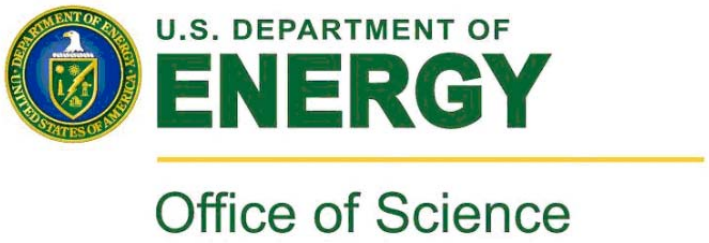

Department of Energy
Office of Nuclear Physics Reviewer Excerpts

on the

Science and Technology Review

of the

Thomas Jefferson National Accelerator Facility (TJNAF)

July 28-30, 2015

EXCERPTS FROM PANEL MEMBER REPORTS

The Science and Technology review of the Thomas Jefferson National Accelerator Facility (TJNAF) was held at TJNAF on July 28-30, 2015.

The quality and significance of the laboratory's scientific and technical accomplishments and the merit, feasibility and impact of its future planned physics program:

Reviewer:
"On the second day we were also presented with some metrics on experiments completed, publications resulting from them particularly in PRL and PL, invited talks by Jefferson staff, number of PhD's completed, number of Jefferson c-spokespersons. These data further substantiate the merit and impact of the JLab program to date.

"On the first day we were also given more specific talks on the experimental and theoretical programs. The Theory Centre is conducting research in a wide variety of topics, which link well to the experimental projects. These range from study of the inter-nucleon force, through the study of the inter-parton force via lattice QCD to the study of multi-dimensional parton distribution functions and their evolution. The Centre is well connected nationally through joint and bridge appointments and through its standing in the USQCD effort. It also has international links through the Joint Physics Analysis Centre (JPAC) in which it already plays a leading role in the Spectroscopy effort and where the data from the 12 GeV experiments will ensure a leading role in the Tomography effort. The JPAC is well organized with weekly phone conferences and regular workshops. It is notable that the Theory Center sees the work of other groups such as those at Mainz and INFN in terms of a fruitful cooperation and collaboration rather than in terms of competition.

"The links to the experimental program are illustrated by the CTEQ-JLAB collaboration which produces proton parton distribution functions. This collaboration has experimentalists as well as theorists as members and uses the BONUS 6 GeV data. The result on the d/u parton ratio is a world leading result. This work will continue and expand into the extraction of multi-dimensional parton distributions using the data from 12 GeV SiDIs and DVCS experiments. The work on neutron spin-PDFs relates to the proposed future MEIC experimental program. The work on the meson spectrum and spectroscopy within JPAC relates directly to the Glue-X 12GeV experiment.

"The links to the experimental program are reinforced by a number of jointly funded theory/experimental positions. The Theory Advisory Committee also reports to the Physics Advisory Committee which selects and prioritizes experimental proposals for run-time.

"There was a recommendation from the previous review to 'Develop a plan for the Theory Group which identifies the theoretical needs of the 12 GeV science program, articulates the role that the Theory Group will play in addressing those needs, and defines goals for

how to implement the plan, within constrained budgets'. In my opinion these goals have been achieved.

Reviewer:
"The superconducting RF group has been in business for several decades now, and continues to lead the countries efforts in SRF cavity development and production. The new building provides all of the necessary equipment and facilities to construct cryomodules for JLab and other labs, and conduct R&D on numerous fronts. They continue to make progress on techniques to increase cavity Q, reduce cavity costs, and new materials for higher temperature operation. The nitrogen doping technique developed has resulted in higher Q cavities, and is being implemented for the LCLSII cavities. We saw an example of a niobium-coated copper cavity, which will be an excellent cost reduction method for large accelerators, and for large (low frequency) cavities. New materials, like Nb_3Sn, may allow cavity operation at 4K, which would reduce cryoplant complexity and reduce operating costs for future machines. They also participate in other cavity R&D efforts, particularly with building cavities for SRF guns at various labs. The SRF group activities are impressive and every effort should be made to continue supporting them.

"The cryogenics engineering team has become the premier group in the nation for designing and building cryogenic systems. Innovations, like the Ganni cycle, have brought new efficiencies to an old field. Their expertise is evidenced by the fact that other national labs and government agencies call on them to help with new systems. They are currently building a cryoplant for FRIB in Michigan, and preparing 2 full plants for LCLSII at Stanford. Due to a nationwide lack of experienced cryogenic engineers, it would be useful to find ways to train new employees in cryogenics, and share their expertise with other labs."

Reviewer:
"During the recent period of 12 GeV construction and early commissioning, JLab experiments carried out in the 6 GeV era have continued to lead to a steady stream of publications, including high-profile papers published in *Science* and *Nature.* Recent results that have attracted my attention even before the review include: the apparent connection between nuclear short-range correlations and the slope of the EMC effect on nuclei; reduction in the uncertainties on the *d/u* quark pdf ratio at high Bjorken *x*-values; first measurement of the neutron skin in lead via parity-violating electron scattering (PREX); early results from the Qweak measurement of the proton's weak charge; the apparent confirmation of two-photon exchange as the effect accounting for differences in proton electric form factors extracted from Rosenbluth separations vs. polarization transfer experiments; and initial tomographic images of quark transverse spatial distributions via Deeply Virtual Compton Scattering. These are only illustrative; the program continues to produce significant science central to the DOE mission in nuclear physics research at a commendable rate.

"The 12 GeV physics program is well thought through and should have high impact within the worldwide nuclear physics research portfolio. Centerpieces of the program include determinations of 2+1-D images of quark distributions in the proton in both coordinate and momentum space, via SIDIS and deep exclusive reaction measurements; Standard Model tests via high-precision parity violation measurements in Moller and deep inelastic scattering; and the search for hybrid mesons with exotic quantum numbers indicative of gluonic excitations of a quark-antiquark system. Execution of this program – even for some of the highest-impact parts of it – is likely to stretch over at least a decade, given the needed (both large and modest) instrumentation upgrades beyond the 12 GeV project. The laboratory management did present a reasonably convincing and feasible early experiment schedule for FY2015-2019, taking into account both scientific impact and technical feasibility, which should provide the early visibility one desires for such a major upgrade. One potential conflict that should be noted between the scientific output and completion of the 12 GeV project is the possibility that completion of the CLAS12 upgrade may preclude mounting the PRAD experiment in Hall B at a time when it could compete favorably with other worldwide efforts to resolve the proton radius puzzle.

"The JLab theory efforts are strong, diverse and cost-effective, given their heavy reliance on contributors in bridge and joint appointments with universities. JLab is one of the national centers for lattice QCD computation and theory relevant to nuclear physics problems.

"The extraction of tomographic images of internal nucleon structure from experiments sensitive to TMDs and GPDs, as well as the analysis of the rich continua to be revealed in GlueX meson spectroscopy measurements, require a coordinated effort in theory to accompany the experimental progress. The laboratory has established a mechanism for attaining the needed theoretical advances through international collaborations spearheaded by the JLab Physics Analysis Center (JPAC). The management of this Center was not well described in the laboratory's written response document to the relevant recommendation from the 2012 S&T review. Given the somewhat disappointing performance of JLab's earlier center (EBAC) focusing on theory needed for the analysis of baryon resonance continua, clearer management oversight of JPAC would be wise. In particular, it would be helpful for the collaborating groups to develop a consensus plan of attack, including benchmarking milestones and a clear division of effort, to have a robust analysis framework ready when 12 GeV data arrive."

Reviewer:
"The scientific program with the 12 GeV upgrade of the Thomas Jefferson National Accelerator Facility (TJNAF) is outstanding and world-wide highly competitive in the context of international activities. There is a well formulated and prepared series of physics experiments, which will yield high impact, visible physics results in the first few years. The highlights of the quantum chromodynamics (QCD) physics program include studies of gluonic meson excitations, the nucleon spin puzzle, the 3D nucleon structure, parity-violating experiments, precision nuclear structure studies. This program is complemented by tests of the Standard Model and a limited search for dark photon

candidates. The laboratory presented a clear view of a day 1 physics program that reaches until the year 2019.

