RECOMMENDATIONS FOR FY 1981 FACILITY CONSTRUCTION

April 1979

The DOE/NSF Nuclear Science Advisory Committee

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Letter of Transmittal

Dr. James Leiss
Department of Energy

Dr. Marcel Bardon
National Science Foundation

Dear James and Marcel:

In this letter the Nuclear Science Advisory Committee transmits to you, with our unanimous endorsement, the attached report "Recommendations for FY 1981 Facility Construction," prepared by our 1979 Facilities Subcommittee. The Subcommittee considered in detail proposals for accelerator construction from Argonne National Laboratory, the University of Colorado, Texas A&M University, the University of Washington and Yale University. In addition, a proposal by American University for the construction of an injector at SLAC and a proposal for the development of an ion source for its 88-inch cyclotron by the Lawrence Berkeley Laboratory were considered. The specific recommendations of the 1979 Facilities Subcommittee for FY 1981 construction as approved by the full Committee are presented on pages 8 and 9 of the attached report. We strongly recommend that construction funds be found for the funding in FY 1981 of both the Argonne National Laboratory and Yale University proposals.

We note with pleasure that the three construction projects (Michigan State University Cyclotron Phase II, the Bates Beam Recirculator and the LAMPF Staging Area) which were our highest priority recommendations for facility construction one year ago, are all included in the President's Budget for FY 1980. We are also pleased to learn that the combined DOE/NSF Nuclear Science Budget for FY 1980, if approved by Congress, will be 12.9% above the current FY 1979 level.

On the other hand, the Subcommittee made its recommendations based on guidelines suggested by DOE, of about $6M for new construction in FY 1981. The Committee agrees with the Subcommittee that $6M for new construction is too low and recommends a substantial increase. This would require a corresponding increase of the total DOE budget, since diverting substantial funds from the "operating" budget would cause unacceptable damage to the national nuclear science program. In this context, the committee notes with regret that funding of construction projects at the NSF seems to be possible only at the expense of ongoing programs.

Looking to the future, we realize that in 1980 the Committee and its Subcommittees must act on the information available at that time. However, we would hope that institutions with deserving proposals, which have been unsuccessful in the 1979 competition for the strictly limited capital funding to be contained in the FY 1981 budget, will realize that the recommendations for funding in future years will be based on scientific merit, established technical feasibility, cost effectiveness, considerations of uniqueness, innovation and diversity and all of the other criteria spelled out in the Subcommittee report, and that future success of a submission is not prejudiced by our recommendations this year.

We note with concern the difficulties experienced by some university laboratories in creating and maintaining the engineering and technical base that is necessary in order to design and construct sophisticated modern accelerators. The Facilities Subcommittee has in some cases decided that a proposal cannot be recommended for funding largely because of the absence of this base of expertise. On the other hand, in the absence of approved proposals the laboratories cannot easily recruit and retain the necessary staff. We strongly recommend that the university and national laboratories explore whether cooperative ways might be found to break this vicious circle.

The preliminary investigations of our 1979 Instrumentation Subcommittee indicate that progress in nuclear science is being hindered by inadequate instrumentation. In particular, the increased complexity of present day experiments requires cost-effective acquisition of data and their subsequent analysis. We are particularly fortunate that technical advances in microelectronics offer a way to deal with this development. However, this means that the computer systems of a decade ago cannot keep pace with modern needs. A new generation of electronics and computers can have an enormous positive impact in our field. The opportunity available to us in this area could be addressed with the investment of some $2M/year for the next three years.

The Facilities Subcommittee was constrained to exclude from its list of recommendations excellent accelerator proposals from three leading educational institutions in the United States which indicated strong commitments to the support of nuclear science. These institutions are the University of Colorado, Texas A&M University, and the University of Washington. Their commitments ranged from tangible financial outlays to the provision of tenure positions in their academic faculty. In being unable to respond in a positive way to these proposals and their explicit commitments, we find ourselves in the dilemma that faces some fields of American science with original, exciting and forward looking goals and aspirations. By providing new facilities and new instrumentation for university laboratories, the United States can strengthen a vital component of its scientific enterprise. Vigorous steps must be taken to preserve the strong intellectual centers of U.S. nuclear science. Our case is substantiated in the detailed analysis which is included in the report of our Facilities Subcommittee. We do not rest the case. We will hold during this coming summer a week of study (July 30 to August 3) on Long Range Plans and Priorities in Nuclear Science. It is our hope that this will result in a document which will express our guide-lines for a healthy and vigorous program in Nuclear Science in University and National Laboratories for the 1980's. It will be in your hands about September 1, 1979.

Our optimism in regard to long range plans and priorities is based on the opportunities for exciting and fundamental progress in nculear science which are within the grasp of a realistic, cost-effective strategy of research support. The precision and adaptability of the existing tandem and cyclotron accelerators are proving to be invaluable assets in the discovery and pursuit of new phenomena at lower energies. Expanded capabilities for studying nuclear phenomena with electromagnetic probes have been created with the developments in electron accelerators at MIT, Illinois and Stanford. These facilities allow the intrinsic electric and magnetic structure of nuclei to be elucidated in precise detail. Capabilities for studying nuclei with medium energy protons at Indiana and LAMPF offer powerful hadronic probes with combine great experimental precision with a stronger foundation for theoretical analysis than has been available for experiments at lower energies. The high-precision pion facilities at LAMPF are opening up a rich new field in which, for the first time, nuclei can be studied with probes beyond those of the electron and nucleon. New vistas continue to emerge in the study of interactions between complex nuclei -- the field of heavy-ion science. The developing facilities at Berkeley, Oak Ridge and Michigan State are opening up for exploration new regions of mass and energy which hold out promises of exciting new discoveries.

The essential requirement for the realization of broad and significant advances in knowledge from these opportunities is a cost-effective level of funding for research operations. Support must be raised up from the level of sustenance which all too often characterizes the present situation in nuclear laboratories to a level at which efficient exploitation of these powerful capabilities is possible. The detailed analysis of how these funding increases can be optimally put into effect will be provided by the results of our aforementioned study of Long Range Planning and Priorities.

We conclude this letter by reiterating our willingness to cooperate with you in all of the aspects of planning for a healthy and dynamic program of research in nuclear science. We have found the exercise which led to the attached recommendations for FY 1981 most stimulating and instructive. We have received excellent cooperation from George Rogosa and Howel Pugh and their staffs. We look forward to further opportunities to assist in the planning for nuclear science in the United States.

Sincerely yours,

William A. Fowler

William A. Fowler, Chairman
Nuclear Science Advisory Committee

RECOMMENDATIONS FOR FY 1981 CONSTRUCTION

A report for the DOE/NSF Nuclear Science Advisory Committee
by the 1979 Facilities Subcommittee

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I. Subcommittee Procedures and Recommendations

I. A. Preamble

Scope Of The Present Report

This report of the 1979 Facilities Subcommittee of the DOE/NSF Nuclear Science Advisory Committee responds to a request from DOE and NSF for recommendations on:

(1) five construction proposals under consideration for inclusion in the FY 1981 budget;

(2) an experiment which requires a modification involving substantial costs to an existing high energy accelerator;

(3) a research and development proposal.

These proposals, with accompanying descriptive project title, proposed costs (normalized to January, 1979 dollars) and date of completion, are as follows.

