U.S. DEPARTMENT OF
ENERGY
Office of Science

Department of Energy
Office of Nuclear Physics Reviewer Excerpts

on the

Joint Science and Technical, Cost, Schedule and Management Review

of the

Super Bigbite Spectrometer (SBS)

October 13-14, 2011

EXCERPTS FROM PANEL MEMBER REPORTS

The Joint Science/Technical, Cost, Schedule, and Management Review of the proposed Super BigBite Spectrometer (SBS) project was held at Thomas Jefferson National Accelerator Facility (TJNAF) on October 13-14, 2011. Provided below are excerpts from the reports of the review panel members regarding their findings in response to the review criteria they were asked to address.

The merit and significance of the proposed scientific program for the SBS:

Reviewer:
"The SBS program is designed to allow for precise measurements of the neutron electric and magnetic form factors, GEn and GMn, and the proton electric form factor, GEp, at high Q^2 values. The neutron measurements will more than double the Q^2 range compared to present data, while the proton measurement will significantly improve both the Q^2 range and precision on the extraction of GEp.

"Individually, these measurements are of significant interest to the community. The form factors encode the spatial distribution of charge and magnetization in nucleons, and thus provide the most direct access to the spatial distributions of quarks in nuclei. The JLab program of form factor measurements at 6 GeV utilizing polarization degrees of freedom has provided a dramatic improvement in our ability to measure form factors. This renewed interest in a program where experimental limitations has nearly halted progress on a topic that was always considered vital to the understanding the structure of protons and neutrons. The proposed measurements of GEp should be sufficient to determine if the proton's charge form factor becomes negative as suggested by the existing measurements and predicted by several models. The measurement of GEn will triple the Q^2 range, extending to the region where there is a dramatic spread in predictions from various models of the nucleon structure. The GMn measurement will extend to the Q^2 values where the proton magnetic form factor shows significant deviations from the dipole form, allowing for a test for this behavior in the neutron form factor.

"While the individual measurements can address specific questions, it is the combined set of result that provides the greatest impact. The proposed program provides a complete set of electromagnetic nucleon form factors up to Q^2=10 GeV^2, compared to the present limit of 3.4 GeV^2. The complete set of form factors provides a much greater ability to confront models of the nucleon. This is especially true as one goes to higher Q^2 values where the contributions from the pion cloud are expected to be small and the form factors are dominated by the 3-quark core. Many models do not include contributions beyond the quark core, or include additional contributions in an ad hoc fashion, making it difficult to evaluate the central ingredients of the model. In addition, a complete set of form factors allows for several model-independent comparisons. For example, any observed difference between proton and neutron magnetic form factors at high Q^2 would be evidence for contributions beyond those included in a non-relativistic model, and probe issues related to the symmetries between the up and down quark distributions. One can go beyond this to use the combination of proton and neutron form factors to separate the up- and down-quark distributions, assuming charge symmetry and neglecting the contributions of heavier quarks. This provides a direct measure of the difference between up- and down-quark contributions under a minimal set of generally well-accepted assumptions.

"Addressing certain questions will require model-dependent interpretations of the data. While current models are not sufficient to provide universally agreed upon interpretations, there is reason to believe that these issues can be meaningfully addressed by the data. Progress is being made in modeling the nucleon structure, including QCD-based calculations using the Dyson-Schwinger Equation formalism or Lattice QCD. In addition, the high Q^2 values of the proposed measurements will make interpretation within models more reliable, as there will be fewer issues related to the contributions of the nucleon's pion cloud. Finally, even though some interpretations of the data are model-dependent, it is still possible to find consensus as to the relevant underlying physics. The drop-off in the ratio of GEp/GMp observed by previous JLab measurements of the proton form factor ratio has been explained in several different models, and the detailed explanation is different in different frameworks. However, while explanations arise in terms of adding additional terms in the perturbative QCD expansion, including relativistic effects, or explicitly addition contributions of orbital angular momentum (OAM) in different frameworks, all of these either explicitly relate to OAM or require a non-zero OAM contribution. Thus, while the microscopic details of the effect differ, there is a general consensus that these data strongly support the role of quark OAM in the nucleon, even though there is no observable that can be directly related to the quark OAM in a model-independent fashion. Similarly, the observed difference in the Q^2 dependence of the up- and down-quark contributions in the existing data may be a signature of the importance of diquark configurations, but higher Q^2 is required before one can attempt to meaningfully interpret deviations from pQCD predictions. While the Q^2 range of this program may not be sufficient to test pQCD predictions for the Q^2 dependence of the form factors, the high Q^2 values obtained will make comparisons of the pattern of deviation from pQCD in different form factors much more significant.

