Scientific Opportunities and Funding Priorities for the DOE Medium Energy Nuclear Physics Program

A Report to the DOE/NSF Nuclear Science Advisory Committee

By the NSAC Subcommittee on
DOE-Sponsored Intermediate Energy Nuclear Science

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EXECUTIVE SUMMARY

In June 1998, the Nuclear Science Advisory Committee (NSAC) to the Department of Energy (DOE) and the National Science Foundation (NSF) was charged by the agencies to reexamine and evaluate the scientific opportunities identified in the area of "To the Quark Structure of Matter" of NSAC's 1996 Long Range Plan. NSAC was also asked to make recommendations of priorities consistent with projected resources available to the DOE Medium Energy Program.

NSAC, in turn, appointed a subcommittee to respond to the charge. The subcommittee investigated the state of the medium energy sub-field in a variety of ways including site visits, presentations, and formal and informal input from members of the nuclear science community. The subcommittee confirmed that the scientific questions being addressed by the DOE Medium Energy Program are of fundamental importance and that the program in place to answer them is effective and truly world class.

The most significant finding of the subcommittee was that funding for Nuclear Physics by the Department of Energy has fallen substantially below the guidance levels provided to NSAC by the DOE when it requested the preparation of the 1996 Long Range Plan. In addition, the Medium Energy Nuclear Physics Program is being affected by the phase-out of support for the AGS at Brookhaven National Laboratory by DOE High Energy Physics. Failure to address these shortfalls will lead to retrenchments in the program even with constant effort funding at the FY1999 President's Budget level. ***The subcommittee urges that every effort be made to restore the budget to the levels anticipated in the 1996 Long Range Plan so that the world-class scientific program laid out in the plan can be fully carried out.***

The subcommittee was asked by NSAC to comment on three budget scenarios provided in the charge: constant effort funding at the FY1999 President's Budget level, constant dollar funding starting at this level and increased funding levels beginning in FY2000. After careful consideration of these scenarios and of anticipated needs in the program, the subcommittee made two general recommendations:

The subcommittee gives the highest priority to effective utilization of the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) in all budget scenarios.

CEBAF has been constructed at a total cost of $600 M and is now fully operational. The capability of the accelerator is outstanding and exceeds expectations. It is essential that the field reap the rich scientific harvest which this unique, world-leading facility can provide.

The subcommittee recommends that very high priority be given to supporting a balanced scientific program in intermediate energy nuclear science.

The subcommittee was extremely impressed by the range of scientific questions being addressed by the intermediate energy nuclear science community and finds that in addition to electron beams, a wide variety of experimental tools is needed to carry out this exciting program including beams of photons, hadrons, neutrons and neutrinos. Without a balanced program, the subcommittee does not believe that the important scientific goals laid out in the 1996 Long Range Plan will be achieved.

The subcommittee then considered the three different funding scenarios and formulated a strategy in each case:

Under a constant effort budget, the subcommittee recommends that a set of actions be taken to maintain balance within the program while capitalizing on the very significant investment that has been made at TJNAF.

One of these actions is that DOE support for operations at the MIT/Bates facility would be terminated after FY2000. This action, which is necessitated by the desire to maintain scientific balance within the sub-field and the flexibility to undertake new initiatives, will result in a failure to capitalize on substantial investments made at this facility and will have negative consequences for the advancement of scientific knowledge, and for the educational mission of the DOE nuclear physics program.

The impact of funding at greater than constant effort in FY2000 and beyond would be extraordinary. Each significant funding increment would enable the community to carry out a larger fraction of the world-class scientific program laid out in the 1996 NSAC Long Range Plan.

Restoration of the budget to the level of the 1996 Long Range Plan would allow continued operation of MIT/Bates and completion of the unique scientific program that has been planned for this facility. A further increase would allow a unique and high quality physics program at the Brookhaven AGS using hadron beams.

Under a constant dollar budget, a serious retrenchment of the program is unavoidable in order to maintain the productivity of its flagship facility and the balance that is essential to the scientific health of the field. The subcommittee recommends that actions be taken which preserve as far as possible utilization of CEBAF while maintaining balance in the program.

In addition to the loss of the MIT/Bates facility, there would be cutbacks in research groups at the national laboratories and in the university research program and CEBAF would not be effectively utilized.

1. INTRODUCTION

Over the past two decades, the Nuclear Science Advisory Committee (NSAC) has overseen the preparation of a series of long range plans, most recently the 1996 Long Range Plan produced under the leadership of Ernest Moniz. These plans, which have been prepared with extensive input from the nation's nuclear science community, have provided guidance which has allowed the funding agencies to strike a prudent balance between investment in new facilities and exploitation of existing capabilities. These plans have also helped program managers in allocating resources to optimize research productivity while ensuring the training of the next generation of nuclear scientists.

The 1996 Long Range Plan recommended a broad nuclear science program of great potential that could be achieved within the funding guidance contained in the agencies' charge to NSAC. It also made clear that the promise of this Long Range Plan would be jeopardized should the actual funding level for the nation's nuclear science programs at DOE and NSF fall short of that envisioned in the charge.

The 1996 Long Range Plan divided the experimental program in nuclear science into four broad components, one of which is described in the chapter entitled "To the Quark Structure of Matter." This component addresses primarily the application of the fundamental theory of the strong interaction, Quantum Chromodynamics (QCD), to elucidating the underlying structure of hadrons and nuclei. Experimentally, this is studied by observing the consequence of scattering electrons, protons and other elementary particles from nucleons and nuclei. Because of the complexity of the phenomena under study, this broad set of complementary probes is needed in order to make fundamental progress in deepening our understanding.

In June 1998, Martha Krebs, Director of the DOE Office of Energy Research (OER) and Robert Eisenstein, Assistant Director of Mathematical and Physical Sciences at the National Science Foundation (NSF), charged NSAC to reexamine and evaluate the scientific priorities identified in the "To the Quark Structure of Matter" component of NSAC's 1996 Long Range Plan, and to make recommendations for priorities consistent with projected resources available to DOE's Medium Energy Nuclear Physics Program. The full text of this charge is provided in Appendix A. At its meeting on June 6, 1998

NSAC formed a subcommittee to prepare this written response to the charge for its consideration.

This subcommittee, chaired by James Symons, consists of eleven members of the nuclear science community, including theorists, experimentalists and a representative from the European physics community. The full membership of the subcommittee is listed in Appendix B. Meetings of the subcommittee were attended by representatives from the DOE/OER and the NSF. From DOE, Peter Rosen, Associate Director for High Energy and Nuclear Physics; Dennis Kovar, Acting Director of the Division of Nuclear Physics; Sherman Fivozinsky, Program Manager for Medium Energy Nuclear Physics; and Joe McGrory, Program Manager for Nuclear Theory; and from NSF, Bradley Keister, Program Director for Nuclear Physics, attended many of the discussions.

The deliberations of the subcommittee were constrained by a number of important considerations. The first involved funding projections for the DOE Medium Energy Nuclear Physics Program. The charge to the subcommittee provided very specific budget scenarios for the subcommittee to consider in making its recommendations. The subcommittee was asked to provide guidance for both constant effort and constant dollar funding for the next six fiscal years as well as for a modest increase above constant effort funding over this period. The subcommittee was fully aware that the actual funding for the field over the coming years will, in all likelihood, not conform in detail with any of the scenarios provided in the charge. However, subcommittee members believe that the recommendations are rather robust with regard to reasonable perturbations to the funding scenarios considered.

The second constraint was that the charge directed the subcommittee to limit its considerations to the science defined in the 1996 Long Range Plan chapter "To the Quark Structure of Matter" and to the three funding scenarios provided in the charge. As a result, two inconsistencies arose.

The first is that some DOE Medium Energy Nuclear Physics funds will support work in other components of nuclear science as defined in the 1996 Long Range Plan, in particular, "Fundamental Symmetries and Nuclear Astrophysics." The second is that some resources from other components will support activities in Medium Energy Nuclear Physics, an obvious example being RHIC operations with polarized proton beams which is funded by the DOE Heavy Ion Nuclear Physics Program. While this may make sense within the context of program management, it provides an artificial constraint on the considerations of the subcommittee because the inconsistency between the scientific and budgetary scopes of our charge means that not all relevant budgets can be considered by the subcommittee in setting priorities and in formulating its recommendations. Following guidance from the DOE program managers, the subcommittee included in its scope all work funded by the DOE Medium Energy Nuclear Physics Program and did not consider setting priorities for resources that fund these activities but are not part of that program.

The final constraint was temporal. The time allotted for the subcommittee to complete its work was quite limited. As a result, the subcommittee was not able to examine the scientific issues in the depth that takes place during the preparation of a long range plan. Nor was the subcommittee able to evaluate the resources needed for effective operation of the accelerator facilities in the detail that would be possible during a formal operations review.

In spite of these constraints the subcommittee believes that it has come to an understanding of the DOE Medium Energy Nuclear Physics Program at sufficient depth to provide cogent and useful recommendations to NSAC and to the program management.

The subcommittee collected information about the program in a number of different ways. Three formal meetings of the subcommittee were held. The first was held at Argonne National Laboratory on July 31 and August 1. During this meeting, the subcommittee heard presentations on scientific opportunities in those parts of the program not specifically associated with the accelerator facilities funded by DOE Medium Energy Nuclear Physics. The other two meetings were held at these accelerator facilities: on August 2 and 3 at the MIT Bates Linear Accelerator Center; on August 4 and 5 at the Thomas Jefferson National Accelerator Facility (TJNAF). At each site the subcommittee toured the experimental areas, heard presentations about the current scientific program and future plans, and met with management and with members of the user community. The agendas for each of these meetings are provided in Appendix C. Programmatic information was provided to the subcommittee by cognizant DOE and NSF program officers.

The subcommittee also broadly solicited input from members of the nation's nuclear science community. Letters were sent to many members of the community informing them of the work of the subcommittee and a web site was set up to provide basic information about the subcommittee and its charge. Over four hundred different people came to the web site and 18 letters and e-mail messages were received by the subcommittee.

The subcommittee then met at Argonne National Laboratory on August 18 and again on September 10, 11 to formulate recommendations and to draft this report. In the sections which follow, the important scientific questions facing the field are summarized in section 2. In section 3 the manner in which these questions are being addressed by the program is described. Changes that have taken place in the field since the 1996 Long Range Plan are discussed in section 4, and, finally, the subcommittee's findings and recommendations are presented in section 5.

2. OPEN SCIENTIFIC QUESTIONS

Over the last 20 years a fundamental theory of the strong interaction, Quantum Chromodynamics (QCD) has emerged from the development of the Standard Model. The Standard Model provides the framework in which the fundamental particles, quarks and leptons, are arranged into three generations. The quarks interact via the exchange of gluons; the quarks themselves each have 3 projections in the "color" space of the group SU(3). The theory is a non-Abelian gauge theory, and as a result is computationally difficult. For example, the eight carriers of the force, the gluons, interact with each other, and the force between quarks grows with distance to the degree that quarks are absolutely confined.

Much progress towards direct calculation of the properties of mesons and nucleons in QCD has been made with an approximation technique, lattice gauge theory. A first-principles calculation of the very lightest nuclei can be foreseen, and one day perhaps even the properties of heavier nuclei can be calculated with QCD. Such a calculation can be expected to have both the merits and the drawbacks of, say, a direct calculation of the structure of DNA from quantum electrodynamics. More immediate and essential insight results from asking what are the appropriate degrees of freedom and the effective carriers of the strong force, and how can they be discovered experimentally? In other words, what is really going on inside the nucleus?

In the naive quark model, protons and neutrons have the structure *uud* and *udd*, respectively, with the quarks in relative s-states. One might then expect that the spin of the nucleon would be just that of the unpaired quark. The extent to which this is the case is now a subject of intense investigation; initial experiments suggest that only about 1/3 to 1/2 of the spin comes directly from the quarks.

More realistic models suggest that the valence quarks must be immersed in a virtual sea of quark-antiquark pairs – it is possible to observe their fleeting existence in properly designed experiments. So one is led to a model of "constituent" quarks that are composites of quarks, antiquarks, and gluons. Are nucleon ground states entirely composed of up and down quarks and antiquarks? Presumably the heavier quarks (s,b,t) must also be present to some degree in the sea. Ingenious experiments are in progress to explore the role of the strange quark, the lightest of the heavy quarks, in nucleons. The spin and flavor content of the nucleon is a fundamental open question.

The surprises in the static properties promise equally surprising dynamics. The neutron is an electrically neutral object that, in the naive quark model, should be neutral even on a microscopic scale. In fact, however, the neutron seems to have a positive core immersed in a negative cloud. Measurements of both the charge and magnetic form factors of the neutron are in progress, and should shed light on the spin puzzle and on quark dynamics.

If our understanding of the nucleon ground state is incomplete, that of nucleon excited states is rudimentary at best. The excitations put to the test our most basic concepts of quark and gluon structure. Why are the odd-parity states expected for excitations in a potential missing, or at least disfavored? Do the spin-3/2 baryons have quadrupole moments? Are bound states of 4 or 6 quarks permitted? Do "glueballs," states of pure glue, exist? (One strong candidate has been seen.) At least 2 mesons with exotic quantum numbers are now known – what is their nature? The answers to these questions will be decisive in forming an effective theory.