(1) Argonne National Laboratory: "ATLAS, A Precision Heavy-Ion Accelerator Facility"; $5.4M; 1984,

(2) University of Colorado: "A Proposal for a National Light-Ion Accelerator Facility"; $12.7M, $3M of which would be provided by the University of Colorado; 1985,

(3) Texas A&M University: "A Superconducting Cyclotron as a Heavy-Ion Injector for the Texas A&M Cyclotron"; $6.0M, $1.7M of which would be provided by Texas A&M University and the Welch Foundation; 1984,

(4) University of Washington: "A Proposal for a 20 Million Volt Tandem Electrostatic Accelerator"; $13.3M; 1985,

(5) Yale University: "Conversion of the Yale MP Tandem Accelerator to an ESTU Tandem; $4.2M; 1983.

In addition to these proposals for accelerator construction, proposals were submitted for the construction of an injector at the Stanford Linear Accelerator Center and for development of an ion source for the LBL 88-inch cyclotron.

(6) American University: "Construction of Injector East at the Stanford Linear Accelerator Center"; $0.9M; 1983,

(7) Lawrence Berkeley Laboratory: "Electron-Cyclotron-Resonance Source for the LBL 88-inch Cyclotron"; The cost for this project in the period FY 1980-82 is $2.2M. The construction of the source would be proposed for FY 1982 at a cost of $2.3M.

Subcommittee Functions

The Facilities Subcommittee had the responsibility of evaluating these proposals and drafting a report on their evaluations for consideration by the Nuclear Science Advisory Committee, which in turn has the responsibility of forwarding recommendations on the proposals to the DOE and the NSF. The Subcommittee heard presentations by the proposing groups on February 12-13, 1979 and held preliminary discussions on February 14. Prior to the presentations, on February 1, a panel consisting of a Committee member and three consultants had visited Argonne National Laboratory for the purpose of evaluating the status of their superconducting linac booster development project, the foundation of their present proposal (proposal #1 above). On March 2-3 the Subcommittee met and prepared a draft of its report and on March 19-20 met jointly with the parent Committee to consider this draft and prepare a final version. The report and its recommendations were approved by the DOE/NSF Nuclear Science Advisory Committee on April 9, 1979.

The membership of the 1979 Facilities Subcommittee is given in Appendix I and its consultants are listed in Appendix II. The agenda for the February 12-14 meeting is given in Appendix III.

Charge To The Subcommittee

The DOE/NSF Nuclear Science Advisory Committee formulated the following charge for its 1979 Facilities Subcommittee during its June 12, 1978 meeting.

> "The Subcommittee shall consider proposals for major new facilities and for substantial modifications and improvements to existing facilities in the field of fundamental nuclear research in the U.S.A. Acting with due regard to needs and opportunities in the field and to the scientific priorities and proper range of capital investment in new facilities as indicated by the Nuclear Science Advisory Committee, the Subcommittee shall draft a plan for facilities construction, viable in the light of probable funding levels, for implementation in FY 1981. The Subcommittee report which accompanies the plan shall include a technical and scientific evaluation of the proposals considered and a justification of the plan's recommendations. In formulating the plan the Subcommittee shall consider factors relevant to encouragement of technical innovation and the maintenance of a strong technical capabilty to respond to future research needs with the development of appropriate new facilities."

Consideration Of Scientific Needs And Opportunities

The contributions that the projects which were proposed for consideration by the 1979 Facilities Subcommittee could make to nuclear research are described below. Four of the construction projects considered involve the upgrading of existing accelerators while the other is for replacing an existing accelerator. The ANL and Texas A&M proposals are for heavy-ion facilities with scopes roughly comparable to the Oak Ridge-Holifield Phase I and MSU Phase I accelerators which are now being constructed. The University of Washington and Yale proposals are for facilities with capabilities for precise heavy-ion and light-ion experiments at energies significantly above those of presently operating tandem accelerators. The University of Colorado proposal is for a facility oriented towards precise experiments with neutrons. The Subcommittee thinks that the research programs implied by these projects form essential components of a vital and well balanced national effort in nuclear science.

These facilities would provide capabilities to increase present understanding of the characteristic modes of motion of nuclei, which is one of the fundamental tasks of nuclear physics described by the Friedlander Panel. Results at lower energies indicate that studies of the giant resonances, of the intermediate structure associated with "nuclear molecules" and of clustering phenomena can all be very productively expanded by using projectiles of higher energy and larger mass. Of course, the use of higher energies and heavier projectiles may also reveal new, unanticipated modes of motion not previously manifested.

An advanced polarized beam capability would make possible the more intensive study of parity non-conserving reactions, which is important for the understanding of the weak interactions. This capability would also make possible significant progress in such fields of nuclear studies as radiative capture reactions.

Four of the five proposed accelerator facilities are focused totally or to a major degree upon heavy-ion science. They would provide capabilities for the vigorous study of heavy-ion reactions in the transition region of energies between those of present lower energy facilities and those of the few large national facilities now under construction. Multi-faceted and detailed investigations of the energy dependence of complex processes such as particle transfer, quasi-elastic scattering, deep inelastic scattering, fusion and fission in the region extending from 10 MeV/amu to 40 MeV/amu, where it appears that major qualitative changes in behavior occur, are essential to a comprehensive understanding of heavy-ion phenomena. The limits to the fusion of systems of high angular momenta which are suggested at the highest energies of present accelerators could be thoroughly explored with these new proposed machines. Other limits of fusion, such as might be imposed by the energy of the system, can perhaps be identified. The mechanisms by which energy and matter are exchanged between projectile and target should depend upon the details of projectile, target and bombarding energy, but in ways which are not yet known. Intriguing indications have been found of dramatic changes which commence at the energies addressed by these proposed facilities.

In all of these investigations of heavy-ion phenomena the variability of the projectile in terms of its mass and its type of internal structure, as well as in terms of its energy, plays an essential role. The proposed facilities offer this needed variability and, as well, feature special capabilities of precision, intensity and beam control which could make possible a new generation of more discriminating and revealing experiments.

The fifth accelerator proposal is focused on light-ion studies and, in particular, studies with neutrons. Reactions involving neutrons as projectiles or reaction products, or both, reach final nuclei which are otherwise accessible only with complex charged particles. The simpler analyses of the reactions which are made possible when neutrons are used can contribute significantly to a better understanding of various aspects of nuclear structure. The combination of high beam intensity, long flight path and advances in fast-timing techniques have made greatly improved precision in neutron experiments feasible. Such experiments would open a significant new avenue to the discovery and understanding of nuclear phenomena.

These remarks provide a brief description of some aspects of the scientific research which would become possible if the facilities in proposals (1) - (5) were constructed. Proposal (6) would make possible an important experiment which would provide information on the electromagnetic properties of the deuteron at very high momentum and provide a stringent test of the nature of the nuclear force. Proposal (7) is concerned with the development of a heavy ion source which, if successful, would have a major impact upon the capabilities of heavy-ion cyclotrons.

Proposal Summaries

Brief descriptions of each of the seven proposals considered by the Subcommittee follow. The energies of the ions from the accelerator have been noted. There are, of course, other important beam parameters, such as average particle current, which must also be considered.