"The high-Q^2 form factor measurements also contribute to the broader hadronic physics programs. Form factors provide the highest Q^2 constraints on generalized parton distributions (GPDs) in exclusive measurements. Because the GPDs are multi-dimensional functions, the relatively straightforward constraints that come from DIS structure functions and the elastic form factors are important in minimizing the freedom of the GPDs, maximizing the constraints from measurements of deeply-virtual Compton scattering or meson production. GPDs relate to information on the longitudinal momentum distribution and transverse spatial structure of the quarks in the proton and neutron. The transverse charge density can be obtained from the form factors, with high Q^2 measurements providing the small-scale transverse structure of the nucleon, related to contributions from high-momentum partons. Other GPD measurements can further map out the transverse structure dependence on quark momentum.

"The JLab high-Q^2 form factor program is not limited to the measurements possible with the SBS. A high-Q^2 measurement of the proton magnetic form factor, not included in the

SBS experiments, will provide measurements of GMp covering the full Q^2 range of the SBS measurements. This is a purely complementary measurement, as the SBS does not propose to measure GMp. There are also experiments that plan to make measurements that have overlap with the proposed SBS program. An experiment is approved for Hall B that will use the same technique as the SBS experiment to measure GMn over the same Q^2 range (up to 14 GeV^2) as the approved SBS experiment. Because both measurements will be limited by the systematic uncertainties over much of the Q^2 range, there is an advantage to having both measurements.

"In addition, the Hall B measurement is statistics limited at the higher Q^2 values. The SBS program has the potential to extend the measurements up to Q^2 =18 GeV^2 with additional running time, while the Hall B measurement does not appear to have the option to extend the Q^2 coverage in any meaningful fashion. For both GEp and GEn, there were 12 GeV proposals to make measurements in Hall C. In both cases, the SBS proposal provides data at higher Q^2 and with higher precision. The Hall C GEp proposal was deferred, as the experiment uses the same basic technique but requires significantly more beamtime and provides a reduced kinematic range. The Hall C GEn proposal was approved and awarded beamtime, largely as a complementary measurement that uses a different technique (recoil polarization measurement on deuterium as opposed to a cross section asymmetry on a polarized 3He target). This yields different systematics, and reduces the uncertainties associated with the nuclear structure corrections, and was thus considered to be sufficiently different and complementary even though the precision and kinematic range are smaller. Thus, while improved measurements of all of the form factors are possible without the SBS, there would be a significant loss in the Q^2 range and precision for both GEp and GEn. Because GEn has the smallest maximum Q^2 value, this would also reduce the Q^2 range over which the complete set of form factors can be measured.

"The measurements that form the primary SBS program have several things in common: a need for high rate capabilities, but limited requirements for resolution and particle identification, as the exclusive (or nearly-exclusive) reactions allow for kinematic identification of the events of interest. This limits the general usefulness of the SBS for non-exclusive reactions, especially at the highest Q^2 values achievable with the 12 GeV upgrade. However, the SBS will be useful for a variety of measurements at slightly reduced Q^2 values, especially with the addition of improved particle identification. There is already an approved experiment to study Semi-inclusive deep-inelastic scattering (SIDIS), and possibilities to use the SBS for other approved experiments (e.g. spin-asymmetry in DIS scattering from the neutron).

"The impact of the proposed measurements relies both on the high-Q^2 values that can be obtained and the high precision that is possible with the large acceptance of both the SBS and the BigBite and BigCal detectors what will be used with the SBS. However, the projections for these experiments were made before many aspects of the SBS system were finalized. Now that the planned detector packages have been finalized and simulated in detail, it would be very beneficial to update the projections, accounting for all known sources of detector and tracking inefficiency, acceptance, deadtime, etc… as well as the final approved beamtime to ensure that sufficient precision is achievable, in particular for the highest Q^2 values, even if that means a small reduction in the Q^2 range of the measurements."

