982)

(iii) Fusion blanket neutronics	50 000 per annum (1982)
(g) Centrifuge enrichment demonstration plant	20 million (1979)
(h) Inactive SYNROC pilot plant	2.75 million (1982)
(i) Electrostatic accelerator for isotope measurement	2-3 million (1982)

* These notional costs are not comparable because they have not been deduced using the same basis for estimation.

** Excluding the cost of a new site.

6. CONCLUSION

Since HIFAR will more than likely be not available by the year 2000, even if it is refurbished, there will be no isotope production and no neutron beams for university research if HIFAR is not replaced or other comparable neutron source made available. This would mean abandoning the ideas of continued isotope production, although imports could continue, and provision of neutron beams for AINSE research as long range obligations of AAEC.

It is concluded that the next step in this study should be to seek formal input on the projects mentioned in this report (not all of which are now options) and any others by drawing together those competent in the fields from the AAEC and AINSE.

7. ACKNOWLEDGEMENTS

This report has been prepared with the help of views and material provided by senior AAEC and AINSE staff which is gratefully acknowledged.