1. The Argonne National Laboratory proposed to expand its present accelerator system, which consists of an FN tandem and a superconducting linear accelerator booster now under development. Additional split-ring resonators would be constructed to make a system capable of producing beams with energies ranging from about

27 MeV/amu for A=10 to about 15 MeV/amu for A=100. Also included in the proposal were additions to the experimental area for the expanded accelerator.

2. The University of Colorado proposed to modify its cyclotron and use it as an injector for a new separated-sector cyclotron. An intermediate storage ring might be employed to further enhance beam-structure characteristics. The system would provide beams of polarized and unpolarized protons up to energies of 75 MeV, deuterons up to 50 MeV, ^{3}He up to 133 MeV, ^{4}He up to 100 MeV, ^{6}Li up to 150 MeV and ^{7}Li up to 129 MeV. A time-of-flight facility would permit the study of neutron-emitting reactions.

3. Texas A&M University proposed to build a superconducting cyclotron, similar to the one under construction at Michigan State University; for use as an injector for their present cyclotron. This coupled-cyclotrons system would provide beams with energies ranging from 35 MeV/amu for the lighter heavy ions to 6 MeV/amu for A=200.

4. The University of Washington proposed the constuction of a vertical folded tandem electrostatic accelerator similar to the one being constructed at the Oak Ridge National Laboratory. The terminal voltage would be adjustable between 2.5 MV and 20 MV. Polarized and unpolarized proton and deuteron beams could be produced as well as heavier ions. The energies of heavy ions would range from 11.4 MeV/amu for ^{7}Li to 7.7 MeV/amu for ^{40}Ca to 2.4 MeV/amu for ^{197}Au.

5. Yale University proposed to upgrade its MP tandem to provide higher terminal voltages. The accelerator length would be increased and the new pressure tank would also have a larger diameter. The proposed new configuration, in conjunction with an insulating gas mixture of $SF_6/N_2/CO_2/H_2O$ at 175 psi, should provide a terminal voltage of at least 20 MV. Unpolarized particle beams with energies similar to those quoted above for the University of Washington proposal would be produced.

6. The American University proposed the construction of a new injector at the Stanford Linear Accelerator Center (SLAC) which would provide beams of electrons with energies varying from 0.4 GeV to 2.9 GeV with average currents ranging from 27 to 54 microamperes. The construction would be carried out by SLAC personnel.

7. The Lawrence Berkeley Laboratory (LBL) proposed to develop an electron-cyclotron-resonance heavy-ion source for use on the LBL 88-inch cyclotron. The goal would be an advanced-design source which could make possible the acceleration of heavy ions in that cyclotron to energies of about 40 MeV/amu for light ions and 8 MeV/amu near A=100. If successfully developed this source could be readily adapted for use in other accelerator systems.

The Subcommittee noted that two of these proposals suggest meritorious research and development programs. These are the development of a storage ring that could be used to increase the instantaneous beam intensity or otherwise adjust the duty cycle of an accelerator and the development of a source for heavy ions, based upon the stripping of ions by energetic plasma electrons, which could significantly enhance the capability of cyclotrons to accelerate heavy ions.

Evaluation Criteria

The Subcommittee's evaluations of the accelerator proposals (see Section II) were focused on the following issues: scientific value of the research goals which the facility addressed, cost-effectiveness with which these goals are addressed, technical feasibility, projected performance capabilities, scientific and technical strength of the sponsoring laboratory, the strength of its associated nuclear theory effort, user involvement (current or potential), support of the project by the sponsoring institution, construction time and operations cost after completion and the project's impact upon the education of students in nuclear science and upon other aspects of the ongoing and future national program.

Does the facility provide capabilities for carrying out new important research? To what degree would the proposed facility have unique capabilities? Can the accelerator be built in the projected cost and time frames? Are there technical aspects of the proposal which are as yet not understood and could advisably be studied further? What is the range of experimental parameters which the projected system will provide? What nuclear species can be accelerated and to what energies? Can the energy be varied easily? What are the intensities, the energy resolution and the time structure of the beam? What ancillary equipment will be required and what is the optimum arrangement of the target areas? How many experiments can be performed simultaneously? In view of the fact that the number of heavy-ion and electron accelerators which will be constructed is small and demand will be great, what provision is made for users at these facilities? What is the ability of the sponsoring laboratory to carry out the proposed program in terms of availability of experienced personnel to participate in construction and in terms of the relevant scientific capability of the resident scientific staff, who will perform and interpret experiments upon completion of the facility? What is the support of the host institution, as manifested by partial provision of construction funds, by provision of new faculty and staff positions, and by other demonstrations that the project has high priority within the institutional framework? The study of these and many other such questions formed the basis for the Subcommittee's decisions.

I. B. Recommendations for Facility Construction in FY 1981

The Subcommittee strongly recommends:

-- The construction of the Argonne Tandem-Linac Accelerator System (ATLAS). --

The demonstrated successful performance of the vital components of this system is the basis for a confident recommendation to proceed with the accelerator construction project described in this proposal. By utilizing breakthroughs in the technology of superconducting rf cavities the facility will be able to provide a unique research capability, equivalent to that of a 50 MV tandem Van de Graaff, which will permit the precision study of heavy-ion reactions in an unexplored energy regime. The Subcommittee is unanimous in its recommendation that the ATLAS proposal be given highest priority for early funding based on its cost effectiveness, the technical feasibility of its innovative design and the scientific merit of the research program which it will make possible.

-- The upgrading of the Yale MP tandem accelerator to 20 MV ESTU status. --

The Subcommittee agrees unanimously that the Yale proposal presents a technically sound and highly cost-effective method for significantly enhancing tandem accelerator performance and thereby expanding the national capability for research in light-ion and heavy-ion nuclear science. It recommends this as the second highest priority project for construction. The facility would strengthen and expand the nuclear science program at Yale, a program which has played a significant role in graduate education in nuclear science. The Subcommittee feels that the increased capability provided by the ESTU warrants substantially increased use of the facility by scientists not formally associated with Yale. The laboratory management should make known its willingness to consider, with outside consultation, proposals from outside users for experiments of high scientific merit which are suitable for the Yale facility.

The Subcommittee found the University of Washington proposal for a new 20 MV tandem meritorious in terms of technical feasibility and the scientific quality of the prospective research program. However, its relatively high capital cost is a serious disadvantage and the Committee thinks that it is too high in the light of the projected budget guidelines for FY 1981.

The Subcommittee does not recommend FY 1981 funding of the proposal presented by the Texas A&M University. The proposal describes a highly cost-effective mechanism for meeting the meritorious scientific goals of the proposal. However, while the existing technical staff at TAMU has a good record for operating and maintaining the present cyclotron, an additional infusion of expertise in design, development, and management is necessary for a major construction project which involves new technology. The uncertain prospects for successfully assembling the necessary construction group in time for this project to start as scheduled appears to the Subcommittee to constitute an unacceptable element of risk.

The Subcommittee does not recommend FY 1981 funding of the proposal presented by the University of Colorado. The Subcommittee thinks that the technical aspects of this proposal are not complete enough for a substantive evaluation. Although the proposed storage ring would provide a unique capability for neutron time-of-flight physics, the conceptual and detailed designs need more work in order to demonstrate its operational feasibility. In addition, the dimensions of the research community for such a facility must be better established.