Reviewer:

"The physics addressed by the three experiments discussed in this program is essential to further our understanding of the inside of a nucleon. A clear path from experimental observables to form factor interpretation is given. The scale-breaking result for $Q^2 <\sim 6$ GeV/c^2 that the G_E/G_M decreases nearly linearly with Q^2 drives the quest to $Q^2 > 10$. The extension of form factor measurements to these larger Q^2 promises to clarify our theoretical understanding significantly. I liked the very clear and comprehensive introduction. I am particularly intrigued by the possibility to uncover strong evidence for di-quark pairing and orbital angular momentum.

"The three experiments are:
1. A measurement of GEn (E12-09-016) up to 10 GeV^2 using the double polarization beam-target technique and a new polarized ^{3}He high-pressure-gas target
2. A measurement of GEp (E12-07-109) up to 12 GeV^2 using the double polarization beam-recoil polarimeter technique with a liquid H_2 target
3. A measurement of GMn (E12-09-019) up to 13.5 GeV^2 by determining the unpolarized cross-section ratio for the two reactions d(e, e'n) and d(e, e'p) using a liquid D target

"All three experiments use a double open geometry spectrometer approach, capturing the scattered electron in one arm and a nucleon in the other. All use an above-threshold trigger signal from an electron in one arm in coincidence with an above-threshold signal in the hadron arm as triggers to a second-level processor that seeks geometrical evidence of the quasi-elastic scatter to assert an event trigger. Each uses a distinct target.

"Experiments 1 and 3 share a setup that uses the existing BigBite as the electron arm, supplemented with GEM (Funded here) and Cherenkov (funded elsewhere) detectors for better position and particle ID. The hadron arm uses a new magnet (48D48 modified, funded here) and new hadron calorimeter (HCal) (construction funded elsewhere, but electronics funded here). The large distance of HCal from the target couples with electron tracking to constrain the kinematics.

"Experiment 2 uses a much larger existing electromagnetic calorimeter (BigCal) for the electron arm, supplemented with a GEM array for position measurements and a thick Al absorber to eat the low energy electron and photon background. The Hadron arm is more complex, including 3 GEM stations: the first tracker (FT) follows the new dipole to provide a track for the scattered proton as it enters the first of 2 polarimeters, CH2 layers followed by GEMs (ST and TT). The GEMs give the kinematics for the electron and for the hadron that record at the trigger level in the calorimeters: BigCal gives the electron energy but trajectories through the 48D48 dipole give the proton momentum.

"The challenge for these experiments concerns kinematic reconstruction of quasi-elastic events in the presence of very large singles rates in each arm of the spectrometers.

Judicious use of thresholds on cluster sums from the calorimeters appears to provide a good throttle on background while preserving efficiency for the electron and hadron coincidence signals of interest. The GEMs were tested at a rate 80% of the highest expected in this program, and apparently have been tested elsewhere to x10 more than needed here, so they appear to be an excellent choice for providing the position/momentum analysis needed. The electronics for the GEMs appears to fit the semi-pipelined architecture of the CODA (JLab standard) based DAQ described here. The 250 MHz FADC being purchased for the HCal is/was developed elsewhere and appears to be a good electronics module that should wear well. The DAQ rate of ~70 MB/s (20kb/evt, 3.5 kHz) does not stretch any technical capabilities."

Reviewer:

"In conjunction with the 12 GeV accelerator upgrade at TJNAF, the SBS program proposed for Hall A will provide the capability for measurements of the nucleon electromagnetic form factors out to a Q^2 of ~ 10 GeV^2, significantly above the current range of ~ 3.4 GeV^2. Indeed, while other form factor measurements are planned to be carried out in other JLAB halls, the SBS program in Hall A will provide the lion's share of the nucleon electromagnetic form factors to high Q^2.

"Understanding measurements of nucleon electromagnetic form factors is basic to our knowledge of nucleon structure. The quest for higher Q^2 measurements has been ongoing since the initial electron scattering experiments at Stanford won Hofstadter the Nobel prize. There has been of course extraordinary progress since then. Recently and most notably, the "unexpected" behavior of the proton electric form factor at high Q^2 (a monotonic decrease vs. Q^2 when measured used using polarization observables as opposed to results from the Rosenbluth separation method) has helped substantiate theoretical developments that suggest among other things the importance of orbital angular momentum as well as providing constraints for Generalized Parton Distributions.