Nucleons interact with each other via a nuclear force that, at low energies, can be described with remarkable accuracy in terms of the exchange of mesons. This success is an inevitable consequence of color confinement in QCD. As the energy increases, an evolution to different degrees of freedom must occur. Perhaps at some energy density a transition to a quark-gluon plasma (QGP) takes place. It is important to gain an understanding of this evolution in the controlled environment of the few-nucleon system, both to allow us to recognize the QGP when we see it, and to build the effective model of the nuclear force that we seek.

The Standard Model of the strong and electroweak interactions is robust and precise at accessible energies, but it is clearly only a part of a larger physical world that includes, for example, gravity. With the objective of finding the more comprehensive description, searches for physics beyond the Standard Model continue. The most promising avenues include neutrino mass, extra generations, and an understanding of parity and time-reversal-symmetry violation.

2.1 Nucleon Structure

2.1.1 Spin and Flavor Structure of the Nucleon

The problem of determining the nucleon's wavefunction in terms of the fundamental quark and gluon degrees of freedom in QCD, and understanding how that description relates to the constituent quark model, is one of the most fundamental problems in hadron structure. The up, down and strange quark components of the nucleon are measured using electromagnetic and weak currents which couple directly to quarks in deep inelastic lepton-nucleon scattering, in large mass μ-pair production and in elastic electron-nucleon scattering.

Spin-independent deep inelastic lepton-nucleon scattering has given good determinations of the u, d, s and G distributions in the nucleon, but such "hard scattering" determinations do not distinguish short distance quark-antiquark fluctuations of the proton, which are less relevant from a nucleon structure point of view, from longer lived fluctuations. Thus, spin-independent deep inelastic scattering indicates that there is a significant s-$\bar{s}$ sea in the proton. Recent experiments at Bates and TJNAF using parity violating elastic electron scattering to measure differences of s and $\bar{s}$ distributions are sensitive to strange-quark contributions in the proton below 10%. If no such contributions are found, the s and $\bar{s}$ may be short-lived fluctuations which play little role in low energy nucleon structure. Further parity violating elastic scattering measurements planned at Bates and TJNAF over a broad range of momentum transfers should confirm whether or not this is indeed the case.

Spin-dependent deep inelastic lepton-nucleon scattering measurements give important information on the total amount of spin carried by s and $\bar{s}$ quarks, and an impressive program of experiments has been carried out at CERN, DESY and SLAC. Measurements of the gluon spin content of the proton, ΔG, are planned at CERN and at RHIC. Taken together, these data can be used to determine the s plus $\bar{s}$ spin content of the proton, Δs. A direct measurement of Δs may also be possible at HERMES. If s-$\bar{s}$ fluctuations are short-lived, one expects Δs to be near zero, while if strange quark fluctuations are long-lived, Δs would not be expected to be small.

In addition to determining the strange sea of the nucleon it is equally important to understand the non-strange sea. The issues are similar. If the $u\bar{u}$ and $d\bar{d}$ fluctuations are mainly short-lived they can be expected to contribute little to the spin of the proton. If they are longer lived, and possibly represented in terms of pions in the proton, they are important for the proton's structure and can be expected to carry a significant amount of the proton's spin. In the next few years direct determinations of the u and d sea contribution to the nucleon spin are expected from HERMES.

Another important way of determining the u and d sea content of the proton comes from the Drell-Yan process of μ-pair production in proton-proton and proton-deuterium collisions. Experiments at CERN and especially at Fermilab show that $\bar{d}/\bar{u}$ is significantly greater than 1 in the medium-x region $0.05 \leq x \leq 0.25$, indicating that the non-strange sea is likely a highly nontrivial and long-lived part of the proton.

The next 5-10 years should be the period when the spin and flavor structure of the proton becomes reasonably well understood. Elastic electron scattering experiments at Bates and TJNAF, direct spin-flavor determinations at HERMES, ΔG measurements at RHIC and μ-pair experiments at Fermilab all have key roles to play in achieving this understanding.

2.1.2 Excited States: The Baryon Spectrum

The experimental determination of the baryon resonance spectrum to masses of ~2 GeV is motivated by the quest to understand the structure of baryonic matter and to identify its key constituents and their effective interactions, as well as the role of confinement in the nonperturbative region. From this should emerge an appropriate description of nucleon (or quark) matter at low energy: constituent quarks and gluons, and the light pseudoscalar meson octet (π, K, η), which are the Goldstone bosons of the spontaneously broken chiral symmetry of QCD.

Perhaps the most fundamental response of the nucleon to excitation is its ground-state polarizability, which can be determined via Compton scattering of real and virtual photons. The polarizabilities set tight constraints on viable models of the nucleon.

Of the expected excited-state resonances of the nucleon and of the Λ, Σ, and Ξ hyperons, only a small number have been observed, and many of those lack quantum-number assignments.

The low-lying positive parity excitations can be described as vibrational states that contain information about the compressibility of nucleon (quark) matter, and the nature of the effective confining interaction between quarks. These states may be highly collective states with considerable $(q\bar{q})^n$ and possibly gluonic components. Because the lowest orbital excitations of all light and strange baryons, with the singular exception of the Λ hyperon, are positive-parity states, in conflict with the normal ordering expected from a monotonic confining interaction, they are crucial to an understanding of the nature of the effective confining interaction and the effective hyperfine interaction between the constituents of the baryons.

Equally intriguing is the structure of the low-lying negative parity states of the N, Λ and Σ. Their puzzling η-decay branching patterns indicate that these negative-parity resonances have a complex structure, not readily describable by conventional versions of the constituent quark model with only 3 valence quarks. The experimental investigation of the spectra of the Σ and the Ξ hyperons is of interest also because, inasmuch as the hyperfine splittings in those spectra should be smaller than in the spectra of the nucleon and the Λ hyperon, these spectra will give more direct information on the form of the confining interaction.

The helicity amplitudes in the electromagnetic transitions $\gamma N \rightarrow N^*$ presently have large uncertainty ranges, which do not allow stringent model discrimination. These amplitudes give the degree of deformation of the spin-3/2 resonances and the role of tensor interaction between the constituent quarks, as well as provide information on the role of nucleon constituents beyond valence quarks.

Nucleon resonance studies with pion and kaon beams allow determination of the πNN^* and KNN^* coupling constants, which are required for the separation of the resonance properties from the continuum background. Separation of the electromagnetic and hadronic resonance couplings requires experimental studies of both electroproduction and mesoproduction of the baryon resonances.

Both the research program at TJNAF and the fixed-target program at the AGS at BNL provide promising opportunities for experimental determination of the baryon resonance spectrum. In addition, the Bates Accelerator Laboratory offers opportunities for studying the structure and decay patterns of the $\Delta(1232)$. TJNAF, LEGS, and Bates provide opportunities to measure the nucleon polarizabilities, as well as the helicity amplitudes of the transitions $\gamma N \rightarrow N^*$ with high precision for most of the nucleon resonances below 2 GeV. The nucleon resonance studies with the pion and kaon beams at the AGS allow determination of the πNN^* coupling constants, which are required for the separation of the resonance properties from the continuum background. The AGS nucleon resonance program therefore complements the nucleon resonance electroproduction research effort at TJNAF and reduces the model-dependence of the resonance parameters.

2.2 Meson Structure and Excited States

The mesons are the simplest bound states of quarks and so have much to tell us about the confining potential. Of particular interest is the ϕ meson and its rare decay modes, as the ϕ meson represents the $s\bar{s}$ analog of the heavy quarkonium systems, which have proven crucial for the phenomenological validation of QCD. The comparison of electroproduction of the light pseudoscalar mesons and the vector mesons will elucidate the fundamental differences between the former, which should be highly collective $(q\,\bar{q})^n$ systems and the latter, which are expected to be simple $q\,\bar{q}$ states.

Precision determination of η-meson decay rates into neutral final states allows determination of several important parameters of the Standard Model. The decay width for $\eta \rightarrow 3\pi^0$ is proportional to the square of the difference between the (current) masses of the u and d quarks:

$$\Gamma(\eta \rightarrow 3\pi^0) = c(m_d - m_u)^2.$$

As the constant of proportionality may be determined by means of chiral perturbation theory (ChPT), measurement of this mass difference would complement the extraction of the current quark masses based on the Gell-Mann-Oakes-Renner relation.

The decay width for $\eta \rightarrow \pi^0\gamma\gamma$ is also important, because as it is highly suppressed, it provides a sensitive test of ChPT. The present empirical value exceeds the ChPT prediction by a factor of 2.

The meson spectrum remains incompletely determined in the region above 1 GeV mass. Knowledge of this spectrum will allow a determination of the detailed form of the effective confining interaction for the constituents of the mesons and a determination of the role of seaquark and gluonic components in the mesons.

An issue of immediate interest is the structure of the two meson states $\pi_1(1370)1^{-+}$ and $\pi_1(1600)1^{-+}$ with exotic quantum numbers recently discovered at the AGS, and which have been confirmed at CERN. As mesons with these quantum numbers cannot be simple quark-antiquark states, the understanding of their structure and the search for other such states provides an immediate opportunity for obtaining new information on the form of the effective strong interaction and the appropriate effective degrees of freedom in the low energy region. The incompleteness in the present understanding is demonstrated by the fact that both numerical lattice methods and quark-model studies alike had predicted that no mesons with exotic quantum numbers would be found below 1.5 GeV.

The study of hybrid mesons ($q\bar{q}g$ states) with exotic quantum numbers and the complete determination of the meson spectrum to ~3 GeV, is also motivated by the search for glueballs, the lowest states of which are predicted to exist in the region immediately above 1.5 GeV. The identification of the glueballs and their distinction from ordinary scalar mesons requires complete determination of their decay patterns.

Both the fixed target program at the BNL/AGS and at CEBAF provide opportunities for mapping out key parts of the meson spectrum at high excitation, and for studying the structure of mesons through their decay patterns. CEBAF provides, in addition, the possibility for determining the form factors of the light mesons, and is well suited for photo- and electroproduction of mesons with masses up to 1 GeV. The high-energy pion beam at the AGS, coupled with the MPS, continues to be an important facility for the production of hybrids. With recent kaon particle ID installed, this program can also be expected to study hybrid states. An upgraded K^- beam (~$10M) at the AGS would provide an opportunity to search for $s\bar{s}$ mesons with gluonic and seaquark components, and should be viewed as an integral part of the exotic-meson search effort. Because the required detectors and instrumentation – the multiparticle spectrometer (MPS) and the recently installed 4π Crystal Ball – are already in place at the AGS, the fixed-target program provides a very cost-effective opportunity to settle important issues in meson spectrometry.

2.3 Properties of Nuclei

2.3.1. Few-Body Physics

Few nucleon systems provide an important testbed for nucleon interaction models, as they permit the use of well-calibrated fundamental amplitudes as input to exact calculations of the nuclear wavefunctions by methods such as the Fadeev equations and the variational Green's function Monte Carlo method. They may also provide means of exploring the appearance of quark effects at decreasing distance scales. Recent results from MIT/Bates show the remarkable success of models where details of the meson exchange and relativistic effects are fully included for deuteron electrodisintegration.

The deuteron is an ideal system in which to test the limits of the relatively large scale where meson exchange provides an excellent description of the internucleon force. New data on the tensor polarization of the recoil deuteron from elastic electron scattering allow separation of the charge monopole, charge quadrupole, and magnetic dipole form factors to moderate values of momentum transfer. This, in turn, allows a determination of the shape of the simplest nucleus, the deuteron, down to 1/10 the proton size.

Studies of polarized deuterium and ^{3}He are important for determining electromagnetic properties of the neutron in addition to testing the theoretical models. Indeed the two problems are closely interwoven and full understanding of the structure and interaction is a prerequisite to reliable extraction of neutron properties. These questions will be studied extensively at Bates and CEBAF.

As experiments on few nucleon systems are extended to higher and higher momentum transfer, they will reveal the short-range nature of the nucleon-nucleon interaction, and complement the information gained from threshold meson production experiments. In particular, it should become possible to examine the transition from the regime in which the nucleon and meson picture is valid to that where the underlying quarks and gluons are the relevant degrees of freedom. Again, early data from CEBAF are probing new domains of precision at large momentum transfer.

2.3.2. Structure of Nuclei

An important component of nuclear structure is the effort to precisely determine the microscopic basis of nuclei. One important tool is the quasi-elastic scattering of electrons. Coincidence studies of (e,e'x) reactions can reveal the wave functions of nucleons in the nucleus and evaluate the short-range correlations between the nucleons. The details of these correlations, particularly at distance scales comparable to that of quark confinement within nucleons, presents a formidable challenge to both experiment and theory. To explore these correlations, it is also important to make measurements for pairs of baryons which can best be performed using large acceptance detector systems such as CLAS at CEBAF or the BLAST detector at Bates.

2.3.3. Hypernuclei

In order to study the short-range hadronic force, it is also important to make measurements for pairs of baryons other than nucleons. One way to do so is through studies of hypernuclei where baryons with strangeness are substituted for nucleons in ordinary nuclei. Hypernuclei allow unique investigation of the weak interaction between a Lambda and a nucleon. The possible existence of double Lambda hypernuclei is also being investigated at the AGS.

The field of hypernuclear physics has been compromised in the past by lack of resolution. New initiatives at both the AGS and at CEBAF promise a new era with an improvement in resolution of an order of magnitude. This improvement will allow separation of close-lying states from different nucleon orbitals which will allow precise measurements of the spin-orbit interaction.

2.4 Effects of the Nuclear Medium

The density in the center of large nuclei corresponds to approximately one nucleon within the volume of a single nucleon, i.e., the nucleons are basically touching each other. In such a hadronic environment novel properties of the strong interaction may manifest themselves. In addition, the hadronic interactions of short-lived particles can be studied by producing them within a nucleus. Thus the nucleus can be used as a new type of "laboratory" for studying the strong interaction.