The Subcommittee considers the proposal by the American University to measure the magnetic structure function of the deuteron to be one which addresses a problem of basic importance in nuclear physics. This experiment would require the construction of a new injector at the Stanford Linear Accelerator Center, the only facility available at present (and for many years in the future) for such studies. The Subcommittee therefore recommends that an appropriate procedure be instituted to permit this experiment, with funding appropriate to its relation to the nuclear science budget, to be considered at SLAC. The Subcommittee further recommends, more generally, that DOE, SLAC and potential users mutually explore possible mechanisms for approval and funding of nuclear physics experiments at SLAC which would use the proposed injector and a possible system for improving energy resolution.

The Lawrence Berkeley Laboratory originally submitted a construction proposal for an electron-cyclotron-resonance ion source. However, at the time of the February 12-13 presentations to the Facilities Subcommittee this proposal was changed to a research and development project. As such, it does not fall within the province of the Subcommittee's responsibilities as defined by its charge. An evaluation of the proposal is therefore transmitted to the Nuclear Science Advisory Committee in a separate communication appended to this report.

I. C. Evaluation Of The Fiscal Impact Of The FY 1981 Recommendations

The support of nuclear science in the FY 1980 Presidential budget request was described to the Subcommittee by representatives of DOE and NSF as follows. The DOE Nuclear Physics budget is $98.4M. In addition, DOE has been asked to supervise the construction of the MSU Phase II heavy-ion facility which originally had been proposed by Michigan State University to the NSF for funding. An additional $6M was added to the FY 1980 DOE Nuclear Physics budget for the MSU project, making a total of $104.4M, and in succeeding years it is expected that amounts of a similar size will continue to be added to the DOE Nuclear Physics budget until the MSU accelerator construction is complete. The projected total expenditure for this project is $27-30M and the projected completion date occurs during FY 1983.

Of the $98.4M budget for the regular DOE Nuclear Physics program, $81.4M is allocated to "operations," $8.2M to "equipment," and $8.8M to "construction." The "construction" figure also includes costs of Accelerator Improvement Projects and General Plant Projects. The actual new facilities construction included in the $8.8M are the beam recirculation capabilities at MIT-Bates, budgeted at $1.8M, and the staging area at LAMPF, budgeted at $2.4M, making a total of $4.2M. The FY 1980 DOE Nuclear Sciences budget is $32M, with none of these funds being assigned to construction. Of the operating funds totaling $30.7M in this budget, approximately $18M ($10.9M for Nuclear Research, $4.8M for Nuclear Data Measurements and $2.3M for Nuclear Data Compilations) is properly assigned to the nuclear science effort.

The FY 1980 Presidential budget request for NSF includes $23.9M for the Nuclear Science Section and an estimated $1.8M of support for nuclear theory via the Theoretical Physics Program. The $23.9M includes $1.0M for continued development of the superconducting booster for the tandem Van de Graaff accelerator at State University of New York at Stony Brook. The booster is projected to be completed in FY 1982 with the expenditure of an additional $2M. Not included in the above request is the construction cost of the MSU accelerator described above, for which $6M is requested in the FY 1980 DOE budget.

The representative of the DOE suggested that the Subcommittee assume that the allocation in the FY 1981 budget for new construction, excluding the MSU construction, would be about $6M. It was pointed out that this figure is tentative since the decisions on the FY 1981 allocations are yet to be made.

The representative of the NSF said that the NSF has no specific allocation for new construction and that hence construction must compete directly with support for research and instrumentation in the budget development process. He said that in view of the tightly constrained funding situation in FY 1980, it was planned to place highest priority in the FY 1981 request on increased support for the ongoing projects, unless a strong indication to the contrary is provided by the Nuclear Science Advisory Committee.

In its considerations the Subcommittee assumed that the new construction items in the FY 1980 budget would be approved by Congress. The facility which the Subcommittee has assigned as its first priority for FY 1981, the ATLAS accelerator at ANL, is projected to cost $5.4M and to be completed in 1984. The facility next in priority, the Yale proposal for an upgraded tandem, is projected to cost $4.2M, with a completion date in 1983. With an average yearly expenditure of $6M, funding both of these projects would substantially reduce the funds available for new construction after FY 1981. The Subcommittee feels that the $6M annual rate for construction, 6 percent of the DOE Nuclear Physics budget, is clearly too low and strongly recommends that it be increased to an average level of the order of $12M. This would require an increase of the total budget from the FY 1980 level of $98.4M to a new base level of $106M, since diverting funds of this magnitude from the "operating" budget would cause unacceptable damage to the national nuclear science program.

The increase in operating funds required for the operation of the ANL-ATLAS project is projected to be $0.4M while the Yale project would require a considerably smaller increase. The Subcommittee feels that such a net increase can be accommodated in the current national program.

Appendix I. Membership of the 1979 Facilities Subcommittee of the DOE/NSF Nuclear Science Advisory Committee

H. Feshbach,* Massachusetts Institute of Technology, Chairman

G. F. Bertsch, Michigan State University

R. L. Burman, Los Alamos Scientific Laboratory

B. G. Harvey,* Lawrence Berkeley Laboratory

H. D. Holmgren, University of Maryland

J. R. Huizenga,* University of Rochester

J. S. McCarthy, University of Virginia

R. Middleton, University of Pennsylvania

R. E. Pollock, * Indiana University

R. G. Stokstad, Oak Ridge National Laboratory

H. E. Wegner, Brookhaven National Laboratory

* Also members of the DOE/NSF Nuclear Science Advisory Committee

Appendix II. Consultants to the 1979 Facilities Subcommittee

P. Paul, State University of New York at Stony Brook

R. H. Stokes, Los Alamos Scientific Laboratory

D. E. Young, Fermi National Accelerator Laboratory

Appendix III Agenda for the February 12-14, 1979 meeting of the 1979 Facilities Subcommittee on the DOE/NSF Nuclear Science Advisory Committee, held at the NSF, 1800 G Street, NW, Washington, D.C.

February 12, 1979

9:00 am - 11:00 am Closed Session

1:00 pm - 5:00 pm Presentations of Facility Proposals and discussion thereof. Approximate times:

1:00 University of Washington: Proposal for a 20 Million Volt Tandem Electrostatic Accelerator

3:00 Argonne National Laboratory: Proposal for a Precision Heavy Ion Accelerator-ATLAS

February 13, 1979

9:00 am - 8:00 pm Continuation of Presentations of Facility Proposals and discussion thereof. Approximate times:

9:00 Lawrence Berkeley Laboratory: Proposal for an Electron-Cyclotron-Resonance Source for the LBL 88-Inch Cyclotron

11:00 Texas A&M University: Proposal to Build a Superconducting Cyclotron as a Heavy-Ion Injector for the Texas A&M Cyclotron

2:00 University of Colorado: Proposal for a National Light-Ion Accelerator Facility

4:00 American University: Proposal for Construction of Injector East at the Stanford Linear Accelerator Center

6:00 Yale University: Proposal for Conversion of the Yale MP Tandem Accelerator to ESTU status

February 14, 1979

9:00 am - 5:00 pm Closed Session

II. Brief Summaries and Evaluations of Proposals Considered by the 1979 Facilities Subcommittee of the DOE/NSF Nuclear Science Advisory Committee

A. ARGONNE NATIONAL LABORATORY

Argonne National Laboratory proposed the construction of superconducting linear accelerator cavities for use in boosting the energies of heavy-ion beams from their present tandem accelerator and of the expansion of experimental-area facilities for the new accelerator system. This proposal is essentially the same as that presented by Argonne to the 1978 Facilities Subcommittee for consideration last year. As foreseen then, the key components and subsystems required for successful booster operation have undergone extensive tests during the intervening year and these tests now provide a thorough basis for evaluation of this project.