“The detectors and collaborations are partially ready and have their hardware installations well under control. The different experimental Halls explore different aspects based on exclusive, semi-inclusive and inclusive hard scattering, striving for a determination of electromagnetic form factors (EM-FF), GPDs, and TMDs. In particular the spectroscopy program at GlueX would benefit from early beam time since it has the potential to provide the first papers from the 12 GeV science program. The other experiment aiming at hadron spectroscopy and at hadron structure, CLAS12 , still awaits some of its hardware to be installed (still on schedule) and seems to be well on track in regards to software readiness for data-taking.Essential for the experimental program is the availability of the beam at full energy.

“For the determination of the nucleon structure, the measurement of the nucleon form factors at high momentum transfer will constrain the integral of the independent determination of GPDs. It would be desirable to develop an integrated picture of what measurements are necessary and will be conducted in determining the GPDs and TMDs. The determination of the contribution to the nucleon spin from the angular momentum of valence quarks represents an important contribution to the nucleon spin puzzle. The CLAS12 program and the determination of some of the GPDs and TMDs depend strongly on the reliable operation of the HD-ice target. While the reliable operation of this target has been successfully demonstrated with photon beam, this has not yet been proven with an electron beam.

“The PRAD experiment aims at a measurement of the proton form factors at very low momentum transfer. This measurement could potentially resolve the proton radius puzzle. It is desirable to realize the PRAD experiment in the window of opportunity that exists before the CLAS12 upgrade is fully installed.

“A series of parity violation experiments on nuclear targets (PREX and CREX) aims at a clean determination of the neutron distribution in nuclei. These measurements have direct impact on the understanding of neutron stars through the nuclear equation of state and address an important puzzle concerning observed neutron star masses. The previous 6 GeV Qweak experiment aims at a measurement of the weak charge of the proton and its data is presently being analyzed. Qweak’s results are eagerly awaited by the community.

“For the future experimental programs two experiments are being planned: the measurement of Lepton-Lepton Electroweak Interaction (MOLLER) experiment for a high precision determination of the weak charge of the electron, and SoLID, which aims for a determination of the weak charge of the quarks. These could allow for a high precision determination of the weak coupling constant $\sin^2 \theta_W$. While the initial parity violation experiments can use the presently achieved beam parameters, a major improvement of parity violation beam parameters is necessary for the proposed experiments, MOLLER and SoLID. These planned parity experiments open a possibility for a test of the standard model complementary to the present direct LHC-search up to a

mass scale of about 50 TeV. In addition these experiments are sensitive to low mass scales down to several 10's of MeV. However, a timeline for implementing these experiments has not yet been agreed upon by the Department of Energy (DOE) and the Laboratory.

"In general, a fruitful collaboration exists between experiments and theory on several issues. The theory support for the experimental program from the proposal stage up to data analysis is vital.

"The Theory Center has seventeen senior staff and joint faculty plus four associate faculty members, nine postdocs and ten graduate students and is conducting research in a wide variety of topics, most of which are of direct interest to the Laboratory's experimental mission. The topics covered, as presented by the Center director, are broadly:

- Understanding short range N-N correlations as a step to understanding the nuclear force
- Calculation of nucleon, pion and meson electromagnetic form factors, coupled channel scattering on the lattice, partial wave analysis and amplitude analysis;
- Parton Distribution Functions (PDFs) for both protons and neutrons, in the polarized and unpolarized sectors
- Multi-dimensional extensions of the PDFs into GPDs and TMDs.
- The evolution of the gluon TMD from small-x to high-x, beyond the conventional QCD evolution in the DGLAP formalism.
- Lattice QCD calculations of the meson spectrum including gluon excitations which produce exotic states beyond the simple quark model and how this may shed light on quark confinement
- A formulation for computing hadronic transitions on the lattice has been implemented.

"An example of this is the work on the meson spectrum and spectroscopy within JPAC relates directly to the GlueX program. It is not clear what new methods are being brought to the longstanding and important issue of creating analytic and unitary model amplitudes. It is strongly encouraged to develop milestones for amplitude construction relevant to spectroscopy experiments, extraction of GPDs and TMDs from experiment, and for lattice gauge computations concerning the production of hybrid mesons relevant to Hall D.

"Similarly, the lattice implementation of coupled channel scattering problems is an important advance that, coupled with the extraction of scattering amplitudes, will provide significant guidance to experiment. Therefore it is strongly encouraged to develop milestones for amplitude construction relevant to spectroscopy experiments, extraction of GPDs and TMDs from experiment, and for lattice gauge computations concerning the production of hybrid mesons relevant to Hall D. Given that the Agency funding for lattice QCD (LQCD) is currently projected to decline, it is important to evaluate the computing

hardware requirements needed for the theory group's planned lattice gauge theory calculations.

"Concerning the development of the Lab's overall science program, the Theory TAC reports are a vital contribution to implementing the experimental program and this effort is to be commended. Also, the international outreach and expansion of the role of the Theory Center is commendable. It is notable that the Theory Center sees the work of other groups such as those at Mainz and INFN in terms of a fruitful cooperation and collaboration rather than in terms of competition.

"The Theory Center has significant links with several external groups, in particular in Europe. In this context, the Theory Center has initiated a Joint Physics Analysis Center (JPAC) with international collaborators. JPAC has works on two topics: the well-established spectroscopy in which JLab takes the lead, and the more recently established Tomography of hadrons. Both of these have weekly phone conferences and regular workshops.

"The Theory Center contributes to TAC reports that are used by PACs."

Reviewer:
"The laboratory plans a series of interesting experiments in the near term. These include experiments on nucleon short range correlations and d/u pdf measurements at Hall A; the HPS dark photon search, PRAD proton radius, pDVCS, and nDVCS experiments at Hall B; SIDIS, kaon scaling, high x neutron spin structure measurements at Hall C; the initiation of measurements at Hall D; and a search for dark photons at LERF.

"It is clear that the experimental program in the 12 GeV era is broad and has the potential for substantial impact in both nuclear and particle physics. The increase in scope as compared to previous decades is most welcome. At a more detailed level, it appears that there are problems with executing a timely analysis of the Qweak results. The laboratory is encouraged to provide necessary resources to facilitate this effort.

"The Theory Center is active, productive, and assists in important ways in achieving strategic laboratory goals. It has seventeen senior staff and joint faculty, four associate faculty members, nine postdocs, and ten graduate students. The group is also supported by several bridge positions. The bridge program is a good method for supporting the development of national expertise in medium energy nuclear physics and is commended and encouraged. It appears that theory bridge positions are created in response to external requests. This is perhaps not the most efficient way to further laboratory goals, and I suggest that an overall strategy for the creation and pursuit of bridge and joint positions be developed. This could be as simple as delineating manpower requirements for future theory group goals, especially with regards to its mandate to support the lab's experimental program.

“The theory group is conducting research in a wide variety of topics, most of which are of direct interest to the laboratory's experimental mission. The group contributes 1-3 page TAC reports to the PAC, which is probably an onerous, but nevertheless very important, duty. This effort is commendable. The group also contributes to the training of young theorists via its strong postdoctoral program. It contributes to laboratory outreach efforts and, through work such as conference organization and strategic planning, contributes to the national effort in nuclear physics. Furthermore, the group has established links with European theory centers, which promotes achieving its mandate.

“A substantial effort in lattice gauge theory is maintained at the lab, with three theorists, one or two postdocs, and several support staff all contributing. In this regard, the Jefferson Lab theory group is an important component of the national lattice effort as manifested by USQCD. The lattice effort can have a direct impact on the Hall D experimental program (GlueX) that is concerned with light hybrid mesons. This program seeks to find evidence for gluonic degrees of freedom in the spectrum and to determine its salient features. Lattice calculations may be vital to this effort — for example an estimate of the spectrum and the coupling of hybrids to photons and light mesons would provide important information. However, this information must appear in a timely fashion. It would therefore be useful if the theory group were to develop a series of milestones that are designed to mesh with the requirements of GlueX. Furthermore, it would be useful to estimate computational resources required to meet these milestones, especially in view of the flat or reduced hardware funding profile of USQCD.