Color transparency is one example of a novel property of the strong interaction that may be observable using the nucleus as a filter. Color transparency is essentially the vanishing of the strong interaction for a hadron produced through a high momentum transfer process. In fact, such a phenomenon can be predicted within QCD. The simplest observable for the occurrence of color transparency is to measure the variation as a function of momentum transfer of the ratio of the quasi-elastic or diffractive production of a hadron from a nucleus compared to a free nucleon. Previous measurements with A(p,2p), A(e,e'p) and A(μ,μ'ρ) have not shown clear evidence of color transparency. Future measurements at Jefferson Lab (particularly at energies higher than 10 GeV) should be able to study this phenomenon in detail.

Nuclei can also be used to study the strong interaction of short-lived systems, as the transit time for a relativistic particle through the nucleus is only a few times 10^{-23} sec. One of the long-claimed signatures of the QGP is the suppression of J/ψ production compared to that in scaled nucleon-nucleon interactions. That the J/ψ cannot form is indicative that the potential is screened by the plethora of free quarks in the hot plasma. Charm quarks end up bound with lighter quarks (or antiquarks) in the hadronization process. J/ψ suppression has been observed as A-A collisions continue to progress to higher energies and higher mass combinations, but explanations have always existed that do not need to invoke the QGP. Recently, in Pb-Pb collisions, the suppression metric has yielded a significant "kink" possibly indicative of the long-anticipated onset of plasma formation. One of the wrinkles in this field is the unknown J/ψ-N cross section at the relatively low energies with which the J/ψ are formed. A novel experiment has been suggested to measure this missing cross section by observing the annihilation of antiprotons in nuclei of various masses.

As photons, both real and virtual, are vector particles, they may fluctuate into short-lived vector mesons or directly into vector quark-antiquark pairs as they pass through a nucleus. It is expected that such fluctuations may dominate the interaction of real and virtual photons (at small Bjorken x) with nuclei.

2.5 Tests of the Standard Model

2.5.1 Neutrino Mass

Notwithstanding the success of the Standard Model, there is general agreement that the Model is incomplete, a low-energy residue of a larger theory. One of the most promising avenues leading beyond the Standard Model is the question of neutrino mass. If neutrinos were Dirac particles like the leptons and quarks, it would be difficult to understand why their masses would not be similar to those other elementary Fermions, arising from a vacuum expectation value of the Higgs field. The architects of the Standard Model resolved this dilemma neatly by proposing that neutrinos were purely left-handed objects and deprived of right-handed components (such an object must always move at the speed of light). In such a framework, and in accord with the experimental situation at the time, neutrinos are exactly massless. Therefore, the discovery of even a tiny neutrino mass presents a serious problem by disposing of the underlying argument and exposing our ignorance of the true origin of mass. Sufficiently massive neutrinos would also be of cosmological importance, affecting the evolution of the universe.

Experimental evidence for neutrino mass has been accumulating steadily over the last few years. The solar neutrino problem has increasingly pointed toward the disappearance of solar ν_e's via neutrino oscillation to another flavor as the only viable solution. The Liquid Scintillator Neutrino Detector (LSND) collaboration found evidence for the $\nu_\mu \rightarrow \nu_e$ process in 1995, and in 1998 the SuperKamiokande collaboration found evidence for the disappearance of ν_μ's from the atmospheric neutrino flux. Confirmation of these extraordinary experimental results and delineation of the full neutrino mixing and mass spectrum is one of the most compelling and exciting activities ahead.

This program is being pursued by both nuclear and particle physicists, and requires both natural and artificial neutrino sources of many different types. The DOE Medium Energy Program has supported the LSND experiment at the LAMPF accelerator and the neutrino oscillation search at the Palo Verde reactors. The proposed BooNE experiment to check LSND at the Fermilab Booster would call for joint HEP and NP funding, with support for the Los Alamos scientists in particular coming through the Medium Energy Program.

2.5.2 Electric Dipole Moment of the Neutron

The Cabibbo-Kobayashi-Maskawa (CKM) matrix describes the transformation between flavor and mass eigenstates for the quarks in the Standard Model. Because there are 3 generations, a single imaginary phase factor is permitted in the matrix, which means that `direct' violation of time-reversal symmetry can occur in the Standard Model. Time-reversal-invariance violation (TRIV) has been experimentally observed in only one instance, neutral kaon mixing, and is consistent with the Standard Model, but the reason for the smallness of the θ parameter that describes strong CP violation lies outside the framework of the Model. The matter-antimatter asymmetry that has caused our observable universe to be entirely matter likely arises from a microscopic violation of time-reversal symmetry. There is a worldwide program to understand the nature of TRIV, as attested, for example, by the construction of B-factories with that objective.

For elementary particles to possess an electric dipole moment (edm) is forbidden by time-reversal symmetry, and searches for such moments in atoms and in the neutron have reached extraordinary levels of sensitivity. The non-elementary nature of neutrons and atoms complicates the interpretation somewhat, but they offer an essentially different and therefore valuable projection of the origin of TRIV.

The transformation of the LAMPF accelerator into an intense spallation neutron facility, LANSCE, has prompted novel proposals for development of subthermal and ultracold neutron sources. A new experimental approach to the determination of the neutron edm might permit an improvement in sensitivity of as much as 3 orders of magnitude. The present limits are in the vicinity of 10^{-25} e-cm; the Standard Model direct CP violation gives approximately 10^{-31} e-cm.

2.5.3. Neutron and Kaon Decay

Another testable aspect of the CKM matrix is its unitarity; a failure to reach the unit sum would suggest the presence of unknown new generations. The largest element of the matrix is V_{ud} that dominates nuclear beta decay, and the highest precision in its determination is required. The least model-dependent measurements of V_{ud} will come ultimately from the beta decay of the free neutron, but it is necessary to determine both the beta decay correlation coefficients and the lifetime. Disturbing discrepancies presently exist in the data used to extract V_{ud}.

Direct information on V_{us}, the next largest element of the top row of the CKM matrix used in unitarity tests, comes from the decays K_{e3}: $K^+ \rightarrow \pi^0 e^+ \nu$ and $K^+_{e3\gamma}$: $K^+ \rightarrow \pi^0 e^+ \nu\gamma$ carried out with a stopped K^+ beam. Significant improvements in the experimental precision are possible and will be needed as the precision of V_{ud} improves.

3. THE EXPERIMENTAL PROGRAM

3.1 Thomas Jefferson National Accelerator Facility (TJNAF)

3.1.1 Status

The Thomas Jefferson National Accelerator Facility (TJNAF or Jefferson Lab) is the site of the Continuous Electron Beam Accelerator Facility (CEBAF), the nuclear physics community's flagship user facility for research utilizing electron scattering techniques. Construction of CEBAF was initiated in 1987 with a total cost of ~$600M; the facility is now completing its second year of full operations for research with an in-house staff of 423 FTEs. The Jefferson Lab user community consists of well over 1000 researchers.

The CEBAF accelerator design is based on a recirculating electron beam and uses superconducting radiofrequency cavities to accelerate the beam. Three experimental halls with complementary, state-of-the-art instrumentation are the sites of the experimental program.

CEBAF was designed to operate at 4 GeV peak energy and has delivered 4.4 GeV for experiments. 5.0 GeV capability has been demonstrated and will be available for users in FY1999, with 6 GeV expected in the near future. The overall footprint of the accelerator is consistent with that needed for operation at 12 GeV (see 3.1.4, below).

The three experimental halls are instrumented as follows: Hall A has two high resolution 4.0 GeV/c spectrometers (HRS) for electrons and hadrons, and a newly commissioned focal plane polarimeter; Hall B contains CLAS (CEBAF Large Acceptance Spectrometer) which consists of 6 superconducting coils in a toroidal arrangement, drift chambers for particle tracking, gas Cerenkov counters for electron identification, scintillation counters for time-of-flight, and calorimeters for e, γ and neutron identification; and Hall C houses a 7.5 GeV/c high momentum spectrometer (HMS) and a 1.8 GeV/c short-orbit spectrometer (SOS) for high momentum final state studies and coincidence experiments with unstable particles.

The research program approved by the Jefferson Lab's Program Advisory Committee (PAC) consists of 105 approved and 16 conditionally approved experiments requiring almost 1700 beam days. About 1/2 of the proposals submitted for use of CEBAF have been approved.

The approved experiments focus primarily on five physics topics:

1. nucleon and meson form factors and sum rules (14 experiments)
2. few body physics (22 experiments)
3. properties of nuclei (18 experiments)
4. N* and meson properties (33 experiments)
5. strange quarks (18 experiments)

with 31 utilizing Hall A, 46 utilizing Hall B and 28 utilizing Hall C.

At the present time, 10 full and 25 partial experiments have taken data. In Hall A, which began a physics program in spring 1997, 2 complete and 3 partial experiments have taken data. In Hall B, which began a physics program in winter 1997, 1 complete and 20 partial experiments have taken data. In Hall C, which began a physics program in fall 1995, 7 complete and 2 partial experiments have taken data.

The current backlog of experiments is 6-7 years for Hall A, 4-5 years for Hall B, and 5-6 years for Hall C. The PAC has recommended that approved experiments that have not taken data within 3 years of their initial approval should be required to petition for re-approval by the PAC. This "jeopardy" category for approved proposals will begin to take effect next year. It is expected that this procedure will reduce the backlog and open up beam time for new and timely proposals and experiments. With initial operational efficiencies well-known, it is important that future beam-time allocations be made to significantly reduce this backlog.

3.1.2 Operational Performance

The CEBAF accelerator was commissioned during FY1995-96 and ran for its first full year of an experimental program during FY1997. It has demonstrated excellent beam quality with the emittance of its cw electron beam being about 100 times better than previous generation electron accelerators. It delivers 800 kW of beam power into a 100 micron beam spot. It has exceeded its original 4 GeV energy specification, with 4.4 GeV being used for research already, and 5 GeV demonstrated. Some running at 6 GeV is planned for FY1999. The photocathode is operated with 3 independent lasers to deliver electrons with 37% polarization and independently specified intensities to the 3 experimental halls. Intensities up to 100 microamps can be delivered to one or more halls while currents as much as 10^7 times weaker are delivered to the other hall. Beam at the energy of any of the five passes can be split off for any hall as needed, or the full energy beam can be rf split to 2 or 3 of the halls. During FY1998 a hall multiplicity of about 2 is being achieved on the average. Three-hall operation has been achieved for six weeks so far this year. During the recent parity violation measurement the beam demonstrated remarkable helicity-correlated stability with respect to intensity, energy and position.

The accelerator has turned out to be more complex to operate than envisioned. There are 120,000 machine control points resulting in a complexity comparable to LEP at CERN. With extra effort in FY1998, an accelerator availability of 66% and experimental equipment availability of 80% is being achieved. The expectation is for 70-75% machine availability in the long run.

3.1.3 Scientific Program and Highlights

The experimental program at Jefferson Lab addresses many of the forefront issues for medium energy nuclear physics. With emphasis on probing the structure of nucleons and identifying the role of the quark-gluon degrees-of-freedom in nuclei, this program should establish a number of new directions for the field. With precision experiments, often utilizing polarized electrons and polarized targets, new insights into the spin structure of nucleons, definitive data on the elastic nucleon form-factors, identification of possible strange quark components in the nucleon's wave function and a characterization of many of the nucleon's excited states will be provided within the next five years. Key experiments exploring the structure and electromagnetic response of nuclei will provide a baseline for more advanced calculations that describe nuclei in terms of meson-nucleon degrees-of-freedom, and possibly give evidence of the need for explicit quark-gluon degrees-of-freedom. The unique capabilities of Jefferson Lab are well matched to addressing these and other issues as discussed below.

The Structure of the Nucleon

The spin structure of the nucleon has been a forefront issue facing intermediate energy physics for the past decade. Because of the polarized electron beams, the array of polarized targets, and the large acceptance spectrometers available at Jefferson Lab, there is a unique opportunity to resolve some key issues in this field by measuring the spin structure function of the neutron at high x and the momentum transfer dependence of the Gerasimov-Drell-Hearn sum rule.

TJNAF is particularly well-suited for unraveling the up, down and strange quark contributions to the proton form factors. Again, the polarized, cw electron beam, polarized targets, focal plane polarimeter and large acceptance spectrometers bring unprecedented power to the study of these light quark components of the proton.

The ratio of G_E^p to G_M^p for the proton is being measured at Jefferson Laboratory using the newly commissioned focal plane polarimeter in Hall A, while the electric form factor of the neutron is being measured using the polarized target in Hall C. Other experiments are planned to measure G_M^n. Measurements of G_E^n are particularly important, not only for testing models of the nucleon, but also in isolating the up, down and strange quark contributions to the form factors, magnetic moment, and charge radius of the nucleon.

Because of the high quality and stability of the multi-GeV polarized electron beam now available at Jefferson Lab, a new opportunity arises to use parity violating electron scattering as a sensitive probe of the strange quark content of the proton. The HAPPEX experiment at Jefferson Lab was successful at measuring parity violating electron scattering from the proton. The resounding success of this experiment signals that parity violating electron scattering experiments are already feasible at Jefferson Lab. The most comprehensive parity violating electron scattering experiment (G0) is planned at Jefferson Lab. This experiment will allow isolation of both the strange electric and magnetic form factors over a large range of momentum transfer. This comprehensive program of experiments focusing on elastic form factors and parity violation measurements represents an outstanding opportunity to explore, in detail, the basic structure of the proton and neutron.