The objective of the system proposed by ANL is to provide beams of heavy ions for nuclear research which, while retaining the ease of energy variability and precision of energy resolution associated with modern tandem Van de Graaff accelerators, have energies considerably higher than achievable with current and projected capabilities of tandem technology. The system would be strongly optimized for acceleration of ions of masses in the range of A=10-100, approximately. For the heavier of these ions the system's performance is comparable to that of a hypothetical 50 MV tandem, yielding 15 MeV/amu for A=100 and 27 MeV/amu for A=10. Another key attribute of the proposed system is its provision for pulsed beams with extremely narrow (< 50 psec) time widths for the beam bursts. This feature makes possible fast-timing measurements which are crucial for certain classes of heavy-ion experiments.

The proposed accelerator system would consist of the upgraded ANL FN tandem accelerator followed by seven superconducting linac sections, each composed of groups of independently phased, split-ring resonators. The ongoing accelerator development program at ANL has progressed to an advanced state. The tandem has been upgraded for its role as an injector and a section of six resonators installed and successfully operated. An additional section is scheduled to be installed in early 1979 and brought into operation by mid-year, and two more sections, bringing the total number of resonators to 24, are scheduled to finish the development stage of the project. The present ANL facility proposal is for the construction of three more accelerator sections, which would; by bringing the total to seven, increase the maximum heavy-ion energies by at least 60%, and for the cost of expanding the experimental area and adding new experimental equipment so that the capabilities of the new accelerator could be properly exploited.

It is the Subcommittee's judgment that the ANL accelerator development group has in large measure demonstrated the technical feasibility of their split-ring superconducting structure. Cavity tests with beam were made in June, September, and December 1978. On the last occasion six cavities were used to accelerate a ^{32}S beam from 85 to 148 MeV and this beam, at a level of one to two particle nA, was then used for several days of nuclear research. The ANL project was visited by a group appointed to conduct an on-site technical evaluation and report back their findings. On the basis of this testimony and its own evaluations, it is the Subcommittee's opinion that the technical innovations incorporated into this project have substantially been proven sound and that the smaller problems which will arise as the project continues can be solved satisfactorily.

The construction costs outlined in the present proposal, including $0.8M for contingency, are estimated at $5.4M in FY 1979 dollars. The costs of the R and D project which is leading to the first four sections of the booster are estimated to be about $6.0M. The complete accelerator system will require an annual increment of $375K operations support over the level projected for the tandem-plus-four-section prototype booster. In addition, it should be expected that there will be additional costs for new capital equipment which will be needed as this project develops. Argonne National Laboratory has demonstrated strong institutional support for this project in providing the funding for major elements of the R and D. The entire project is scheduled for completion at the end of 1983. However, the existing accelerator system would begin to improve in capabilities as early as 1981 as components are brought on line.

It is stated by ANL that the proposed facility will be operated under the control of a program advisory committee with access open equally to inside and outside users on a competitive basis. It is the Subcommittee's expectation that ANL will provide outside users with sufficient services for the maintaining of independent research efforts. The Subcommittee notes that the facility's potential capability of accommodating two simultaneous experiments, by splitting beams with different energies and charge states to two different areas (II and III), is an important feature. The final design of the Area III beam layout should plan for the special needs of user setups, including, for example, space for a considerable variety of detector arrays and for shielding between sections so that there is ready access for preparations. It should also allow for easy future expansion if that should be required. The Subcommittee notes that the ATLAS project expands the experimental capabilities of ANL into the area of heavy-ion research emphasizing nuclear structure and macroscopic properties of nuclei. The Subcommittee recommends that ANL develop more theoretical support for these experimental programs so as to optimize research results.

It is the Subcommittee's opinion that the research capability which would be provided by this proposed facility would provide a significant enhancement of the national program in nuclear science and that the technical innovations incorporated into the design achieve this enhancement with an advantageous ratio of benefits to costs. The Subcommittee furthermore judges that these technical innovations have been tested and proved to the point that it is appropriate to proceed now with a full accelerator construction program. It recommends funding for this project as its highest priority for FY 1981 on the basis of its technical feasibility, its cost-effectiveness and its scientific merit.

B. UNIVERSITY OF COLORADO

The University of Colorado proposed the construction of an open four-sector cyclotron which would utilize their present cyclotron, suitably modified, as an injector to provide reliable high current (up to 50 μA) light-ion beams. Protons and deuterons (polarized as well as unpolarized), ^3He, ^4He and Li beams would be provided. Proton energies would extend up to 75 MeV, deuteron energies to 50 MeV and He and Li energies would follow from the value of $K=AE/Q^2 \leq 100$ MeV.

It is contemplated to couple the two cyclotrons through an intermediate storage ring that could be utilized to yield a 20-fold increase in instantaneous beam intensity and to adjust the duty cycle to optimize various experiments. Also incorporated in the proposal are new experimental area and office-shop facilities. A special feature of the experimental area is a 180 meter long time-of-flight path for neutron studies. The proposed facility is specifically for light-ion experimentation and is focused strongly towards studies with neutrons.

It was the opinion of the Subcommittee that all elements of the proposal were probably technically feasible and that the storage-ring concept might yield an interesting and innovative device for nuclear studies. However the Subcommittee concluded that neither the conceptual nor the detailed design studies incorporated in the proposal were advanced enough to constitute the basis for a final technical evaluation of the proposal.

The proposed construction cost of the facility, including contingency costs, is \$12.7M (FY 1979 dollars), \$3.0M of which is to be provided by the institution and \$9.7M requested in federal funds. The increase in federally funded operating expenses which are entailed by this expansion of the present facility is estimated to be \$0.8M annually.

The time schedule for this project calls for completion of study and design work two years after funding approval, after which construction will start. Modification of the existing cyclotron will be completed in two years and the final coupled system in three years, presumably along with the intermediate storage ring.

The proposal is predicated upon the substantial contribution from the University of Colorado noted above. At this time a proposal for this University support is being considered in competition with two other projects. Part of the proposal's justification for the new facility involves the national need for its special light-ion and neutron capabilities. The method proposed by Colorado to implement outside use of the facility was patterned after the operational mode of the Joint Institute for Laboratory Astrophysics. A formal program advisory committee with outside members was not proposed.

In the Subcommittee's opinion, the need for a major new dedicated light-ion facility was not adequately developed in this proposal, particularly in the contexts of presently existing facilities and of the potential community of users. The concept of coupling two cyclotrons via an intermediate storage ring was regarded as an attractive technical innovation but the incomplete design concepts for the storage ring and many aspects of the coupled cyclotrons and a general lack of detail led to the conclusion that the proposal was not complete enough to make a solid evaluation of the operational feasibility of the system possible.