“Finally, I note that a formulation for computing hadronic transitions on the lattice has been implemented and applied to $\pi\gamma \to \pi\pi$. This is an important achievement that points to useful future photocoupling measurements.

“Developing milestones for theoretical work in support of GPD and TMD measurements is strongly encouraged. At a broader level, assessing the experimental requirements to extract TMDs and GPDs in as model-independent fashion as possible would be useful.

“The theory group has demonstrated that it is feasible to measure neutron spin asymmetries at the MEIC and that this provides a clean way to extract neutron properties. This is a welcome example of the utility of the theory group to the lab’s experimental program.

“In 2013 the theory group initiated the Joint Physics Analysis Center (JPAC) as a successor to EBAC. This group has substantial support in terms of personnel, with seven or eight associated faculty or staff and four or five postdoctoral positions. Its primary mandate appears to be developing methods for the analysis of experimental results, primarily in the area of amplitude construction. JPAC has established links with at least two European analysis collaborations, which is a positive development.

“One of the stated goals of the group is to develop amplitude models that obey the constraints of unitarity and analyticity. Achieving this is a longstanding and difficult issue and it was not made clear what new ideas are being applied. A problem with EBAC

was that the same issues were addressed within the context of a specific model, and thus the group results may not have had as a broad an impact as desired. It would be preferable to avoid this with JPAC. Finally, it may be useful for JPAC to develop milestones with regards to amplitude modelling that can be useful to the extraction of experimental observables from experiments being conducted at Jefferson Lab."

The effectiveness and appropriateness of facility operations and the planning for future facility upgrades in support of the research program:

Reviewer:
"The review talks also introduced us to what is ready in the Halls and the time-scale for enhancement of facilities for the 12 GeV upgrade year-by-year. This covered accelerator readiness, magnets, solenoids, targets, detectors, software and computing, cryogenic capability and synergy amongst enhancements.

"Capital Equipment project planning was outlined with emphasis on generic detector R&D for future projects such as MEIC, as well as the forthcoming 12 GeV running.

"A tour of the Halls allowed us to see many of the detectors, and the level of readiness for ourselves. I found the work on the polarized targets particularly impressive, and whereas everything is not yet ready I am satisfied that the facilities are excellent and the planning for future facilities is both effective and appropriate."

Reviewer:
"One of the cryogenic plants suffered a severe failure during a power outage recently, which effectively limits the machine energy to half. They were lucky in that a spare system from SNS is available to use while the current machine is repaired. While the failure was a bit of a fluke, they obviously need to revisit their failure mode analysis and look for any other flaws which could potentially reduce machine up-time.

"The majority of experiments performed at Jlab require high-quality, polarized electron beams. Parity violation experiments in particular put heavy demands on having helicity independent beam parameters, like beam position, angular spread and charge. The injector team has done an excellent job of meeting the needs of these experiments up to now, and the beam properties are adequate for the next round of experiments using the 12 GeV machine."

"To prepare for future experiments with even tighter requirements on helicity independent parameters, a number of upgrades are planned. Current R&D efforts are focused on these requirements. They are planning on increasing the DC gun voltage to improve beam quality. A gun has been built with new insulators, which can allow operation around 200 kV. Other related R&D may push this towards 300 kV. Along with this, a new superconducting RF cavity/capture section will be installed, replacing the old normal conducting capture section and beta=1 SRF booster. The coupling has been modified to eliminate x-y coupling, another source of beam degradation. Cathode improvements are being investigated with an outside company through and SBIR. Results suggest cathodes with higher quantum efficiency can be produced while maintaining high QE. This, along with vacuum improvements, may increase cathode lifetime. Overall, the injector group provides the highest parity-quality beam for nuclear physics experiments in the world, a great accomplishment given the small size of the injector group.

"Work on an electron-ion collider has been ongoing for several years, and an official MEIC design group was formed in 2014. The design has evolved over the years, trying to balance risk mitigation, civil construction costs, and general cost reduction. There are a number of difficult items that are being addressed to reduce risks to a low level. For instance, the PEP-II ring design was adopted rather than starting from scratch (and may also obtain PEPII components?). Lower cost superferric magnets are being considered for the ion rings, again lowering cost and lowering complexity. The booster and pre-booster rings were modified to fit in the same tunnel, again reducing construction costs.

"A number of R&D efforts were outlined and will be carried out in 2015 and beyond, including: ion source design; superferric magnet studies; crab cavities; SRF cavities at 952 MHz; magnetized electron sources; IR magnet designs; and studies of electron cooling. MEIC R&D will be undergoing a thorough review later in the summer. While the final site selection has yet to be made, Jlab is working hard to complete their design and reduce the highest risk items.

"The FEL operation has been stopped, and the people absorbed back into various accelerator groups. The facility was renamed LERF ('low energy recirculation facility' or '… research facility') and a new mission is being sought. An initial 'DarkLight' experiment will be carried out soon, to search for dark photons. Other options being considered include: using an ERL for isotope production; industrial uses like lithography; and accelerator R&D, including MEIC, diagnostics, and positron production. The LERF is a unique machine and has great potential, but they are struggling to find funding for these new endeavors.

"Commissioning of the 12 GeV machine began recently after a long construction period. The commissioning process has gone well and is ahead of schedule, with beam delivered to all of the halls that are available at this time, with adequate beam quality. They have yet to deliver the full 12 GeV beam to Hall D, and will need to measure the beam degradation due to synchrotron radiation. A novel method was developed to allow beam to be delivered to all four halls simultaneously. In the past, only 3 halls could be serviced at one time. In the new scheme, the injector uses a different frequency laser, and one of the RF separators at the end is changed to allow the fourth beam to be delivered to Hall D.

"They are pursuing a number of accelerator improvement projects, including upgrades to the injector to meet future requirements for parity experiments. We had some discussions on why these projects were being undertaken now, when the improved parity quality beams are not needed for many years, and perhaps more beneficial reliability improvements should be started sooner. The panel suggested that they should revisit the prioritization of AIP projects.

"To increase the operating gradient of older cavities, they have replace C20 modules with C50 modules, and are using helium processing to improve cavities in place. As many experiments require the full beam energy, we discussed the desirability of having a spare C100 module. The likelihood of a failure is low, but the impact would be very high to

the nuclear physics programs. To increase reliability, a future replacement of an additional C50 with a C100 would provide even more headroom, allowing lower gradients which would lower trip rates. This would cost more than just a new cryomodule, as RF power would need to be upgraded as well, so would not be inexpensive.

"Jlab has an extensive amount of 'work for others' in progress. The largest project is for the LCLSII project at Stanford. They are constructing ½ of the total cryomodules, carrying out R&D on cavities process techniques, and designing and constructing 2 cryo plants. Their expertise in these areas is clear, and I have no doubt they will do an excellent job. At the peak of construction, nearly 70 FTE's will be used. They will need to carefully monitor the needs of this project to make sure it does not interfere with the needs of the 12 GeV program. They are also building a cryo plant for FRIB, and build and test SRF gun cavities for HZB.

"An LDRD program was started several years ago at a modest level of about $800k per year. This enables researchers to get a head start on R&D efforts for future projects that might otherwise be difficult to get funding for. It has been an effective way to begin work on MEIC concepts, for example."