The Hall B CLAS detector, photon tagging system and the multi-GeV, cw electron beam give rise to unprecedented capability for probing the nucleon structure. One of the main goals of this effort is to search for the "missing" resonances that are predicted by the constituent quark model. Prior searches have focused on the pion-nucleon channel. However, it is suspected that the missing resonances may couple to two pions much more favorably than to the single pion channel. The program in Hall B is aimed at examining a variety of decay channels to search for these resonances. Initial commissioning data taken with CLAS have demonstrated the enormous potential of this device, with only a few hours of data-taking providing significant increases in the world's data for some of the resonance decay channels. An excellent program of resonance studies is thus anticipated with the CLAS.

The new capabilities at Jefferson Lab will also permit the first exploratory look at virtual Compton scattering from the proton. This work will represent the first attempt at isolating the generalized electric and magnetic polarizabilities of the proton over a large range of energy and momentum transfer.

Properties of Nuclei

The facilities at TJNAF are being used to study many aspects of the science discussed in Section 2. Excellent extensive studies of few nucleon systems over a wide kinematic range, including spin dependence, are a major part of the program in all three halls. First, experiments on the separation of the elastic form factors of the deuteron and of the neutron's electric form factor are underway and elastic electron scattering on A=2 and 3 nuclei have already extended our knowledge to much higher Q^2, confirming the power of these new tools. These studies of few-nucleon systems are expected to greatly advance our understanding of the basic nuclear force. Fully utilizing its unique capabilities, there is outstanding potential for TJNAF to make major contributions to this field.

Studies of hadron and multiparticle knockout will provide important new insights into the role of short-range correlations in nuclei. The high resolution dual spectrometer system of Hall A is ideally matched to the needs to resolve individual residual nuclear states following nucleon knockout, and the large acceptance detector CLAS will provide comprehensive information on multi-particle knockout from nuclei with lower resolution.

A program to study transition form factors in the production of hypernuclei and of hypernuclear spectroscopy is also planned in Hall C. Early data as a test of the production mechanism from the proton have already provided good Longitudinal/Transverse cross section separation with very good missing mass resolution. The anticipated resolution of about 0.3 MeV may resolve the spin-dependent doublet splitting.

Nucleus as a Laboratory

Because of the unique high density environment within a nucleus, novel predictions of QCD and QCD-based models can be tested with nucleons embedded in a nucleus. The high luminosity and large solid angle detectors available at Jefferson Lab permit new experiments that can test a number of these predictions. Tests of color transparency (where nucleon-nucleon interactions vanish for a nucleon produced in a high momentum-transfer process), searches for modification of vector meson masses in nuclei, and comparisons of basic nucleon properties (e.g., form factors) for nucleons within a nucleus are expected to be carried out in initial data taking.

Meson Properties and Structure

The high flux of tagged photons allows new searches for exotic mesons that may preferentially couple to photons rather than hadrons. Very little data exist for the production of mesons via a photon probe, and it is anticipated that the vector character of the photon should bring an important new degree-of-freedom to the problem. These studies are of only limited use with 4 GeV beam energy, but become useful at 6 GeV. In fact, at higher energies there is outstanding potential for providing crucial information on the basic structure of simple systems composed of gluons and quarks.

There is also promise that new information on the high momentum transfer behavior of the pion and kaon electromagnetic form factors may be obtained using pion and kaon electroproduction from the proton. These high statistics measurements are possible due to the cw beam, high luminosity and large acceptance detectors at Jefferson Lab.

3.1.4 Plans for the 12 GeV Upgrade

The possibility of tripling the CEBAF design energy opens up a wealth of scientific opportunities. In particular, it adds a powerful new probe into gluonic degrees of freedom in mesons and strange quarkonia, permits precision studies of deep inelastic scattering in the valence quark region, opens up studies of few body systems at the shortest possible range, and provides the most powerful means to study scaling effects and nuclear transparency.

The overall plan is to attain 6 GeV by 1999, with evolutionary upgrades to nearly 8 GeV possible. Following this, the construction for the 12 GeV upgrade would begin by 2004. Operation at 12 GeV would then begin in approximately 2006. This gain of a factor of three in energy is expected to have a cost of approximately $40M. This preliminary cost estimate accounts for improvements in cryomodules, new cryomodules to be placed in existing drift space in the linac regions, new power supplies for the existing arcs, and construction of a tenth arc to give 5 1/2 passes.

A new photon-only Hall (Hall D) and detector would be added after 5 1/2 passes to make use of the highest possible energy. The approximate cost of this new Hall and upgrade of existing experimental equipment is expected to be approximately $40 M. This cost has been reduced by the proposed use of the existing LASS solenoid at LANL as a central part of the Hall D spectrometer. In addition, the upgrade of experimental equipment in Hall A and B is expected to be relatively modest, although the region I detector package would have to be rebuilt in Hall B. A new Super High Momentum Spectrometer (12 GeV/c) would be required for Hall C.

3.2 MIT/Bates Linear Accelerator Facility

3.2.1 Status of the Facility

The MIT/Bates Linear Accelerator Facility in Middleton, MA, is operated by MIT as a national user facility. At this time there are approximately 65 FTEs at MIT/Bates supported directly by the DOE Nuclear Physics Medium Energy Program, with about 20 additional FTEs supported by MIT. The original 500 MeV linear accelerator, which began operation in 1974, was upgraded to 1 GeV by the addition of a recirculator which was operational in 1982. Major additional construction and upgrades have been in progress since 1988 when the South Hall Ring (SHR) Project was initiated. The purpose of the SHR is to increase the duty cycle from 1% to near 100% for both internal target operation and external beams. The MIT/Bates Facility has over 200 active users representing 52 different institutions.

The construction of the SHR, substantially completed in 1993, was followed by major upgrades of the linac and recirculator. Presently, those upgrades are about 80% completed. During 1998 the linac is running very reliably with high currents of polarized electrons for the SAMPLE experiment. The out-of-plane spectrometers (OOPS), which have been under construction since 1989, are nearing completion, and the Bates Large Acceptance Spectrometer Toroid (BLAST) is under construction.

The SHR has been partially commissioned for both the stored beam (60 mA stacked and 6 min lifetime at 750 MeV) and extracted beam with an 80% extraction efficiency. To date, no research using the SHR has been performed. Substantial effort remains to achieve the goals of high current, polarized stored beam and high duty factor, extracted polarized beam.

3.2.2 Machine Performance

The upgraded linac is providing very reliable and stable polarized electron beams at 200 MeV for the SAMPLE experiment. The machine is delivering 4 mA peak currents with integrated charge of approximately 2 Coulombs per day. The position and energy stability during spin flips at 600 Hz have been excellent.

The final stages of accelerator upgrade include new klystrons and transmitter modifications for the linac and further development of the polarized source to increase the polarization at high intensity.

Under a full funding scenario SAMPLE would continue running in 1999 and the OOPS spectrometers would begin data taking with pulsed beam. South Hall Ring extracted beam would be developed in 1999, leading to extracted polarized cw beam in 2000. Stored polarized internal beam would also be developed in 2000, prior to the completion and initial operation of BLAST with that beam in 2001. Under the FY1999 President's Budget, there is no plan to complete the SAMPLE experiment. The subcommittee found the physics case for the SAMPLE experiment to be outstanding and believes that it should be completed under any funding scenario.

3.2.3 Scientific Program and Highlights

The scientific program at MIT/Bates was presented in three well-defined categories: the SAMPLE experiment, the OOPS program and the BLAST program.

The SAMPLE Experiment

The SAMPLE experiment at MIT/Bates is searching for contributions of $s\bar{s}$ to the proton magnetic form factor G_M^S at very low momentum transfer Q^2=0.1 GeV^2/c^2. The measurement utilizes the interference between the parity violating component of Z^0 and parity conserving γ exchange interactions between the electron and the nucleon. Because the electromagnetic and weak currents of the hadrons have different, but known, coefficients for the different flavor components in the standard model, the experiment allows a separate determination of the matrix element $\langle p|\bar{s}\gamma_\mu s|p\rangle$, which yields the contribution of $s\bar{s}$ components to the magnetic form factor of the proton. This is a fundamental quantity of the proton, similar in importance with its magnetic moment, and in particular with the contribution of strange quarks to the proton spin and mass.

The 1998 run of the SAMPLE experiment was successfully completed for the proton. This work should admit a significant reduction of the statistical uncertainty range of the published preliminary result of the SAMPLE experiment G_M^S (0.1 GeV^2/c^2) =0.23± 0.37± 0.15 μ_N. The preliminary value appears to exclude theoretical predictions with large negative values.

Conventional theoretical models as well as a recent lattice calculation based on the "valence" approximation to QCD suggest that $G_M^S(0)$ should be negative. Should the SAMPLE experiment yield a definitely positive value for $G_M^S(0)$, it would stimulate a considerable theoretical effort for correcting the present qualitative understanding of the proton. Inevitably such a result would raise the question of the momentum dependence of the form factor, and stimulate further experimental effort.

The SAMPLE experiment yields information on the $s\bar{s}$ components of the proton, which is important in itself and complementary to that gained in the experimental efforts to determine the strange quark contribution to the proton spin Δs and the understanding of the strange quark contribution to the proton mass that has been obtained by means of chiral perturbation theory.

In order to significantly reduce the remaining systematic error, the SAMPLE experiment will be repeated in 1999 with a deuterium target. The nuclear structure corrections are expected to be small and calculable. The crucial gain in the deuterium target experiment is that it allows elimination of the systematic error due to the contribution of the poorly known weak axial form factor of the nucleon to the measured parity violating asymmetry.

Successful completion of the SAMPLE experiment on a deuterium target presents an outstanding opportunity for gaining a new fundamental understanding of the structure of the proton.

The OOPS Program

The Out of Plane Spectrometers (OOPS) system at Bates is a unique system of four spectrometers which can be positioned accurately about the recoil momentum vector q. This permits measurements of interference response functions from which one can extract new information on the structure of nucleons and nuclei. The system is optimized to measure small effects with relatively high luminosity, and this is complementary to large solid angle detectors such as the BLAST detector.

The central areas of interest covered by the OOPS program are studies of the nucleon and few body systems. In particular, virtual Compton scattering and the $N \rightarrow \Delta$ transition experiments are proposed as a way of studying the generalized polarizabilities of the proton and the deformation of the Δ, respectively. The studies of few-body systems are aimed at testing microscopic models of nuclei.

The out-of-plane feature of OOPS should allow selection of kinematics, which greatly enhances the signal in Virtual Compton Scattering relative to the competing Bethe-Heitler background. This would be an excellent way, certainly at low Q^2, to determine these polarizabilities in purely electromagnetic processes. Such data will provide important tests of QCD in the low Q^2 domain. The OOPS represent an excellent opportunity to study these generalized polarizabilities without the severe problem of Bethe-Heitler background.

The unique kinematics of OOPS and the high luminosity capability will facilitate studies of small components of the wave functions of few nucleon systems which can be calculated exactly. Data already taken for the deuteron showing the importance of relativistic effects are indicative of the power of this approach.

Another primary thrust of the OOPS program is detailed study of the $N \rightarrow \Delta$ transition. This provides amplitudes of key interest in hadronic physics, namely that involving the resonant quadrupole excitation of the Delta. Extraction of this is difficult both because it is very small and because of larger non-resonant background from coherent processes. In order to isolate the systematic errors associated with these background processes, a program of measuring all the $N \rightarrow \Delta$ channels is proposed. Although competing approaches have been proposed at TJNAF and at the BLAST, OOPS allows a good opportunity to study this important problem without the complication associated with polarized targets or proton polarimeters.

The BLAST Program

The BLAST coupled with internal polarized gas targets and the high-current polarized electron beam in the SHR provides a unique and powerful capability to probe nucleons and nuclei. The main BLAST physics thrusts are (1) nucleon electromagnetic form factors, (2) precise measurements of spin-dependent momentum distributions in few-body nuclei, (3) spin-dependent reaction mechanisms, (4) spin-dependent pion electroproduction, and (5) the $N \rightarrow \Delta$ transition with polarized beam and target. The SHR in conjunction with BLAST is expected to address these issues in the low-momentum transfer region better than with any other facility.

The capability to use pure targets of polarized hydrogen, deuterium and ^{3}He will provide a better systematic error than previously available for the nucleon form factors and the few body systems. In particular, the neutron electromagnetic form factors can be determined from either a deuteron or ^{3}He target. With the BLAST, a detailed comparison can be made for these targets, pinning down the relatively large final state interactions as well as comparing to the proton form factors which are measured in the same experiment for the deuteron target.

Measurements of G_E^n are expected to be made with unprecedented statistical and systematic accuracy in the low momentum transfer region ($Q^2 < 0.5$ GeV^2). This would permit the study of G_E^n in the nuclear medium and should provide the most sensitive test of medium modifications on G_E^n.

The BLAST in conjunction with the polarized beam and polarized internal targets will provide a sensitive probe of few body systems. For example, the spin-dependent momentum distributions in deuterium and ^3He can be probed both on the quasi-elastic ridge and far off the quasi-elastic ridge to study the effects of reaction mechanisms on the results. This should lead to a good understanding of few-body systems. In the case of the deuteron, one can also study the D(e,e'p) reaction from tensor polarized deuterium. This will probe the deuteron S and D states at relatively high missing momenta where the D state dominates. In the case of ^3He, the S' state may be determined experimentally. Since these are relatively small pieces of the few-body wave functions, the data taken over the widest possible kinematic range are necessary to unravel effects from final state interactions, Δ excitation, and meson exchange currents. All these effects may be studied simultaneously with the large kinematic acceptance of the BLAST.