C. TEXAS A&M UNIVERSITY

Texas A&M University proposed to construct a superconducting cyclotron of mass-energy product $K=AE/Q^2=400$ MeV to serve as an injector to their present K=147 cyclotron. Heavy-ion beams produced by an internal ion source in the new cyclotron would be accelerated, extracted, injected into the present cyclotron, stripped to a higher charge state and then accelerated to still higher energies. The final beams, whose magnetic rigidities would necessarily be compatible with the present bending magnets and spectrometer, would utilize the existing beam lines and target stations. The thrust of the proposal is to provide intense heavy ion beams in the A=15-150 region at energies (10-40 MeV/amu) which, while lower than those which will be provided by the MSU Phase II facility, are significantly higher than at any other U.S. facility under either construction or active consideration for funding.

While not a copy of an existing model, the design of the proposed new cyclotron has evolved directly from the Michigan State University development project. Texas A&M proposes to create an accelerator design and development team to execute the construction project in-house. The proposal considered the technical question of matching the new cyclotron to the existing machine, the variation in performance with machine size, and whether it would be better to use the new larger machine as injector or as booster. Higher energy beams could be obtained by using it as a booster, but at the cost of a) substantial interference with the existing program because of the more extensive rearrangements required, b) upgrading the existing beam-line magnets to sufficent strength for transporting many of the new beams and c) the loss of stand-alone capability of the new machine. Designed for use as an injector, the new cyclotron could be constructed with only limited effect on the ongoing program. Some changes to the interior of the existing cyclotron are proposed, including a foil stripper positioning mechanism, a change in the dee end to avoid stripper interference and some changes to the extraction system. The lost time for these changes is estimated at two months.

Recent successful operation of the MSU superconducting magnet and internal ion sources indicates a fairly low technical risk associated with the injector design. However, the very-low-frequency rf system might be a troublesome problem in detail. The existing technical staff of Texas A&M has very little accelerator design experience. (The first TAMU cyclotron was an improved copy of the LBL 88-inch cyclotron and was commercially produced.) The project would be critically dependent on technical leadership and design skills of people not yet engaged; for example the group has minimal cryogenic experience. The construction schedule requires a buildup of design and engineering staff which is probably unrealistically rapid. A schedule slippage could make the cost significantly larger.

The proposed cost estimate for the project is \$6.0M (FY 1979 dollars) of which approximately \$1.7M is to be provided by local sources. The budget for research and operations following completion is estimated at \$2.0M for 1985, which represents an increment over the present federal support level of perhaps \$0.8M in FY 1979 dollars. The proposed schedule calls for construction starting in late 1981 and finishing in 1984.

Texas A&M University gave strong support for this project, agreeing to allocate all the construction funds for the building addition and to create three new faculty positions. Moreover, it is presently providing matching funds for the upgrading of the laboratory's computer system and there has been significant continuing operational support for the laboratory by the State of Texas and the Robert A. Welch Foundation.

The proposal did not meaningfully address the issue of utilization of the new facility by non-resident scientists. While the laboratory management indicated a general receptivity towards taking actions designed to provide organized access by outside users, no concrete plan was offered and no extensive documentation on a prospective users' community was presented.

The proposed facility would provide capabilities for heavy-ion research in an energy range considered to be important by a significant component of the scientific community active in this field. It would also provide flexible light-ion capabilities when the cyclotrons were operated in the uncoupled mode. These capabilities would be provided with high cost-effectiveness and the facility would further strengthen a university group which has constituted a significant addition to the national program in nuclear science.

However, the technical success of the project is critically dependent upon assembling the appropriate additional staff at Texas A&M. The existing staff has a good record in maintaining and operating their present cyclotron but there is an acknowledged need for additional talent for the design, development and management of a major construction project involving new technology. The uncertain prospect for successfully assembling the construction group in time to proceed with the proposed schedule appears to constitute an unacceptable element of risk.

D. UNIVERSITY OF WASHINGTON

The University of Washington submitted a proposal for a nuclear research facility featuring the purchase of a 20 MV folded tandem Van de Graaff accelerator of the type offered for sale by the National Electrostatics Corporation.

The research objectives addressed by the Washington proposal include a variety of topics in both light-ion and heavy-ion physics in the full energy range of the proposed accelerator facility, 2.5 to 20 MV. Special emphasis is directed to the exploitation of a new polarized ion source which is also to be purchased as part of the proposal. This new source features both high intensity and small spin-correlated beam modulation, which should make possible improved precision in experimental studies of parity violation in complex nuclei. The new accelerator would be housed in a tower sited so that the existing target areas and experimental facilities can continue to be used. The present two FN tandem accelerators would be removed to create additional experimental areas.

In evaluating the technical aspects of this proposal, the Subcommittee noted that NEC folded tandems with rated terminal voltages of 20 and 25 MV are scheduled to become operational within the year at the JAERI (Japan) and Oak Ridge-Holifield laboratories. The experience gained in these installations would be applicable to the Washington project. While at present the results of attempting to operate NEC accelerating tubes at their maximum design voltages are not uniform from laboratory to laboratory, and 14 MV is the highest operating voltage achieved at any existing tandem, the Subcommittee's opinion is that there is no substantial doubt about the technical feasibility of this proposal. The Washington technical staff, as supplemented during the construction period, is adequate in size and expertise for this type of project.

The estimated cost of the proposed facility, including the accelerator proper, injector, ion sources, beam transport system, laboratory building and 2000 sq. ft. of additional office space, is $11.9M in 1979 dollars, exclusive of engineering, design and inspection costs of $1.4M. The annual increment in operating costs which would be needed to properly exploit the new facility is approximately $1.0M. This increase would cover additional costs of research, operations and an outside user program.

The time estimated for implementing the proposed facility is four years from funding date. The facility plans are such that the present laboratory accelerators would remain usable until the last three months of this period, so that the project entails a minimum of lost research operations.

The institutional support pledged to this project, should it be funded, consists of financing the $200K cost of the architectural study for the building, providing $250K over five years for support of associated technical staff, two man-years of faculty time released from teaching and creation of two tenure-track faculty positions for nuclear experimentalists.

In addressing the issue of the involvement of outside scientists in the research program of the proposed facility, Washington proposed to expand the present system in which non-resident scientists can request beam time from the laboratory administration by forming an association of approximately ten regular outside users into an "extended faculty" arrangement. Members of this group would have the same claim on the laboratory facilities as would the regular Washington staff. The Subcommittee endorsed the commitment to accommodation of non-resident scientists indicated in the proposal. It recognized the advantages of the novel approach of an "extended faculty," an approach which would seem to preserve the essential aspects of the current methods of establishing scientific priorities and allocating resources at university laboratories. However, while the Committee recognizes the advantages of this method, it feels that when construction and operation costs of a facility increase to the levels requested in this proposal a form of external peer review is needed.

In the Subcommittee's opinion the proposed facility would significantly enhance the national program by providing light and heavy ion capability in the energy range between that of currently operating tandems and of the Oak Ridge-Holifield tandem. The associated polarized ion source would provide additional specialized capabilities. The facility would strengthen and expand the nuclear science program at Washington, a program which has played a significant role in graduate education in nuclear science. The serious disadvantage of this proposal is its relatively high capital cost.

E. YALE UNIVERSITY

Yale University submitted a proposal for an upgrading of its MP tandem accelerator to 20 MV capability. This proposal from Yale was substantially the same as that considered by the 1978 Facilities Subcommittee and included in their priority listing for FY 1980 construction. Since the project was not funded for FY 1980, Yale resubmitted the proposal, with one significant modification, for consideration by the 1979 Facilities Subcommittee.