Reviewer:
"Past facility operations at JLab have supported a high-profile international science program with outstanding performance. Strong progress has been made during 2014-15 toward commissioning the 12-GeV upgraded accelerator facility. Beam performance meeting or exceeding the requirements set by the science program has been largely demonstrated at an energy of 10.5 GeV, but an untimely power outage in March 2015 prevented a comparable demonstration at closer to full energy prior to this review. Given the decade-long backlog of experiments already approved for the 12 GeV era, two specific plans presented to improve the machine's operational efficiency in providing beam to multiple halls seem especially welcome: an SLI proposal to upgrade the End Station Refrigerator plant to reduce risk of failure and enhance capacity to accommodate simultaneous operation of Halls A, B and C; and the development of 750 MHz separators that will facilitate simultaneous delivery of beam to Hall D, as well.

"The short- and long-term stability of accelerator operation at full energy is extremely important to the 12 GeV science program. The early commissioning operations have been plagued by frequent RF trips even at energies significantly below the 2.2 GeV/pass needed to deliver full energy. Such trips degrade beam availability. It is anticipated that helium processing of all the superconducting RF cryomodules during Summer 2015 will increase the achievable gradients at acceptable trip rates sufficiently to achieve about 5% headroom over full-energy operation. However, that performance is expected to degrade gradually over the years, at a rate that is reasonably well known from earlier 6 GeV experience. In addition, there is an appreciable single-point failure risk associated with the failure of a single C100 cryomodule (one of which already suffered a vacuum event in Fall 2014), which would prevent full-energy operation. The steady refurbishment of one C20 cryomodule per year to operate as a C50 provides some safety margin. But

given the scientific importance of robust full-energy operation, it would seem prudent to construct a spare C100 cryomodule to have available, or even eventually installed in the accelerator, to provide backup or improved headroom.

"Recently or nearly completed Accelerator Improvement Projects have enhanced reliability of the Central Helium Liquefier and matched the injector and dogleg to 12 GeV operation. The further AIP projects proposed for FY15-19 are aimed primarily at improving the beam quality needed for advanced parity violation experiments. Parity experiments are a high-profile centerpiece of JLab's past and future programs, and the desirability of these upgrades is clear. However, it is not clear at this time that the timing of these AIP projects is optimally matched to the projected timelines of the 12 GeV science program. Improved beam quality is unlikely to be ready, and is really not necessary, for the PREX-II and CREX experiments that are currently projected to run in Hall A in 2017-18. The beam quality improvements are essential for the MOLLER and SoLID parity violation experiments, but since both experiments rely on sizable future MIE detector projects, it is highly unlikely these can be ready for beam before approximately 2022. In light of these timelines, it seems wise to reconsider whether some stretch-out of the AIP projects might free up enough funding in the next few years to fabricate the spare C100 cryomodule discussed above.

"Very good progress has been made toward completing the 12 GeV upgrade project, including early commissioning of beams at an energy of 10.5 GeV. Especially noteworthy during the commissioning stage has been the opportunity for the GlueX detector to see early beam and begin to optimize event reconstruction algorithms. Most of the problematic superconducting magnets needed for the experimental hall upgrades seem now to be under control, although appreciable risk remains for the superconducting solenoid for CLAS12.

"Upgrades to the experimental halls associated with the 12 GeV project are close to completion, although the Hall B superconducting solenoid remains on the critical path for reaching the proposed early completion date at the end of calendar year 2016. However, a substantial fraction of the PAC-approved beam time for the 12 GeV era relies, in addition, on the two major not-yet-approved detector construction projects MOLLER and SoLID, or on a large suite of 22 smaller detector and target upgrades. Bringing all of these further upgrades in on a timescale that allows the current backlog to be run even over a decade represents a serious challenge for JLab management. Among the smaller projects, particular risk concerns were raised during the review about the HDIce transversely polarized target development, which is absolutely essential for the substantial transverse spin program at CLAS12, but which needs significant R&D to solve beam heating problems and appears, in the current tentative planning, to come in just under the $2M limit imposed on capital equipment projects.

"The superconducting RF and cryogenic design and engineering teams at JLab provide clear technical leadership within the U.S. This leadership is evident both in the 12 GeV accelerator upgrades and in the substantial new roles the group has taken on Work for Others projects, most prominently for LCLS-II and FRIB. In particular, the commitment

to provide half of the cryomodules for LCLS-II will require a large fraction of the available SRF and cryogenic FTEs at JLab. Bottlenecks are foreseen in cryo-engineering person-power, and JLab management will have to monitor the situation carefully to anticipate any possible conflicts between 12 GeV operations and improvements, on the one hand, and meeting LCLS-II project milestones, on the other.

"The newly renamed Low Energy Recirculating Facility (LERF) is a one-of-a-kind machine with strong potential to serve as a base for advanced accelerator R&D experiments. However, the laboratory has struggled for some years to establish a suitable user base for this facility, and defining its scientific mission going forward remains a work in progress. One of the intended future uses of LERF is for an experiment – DarkLight – that is well aligned with the CEBAF program searching for massive neutral vector bosons that potentially couple to dark matter. However, given the other worldwide searches that are gradually encroaching on the specific sensitivity range for DarkLight, the urgency of this particular experiment was not clear to me. JLab preparations for it should not be allowed to compromise progress on the many other construction projects more central to the 12 GeV science program impact.

"JLab staff and users have contributed quite significantly over the past few years to the development of the science case for an Electron Ion Collider, culminating in the recommendation in the ongoing 2015 Long Range Plan of an EIC "as the highest priority for new facility construction following the completion of FRIB." Very good progress has been made as well on the bottom-up machine design and cost estimation for the JLab version (MEIC) of this accelerator."

Reviewer:
"The accelerator group consists of 154 people and 14 graduate students. Several accelerator staff members also teach classes at Old Dominion University (ODU). The group concentrates on 12 GeV performance and operations, MEIC, core competencies, work for others, and education. The Critical Decision-4A (CD-4A) achieved for the 12GeV upgrade in July 2014, was achieved five months ahead of schedule and CEBAF is transitioning into user operations. CEBAF delivered 10.5 GeV beam to Hall D for commissioning and to Halls A, B and C simultaneously. A plan for an upgrade to deliver beam to all 4 halls simultaneously was presented. By switching to a new laser frequency and adding different RF separators, beams could be delivered to 4 halls simultaneously. This is an important improvement that will provide more beam time to the users. The beam performance at 10.5 GeV is generally better than required. Performance requirements should be proven as soon as possible at the design energy of 12 GeV.

"In general, the accelerator performance continues to be world class at JLab. Well-planned transition to operation following completion of the 12 GeV upgrade project is essential for JLab's early physics programs to succeed. This requires a reliable operation with minimum number of interruptions (trips, failures) and is essential to maximize the beam availability. The beam energy management, as well as low trip rates, require high performance cryomodules and a continuous improvement program. A failure of a C100 cryomodule will reduce the available beam energy to below 12 GeV. It seems prudent to

build a spare cryomodule (C100) to ensure 12 GeV capability, and eventually put it online to reduce the number of trips per hour. A risk assessment for the facility should be redone and funding priorities (AIP, GPP, operations funds) be re-evaluated.

"The cryogenic group is doing an impressive job covering a number of large projects (LCLSII, FRIB, and 12 GeV). However, they have barely enough staff, and challenges in meeting the commitments in any one of these projects will impact progress on the others. This should be tracked carefully. Since the cryogenic team is the premier group in the U.S. in this field, they should work towards developing new engineering talent so as to maintain this important skill set for the U.S., and to provide expertise for other DOE laboratories. In general, one should consider an increasing university involvement in accelerator science by expanding the use of bridge and joint appointments, particularly for universities without accelerator science programs. Being engaged in a number of high profile DOE projects, which commit a substantial fraction of the staff, it is crucial for JLab's reputation to deliver on them and that requires enough well-trained staff. The 'work for other' contracts include building half of the cryomodules for LCLS II and 2 full cryoplant, as well as a cryoplant for the Facility for Rare Isotope Beams (FRIB). The superconducting radio frequency (SRF) group is engaged in a wide variety of projects across the world, with work at HZB, CERN, FRIB, LCLS II, to name a few. The former Free Electron Laser (FEL) facility has been renamed the Low Energy Recirculating Facility (LERF), and a new mission for the facility is being developed, including nuclear physics, isotope production and accelerator physics research.