Spin dependent electroproduction on few-body nuclei may be studied from threshold to the resonance region. One may use this technique to search for pre-existing Δ's in the ground state of ^3He. This will be very interesting from the viewpoint of confirming the Fujita-Miyazawa mechanism which is common to all theoretical treatments of the three-body force.

The $N \rightarrow \Delta$ interaction may be studied with sufficient kinematic range and decay channels to unravel the resonance from the nonresonant background parts of the reaction in a single experiment at BLAST. Here, the goal would be to isolate the resonant part of the interaction. Previous experiments do not measure sufficient energy transfer range to map out the nonresonant parts.

In summary, the BLAST program provides an excellent opportunity to make a significant advance in our understanding of the structure of the nucleon and few-body nuclei.

3.2.4 Plans for the BLAST/SHR

In order to prepare the SHR for an internal target program, it is necessary to have high current, polarized stored beams. Clearing electrodes will be installed in the SHR in 1998, and the Siberian snake will be installed and commissioned in 1999. The SHR commissioning program calls for stacking of high current beam up to about 300 mA with a lifetime of more than 5 minutes. In addition, beam scrapers will be installed to minimize the injection flash for BLAST. The stored beam operation is expected to be both simpler and less expensive than extracted beam operation.

For the extracted, polarized beam, a spin rotator must be installed and commissioned on the external beam line during 1999. Extraction line instrumentation must also be installed during 1999. The first extracted, unpolarized beam experiment could begin during 1999. MIT/Bates plans to benefit from NIKHEF's experience in commissioning both stored and extracted beams through collaboration with the NIKHEF accelerator physicists.

The Bates Large Acceptance Spectrometer (BLAST) is a nearly 4π large acceptance spectrometer with a momentum acceptance from 0.15 to 0.9 GeV/c and resolution of 1-2 %. The angular resolution of the device is typically < 5 mrad. The design has a relatively large field and gradient field free region which is optimized both for use with polarized targets and to minimize the "sheet of flame" problem associated with pair production in a large dipole field. The detector should accommodate a luminosity of 10^{33} $cm^{-2}s^{-1}$.

The internal polarized ^3He target should be installed and tested in 1999. The polarized hydrogen/deuterium targets will be provided by NIKHEF through a collaborative effort. A laser-driven target is being developed at MIT for use in BLAST.

The toroid consists of 8 sectors, of which two will be instrumented with detectors and two will be reserved for polarized gas target inlets and vacuum pumps. The toroid is expected to be installed in 1999, the beam polarimeters and detectors will be installed in 2000, and the BLAST will be commissioned in 2001. In order to complete the scientific program, the BLAST would have to operate through 2004. The cost of the BLAST including targets is approximately $5.8M.

3.3 Other Experimental Programs

Much of the balance in the overall DOE Medium Energy Physics Program stems from the unique opportunities described next. In each case, nuclear physicists have or will employ accelerators whose primary support is drawn from resources outside of the Medium Energy Physics budget. As such, many of the programs are particularly cost effective and include several outstanding opportunities.

3.3 AGS Fixed-Target Program

The AGS delivers high-intensity secondary beams of muons, pions, kaons and antiprotons to numerous experiments in the fixed-target areas. Several beamlines have been used and adapted over nearly four decades to accommodate a wide variety of physics initiatives stemming from both high-energy and nuclear-physics domains. The facility is unique in the world; no other beams will exist with such rates at intermediate energies until the middle of the next decade when the Japan Hadron Facility is planned to come online offering beams of even greater intensity.

Nuclear physics efforts at the AGS fixed-target area now use three distinct beam lines. Physics addressed includes the search for exotic mesons, hypernuclear production and decay measurements, eta decay studies, and programmatic evaluation of nucleon and hyperon resonances. At the crossroads of nuclear and particle physics are efforts ongoing and planned including the semi-rare K_{e3} decay (V_{us} in the CKM matrix), the muon anomalous magnetic moment, and a letter of intent for measuring G_F by a precision measurement of the muon lifetime. Typical of these projects is a significant number of nuclear physicists as main participants (for example, all three are led by nuclear physicists). High-energy physics efforts have been centered on a diverse program of rare K-decay measurements. Future projects which are now in development aim to measure the decay rate for $K^0 \to \pi^0 \nu\bar{\nu}$ and to test direct muon to electron conversion to unprecedented precision.

The AGS is currently funded by the DOE High-Energy Physics Program. This arrangement will cease at the end of FY1999. The new nuclear physics experiments described below are subject to availability of slow-extracted beam. Funding implications are discussed in Sections 4 and 5.

Program highlights over the past few years include the discovery by the E852 Collaboration of a 1^{-+} exotic meson candidate at 1400 MeV. The announcement of this finding generated a great deal of worldwide attention and some controversy within the physics community. Among other issues, the theoretical bias suggests that exotic mesons have masses closer to 2 GeV. Within the year, the Crystal Barrel experiment at LEAR confirmed the discovery and E852 reported a second exotic at 1600 MeV. The higher mass state is observed in two different decay modes. Understanding the nature of these states and whether additional exotics exist is very important. A natural future extension to this excellent program is to run at higher incident pion energies. A letter of intent is being submitted to management at present and the fiscal implications are being evaluated.

A first-rate program of strangeness nuclear physics has been carried out at the AGS. A decade-long search for the elusive H particle has resulted in stringent limits on its production, but no H. Present efforts are aimed instead at production of $\Lambda\Lambda$ hypernuclei, the observation of which would set lower mass limits and greatly restrict the possibility of a bound H particle. This search has garnered much theoretical attention as a vast array of models on confinement predict H masses ranging from deeply bound to "deeply" unbound. New instrumentation, provided largely by Japanese collaborators, has enabled precision measurement of gamma rays following hypernuclear formation. With a new GeBall, resolution improvements by a factor of 1000 are expected compared to conventional efforts, yielding information on the spin-spin, spin-orbit, and tensor interaction in the ΛN system. In another experiment, the LANL Neutral Meson Spectrometer is being used to make an important test of the $\Delta I=1/2$ rule in the non-mesonic weak decay of the Λ.

The SLAC Crystal Ball was recently moved to BNL. Experiments employing this hermetic NaI calorimeter are diverse. They include a completed precision measurement of $\eta \rightarrow 3\pi^0$ decay (relevance to ChpT), study of the low-lying nucleon resonances, study of the low-lying hyperon resonances, and a precision measurement of K_{e3}. The π and K induced resonance program is important because of its complementary contributions to the CEBAF/CLAS N* effort. The combined data will be used in a modern coupled-channel analysis of the nucleon and hyperon resonances. The K_{e3} experiment ($K^+ \rightarrow \pi^0 e^+ \nu$ decay rate) aims to determine V_{us} to 0.35%, a level comparable to the precision aimed for in V_{ud} (see below, neutron beta decay). Together, these measurements test unitarity in the top row of the CKM matrix. At present, V_{us} contributes significantly to the uncertainty in the expression $\Delta = 1 - |V_{ud}|^2 - |V_{us}|^2 - |V_{ub}|^2 = 0.0027 \pm 0.0019$. A new precision measurement of V_{us} is therefore an excellent physics goal.

3.3.2 RHIC Spin and p-A Opportunities

Anticipated running of the RHIC collider in pp, p-A, and polarized pp modes suggests exciting physics opportunities pertinent to Medium Energy Physics priorities. Such endeavors are particularly cost effective.

Commensurate with the excitement over the past decade in the nucleon spin decomposition problem, is a new and outstanding opportunity to probe the gluon contribution to the spin structure function. The RHIC spin program is aimed primarily at a measurement of $\Delta G/G$ of the proton as well as measurements of the light quark contributions to the proton spin. These measurements will be performed in the STAR and PHENIX detectors. In addition, cross sections and polarizations (the $pp \rightarrow pp$ experiment) will be measured for proton-proton elastic scattering. Finally, the Brahms and Phobos detectors will be used to measure twist-3 quark-gluon correlations.

An array of new equipment is necessary to perform the RHIC spin program. In conjunction with the Riken/BNL MOU, a second muon arm is being provided by the Japanese Riken Laboratory for the Phenix detector. Additionally, Riken will provide funding for the essential accelerator additions responsible for spin transport (snakes, rotators), the initial polarimetry, and a new polarized proton source. Additional equipment needs exist. An endcap EM calorimeter is necessary for the STAR detector in order to cover a larger x region in the $\Delta G(x)/G(x)$ measurement. A helical Siberian snake is needed for the AGS to achieve full polarization. Finally, a polarized jet target is essential for the beam polarimetry. The recently established Riken BNL Research Center will initially offer on-site theoretical support. On-site experimentalists devoted to the particular RHIC spin efforts have not yet been identified and make up part of a request by BNL for additional funding which would go a long way toward realization of this program.

An additional program of unpolarized p-A collisions could be of considerable interest if the necessary running time can be found within the context of the base program. J/ψ, ψ' and μ-pair production in very high energy p-A collisions are of interest in their own right and could be important in using charmonium and μ-pair production as a diagnostic for quark-gluon plasma formation in A-A collisions. p-A collisions at RHIC could also furnish a means of measuring the amount of gluon shadowing, an important element in calculating the amount of energy freed in a heavy ion collision, from the rate of open charm production. This program is a natural extension of the very productive high-energy Drell-Yan program at Fermilab.

3.3.3 Fermilab Opportunities

As discussed above, μ-pair production at Fermilab has already given important information on $\bar{d}/\bar{u}$ which is a key element in understanding the flavor structure of the proton. Significantly more precise results, especially in the large x region, could be obtained using the beam from the Fermilab Main Injector, a beam which has 7 times the luminosity of the higher energy beam used in previous μ-pair experiments. A proposal, now pending at FNAL, aims to extend the successful NuSea Collaboration work to the high-x region. If successful, this new initiative represents an attractive and logical next phase. Reconfiguration of the spectrometer and construction of a new magnet require nuclear physics funding.

Another interesting opportunity is to use the beam from the Fermilab Antiproton Accumulator to produce low energy J/ψ's in a nuclear target. Since the J/ψ's would be formed inside the nucleus the J/ψ-nucleon cross section, an important ingredient in interpreting data in relativistic heavy ion collisions, could be determined from the A-dependence of the production cross section.

3.3.4 DESY Opportunities in Spin Physics

A major U.S. nuclear physics investment has been made in the HERMES experiment at DESY lab in Hamburg, Germany. This fixed-target experiment uses deep inelastic scattering of electrons and positrons (from the HERA storage ring) from polarized hydrogen, deuterium and ^{3}He to explore the spin structure of the proton and neutron. The experiment has confirmed the inclusive scattering results from SLAC and CERN, where the total contribution of quarks to the nucleon spin can be determined. But, with large forward angle acceptance and extensive RICH-based particle identification, HERMES should provide new information on the separate flavor contributions (including the contributions of the strange quark) as well as valence vs. sea quark components. This is possible by detecting one or more scattered hadrons in coincidence with the scattered positron or electron. A recent upgrade of the detector to enhance detection of particles containing a charm quark may allow a first measurement of the gluon contribution to the nucleon's spin.

After a significant capital investment, the apparatus is completed and preparing to take data from a longitudinally polarized deuterium target for the next two years. At that point the collaboration intends to reassess the physics issues and the state of the data set and will decide between continued running with longitudinal polarization or change to a several-year run with transversely polarized targets to address new structure functions that are accessible with such targets. The subcommittee was impressed with this program and its prospects for potentially outstanding discoveries.

On a longer time scale, studies are under way to determine the feasibility of colliding the presently polarized electrons and positrons with a polarized proton beam in the collider. Such a measurement could provide important information on the gluon contribution to the nucleon's spin via measurements at large momentum transfer where the gluon's role in the nucleon's structure is enhanced. The technical design of producing polarized protons in the storage ring is under development and the laboratory should make a decision on this upgrade within 4 - 5 years.

3.3.5 Neutron Physics at LANSCE

The LAMPF accelerator continues to operate with funding provided by the DOE-DP office. The intense proton beam is used to produce neutrons by spallation for a variety of defense and non-defense research interests at the Los Alamos Neutron Science Center (LANSCE). Beams of polarized cold neutrons and techniques for production of ultra-cold neutrons have been developed. LANSCE is a pulsed (high-peak flux) neutron source unlike the ILL reactor (cw) facility where the integrated flux is higher. Three initiatives have been identified which are appropriate for staging at LANSCE.

An outstanding example is a proposed measurement of the neutron beta decay asymmetry. Evaluated with a comparable neutron lifetime measurement (elsewhere), this leads to a precise determination of V_{ud} in the CKM matrix. V_{ud} is a fundamental and important cornerstone of the matrix which is usually extracted from superallowed 0^+ to 0^+ transitions in nuclei. Nuclear physics theory is necessary to extract V_{ud} in those measurements but does not enter for the bare neutron decay. As mentioned above (see V_{us} in AGS programs) unitarity in the top row of the CKM matrix is violated by approximately 1.5 σ. A precision measurement of V_{ud} is very important. In addition to a direct contribution to this problem, the neutron beta decay asymmetry has bearing on extensions of the Standard Model such as scalar, or tensor terms and right-handed currents. The experimenters have developed a mechanical rotor source for ultra-cold neutron (UCN) production and recently have entered into R&D efforts to make a more promising superthermal solid deuterium source which should result in a 10-fold increase in UCN density. The essence of the beta decay experiment is to trap polarized UCN in a vessel (with internally reflective walls) contained in a solenoid field (neutron spin along axial direction). Neutron decay electrons then spiral to either end of the vessel representing aligned and antialigned decay rates. The asymmetry, A, would be measured to 0.2% in approximately 100 days with the rotor source; with the superthermal source, an improvement by a factor of 10 or more is possible.