The proposal calls for the purchase of equipment from High Voltage Engineering Corporation (HVEC) to convert Yale's existing MP Tandem accelerator, which has a maximum operating voltage of 13-14 MV, into an Extended STU (ESTU) configuration, which would have an operating voltage rated at 20 MV. The major modifications to be made are: 1) replacing the present 18-foot diameter pressure tank with a 25-foot diameter tank rated at 175 psi; 2) increasing the number of accelerating sections on each side of the terminal from four to five; 3) replacing the present 72" tubes in each accelerating section with new 88" tubes; 4) installing a rotating-shaft mechanical power system in parallel with the existing Pelletron charging chains; 5) enlarging the terminal; 6) adding a new 90° momentum-analyzing magnet to accommodate beams of higher rigidity.

The major difference between the present proposal and that submitted in 1978 is the plan to lengthen the accelerating tube sections from 72" to 88". The extended lengths serve to reduce the tube voltage gradient at 20 MV terminal voltage from 55.5 kV/inch in the previous configuration to 45.5 kV/inch. This new lower gradient is almost identical with the values achieved with present MP tandems operating at 13 MV terminal voltage. While the longer tube sections will reduce the inter-tube dead space from 24" to 8" and thereby decrease the freedom with which beam-limiting apertures and magnetic traps can be inserted between the tube sections, it is now the consensus that such devices are unnecessary in MP tandems.

The 1978 proposal called for an accelerator tank with a pressure rating of 175 psi so that insulating gas mixtures such as SF_6(40%)/N_2(50%)/CO_2(10%) could be used. Research at Minnesota and Brookhaven during the past year has confirmed that such a high-pressure mixture is better than the previously preferred insulation of pure SF_6 at 120 psi in that it reduces both the number of sparks and the time of recovery from a spark. The larger quantity of gas entailed in the proposed new system would be handled by storing 60% of it at 300 psi in the present MP tank, converted to an underground receptacle, and the remainder at 2000 psi in the existing storage facility. The turn-around time for emptying and refilling the ESTU tank is expected to be similar to that currently achieved with the present installation.

It is the Subcommittee's opinion that the proposed facility would achieve stable, research-quality operation at the design goal of 20 MV terminal voltage without difficulty. This is based upon consideration of the reduced tube voltage gradients achieved by the use of the longer tubes and the documented advantages of the proposed insulating gas.

Since HVEC will engineer and manufacture the needed new components, the responsiblity for these aspects of the conversion does not rest with Yale personnel. The local laboratory staff will, however, have the responsibility for acceptance and installation of the components and operation of the complete ESTU system. The Subcommittee believes that there is adequate technical competence and prior experience at Yale for this work to be successfully completed in a timely fashion. The proposal states that research will continue on the present accelerator until all the major new components for the conversion have been delivered. The estimated nine months interruption of research while the conversion takes place appears to be realistic.

From the perspective of the overall national program, this proposal would strengthen the in-house capabilities for both light-ion and heavy-ion research by one of the significant university groups in nuclear science, one which has traditionally supported a substantial program of graduate education. The facility would provide beams at energies intermediate between those of present tandems and those from the 25 MV tandem being constructed at Oak Ridge-Holifield and the linac-boosted tandem system being developed at Argonne.

Yale University does not propose any direct supplemental support for this project. However, the Subcommittee did note that nuclear science at Yale has been significantly strengthened by the appointment of a nuclear theorist as a senior faculty member in the Physics Department. The additional appointment of an assistant professor in nuclear theory is anticipated by July 1979.

The Yale group has no intention of creating a formal outside users' organization, but rather states its intention to maintain an hospitable climate for the reception of individual proposals of outside scientists to use the Yale facility and to foster collaborative research, in part by the selection of Research Affiliates who will spend some part of their research time at Yale.

The estimated cost of the proposed facility, is $4.2M in FY 1979 dollars. This amount does not include a contingency allowance, since almost all components are to be purchased, or most of the cost of installation at Yale, since that would be done by the present Yale operating and maintenance staff and be supported by Yale's ongoing funding for research and operations.

Incremental operating costs resulting from this project should be minor, corresponding to the addition of perhaps one person to the support staff and a presumed higher cost for replacement parts. For example, the 88" tubes cost $52,800 each instead of $43,800 for the 72" tubes and there would be ten of them instead of eight. The cost of a complete tube replacement would thus be $178K greater than in the existing MP tandem.

The time schedule for this proposal, assuming FY 1981 funding, calls for shutdown of operations of the present accelerator on October 1, 1982, completion of installation on April 1, 1983, and resumption of research with the new facility on June 1, 1983.

In the Subcommittee's opinion the Yale proposal provides a highly cost-effective enhancement of the overall national program in nuclear science and recommends it as the second highest priority project for construction in FY 1981. The facility would strengthen and expand the nuclear science program at Yale, a program which has played a significant role in graduate eduction in nuclear science. The Subcommittee feels strongly that the increased capability provided by the 20 MV ESTU warrants substantially increased use of the facility by scientists not formally associated with Yale. The laboratory management should make known its willingness to consider, with outside consultation, proposals from outside users and to accommodate experiments of high scientific merit which are suitable for the Yale facility.

F. AMERICAN UNIVERSITY

The American University proposed the construction of a new injector at the Stanford Linear Accelerator Center, the construction to be carried out by SLAC staff. This new electron beam would make possible a significant extension in the investigations of the structure functions of the deuteron by The American University group and its collaborators.

The maximum intensity for low energy beams at SLAC is severely limited by a combination of beam blow-up, beam loading, and a positron radiator at the low energy end. The new injector, called "Injector East," to be located at the high energy end of the accelerator, would bypass most of the present limitations and enable the electron current to be increased by factors of 50-100, to an average beam intensity of 25-50 microamperes over the energy range of 0.4 to 2.9 GeV. Injector East would be essentially a copy of the present SLAC injector and would fit into Sector 26 of the 30-section accelerator. This would be accomplished by removing two 10-foot sections at the beginning of the sector and inserting an injection section, with an off-axis electron gun, in their place. The entire device could be switched on/off on a pulse-to-pulse basis, and operated alone or interleaved with normal full energy beams.

A successful test of this scheme was performed by using the first five sectors of the SLAC linac to simulate the last five sectors. This test showed that the basic concept of focusing and maintaining a high intensity, low energy, electron beam in the SLAC linac would work as proposed. Since the new injector sections would be a (simplified) replica of the existing injector, the project should experience no technical difficulties. There may be scheduling problems for installation, as a result of future accelerator schedules, which would extend the project construction period.

The American University proposes to measure the deuteron's magnetic structure functions $B(q^2)$ and $2\ MW_2(q^2,\nu)$ at large q^2. This would be done by measuring elastic and inelastic electron scattering from the deuteron at backward ($\sim$155°) and forward ($\sim$40°) angles, utilizing the existing 1.6 GeV and 8 GeV spectrometers in end station "A." Similar experiments on ^{3}He and on ^{3}H are mentioned as possible future uses for the electron beam facility, if it were to be further augmented by an energy compression system to improve energy resolution.