"The Accelerator Improvement Projects (AIPs) and investments funded from the operations budget are used to maintain or improve accelerator performance in several areas (injector upgrade, parity priorities, energy stability etc). A new ¼ cryomodule for the injector will reduce x-y coupling and allow lowering the emittance and improving helicity dependent effects, and an increase the gun energy will similarly improve performance. However, the projected operations budgets corrected for inflation do not allow full utilization of the CEBAF facility.

"The injector group continues to make excellent progress on developing DC high voltage, polarized electron sources. Electron beam diagnostics, particularly with wide dynamic range, are actively pursued by the accelerator group.

"For the future, MEIC is becoming a cornerstone of JLab's strategic plan. A modest research and development (R&D) program is underway. The MEIC design plan was updated in 2015, and a preliminary cost estimate was reviewed by the Nuclear Science Advisory Committee (NSAC). An internal MEIC laboratory organization was formed in 2014. The former Free Electron Laser (FEL) facility has been renamed the Low Energy Recirculating Facility (LERF), and a new mission for the facility is being developed, including nuclear physics, isotope production and accelerator physics research."

Reviewer:
"Accelerator performance continues to be world-class at Jefferson Laboratory. Well planned transition to operation coming off the 12Gev upgrade project is essential for

JLabs early physics programs to succeed. With CD-4A achieved for the 12GeV upgrade in July 2014, which was 5 months ahead of schedule, CEBAF is transitioning into user operations and JLAB has to be congratulated.

"Soon after CD-4A, CEBAF delivered 10.5 GeV beams for commissioning to Halls A, B and C. An innovative plan also delivers high energy beams to Hall D which was presented and will be implemented.

"The increased number of beam trips and gradient limitations made operating during commissioning at the lower energy, a prudent choice. A clear correlation between gradient and trip rate was shown. Nevertheless, the science program demands over the next decade or so a reliable operation at 12GeV or above. Beam energy management, as well as low trip rates require high performance cryomodules. It is a continuous improvement program not only on the old, but also on the new cryomodules. Should a C100 cryomodule fail, the available beam energy will inevitably be reduced to below 12 GeV.

"Accelerator Improvement Projects (AIPs) and investments funded from the operations budget are used to maintain or improve accelerator performance in several areas (injector upgrade, parity priorities, energy stability etc). A new ¼ cryomodule for the injector will reduce x-y coupling and allow lowering the emittance and improving helicity dependent effects, and an increase in gun energy will similarly improve performance.

"Reliable operation with minimum number of interruptions (trips, failures) is essential to maximize the beam availability. A risk assessment for the facility should be redone and funding priorities (AIP, GPP, operations funds) be re-evaluated. It seems prudent to build a spare cryomodule (C100) to ensure 12 GeV capability as a first step. Eventually it should be placed online to allow steady beam energy management and/or reduce the number of trips per hour by reducing the average gradient required to achieve 12 GeV.

"During the commissioning period, the beam quality (emittance, energy jitter, etc) generally exceeded the requirements apart from a few locations where the quality still has to be verified. Since these measurements were done at 10.5 GeV, the emittance will grow due to synchrotron radiation and the beam performance should be verified as soon as possible during the next commissioning run at the design energy.

"A recent power loss incident in a 2K cold box, driven by an uncontrolled loss of electrical energy resulted in a catastrophic failure of a turbine. Back-up power usually should prevent catastrophic events like this that was not functioning. With the repair in place and an extent of condition assessment done, the cryogenics team should make sure that the risk of such events is reduced to an absolute minimum.

"Following the outyear budget guidance from the Office of Nuclear Physics' projection, it is clear that the projected operations budgets when corrected for inflation, do not allow full utilization of the CEBAF facility. The beam time provided to users is shortened, as compared to the possible operations time. Commissioning the accelerator complex in

preparation of user operation, as well as the scheduling of experiments, require significant scrutiny and transparent prioritization of experiments. The backlog of approved experiments was only recently reduced to one or more manageable level of 600 PAC days and even that seems high as compared to the operations scenarios represented by the budget scenario.

“MEIC is becoming a cornerstone of JLAB’s strategic plan. A modest R&D program is underway. A preliminary cost estimate was positively reviewed and JLab’s management is committed to continue the development of their concept. JLab has set up an internal organization to support this effort and we were told that setting up a larger collaboration is being considered. Given the scale and scope of the MEIC, this is a prudent step. From the laboratory’s and the Program Office’s point of view, it would be good to reach out to the High Energy Physics part of the world since the MEIC physics case has some overlap.

“After the shutdown of the FEL program, a new mission for LERF will be developed over the next 9 months. A management retreat is being planned within this time period and a clear direction is missing for now. The FEL is the highest performing VUV FEL worldwide and it would be a pity if the program does not continue. Although, it is understood that it might be somewhat outside the mission of a Nuclear Physics Laboratory.

“Being engaged in a number of high profile DOE projects which commit a substantial fraction of the staff, it is crucial for JLab’s reputation to deliver on them. This is both a strength and a weakness. It is an attest to the tremendous expertise the laboratory has built up. Nevertheless, the resources are stretched to the limit and an extraordinary event or delay can impact JLab’s operation on one of the high profile projects. A bit more formal risk analysis and development of mitigation strategies is something very useful. The management may not necessarily agree with this but having it is of great advantage because it will make reaction to a crisis, a more planned act rather than “a quick fix”.”

Reviewer:
“At present it appears that the halls have developed, or are employing, separate software suites. If this is the case, and if it is possible, developing an overall laboratory computational strategy and platforms would be useful. For example, Monte Carlo methods, event generation, detector simulation, data storage, etc could all benefit from a cohesive approach.

“Substantial research and development effort is being applied to the proposed MEIC. This planning appears to be mature and well-developed, and has not interfered with the lab’s core mission. Furthermore, a variety of facility upgrades are in development on detectors, targets, and controls. Some of this effort is devoted to reliability issues. The importance of reliability has been demonstrated with the recent power supply disruption incident. It is clear that a careful risk analysis and prioritization of mitigation methods is of primary importance.

“Only 16 weeks of beam time are currently approved. Hopefully this will improve in future. The paucity of beam time implies that smooth accelerator operation is crucial. Thus it is desirable that the current trip rate (which amounts to 12% of beam time) be reduced. Lab staff is well aware of this issue and is performing R&D to address it.

“The PAC has approved 3400 days of running split approximately as Hall A: 1350 days, Hall B: 670 days, Hall C: 670 days, and Hall D: 640 days. This amounts to a ten year backlog in the experimental program, which one suspects is problematic for experimentalists seeking to manage their effort. The lab is considering implementing “jeopardy” to reduce this backlog. Any effort to clarify the situation for the users and to fairly and efficiently prioritize resource usage is encouraged.

“The Low Energy Recirculator Facility (LERF) has been defunded by the naval research office, thus seeking a viable mandate for this facility is of primary importance. In this regard, the planned R&D effort on medical isotope production can be very useful, especially in view of the anticipated reduction in global supply capabilities.”

The leadership, creativity, and productivity of the facility's scientific and technical staff in carrying out the above activities:

Reviewer:
"The review process began with talks to introduce us to the Lab and its science program. Data was presented which back up its national and international physics leadership. For example, the national leadership was substantiated by the scores in the national comparative research review and the international leadership by the hosting of international conferences and workshops.

"This has largely been covered in outlining the national and international leadership of the Lab above. The scores in the national comparative research review substantiate this as do the awards to individuals, the many invited reviews and talks given by Jefferson staff."

Reviewer:
"The accelerator department has 154 staff with 13 graduate students. They have a close association with Old Dominion University and several Jlab staff teach classes there. They are trying to develop associations with other universities. They should try to start more joint and/or bridge appointments with faculty at other universities. These appointments have been very successful in the theory and experimental nuclear physics groups. They should also continue maintaining 12 or more accelerator physics graduate students, to help fill the needs at other labs around the country."