A second solid effort involves the use of polarized cold neutrons in a proposed new beam line at the Lujan Scattering Center. The measurement of parity violation in neutron on para-hydrogen is indicated in the decay asymmetry (A_γ^{np}) of the emitted γ in the d + γ final state, enabling the determination of the amplitude h_π^1, one of seven terms describing the hadronic weak interaction. Complementary measurements of other parameters are ongoing or planned and utilize different facilities. h_π^1 can be calculated in both QCD sum rule approaches as well as ChPT. The experiment, whose total equipment cost is approximately $2.5M, is technically quite challenging; however, outside review by experts is very positive and the collaboration is first rate.

A third initiative aims to probe the neutron's electric dipole moment (edm), d, to a level 100 times beyond the currently anticipated limit of 1×10^{-26} e-cm aimed for by physicists at the ILL. Historically, limits on the neutron's edm have steadily been reduced, eliminating large classes of beyond the Standard Model theories along the way. The proposed LANSCE limit serves as an impressive test of modern super-gravity-based SUSY theory. To accomplish this feat, the entire experiment would be developed in a superfluid ^{4}He bath, doped with polarized ^{3}He which would serve as the UCN polarizer, spin analyzer and magnetometer. This project is in the conceptual design stage with a full proposal not expected for several years. If the program can be realized, it represents an outstanding opportunity that should be pursued.

3.3.6 Real Photons

LEGS Facility

The LEGS facility consists of a polarized, nearly monochromatic photon source in the energy range from 140 MeV to 470 MeV, a newly developed large acceptance detector, and a novel polarized hydrogen/deuterium target as well as unpolarized targets. The

LEGS Collaboration has done an excellent job in recent measurements and in state-of-the-art technical developments

High accuracy studies were performed for the nucleon and Δ with this facility. In particular, the E2/M1 ratio in Δ photoexcitation was measured to high accuracy, confirming that the Δ has a non-vanishing D-wave component. In addition, the backward spin polarizibilities of the proton were measured and found to be in disagreement with existing chiral perturbation theory models.

The focus of studies over the next five years centers around studies with polarized photons and polarized H/D targets. These studies include (1) nucleon spin polarizabilities in polarized Compton scattering, (2) nucleon spin sum rules such as the Gerasimov-Drell-Hearn sum rule, and (3) experiments at other facilities such as Jefferson Lab or SPring8.

With the development of a new detector, a new laser system which extends the photon energy range from 300 to 470 MeV, and a novel polarized H/D target, the BNL group is well-situated to address some excellent physics issues during the next five years. In particular, the photo-phi production experiment proposed for the SPring8 facility addresses the forefront question of the strangeness content of the proton.

TUNL/Duke Free Electron Laser (FEL) Gamma-ray Source

The proposed gamma-ray source at TUNL would be high intensity, polarized, nearly monochromatic and in the 2 to 165 MeV energy range. The expected photon intensity is approximately two orders of magnitude higher than existing photon sources. The source relies upon an advanced technology where light from the FEL is backscattered from the electron beam in the FEL ring.

Some highlights of physics opportunities that this new photon source is expected to address are: (1) cross section measurements for astrophysics studies, (2) the Gerasimov-Drell-Hearn sum rule for the deuteron, (3) photodisintegration studies of few-body systems, and (4) tests of effective field theories in near threshold photopion experiments.

An excellent scientific opportunity could be the measurement of the target asymmetry near the photopion threshold. The region between the $H(\gamma,\pi^0)p$ and $H(\gamma,\pi^+)n$ threshold is particularly sensitive to isospin breaking from the up-down quark mass difference. Here, the intensity, resolution and low background expected from this type of source would be essential for this experiment.

The cost of the facility upgrade was estimated to be $4.67 M over 3 years. This cost includes an average of 3.5 FTEs of new manpower for this project. The operating expense is expected to be approximately $300K/year for 1000 hrs/year dedicated to nuclear physics.

The subcommittee recommends that DOE proceed with a scientific and technical review of this interesting proposal.

3.3.7 Neutrino Physics

In 1994 the Liquid Scintillator Neutrino Detector (LSND) collaboration reported evidence for neutrino oscillations in the conversion of ν_μ from the decay of stopped positive muons to ν_e. The result was born in controversy but has in subsequent runs been reproduced, and most recently has been corroborated by observation of the $\bar{\nu}_\mu$ to $\bar{\nu}_e$ transition with decay-in-flight neutrinos, albeit at a somewhat lower level of significance. The LSND conclusion, that neutrino flavor is not conserved, that neutrinos oscillate, and that they have mass, was the clearest and most direct indication of a breakdown of the Standard Model. Evidence for solar neutrino oscillations has grown steadily over the years, and in 1998 the SuperKamiokande collaboration announced strong evidence for oscillations in atmospheric neutrinos.

These three indications of neutrino oscillations are important in providing evidence for physics beyond the Standard Model and a cosmological role for massive neutrinos. It is highly desirable to confirm these results. The Karmen collaboration has recently upgraded its detector at the ISIS facility in England to reduce backgrounds. After more than a year's operation, no events have been seen, a result in moderate conflict with LSND. When the MINOS experiment begins operation it will have sensitivity to the LSND space, but with limited precision for small mixing angles.

A new collaboration has been formed to build a new and larger detector at the Fermilab Booster. Support for the program would come from both DOE HEP and NP, and a first phase, MiniBooNE, in which the LSND detector is re-sited at FNAL, has been approved by the Fermilab PAC. The nuclear physics component of this program would come from in-kind contributions augmented by modest new capital equipment for repairs and upgrades. Subject to a successful technical review, this program is viewed by the subcommittee as having major consequences for physics and, therefore, high priority.

The evidence for oscillations in the atmospheric neutrino spectrum and angular distribution makes it of interest to carry out reactor oscillation experiments at baselines of order 1 km. One such experiment, Chooz, indicates that conversion of ν_μ to ν_e is not the dominant process in the atmospheric neutrino phenomenon. The Palo Verde experiment now in progress explores the same mass range. Unfortunate delays have made it unlikely that Palo Verde will have a major impact, but completion of this program in FY1999 seems feasible and will provide a check on the very significant conclusion reached by Chooz. The former Kamioka detector is the site for a new scintillation detector, KamLAND, proposed by a Japan-U.S.-Hungary collaboration. KamLAND will be, among other things, a very long-baseline reactor antineutrino oscillation experiment with a reach in Δm^2 that extends partly into the solar neutrino parameter space.

3.4 National Laboratory Programs

In addition to the research effort at TJNAF, DOE Medium Energy Physics supports research programs at three other national laboratories – Los Alamos National Laboratory, Argonne National Laboratory, and Brookhaven National Laboratory. The subcommittee heard overview presentations for each of these programs. In addition, the research activities which they support have appeared implicitly or explicitly in many sections above.

The scientific and technical resources of the national laboratories have been essential for the development, construction and implementation of almost all the experimental activities described in section 3.3. With very few exceptions, the university groups do not have the resources to take on major components of modern experiments in medium energy nuclear physics. Support of these laboratories which do have the necessary infrastructure is essential to maintaining a balanced scientific program in medium energy nuclear science.

The largest of the three programs is at LANL ($7M per year). It has evolved in recent years from a research program which mainly supported activities at LAMPF to one working on the cutting edge of many areas of intermediate energy nuclear science. An ambitious plan was presented to focus activities in three directions: research with cold and ultra-cold neutrons at LANSCE, research at RHIC and the BooNE experiment at FNAL. In order to carry out this program within a constant effort budget, other areas of the LANL research program will be phased out and the Laboratory presented a convincing plan to do this. This transition will be greatly facilitated by a modest increase in operating funds in the years FY2000-2002, returning to the FY1999 effort level thereafter.

A smaller ($3M per year), but also very effective research program is in place at ANL. This program has made outstanding contributions in recent years to the CEBAF experimental program, to the HERMES experiment and to Drell-Yan experiments at FNAL. For the future, ANL expects to continue strong participation at CEBAF and is taking the lead in development of a new experiment at FNAL. In addition, a new program in weak interactions and laser trapping is being started. This is an exciting area of physics but the subcommittee has not been able to evaluate the promise of this effort compared to that of other groups working in the same field.

At BNL, the program is in transition. In recent years Medium Energy Nuclear Physics has supported two strong and independent research groups: the LEGS group at the NSLS and the medium energy group working at the AGS. Currently, planning is very difficult owing to uncertainties in the future of the fixed target program at the AGS. The outcome of this is unpredictable but in any event the subcommittee strongly supports the development of a focused program at BNL directed towards RHIC spin. This is an area of outstanding promise which will need effective local support to be successful.

3.5 The DOE University Program

The university component of DOE's Medium Energy Nuclear Physics Program is a major intellectual foundation of the field and is an essential component for the training of the next generation of nuclear scientists. The mission of the university program includes research at the cutting-edge of medium energy nuclear physics, training of graduate students and postdoctoral fellows, and the education of undergraduates.

University groups constitute a diverse set of program tasks with groups located at universities in 16 states plus the District of Columbia. In addition to using local facilities, many university experimental groups actively use the forefront large-scale facilities available to the field including Bates at MIT, CEBAF at TJNAF and the AGS at Brookhaven. Participation of university groups in collaboration with other university groups and/or groups from the national laboratories is an important strength of the field and results in the strong technical and scientific teams needed to fully exploit the potential of these facilities. Theory also constitutes an important part of the university program and contributes both to basic nuclear theory and to the phenomenology needed to parameterize and systematize data.

The DOE Medium Energy Nuclear Physics Program consists of 40 tasks located at 32 universities with an overall budget of just under $15M (FY1998$). At present, the program supports the research of 81 faculty members, 30 non-faculty researchers, 56 postdoctoral fellows, 113 graduate students and 24 undergraduate students. These research activities result in an average of about 12-15 PhDs being awarded each year.

The scope of the 40 tasks that make up the university program varies greatly, ranging from the MIT task at the Laboratory for Nuclear Science with a budget of almost $4M to almost a dozen tasks with budgets under $100k. Seven tasks have a budget in excess of $500k. The budget distribution of the tasks is very strongly dominated by numerous small tasks supporting a faculty summer salary, students and perhaps a postdoctoral fellow.

This subcommittee is concerned that the current budget distribution may not be optimum for the scale of coordinated effort that modern experiments in the field require. It may be better to increase support for some of the stronger groups to keep them viable. Also, it is especially important that outstanding young people with great potential be nurtured and given an opportunity in the field. Although there is significant value in having programs in this field located in many universities in diverse settings with groups of wide-ranging size and styles, the exigencies of tight budgets may require some redirection of funds to assure that the most important scientific opportunities can be successfully exploited.

4. ISSUES FACING THE MEDIUM ENERGY PROGRAM

4.1 Developments Since the 1996 Long Range Plan

In their letter to NSAC, Martha Krebs and Robert Eisenstein place particular emphasis on the changes that have occurred in the Medium Energy Nuclear Physics Program since the submission of the 1996 Long Range Plan (LRP), writing:

> In the Medium Energy program significant changes have occurred and new opportunities have emerged since the writing of the LRP. In the FY 1999 DOE Nuclear Physics Congressional Budget Request, support is provided for TJNAF at the NSAC recommended level, for Bates to develop BLAST, for a wide range of experiments at various stages of implementation at a number of facilities world-wide (e.g., AGS, DESY, FNAL, LANSCE, LEGS, SLAC, TRIUMF, Palo Verde, etc.) and for an on-going level of research, including university scientists and students. It is a world-class, forefront program with great promise. However, the 1999 Congressional Budget Request does not include support for a number of other opportunities which have been identified.

From this paragraph, one might infer that the current budget problems facing the field arise from the identification of new scientific opportunities *since* the publication of the 1996 Long Range Plan. It is the view of the subcommittee that this inference would be wrong. Certainly, there have been new ideas in the past three years but nothing at a level that was unanticipated in the Plan. However, there have been many changes which impact the Medium Energy Nuclear Physics Program.

The most important change that has occurred is that the budget has fallen significantly below the lowest guidance level provided to NSAC when it prepared the Long Range Plan. In addition, as high energy physics reduces its support, the cost of nuclear physics at the AGS is likely to increase dramatically, further increasing the budget pressure on this part of the program. Also, the Continuous Electron Beam Accelerator Facility (CEBAF) at TJNAF is now operating in support of research and it is becoming apparent that additional resources would result in more effective utilization. Finally, there has indeed been an evolution of the scientific program and several new initiatives have progressed since 1996, but in a quite natural way that was anticipated in the Long Range Plan.

These changes have sufficiently serious impact on the overall program that they require some further amplification.

Overall Budget Contraction

In its guidance to NSAC, DOE asked for the 1996 Long Range Plan to be formulated for budget levels of $325M and $350M (in FY1997$). In fact, the plan was formulated for the $350M level and NSAC noted that at the lower level "substantial retrenchments would be necessary" including "substantially less utilization of facilities and of other new capabilities." In this context, it is interesting to note that the FY1999 President's Budget of $332M for nuclear physics is, after correction for inflation using the OMB inflators, only $317M in FY1997$, $33M below the budget level considered by NSAC in the LRP to maintain a world-class program. This is the reduction applied to the whole field. The situation facing the medium energy physics sub-field is somewhat worse because of the start-up costs of TJNAF and the likely loss of AGS funding from the DOE High Energy Physics Program.