In the proposal it is assumed that the experiment will be sensitive to two aspects of the deuteron: meson exchange and relativistic effects in the deuteron wave function and the approach to quark-constituent scaling. The Subcommittee agrees that the meson exchange and relativistic efforts are important questions of nuclear physics and that the proposed experiment is a good way to investigate them.

In terms of a program in electron scattering from light nuclei, it should be noted that the further extension of the measurements in this proposal to ^3He and ^3H will most likely require a ten-fold improvement in energy resolution. This requirement was addressed in Appendix B of the American University proposal: their solution is the installation of a monochromator (a radiofrequency separator at a chromatic focus) in the beam transport leading to end station "A." This device is estimated to cost $0.4M in FY 1979 funds; it is not included in the present funding request.

The cost estimated by SLAC for the injector is $0.9M in FY 1979 dollars. However, this includes indirect labor charges of 85%, depreciation of 10%, an "added factor" of 10%, and a contingency of 20%. Since this could be a DOE-funded project at a DOE laboratory (SLAC), it is possible that many of these "added" costs could be eliminated, leading to an actual cost closer to $0.5M. The estimated time for the construction project is 18 months from availability of funds, although it is possible that delays could occur because of interference with other accelerator projects at SLAC.

The Subcommittee considers this proposed measurement of the magnetic structure functions of the deuteron to be of basic importance. Although the regions of momentum transfer up to $q^2 = 25\ fm^{-2}$ will be available at the MIT-Bates facility, the extension of measurements up to $q^2 = 80\ fm^{-2}$ can, in the next decade, only be accomplished at SLAC. The Subcommittee notes that with its presently available information it is unable to estimate the total costs of performing this experiment at SLAC. In its opinion, however, if the proposed experiment can be accomplished for a total incremental cost of $0.5M it represents a highly cost-effective experiment in the area of nuclear structure studies with large-momentum-transfer electron scattering. The Subcommittee therefore recommends that an appropriate procedure be instituted to permit this experiment, with funding appropriate to its relation to the nuclear science budget, to be considered at SLAC. The Subcommittee further recommends, more generally, that DOE, SLAC, and potential users explore possible mechanisms for approval and funding of nuclear physics experiments at SLAC which would use the injector and a possible system for improving the energy resolution.

G. LAWRENCE BERKELEY LABORATORY

Lawrence Berkeley Laboratory proposed to conduct an extensive R and D program on electron cyclotron resonance sources (ECR) for heavy ions and to construct for the LBL 88-inch cyclotron an improved version of such a source using superconducting magnets. The design goal is to develop a source which will provide fully stripped light heavy ions and useful intensities of ions with charge states greater than 20 in the region of A=100. The installation of such a source on the 88-inch cyclotron would provide 40 MeV/amu light heavy ions and approximately 8 MeV/amu near A=100 at intensities of 10^{10} particles/second. The objective is to produce heavy ions at the 88-inch cyclotron with energies that overlap the lowest energies available with the improved Bevalac. The general advancement of ion source technology is an important second objective. The primary R and D effort leading to a test facility would be conducted during FY 1980, 1981 and 1982 as a joint project between the Accelerator and Fusion Research Division and the Nuclear Science Division. The schedule calls for construction of the source to start in FY 1982 and operation in FY 1984. The total R and D effort is estimated at $2.2M and the source construction, $2.34M.

The ECR ion source is a plasma device. High charge state ions are produced by sequential stripping of ions by energetic plasma electrons. The critical parameter determining the mean charge state reached is $n_e \tau_i$ where n_e is the plasma electron density and τ_i the ion confinement time. The usual plasma instability problems must be overcome to obtain useful values of $n_e \tau_i$. The relative velocity of the electrons and ions must be sufficiently high to strip ions to high charge states. High vacuum is required to prevent charge exchange between ions and yet adequate ions must be available to provide useful beam intensities. Microwave power must be coupled into the plasma. (Much higher levels of microwave power than those needed for an ion source have been used on existing plasma machines.)

A prototype ECR source has been constructed and tested at Grenoble by Geller. The performance of the source reported by Geller at the 1978 Cyclotron Conference would approximately double the heavy-ion energy capability of the 88-inch cyclotron. The breakthrough of the Grenoble group was due to the use of the two stage system. Intense beams of low-charge-state ions were produced in the first stage under conditions similar to conventional PIG sources. The second stage was a high vacuum magnetic mirror system. Electrons were accelerated with microwaves by means of the electron cyclotron resonance to energies adequate for stripping ions to high charge states. Plasma instabilities were overcome by superimposing a sextupole magnetic field on the mirror configuration. Geller's results imply a value of $n_e \tau_i = 4 \times 10^9\ cm^{-3} \cdot$ sec (plasma mirror machines have reached $n_e \tau_i = 10^{11} cm^{-3} \cdot$sec). Beams of the order 10^{12} to 10^{13} particles/second (D.C.) were obtained for N^{7+}, O^{7+}, and Ar^{12+} ions, with emittance suitable for axial ejection into the 88-inch cyclotron. The power consumption of the coils of the second stage at Grenoble was 3 MW. The vacuum pumping capacity in the test limited the pressure to 10^{-7} torr.

LBL will reduce the power requirements by using superconducting coils and improve the vacuum to 10^{-8} torr with cryopumping. The higher vacuum should improve the source performance. Superconducting coils will enable the magnet fields in the second stage to be increased and allow the use of higher microwave frequencies. LBL plans to increase the frequency by a factor of two. Geller's analysis of the plasma behavior predicts that both n_e and τ_i will increase rapidly with frequency. A factor of two in frequencies may result in a factor 500 increase in $n_e \tau_i$, making possible charge states greater than 70 for uranium. As Geller's analysis of the increased confinement time is not generally accepted by plasma theorists, the initial LBL objective is to obtain a value of $n_e \tau_i = 1.6 \times 10^{10} cm^{-3}$ sec, the value predicted assuming no increase in τ_i.

The Grenoble results indicate that the confinement time is significantly greater than the time corresponding to the ion drift velocity, indicating that the ions are trapped in the mirror region by some mechanism. In view of the uncertainty of the theoretical model for this mechanism and possible plasma instabilities which may appear with increased $n_e \tau_i$, LBL proposes to establish an ECR source test facility and to conduct experiments to test possible models. The studies are expected to be sufficiently advanced that construction of a source for the 88-inch cyclotron can begin in FY 1982. Once the source for the 88-inch cyclotron has been constructed the LBL group estimates that the hardware cost of fabricating a copy will be about $1.0M. LBL has started theoretical studies and has available a number of components needed for the test facility; e.g., a cryostat. LBL is one of the few laboratories in the U.S. with combined expertise in cryogenics, superconducting magnet, plasma and heavy-ion-source technologies needed to undertake such a project.

The proposed R and D project, which does not include production of a full-scale prototype, is expensive. To provide the funds requested might involve sacrifices on the part of the heavy-ion community. The Subcommittee considers this project to be one which potentially could have a significant impact on the future national research program in heavy-ion science. However, because the original LBL proposal for a FY 1981 construction project was withdrawn at the time of the presentations to the 1979 Facilities Subcommittee and converted into the present proposal for an R and D project, the Subcommittee does not have the information on other R and D projects which would be needed to judge their merits relative to the present proposal. In absolute terms, however, it considers this project for development of an ECR ion source to be meritorious.