Reviewer:
"JLab staff provide clear U.S., and often international, leadership in electromagnetic physics (both experiment and theory), in various aspects of detector design, in lattice QCD computation, in superconducting RF technology, and in the continuing development of high performance polarized electron sources. A number of the senior staff members play prominent roles in U.S. advisory, review and planning panels. Bob McKeown recently served as the Chair of the APS Division of Nuclear Physics. Several of their more junior bridge and joint faculty appointees have won DOE Early Career Awards and, in the case of Andre Walker-Loud, the prestigious Kenneth G. Wilson Award for Excellence in Lattice Field Theory. JLab staff have been involved in organizing many national and international workshops and conferences. In particular, the accelerator staff was prominent in hosting the IPAC2015 international accelerator physics conference. All of these roles and awards speak to the respect of the broader nuclear and accelerator physics community for JLab staff members.

"JLab scientific staff play central roles in executing the 12 GeV science program. Two-thirds of the approved experiments, including the highest science impact experiments selected by PAC, have JLab co-spokespersons. The experimental hall leaders play dominant roles in planning the schedule and ensuring the readiness of experiments, and in communicating with users about hall priorities. Both the experimental and theoretical groups at JLab received scores near the top of those awarded in the 2013 ONP comparative review of DOE-funded research groups.

"Several of the technical innovations developed recently at JLab seem especially noteworthy. They have achieved world records for polarized electron source current. The figure-8 design of the MEIC storage rings provides a very clever way to maintain beam polarization through acceleration to high energies, even for deuterons with their small intrinsic magnetic moment. The ongoing development of Nb/Cu films provides a promising avenue for further improvements in superconducting RF cavity performance. The first extensive use of silicon photomultipliers in a large detector (the GlueX Barrel Calorimeter) has fueled an innovative application adapting SiPMs to a compact hand-held gamma camera."

Reviewer:
"The TJNAF supports in total 673 FTEs and accounts for app. 1/3 of the U.S. PhDs in Nuclear physics. The Laboratory's training mission for junior scientists is commendable. JLab staff has won a suite of awards, including Early Career Awards, APS Fellows, and DOE Secretarial Awards and the Laboratory scores in the DOE NP Comparative Reviews in Theory and Experimental Physics, which were well above average.

"The management team is a highly competent, effective and well-balanced. The lab staff itself is heavily engaged in the experiments, often in leading positions in the collaborations. This shows leadership and creativity in proposing and shaping the physics program for JLab. The leadership role that JLab staff plays in the community is evident from the numerous appointments of their staff to important committees which help guide the national program in nuclear science.

"JLab has strong accelerator leadership engaged in all aspects of the Laboratory's programs. The technical staff is excellent at all levels. Given the competence of the staff, they are engaged in a number of high-profile construction projects outside the lab, like LCLS II, FRIB, LARP within the DOE complex. The recent hosting of IPAC2015 and ICFA, demonstrates JLab's leadership in the international accelerator physics community.

"The SRF developments, MEIC studies and polarized source R&D illustrate the scientific creativity and productivity of the JLab staff. The development of detector technologies for nuclear physics has led to spin-offs and new applications. Several innovations appear in connection with the research done at JLab.

"The responsiveness of the staff to questions during the review was very impressive and extremely effective, generally answering with the required level of detail."

Reviewer:
"Lab staff continues to win accolades from the community. This is illustrated with the Career Awards that have been won by Solvignon (UNH) and Puckett (UConn). Furthermore, lab staff contributes in substantial ways to the development of nuclear physics at the national level. This is demonstrated by a long list of contributions to panels, editorial boards, organizing committees, etc.

“My overall impression is that the staff is impressively competent. This impression is confirmed whenever I speak with individuals about their specific work. Furthermore, management appears to be focused, knowledgeable, and industrious. The communication with staff appears to be excellent.”

The quality and appropriateness of the laboratory's interactions with, and nurturing of, its scientific community:

Reviewer:
"Interaction with the US community is promoted in various ways. The appointment of joint and bridged staff has already been mentioned. Most experiments have a external spokesperson and a Jefferson co-spokesperson. The selection of experiments is done by the meetings of a Physics Advisory Committee (PAC) with external members.

"Interaction with the users of the experimental facility is managed through a user's group and we also heard a presentation from them. Their board meets twice annually to review complaints, comments and feedback. The whole users group meets once a year. These meetings allow users to understand the experiment selections made by PAC and the decisions on scheduling of the selected experiments. The users group can also suggest the names of members of PAC and the DNP executive and thus have input to management. There is a user's voice on the use of JSA funds. They also have input on issues such as diverse as safety, adequacy of teleconferencing facilities, race and gender discrimination. To mention embedding in the broader community the users group also organize an outreach day to Washington DC.

"Interaction within the international community has already been mentioned when describing the activities of the JPAC, but it is also important to mention that usage of the experimental facilities is ~30% international.

"Also under the category of interaction with the scientific community I think it is important to mention that spin-off from the direct physics concern of JLab has led to technology transfer in the 3-D imaging of the brains of mice, which will have impact in research into brain defects, Alzheimer's disease, etc."

Reviewer:
"Interactions with the laboratory's scientific community appear strong and healthy. The JLab user community is strongly engaged in contributing to both the near- and long-term health of the laboratory. There is very strong user interest in the 12 GeV science opportunities, as witnessed by the decade-long backlog of already PAC-approved experiments. This backlog is more than the optimum amount needed to provide sufficient flexibility in scheduling. It will likely require the PAC "jeopardy" review program to be reinstituted a few years into the 12 GeV operations era, with the potential to introduce some tension among users. However, the Users Group representatives seem to understand the necessity of such reviews and accept them as a reasonable approach to maintaining the vitality of the science program. JLab management took a first constructive step in setting priorities among the approved experiments by convening a special PAC meeting in 2014, charged with selecting about 600 PAC-days of the highest-impact science proposals that could run during the early years of 12 GeV operations. These impact judgments have informed the early physics plan presented at the review.

"Laboratory management typically develops 18-24 month detailed beam schedules with major input from the experimental hall leaders, who serve as intermediaries to the broader user community. The Users Group expressed satisfaction with the level of communications from the laboratory during and after the construction of these schedules. In addition to this detailed schedule, management presented a more conceptual 4-5 year early physics plan, providing a sketch of which experiments in each hall would likely run in which years. It would be advisable to maintain a running 5-year conceptual schedule such as this going forward, informed by jeopardy reviews and occasional reevaluation of science impact, because it helps users greatly in planning student and post-doc projects, teaching and sabbatical schedules, and balancing of different commitments.

"With the exception of the special science impact PAC meeting in 2014, laboratory management has not so far given the PAC explicit guidelines regarding how much 12 GeV beam time they should approve. This will probably need to change as the upgraded CEBAF approaches steady-state operations, in order to avoid building up an even larger backlog and to maintain high overall science impact. When there are explicit guidelines for PAC-days to approve, it will be important also to involve the PAC chair more fully in crafting an agenda for the meetings, in order to ensure efficient discussions of tough choices that will be needed to meet the guidelines.

"Another method to optimize science impact is to request the collaborations associated with the large general-purpose detectors – CLAS12, GlueX, SoLID – to set internal priorities for new beam proposals before they are submitted for PAC approval. This works well for large collaborations at other facilities, forcing healthy science discussions within each collaboration. Laboratory management made a first step in this direction with their policy change before the most recent PAC meeting, removing the need for explicit PAC approval of new proposals that fit within already approved Run Groups, and which require neither new beam time nor significant equipment modifications. However, the proposals submitted to the most recent PAC attest to the fact that the users have not yet fully absorbed this policy change.