In this context, it is interesting to compare operating budgets for medium energy nuclear physics in FY1996 (the year in which the Long Range Plan was published) with the FY1999 President's Budget which is the baseline for the subcommittee. The most important points to note are that the budget has not kept pace with inflation, that the increase in actual dollars ($4.8M) has been mostly allocated to additional support of non-programmatic items and costs associated with the start-up of the TJNAF program. Large parts of the program have been living with a constant dollar scenario for several years with the resultant erosion of purchasing power having a serious impact on the scientific mission of the program.

It is clear that the principal reason why there are difficulties in carrying out the outstanding program in medium energy physics proposed in the 1996 Long Range Plan is that the budget has fallen below the lowest level anticipated. The most straightforward way to remedy this is to increase the budget to the guidance levels provided by the DOE at the time when the plan was formulated.

Loss of Support for the AGS

The second change since 1996 is that the DOE High Energy Physics Program has indicated that it will, at best, only provide very limited funding for experiments at the AGS in FY2000 and beyond. This will greatly increase the cost of performing nuclear physics experiments at the AGS (by an amount varying from about \$4M to \$10M depending on the level of high energy physics participation). A nuclear physics program at the AGS using intense kaon beams was anticipated in the 1996 Long Range Plan; however, the increased cost to run the program may curtail the unique scientific opportunities already identified.

Startup of TJNAF

At the time of the 1996 plan, CEBAF was just entering the commissioning phase. Since that time the performance of the accelerator has exceeded expectations. Both the Laboratory and the user community are highly motivated to capitalize on the unique scientific opportunities provided and are constrained at current budget levels. Additionally, it was noted in the Long Range Plan that "With the superconducting technology at CEBAF performing so well, the community looks forward to future increases in CEBAF's energy, and to the scientific opportunities that would bring." The current push to increase the energy of the accelerator to 6 GeV and with a more substantial upgrade to 12 GeV were certainly anticipated in the Long Range Plan.

Identification of New Scientific Opportunities Since 1996

Many of the new initiatives presented to the subcommittee were already anticipated in the 1996 Plan. These include the program of research with cold and ultra-cold neutrons at LANSCE, the RHIC spin program and the opportunity for a polarized photon source at the TUNL FEL, all of which have been studied in greater depth since that time and are now much better defined. Some, such as the BooNE experiment at FNAL, were not in the Long Range Plan but are now well on the way. Others, such as the proposal for a new experiment using the main injector at FNAL are in the early proposal phase and finally, there are ideas for experiments well into the future such as the possibility of a polarized collider at HERA. It is important to emphasize that this is a natural progression with new ideas being developed as understanding of the physics is advanced. Funding of experiments of this scale was certainly anticipated in the 1996 Long Range Plan at the DOE guidance funding levels. The problem is not that there are unanticipated opportunities but that the funding has fallen below the level at which they can be funded.

4.2 Medium Energy Nuclear Physics Funding Needs for FY1999-2004

Input from the community made the subcommittee aware of a number of components of the program where there are needs for operating funds above the constant effort level if the full range of scientific opportunities is to be realized. These include:

TJNAF has identified a \$3M/year shortfall in the funds needed to maintain (not increase) the running hours of CEBAF at the 1998 level.

2. BNL has estimated that the AGS fixed-target program continuation requires \$3.4M/year minimally; this figure anticipates that a limited HEP program will take place at the AGS concurrently. Without HEP running, the cost would triple.

3. The BATES facility funding has been cut by \$2.4M/year compared to past levels. This severely jeopardizes the SAMPLE completion and the entire OOPS program if BLAST construction remains the lab's highest priority.

4. The emergence of an excellent cold and ultra-cold neutron program opportunity at LANSCE and the implied increased facility costs there introduce new capital equipment requirements and implied increased future costs. Estimates of \$2-3M/year were presented by LANL.

5. The RHIC spin program has continued to rise in scientific interest. To carry out this program, additional funding to BNL for research physicists and modest specialized equipment will be required at the \$1-2M/year level.

6. The proposed polarized gamma-ray source at the TUNL FEL would provide polarized, nearly monochromatic beams at an expected intensity approximately 2 orders of magnitude higher than existing photon sources. The cost of the facility upgrade is estimated in the proposal to be ~\$4.7M over 3 years, with an operating cost of ~\$300k/year.

The subcommittee believes that exceptional efforts have already been made to accommodate declining budgets while maintaining the breadth of the Medium Energy Nuclear Physics Program. Although the subcommittee has not evaluated the estimated costs in detail, it is clear there will be a major loss of first class science if these needs are not met.

4.3 The Future of U.S. Hadron Facilities

The AGS is currently unique in the world in providing high-intensity secondary beams of muons, pions, kaons and antiprotons for fixed-target experiments. The 1996 Long Range Plan anticipated that this capability would be available for the Medium Energy Physics Program. The fixed-target operations are currently funded by DOE High Energy Physics. As DOE Nuclear Physics assumes landlordship of the AGS as an injector for RHIC, this will change. In order to sustain fixed-target operations, substantial funding from the DOE Medium Energy Nuclear Physics Program would be required. The amount needed ranges from about $4M to $10M per year, depending on whether the high energy physics community will also utilize the AGS after the year 2000. However, since no funds are currently in the DOE Nuclear Physics budget for such operations, continuation of the AGS program falls in the category of "new initiatives."

The termination of such an important nuclear physics program would have serious consequences. Not only will there be a loss of excellent science, but the balance in the U.S. Medium Energy Program would be jeopardized. A program at the AGS of a few selective, high priority experiments would have considerable scientific impact and would capitalize on the experimental equipment which has recently been installed. In addition, it would help to maintain the expertise of the physics community and its productive collaboration with the Japanese community until the middle of the next decade when the Japan Hadron Facility begins operations.

5. RECOMMENDATIONS

5.1 Guiding Principles

In formulating its recommendations, the subcommittee has adopted the following guiding principles which are consistent with the 1996 NSAC Long Range Plan for Nuclear Physics and the views expressed to us by members of the medium energy nuclear physics community.

1. Very significant investments have been made in the development of forefront facilities for medium energy nuclear physics. The field must fully realize the potential of these facilities for major scientific discoveries and insight.

2. The foundation for the field is provided by the intellectual resources at the universities and the national laboratories. Support of the best and the brightest in the field and nurture of the coming generation of medium energy nuclear scientists is of unquestioned importance.

3. Medium energy nuclear science is a diverse discipline that utilizes many different techniques and approaches to successfully address important scientific problems. The importance of maintaining a balance among the various components of the field for the overall benefit of science must be recognized.

4. In planning for the future of the field, it must be recognized that important scientific ideas and opportunities that are not now apparent will undoubtedly present themselves.

5.2 Recommendation Concerning Implementation of the 1996 Long Range Plan

The most significant finding of the subcommittee was that funding for Nuclear Physics by the Department of Energy has fallen substantially below the guidance levels provided to NSAC by the DOE when it requested the preparation of the 1996 Long Range Plan. In addition, the Medium Energy Nuclear Physics Program is being affected by the phase-out of support for the AGS at Brookhaven National Laboratory by DOE High Energy Physics. Failure to address these shortfalls will lead to retrenchments in the program even with constant effort funding at the FY1999 President's Budget level. ***The subcommittee urges that every effort be made to restore the budget to the levels anticipated in the 1996 Long Range Plan so that the world-class scientific program laid out in the plan can be fully carried out.***

5.3 Recommendations Common to All Budget Scenarios

In the charge from DOE and NSF, NSAC was asked to respond to the following questions:

> "What is the optimum mix of facilities and research support needed to address the scientific priorities within the context of the FY1999 Congressional Budget Request ($116.9 million, including Capital Equipment) and constant dollars into the out years?
>
> What scientific opportunities could be addressed with a program funded at a FY1999 constant level of effort into the out years?
>
> What important scientific opportunities could be addressed with additional funds beyond constant level of effort beginning in FY 2000?"

The subcommittee has developed answers to each of these questions. In addition, the subcommittee has some general recommendations that are common to all scenarios.

The subcommittee concurs with the first recommendation of the 1996 Long Range Plan that the highest priority for the field is vigorous pursuit of the scientific opportunities provided by the nation's recent investments in forefront instrumentation and facilities. In medium energy nuclear physics, CEBAF is the flagship facility. ***The subcommittee gives the highest priority to effective utilization of CEBAF in all budget scenarios.***

The subcommittee has been extraordinarily impressed by the range of scientific questions being addressed by the medium energy nuclear science community and finds that a wide variety of experimental tools is needed to carry out this program. ***The subcommittee recommends that very high priority be given to supporting a balanced scientific program in medium energy nuclear physics.*** Without a balanced program, the subcommittee does not believe that the important scientific goals laid out in the 1996 Long Range Plan can be achieved.

5.4 Constant Effort Scenario FY1999-2004

In this scenario, the budget grows to compensate for the effects of inflation. However, as noted above, the starting point of the FY1999 President's budget is approximately 10% below that anticipated in the 1996 Long Range Plan. ***Under a constant effort budget, the subcommittee recommends that a set of actions be taken to maintain balance within the program while capitalizing on the very significant investment that has been made at TJNAF.***

DOE support for operations at MIT/Bates would cease following completion of the SAMPLE experiment in FY1999 and a limited experimental program using the OOPS spectrometers in FY2000. The FY2000 program would be contingent on successful development of an extracted, polarized beam from the South Hall Ring in FY1999.

Savings from closure of the BATES facility would begin to become available in FY2001 and would be used to address needs identified in other parts of the program. This would allow effective utilization of TJNAF; a modest increase in the university program; and support of complementary high priority new activities such as RHIC spin, BooNE and the neutron experiments at LANSCE.

Under this scenario, there could be an opportunity for one or two select high scientific impact experiments at the AGS while high energy physics experiments are still running. Unfortunately, the subcommittee notes that significant savings from the closure of Bates are not realized until after the years in which high energy presence is most likely (FY1999-2000). However, the subcommittee believes that these options should continue to be explored actively by BNL and DOE. A program of a few selective, high priority experiments would have considerable scientific impact. It would capitalize on the experimental equipment which has been installed at the AGS. Finally, it would help to maintain the expertise of the physics community until the Japan Hadron Facility begins operations in the middle of the next decade.

Under this scenario, there is inadequate funding for a dedicated program at the AGS supported only by Medium Energy Nuclear Physics.

5.5 Scenarios in which Additional Resources are Available Beginning in FY2000

The impact of funding at greater than constant effort in FY2000 and beyond would be extraordinary. Each funding increment would enable the community to carry out a larger fraction of the world-class scientific program laid out in the 1996 NSAC Long Range Plan..

A modest increase of a few million dollars above constant effort would have significant impact on the program. Such an increase would allow more effective utilization of TJNAF (CEBAF) and permit an aggressive program to develop higher energy beams. It would also allow timely support of high priority activities identified in the 1996 Long Range Plan such as RHIC spin, cold neutrons at LANSCE, and selective experiments at the AGS.

Increased funding at the $8-10M level above constant effort would also allow MIT/Bates to run beyond FY2000. Unique scientific opportunities would then be realized using the combination of internal targets and the BLAST detector as envisioned in the 1996 Long Range Plan. This would give excellent scientific return on the very substantial investment that has been made in the South Hall Ring at Bates. *The subcommittee notes that a commitment of funding at this level is necessary through FY2004 in order to complete construction of BLAST and carry out its experimental program.*

A further increment of $8-10M would allow an ongoing program of high priority experiments at the AGS supported by the Medium Energy Nuclear Physics Program. We reiterate that such a program could have great scientific impact and would help maintain the expertise of the scientific community during the construction of the Japan Hadron Facility.

The subcommittee discussed the relative merits of continuing Bates and providing new funding to exploit the unique opportunities at the AGS. The scientific opportunities of both programs are excellent; from the point of view of balance and diversity in the field, a program in hadron physics at the AGS is more important; from the point of view of return on investment, exploitation of the South Hall Ring may be more important. There is also the matter of finality. Once operations have been terminated at MIT/Bates, it is very unlikely that the decision could ever be reversed, whereas the AGS will continue to be supported as the injector for RHIC. Thus, in the event that only one of these can be funded, the subcommittee supports the continuation of MIT/Bates to allow completion of the approved experimental program using BLAST.

5.6 Constant Dollar Scenario

In this scenario, funding for the program contracts at 3% per year for FY2000-2004. By the year 2004, the budget in FY1999 dollars would be reduced 14% below the FY1999 President's Budget level, which would then be 22% below the NSAC Long Range Plan. ***Under a constant dollar budget, a serious retrenchment of the program is unavoidable in order to maintain the productivity of its flagship facility and the balance that is essential to the scientific health of the field. The subcommittee recommends that actions be taken which preserve, as far as possible, utilization of CEBAF while maintaining balance in the field.***

MIT/Bates would cease operations following the completion of the deuterium target run of the SAMPLE experiment in FY1999.

Savings from the closure of MIT/Bates would be applied proportionately to limit cuts in the university programs and in research and operations of CEBAF. Even so, there would be a 5% reduction in these programs by 2004. This would lead to a significant reduction in the university program and to under-utilization of CEBAF.