"The laboratory has taken a number of other positive recent steps to enhance the involvement of users in helping to guide laboratory directions. A series of workshops for JLab user community members has increased user involvement in EIC science and detector planning. The Users Group expressed strong appreciation for laboratory efforts to solicit user opinion on JLab policies, with the recent inclusion of a user representative on the Director's Safety Council as a good example. A Jefferson Science Associates Initiative fund of roughly $400K/year provides critical support for Users Group activities. And a number of new bridge and joint university faculty appointments have been made with JLab support. These appointments are effective in nurturing maintenance of a strong JLab scientific community, in addition to enhancing the laboratory's productivity."

Reviewer:
"The JLab management receives advice from a PAC.

"The decade-long backlog of approved experiments for the 12 GeV era is more than the optimal amount needed to provide sufficient flexibility in scheduling. It will likely require the PAC "jeopardy" review program to be reinstituted a few years into 12 GeV operations, with the potential for introducing some tension among users. However, the Users' Group seems to understand the necessity of such reviews. In order to start such a process. the JLab management charged a special Program Advisory Committee meeting in 2014 with selecting about 600 PAC-days of the highest-impact science proposals among a nearly decade-long suite of already approved experiments for the 12 GeV era. At previous other PAC meetings, the Laboratory had not provided the PAC with explicit guidelines regarding how much 12 GeV beam time should be approved. As the Laboratory approaches steady-state 12 GeV operations, it will be useful for them to provide the PAC with more explicit guidelines regarding the number of beam hours to approve at each meeting, in order to maintain scheduling flexibility and high science impact.

"The Laboratory has initiated a change regarding the need for explicit PAC approval of new proposals that fit within already approved Run Groups and require no new beam time or significant equipment modifications. The Run Group participants have not yet absorbed this message. It may be useful for the Laboratory to consider encouraging the Collaborations – especially those associated with large general-purpose detector facilities such as CLAS12, SoLID and GlueX – to more strongly set internal priorities for beam proposals prior to submission of collaboration proposals for PAC approval. The change in policies for Run Group experiments is an initial step in this direction. The Laboratory management should involve the PAC Chairperson in developing the PAC agenda.

"The Laboratory noted that scheduling of experiments is a difficult multi-parameter issue that involves the readiness of the experiments and other constraints. Early science and more detailed 18-24 month beam schedules are developed with major input from the experimental hall leaders, who serve as intermediaries to the broader user community. The Laboratory should consider establishing a running five year schedule, which could be informed by a "jeopardy" review program.

"The Laboratory requires each experiment to undergo a rigorous Experimental Readiness Review before it can be scheduled for beam time. The user community seems strongly engaged in contributing to both the near- and long-term health of the Laboratory. The Users' Group seems reasonably content with the level of communications from the Laboratory regarding scheduling and priorities.

"The Laboratory makes extensive use of bridge and joint faculty positions at universities to grow and nurture their scientific community, as well as to enhance JLab science productivity.

"A Jefferson Science Associates (JSA) Initiative fund of roughly $400,000/year is judged by the Users' Group Board of Directors to provide critical support for Users' Group activities.

“The Users’ Group expressed strong appreciation of Laboratory efforts to solicit user opinion and provide updates on Laboratory policies. A specific example is the recent inclusion of a user representative on the Director’s Safety Council.

“A series of workshops for JLab user community members has served to increase user involvement in EIC science and detector planning. A number of talks and international discussions within the past two years have been used in attempts to grow international participation in development of MEIC.”

Reviewer:
“JLab’s management and staff are engaged in a wide variety of activities, including the management of a number of international workshops and conferences. JLab is clearly catering to its community and the fact that there is a large over commitment in experimental time requested, gives some hint that the community is very interested and wants to use the opportunities presented by the lab’s infrastructure. JLab also continues to plan improvements and build outs of their infrastructure and instruments consistent with the requests from the community.”

Reviewer:
“Outreach and service activities by the staff are excellent. This effort ranges from public open houses, to scientific service work, as mentioned previously. Creating joint and bridge positions is an additional and important outreach activity. As mentioned before, this activity would benefit by creating a overall strategy for implementation, with an eye to meeting anticipated future experimental support requirements.

“Lab interaction with the user’s group appears to be good — no issues were raised during the review. However, it may nevertheless be useful to implement small changes. For example, it would be desirable if the PAC were to create a charter; involving the PAC chair in setting the PAC agenda would smooth the work of that body; placing a user group member on the experiment scheduling committee would be sign of good faith; as would generally improving the level of communication with the users.”

The effectiveness of management in strategic planning, developing appropriate core competencies, implementing a prioritized and optimized program, and promoting and implementing a safe work environment:

Reviewer:
"The good safety record was presented in the initial presentation about the Lab by the director. The competence of the staff has already been covered. The strategic planning, prioritization and optimization is guided by the PAC meetings, which are the means by which experiments are selected for beam time. These are held roughly yearly and we were given some statistics on typical success rates, e.g. 5 experiments approved out of 19 proposals. Sometimes proposals are conditionally approved pending technical requirements. The role of management is then to schedule the approved experiments.

"This procedure had led to a 10year back-log of experiments and so a special PAC, PAC-41, was held to select the high impact proposals to be conducted in the first 600 days of 12 GeV running. Practicalities such as beam specifications and requirements, readiness of detector equipment and time to analysis were also considered and 643 days of experiments were finally selected. Future submissions to PAC have been asked to consider the following: i) proposals may need no new beam time—i.e. they are additional analyses internal to a collaboration, possibly needing augmentation of target/detector facilities; ii) when new beam time is applied for the proposal should also consider other experiments that could use the same beam. In this way beam time can be optimized.

"These procedures will streamline the effectiveness of management. The users' group seemed satisfied with these procedures and with the safety record."

Reviewer:
"JLab has a highly competent, effective and well-balanced management team. This includes the experimental hall leaders, who play key roles in drafting early science schedules, communicating them to the users and gathering feedback from the users.

"The early 12 GeV physics plan presented by the management does an effective job of balancing the multi-dimensional scheduling constraints, including: science impact and timeliness; technical risk and readiness of each experiment; suitability for early beam performance characteristics; compatibility with completion of 12 GeV upgrade construction projects in the experimental halls; and involvement of students and junior scientists. Operations funding uncertainties going forward, combined with reliance on a large number of ongoing and planned modest target and detector upgrades, imply that the schedule will have to be kept flexible for the next several years to accommodate unanticipated delays. One particular very positive step the management has recently taken to enhance the early science impact is the establishment of an external software and computing review team, to help ensure that detector data acquisition, simulation and analysis software will be ready to facilitate timely reporting of early physics results.

"Several of the potential risk concerns mentioned previously in this report will have to be monitored closely by management: (1) the priority for fabrication of a spare C100

cryomodule to mitigate risk for reliable delivery of full energy beams, vis-à-vis other planned accelerator improvements; (2) potential overstressing of cryogenic staff in meeting the demands of the JLab contributions to the LCLS-II and FRIB projects, while maintaining reliable performance of the 12 GeV CEBAF; (3) progress on the HDIce development, with the possible need for an early decision point regarding how to proceed to optimize the CLAS12 scientific program; (4) schedule slippage or cost overruns on some of the 22 capital equipment projects being pursued in FY2013-2019.

"The management has devoted sufficient resources, during the heavy work load associated with 12 GeV construction, to work on EIC science simulations, as well as MEIC design and costing exercises, to maintain a viable case going forward for an EIC built at JLab. This progress has been aided by the initial establishment of a modest JLab LDRD program, whose funds have so far been devoted largely to EIC-related R&D. These funds complement MEIC accelerator R&D support from JLab operations funds and from a competitive Nuclear Physics Office funding program. Even if an EIC were to be built at Brookhaven, JLab would undoubtedly make major contributions to the accelerator and detector construction. JLab management has also been proactive in enhancing international interest in EIC, boosted by JLab's recent hosting of the ICFA, IUPAP and International Particle Accelerator Conference meetings.

"The management continues to be quite effective in nurturing laboratory core technical competencies in superconducting RF, polarized electron source development, advanced detector development and lattice QCD computation. Nurturing of their future user community is centered around a healthy program of bridge and joint faculty positions with a substantial number of universities. However, the laboratory's strategy behind the choice of which such appointments to fund was not made clear. In particular, it was not clear how proactive the laboratory is in stimulating appointments aligned with JLab strategic planning.

"The laboratory is to be commended for their improved safety record in FY2014-2015, following a slight deterioration during the peak years of 12 GeV construction, with TRC and DART rates now well below the goals set. Of particular note are the significant revisions made to the Safety Awareness Training for the experimental halls and the initiation of a student safety mentorship program."

Reviewer:
"JLab management has developed and presented a sketch of an early 11-12 GeV physics program for each experimental hall during FY2015-2019. The experimental hall leaders play key roles in drafting early science schedules, communicating them to the users and gathering user feedback. A new external software and computing review team has been established, and has met three times to date, to ensure that detector data acquisition, simulation and analysis software will be ready for 12 GeV science and facilitate timely reporting of early physics results. The early physics plan effectively addresses the challenging multi-dimensional balancing of science impact and timeliness, technical risk and readiness, suitability for early beam performance characteristics, compatibility with

completion of 12 GeV upgrade construction in the halls, and involvement of junior scientists.

"JLab management is providing oversight of 22 modest detector and target upgrade projects being funded in FY2013-2019 by Capital Equipment and non-DOE sources, in addition to preparing major items of equipment (MIE) cases for the proposed major MOLLER and SoLID detectors. With so many small target and detector upgrades required, coupled with operations funding uncertainties, the 12 GeV schedule for the next several years will need to be kept flexible to accommodate unanticipated delays. JLab management has very recently instituted efforts to do more quantitative risk analysis for single points of failure affecting accelerator operations. On a slightly longer time scale, a significant portion of the CLAS12 science program relies on overcoming significant risks inherent in the HDIce development for transverse polarization operation. Laboratory management should consider a decision point at which backup plans are developed.

"The Laboratory maintains an impressively broad expertise in accelerator design, construction and operation as well as cryogenic engineering. It will be important to have a well thought out succession plan to maintain these standards. The management continues to nurture the Laboratory's core technical competencies in superconducting RF, lattice QCD computation, and advanced detector development. The superconducting expertise, in particular, is being exploited in JLab projects that are part of the LCLS-II (SLAC) and FRIB (Michigan State University) construction projects. The JLab commitment to LCLS-II cryomodule fabrication involves a significant fraction of available SRF and cryogenic workforce, especially with regard to process engineers. Management will have to carefully monitor and manage the impact of possible delays in LCLS-II fabrications on 12 GeV operations.

"An R&D program supporting EIC science and technology has been put in place, using a newly established Laboratory Directed R&D (LDRD) program in addition to operations funds and competitive accelerator R&D funds from the Office of Nuclear Physics. Substantial progress has been made over the past two years on MEIC design and costing estimates. The management has also worked to increase involvement of the JLab user community in developments of the EIC science case and detector requirements.

"The Laboratory continues to make extensive use of joint and bridge appointments with universities to support both the experimental and theoretical research programs. However, the JLab strategy behind choices of joint and bridge faculty appointments was not made clear. In particular, it was not clear how proactive the Laboratory is in stimulating appointments aligned with the Laboratory's strategic planning. It would be useful to create an overall strategy for the creation and pursuit of bridge and joint positions.

"JLab's safety record has improved in FY2014-2015 following a slight deterioration during the peak years of 12 GeV construction, with TRC and DART rates now well below the goals set. The Safety Awareness Training for the experimental halls has been

significantly revised. The Laboratory is commended for implementing a student safety mentorship program."

Reviewer:
"Over the last decade, JLab has continued to build out its cryogenics infrastructure. Today the cryogenics facilities, as well as the labs and shops are a 'one-of-a-kind' infrastructure in the DOE complex and a unique asset to the Mission of the Department of Energy beyond the Office of Science. The R&D, the construction and the operation is world class and recognized as such. JLab management promotes a safe and clean work environment.

"Based on JLab's key competencies in SCRF and Cryogenics, the staff is engaged in number of high profile construction projects (e.g. LCLS II, FRIB, LARP,12 GeV) within the DOE complex. The cryogenic group is doing an impressive job covering such a large number of projects. JLab has barely enough staff, and challenges in meeting the commitments in any one of the projects will impact progress on the others. This has to be tracked carefully.

"JLab has a strong accelerator leadership engaged in all aspects of the laboratories program. Clear lines of authority exist and understood by everybody. The technical staff is excellent at all levels. The laboratory maintains an impressively broad expertise in accelerator design, construction and operation, as well as cryogenic and mechanical engineering. It will be important to have a well thought out succession plan to maintain these high standards for the laboratory."

Reviewer:
"The laboratory has implemented an extensive system of equipment and experimental readiness reviews. Although I suspect that this can sometimes be onerous for the persons involved, I believe that this is an effective management practice that ensures safe and productive lab operations.

"Extensive R&D is being conducted in all aspects of the lab's activities. Indeed, the breadth of the R&D effort is impressive for a relatively small national laboratory. This effort assists in achieving national goals in nuclear physics and is making substantive impact on other areas, such as particle physics.

"An uptick in safety incidents was noted during the civil construction phase of the12 GeV upgrade. The rate has since dropped to its previous, very low, levels. A student safety mentoring program has been implemented, which is a commendable effort."

Overall Impression:

Strengths of the overall research program as presented:

Reviewer:
"There is very strong user interest in the opportunities afforded by the 12 GeV upgrade. The science program presented offers the promise of significant impact on worldwide nuclear physics research in both the short and longer terms. The experimental collaborations appear to be making good progress toward technical readiness to produce early results in a timely fashion. A few of the most prominent proposed experiments, such as the searches for physics beyond the Standard Model in parity-violating Moller and deep inelastic scattering, are technically very challenging, but should not require advances in theoretical understanding to analyze the results. Other prominent aspects of the science program – including the 3D imaging of nucleon structure from semi-inclusive deep inelastic and deeply exclusive reactions, and the search for hybrid mesons with exotic quantum numbers – do require concomitant progress on theoretical analysis tools. Establishment of the JLab Physics Analysis Center at an early stage in 12 GeV science planning has the potential to foster the required theoretical progress on a suitable time schedule."

Weaknesses of overall research program as presented:

Reviewer:
"Some prominent aspects of the 12 GeV science program are subject to significant technical, funding and timeline risks. The 3D nucleon imaging prospects rely heavily on the transverse spin program to be carried out with CLAS12 and on eventual semi-inclusive deep inelastic scattering measurements with the proposed SoLID detector. The former measurement program is dependent on the HDIce target being able to withstand electron beam heating, a requirement that needs significant R&D on a target design that has a somewhat checkered history. SoLID will require a large MIE project, likely to follow the MOLLER apparatus in funding profile. That timeline will put the project into significant competition for DOE NP funds with a ton-scale double beta decay experiment, with major MIE proposals from other laboratories, with a desirable startup profile for an Electron Ion Collider and, of course, with maintaining sufficient operations funds for the upgraded CEBAF. If SoLID is pushed back in time or not funded, the proposed program of parity violation measurements in deep inelastic scattering would be jeopardized as well.

"The JLab management team will have their hands full in bringing in the entire suite of capital equipment projects needed for the 12 GeV program on time, getting MOLLER and SoLID projects approved and funded on suitable time scales, making suitable progress toward an MEIC proposal, and managing potential resource conflicts with the laboratory's heavy commitment to LCLS-II. Of course, such challenges are much preferable to the alternative of having too few projects to keep the talented staff fully engaged."

Reviewer:
“More than a weakness, it seems a necessity to give clearer guidance to the PAC and prioritization for scheduling of experiments. While it is clearly understood that JLab management at the end will decide on the execution and sequence of experiments, a transparent process supporting the decision making process after initial prioritization is essential. Presently too many experiments are in line to easily understand the outcome of the existing process.”