The national laboratory program (ANL, BNL, and LANL) would be kept to constant dollars leading to a 14% reduction of effort by 2004. Under this scenario, the highest priority new opportunities would still be supported, such as some elements of the RHIC spin program and a limited cold neutron program at LANSCE. However, this would only come about at the cost of serious reductions in other parts of the national laboratory program. New initiatives requiring significant capital would be delayed.

No experimental program at the AGS could be funded under this scenario.

ACKNOWLEDGMENTS

The subcommittee could not have carried out its charge from DOE and NSAC within the allotted time frame without the help and cooperation of many people. We particularly wish to thank:

Members of the intermediate energy nuclear science research community, from both universities and national laboratories, who prepared high quality, thoughtful, and informative documents and presentations at very short notice.

DOE and NSF representatives who met with the subcommittee and provided programmatic information.

Staff and management at TJNAF and MIT/Bates who hosted visits of the subcommittee and made every effort to ensure that these visits were a success.

The ANL Physics Division for hosting three subcommittee meetings.

Anne Marie Piche, LBNL, and Barbara Fletcher, ANL, who ably arranged for all the support, logistics, and travel involved in such a review. Ms. Piche also helped in the preparation of the final document.

Department of Energy
Washington, DC 20585

June 5, 1998

Professor Konrad Gelbke
Chairman
DOE/NSF Nuclear Science Advisory Committee
Michigan State University
East Lansing, MI 48824

Dear Professor Gelbke:

In 1996 the DOE/NSF Nuclear Science Advisory Committee (NSAC) submitted a Long Range Plan (LRP) for nuclear science research in the nation. The scientific opportunities identified and priorities recommended in this plan provide important guidance for taking our programs into the next century. An important aspect of the plan is the coordination of the DOE and NSF programs which recognizes the important stewardship roles which both agencies play in university-based research and DOE's lead role in building and operating forefront national facilities for users. DOE, in this latter role, is presently faced with making long term programmatic decisions, particularly regarding facility operations, which affect the scientific programs of both agencies.

This letter requests that NSAC reexamine and evaluate the scientific opportunities identified in the area of "To the Quark Structure of Matter" of the 1996 LRP, and make recommendations of priorities consistent with projected resources available to the DOE Medium Energy program.

Recent Nuclear Physics budgets in DOE have not attained the levels assumed in establishing the FY 1996 LRP. The DOE Nuclear Physics Program office has distributed resources between the major subprograms in order to reflect the priorities expressed in the LRP. These budget levels have introduced pressures within all the subprograms, but the priorities in the other subfields are relatively clear and include the development of RHIC, ISOL and SNO.

In the Medium Energy program significant changes have occurred and new opportunities have emerged since the writing of the LRP. In the FY 1999 DOE Nuclear Physics Congressional Budget Request, support is provided for TJNAF at the NSAC recommended level, for Bates to develop BLAST, for a wide ranges of experiments at various stages of implementation at a number of facilities world-wide (e.g., AGS, DESY, FNAL, LANSCE, LEGS, SLAC, TRIUMF, Palo Verde, etc.) and for an on-going level of research, including university scientists and students. It is a world-class, forefront program with great promise. However, the 1999 Congressional Budget Request does not include support for a number of other opportunities which have been identified.

These considerations require updated scientific guidance on the options available in the DOE Medium Energy program. The evaluations and recommendations of this review are expected to provide a scientific basis for programmatic decisions, on both facility and research support needs in the next few years (FY 1999-2004). In the report of your examination of the facilities and research activities supported by DOE's Medium Energy subprogram, please respond to the following questions:

> What is the optimum mix of facilities and research support needed to address the scientific priorities within the context of the FY 1999 Congressional Budget Request ($116.9 million, including Capital Equipment) with constant dollars into the out years?
>
> What scientific opportunities could be addressed with a program funded at a FY 1999 constant level of effort into the out years?
>
> What important scientific opportunities could be addressed with additional funds beyond constant level of effort beginning in FY 2000?

We request that a written report responsive to this charge be provided by October 1, 1998.

Sincerely,

Robert A. Eisenstein

Robert A. Eisenstein
Assistant Director
Mathematical and Physical Science
National Science Foundation

Martha Krebs

Martha A. Krebs
Director
Office of Energy Research
U.S. Department of Energy

MICHIGAN STATE
UNIVERSITY

July 1, 1998

Dr. T. James M. Symons
Nuclear Science Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

Dear James:

In a letter dated June 5, 1998, NSAC has been charged to reexamine and evaluate the scientific opportunities identified in area of "To the Quark Structure of Matter" of NSAC's 1996 Long Range Plan (LRP), and to make recommendations of priorities consistent with projected resources available to the DOE Medium Energy Program.

While the priorities in other subfields are sufficiently clear and include the development of RHIC, ISOL and SNO, significant changes have occurred in the Medium Energy program and new opportunities have emerged since the writing of the LRP. DOE's FY99 Congressional Budget Request would support TJNAF at the NSAC recommended level, Bates to develop BLAST, a wide range of experiments at facilities world-wide (e.g. AGS, DESY, FNAL, LANSCE, LEGS, SLAC, TRIUMF, Palo Verde, etc.), and an on-going level of research, including university scientists and students. However, it does not include support for a number of other identified opportunities or needs. In view of these developments, NSAC has been requested to provide updated scientific guidance on the options available in the DOE intermediate energy program which would provide the scientific basis for programmatic decisions on both facility and research support for the next few years (FY2000 - FY2004).

In response to this charge, NSAC has established a Subcommittee on DOE-Sponsored Intermediate Energy Nuclear Science. Its membership includes:

James Symons (Lawrence Berkeley National Laboratory), Chairman
John Cameron (Indiana University)
Brad Filippone (California Institute of Technology)
David Hertzog (University of Illinois at Urbana-Champaign)
Roy Holt (University of Illinois at Urbana-Champaign)
Jay Marx (Lawrence Berkeley National Laboratory)
Al Mueller (Columbia University)
Jerry Nolen (Argonne National Laboratory)
Dan Riska (University of Helsinki)
Hamish Robertson (University of Washington)

The Subcommittee is asked to study and evaluate the scientific opportunities in the DOE Intermediate Energy program and assess the impact of the three budget scenarios spelled out in the charge to NSAC on the ability to address

NSCL MSU

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these opportunities. In establishing how the priorities can be addressed at the three funding levels, the Subcommittee should take into account the gains and losses in science, the impact on the education and training of scientists, the cost-effectiveness of facility operations and different research activities, the ramifications for user groups presently funded by DOE and NSF, and the risks and opportunities for maintaining a world-leadership position of the U.S. in nuclear science. The report of the Subcommittee should provide NSAC with recommendations consistent with the request spelled out in the charge to NSAC.

In order to be able to meet the October 1 deadline for NSAC's response to the agencies, the Subcommittee's report should be submitted to NSAC by September 18, 1998, and presented and discussed at a NSAC meeting in late September.

On behalf of the Nuclear Science Advisory Committee, I thank all members of the Subcommittee to be willing to undertake this difficult, but very important task.

Sincerely,

C. Konrad Gelbke
Chairman, DOE/NSF Nuclear Science Advisory Committee (NSAC)

Appendix: DOE/NSF charge to NSAC

CC: Brad Keister, Dennis Kovar, Subcommittee members

Appendix B. NSAC Subcommittee Members

NSAC Subcommittee on DOE-sponsored Intermediate Energy Nuclear Science

James Symons	Lawrence Berkeley National Laboratory, Chair
John Cameron	Indiana University
Brad Filippone	California Institute of Technology
Konrad Gelbke	Michigan State University
David Hertzog	University of Illinois
Roy Holt	University of Illinois
Jay Marx	Lawrence Berkeley National Laboratory
Al Mueller	Columbia University
Jerry Nolen	Argonne National Laboratory
Dan-Olof Riska	University of Helsinki
Hamish Robertson	University of Washington

Janis Dairiki	Lawrence Berkeley National Laboratory, Report Editor

Appendix C.1 Argonne Agenda

NSAC sub-committee Meeting
Advanced Photon Source Building, Argonne National Laboratory

Friday, July 31

Session 1 Laboratory Overviews

9.15	Argonne Overview	
10:15	Brookhaven Overview	
10:30	break	
12:00	Los Alamos Overview	

Session 2 Non-perturbative QCD

13:15 - 14:00	Opportunities in meson spectroscopy	Ted Barnes, ORNL
14:00 14:35	Baryon Resonances	Mark Manley, Kent State
14:35 - 15:20	Meson decays and hyperons	Ben Nefkens, UCLA
15:20 - 16:00	Strangeness	Gregg Franklin, Carnegie-Mellon
16:00 - 16:15	break	

Session 3 Opportunities in Neutrino Physics

16:15 - 17:15	BooNE	William Louis, LANL
17:15 - 18:00	Palo Verde	Felix Boehm, Caltech

Saturday August, 1

Session 4 Short Range Nucleon Properties

08:15 - 08:55	Hermes	Ed Kinney, University of Colorado
08:55 - 09:45	RHIC Spin	Gerry Bunce, BNL
09:45 - 10:05	break	
10:05 - 10:35	Opportunities for p-A at RHIC	Joel Moss LANL
10:35 - 11:15	Drell-Yan Experiments at FNAL	Don Geesaman, ANL

Special Session

11:15 - 12:15	Comments from members of the medium energy community	

13:00 - 13:15 Nuclear Physics at LANSCE Geoff Greene

13:15 - 13:40 Measurement of the parity violating asymmetry in N+p -> D + gamma
David Bowman, LANL

13:40 - 14:05 Measurement of the Beta Asymmetry with Ultra-Cold Neutrons
Tom Bowles, LANL

14:30 Development of a new Neutron Electric Dipole Moment at LANSCE
Steve Lamoreaux, LANL

14:30 - 14:45 break

Session 6 Opportunities with Polarized Photon Beams

15:25 Laser backscattered photon sources Andrew Sandorfi, BNL

16:10 Proposal for a back-scattered FEL WernerTornow, Henry Weller TUNL

Bates Linear Accelerator Center NSAC Review

August 2-3, 1998

AGENDA

Sunday, August 2

2:00	Overview:	R. Milner (Bates)
3:30	Operations:	C. Tschalaer (Bates)
	Coffee	
5:00	The SAMPLE Experiments:	R. McKeown (Caltech)
5:45	Tour of the Bates Facility	
6:45	Executive session / meeting with senior users	
	Barbecue at Bates (open to all)	

Monday, August 3

8:00	Executive session / breakfast	
9:00	The OOPS Program:	A. Sarty (Florida State University) Z.-L. Zhou (MIT) C. Papanicolas (University of Athens)
10:15	Coffee	
10:30	The BLAST Program:	J. Matthews (MIT) J. van den Brand (Vrije U., Amsterdam) G. Dodson (Bates)
12:00	Lunch with students and post-docs	
1:00	Executive session / MIT Institutional Support	
	He-3 Magnetic Form Factor:	G. Peterson (University of Massachusetts-Amherst)
2:00	Report on BLAUGI activities/issues:	R. Alarcon (Arizona State University)
2:20	Report on theory-experiment collaboration:	T.W. Donnelly (MIT)
2:30	Summary: R. Milner (Bates)	
	Coffee	
	Executive session	
	Transportation to Logan airport	

Appendix C.3 CEBAF Agenda

Agenda
NSAC Medium-Energy Review, CEBAF
August 3-5, 1998

Monday, August 3, 1998

Evening	Arrival of panel members	

Tuesday, August 4, 1998 (Rm. L102-104)

7:30 AM	Continental breakfast	Panel members
8:00 AM	Executive Session	Panel members
8:30 AM	Lab Overview	Hermann Grunder (10+5)
8:45 AM	Science Overview	Nathan Isgur (30+15)
9:30 AM	Physics Status and Plans	Larry Cardman (30+15)
10:15 AM	Break	
10:30 AM	Accelerator Status and Plans	Christoph Leemann (30+15)
11:15 AM	Tour of Accelerator and Experimental Halls 12 members +3 speakers(HG,CL,CS) +3 "shadows"(NI,LC,FD) Accelerator- Hermann Grunder and Christoph Leemann (Drive site enter klystron gallery in middle of n. linac, enter injector klystron gallery and steps to tunnel; walk west arc to s. linac, see empty slots; enter Hall A through BSY) Hall A - Kees DeJager Hall C - Roger Carlini Hall B - Bernhard Mecking	
1:00 PM	Working Lunch	
2:00 PM	User Presentations (30 minutes per talk-20+10)	
	Overview	Don Geesaman
	Nucleon and Meson Form Factors and Sum Rules	Sebastian Kuhn
	Few Body Systems	Betsy Beise
3:30 PM	Break	
3:45 PM	User Presentations (30 minutes per talk-20+10)	
	Properties of Nuclei	Rolf Ent
	N* and Meson Properties	Steve Dytman
	Strange Quarks and Parity	Krishna Kumar
	International Users at Jefferson Lab	Jean-Marc Laget
5:45 PM	Executive Session with JLab Management	

6:30 PM	Reception/Dinner	

Wednesday, August 5, 1998 (Rm. L102-104)

7:30 AM	Continental Breakfast	Panel members
8:00 AM	Executive Session	Panel members
9:00 AM	Science of Higher Energies	Nathan Isgur (30+15)
9:45 AM	Upgrade Plan	Larry Cardman (20+10)
10:15 AM	Executive Session	Panel members
12:00 PM	Pizza in ARC with users, PDFs, students	
1:30 PM	Closeout with JLab Management	
2:00 PM	Panel continues to meet on site	