"One might say that the SBS program push to higher Q^2 is largely programmatic, and given what has been learned so far in previous extensions of the Q^2 range, this indeed has merit. But there is also hope (if not evidence) that this extension will actually land one in a new regime where sensitivity to the quark core states dominates, QCD descriptions (along with simple Q^2 dependencies) become manifest and essentially model independent separation of up and down quark contributions to the form factors is further possible. For the latter, it is already suggested with present JLAB data that the Q^2 dependences are different. Pursuing such quark flavor separation analyses to higher Q^2 is of course of great interest and will likely lead to new insights.

"The 3 nucleon electromagnetic form factor measurements of SBS will address these and other questions in the initial 3-4 year time window of operations. It is expected that the SIDIS measurements, with more detailed information on the Collins and Sivers asymmetries (expanding on the work by COMPASS and HERMES) will come later. If all goes well this should be achievable; the results are highly anticipated by the broader nucleon substructure physics community.

“Of course the physics of the core SBS program experiments has been approved and reviewed by the JLAB PAC and discussed in other venues.

“As mentioned above, beyond the programmatic expectations there is real hope for landing in a new territory with game changer/discovery potential with these new capabilities at JLAB.

“Regarding the impact and other capabilities, perhaps it is worth mentioning that there are other types of measurements that are being addressed within the same formalism. For example, recent results from BaBar for the pion transition form factor show a surprising high Q^2 dependence. Out to a Q^2 of ~ 30 Gev^2 the quantity Q^2*TFF continues to rise whereas the evidence from other experiments (JLAB, etc.) is that it should be leveling off in accord with QCD expectations. The new data from JLAB will go up into this region and perhaps some of the SBS Program projected outcomes (e.g., as mentioned above) will not be born out ... and we will have something new and differently interesting. Experiments ultimately do lead!

“Well at least the first important aspects of the experimental part are touched on below ... getting the new equipment together, commissioned and calibrated to make the measurements. With clean experimental conditions I believe the data analysis in itself does not provide significant new challenges. For the theory part, my prejudice is that the data will drive the next insights, although in the meantime progress on the lattice calculations will certainly be extremely beneficial.”

All aspects of the SBS project's conceptual design and associated plans—technical, cost, schedule, management, and environment, safety and health (ES&H); specifically:

Reviewer:
"The Super BigBite Spectrometer (SBS) program involves refurbishing a 48D48 dipole magnet from Brookhaven, modifying it so that it can be put around the beamline for small angle measurements, constructing several new detectors, ensuring adequate shielding of the detectors from the beamline and adequate magnetic shielding of the beamline from the dipole field. Because this is a large solid angle detector with open detectors working in a high-background environment, the understanding of rates and backgrounds, and the high-rate performance of the detectors is critical to the program. The SBS performance requirements are set by the proposed physics program and the experiments involve exclusive or nearly exclusive reactions, which simplifies event selection, making it possible to identify events with moderate resolution and limited particle identification capabilities. The collaboration has provided credible tests and simulations to demonstrate that the measurement is possible. However, the high rate operation of the detectors required, in particular for the measurement of GEp and the separation of inelastic backgrounds are potential areas of concern.

"The choice of detector technologies, in particular the use of GEM detectors tracking chambers, is driven by the requirement of high-rate tracking in a high-environment condition. Significant work has gone into simulations to demonstrating the feasibility of such detectors in these conditions, and prototyping of some aspects of the detectors is underway. The raw occupancy for the front and second layer trackers for the GEp experiment is expected to be extremely high (~70%). Based on detailed simulations, the collaboration has made the case that timing cuts and other filters will allow for a tolerable multiplicity in the chambers, yielding high-efficiency (~90%) tracking with good resolution. However, the multiplicity is large enough that tracking will be one of the key issues in the experiment, and if backgrounds are worse than simulated or the rejection of background events is somewhat less than expected based on the simulations, this could impact the efficiency (or possibly the maximum luminosity) of the experiments. The collaboration should have plans to quickly verify the performance online to determine the optimal luminosity for the experiment. In addition, the impact of non-gaussian tails in the track reconstruction should be evaluated, in particular for their impact on the measurement of rescattering angle of the recoil proton in the analyzer. The other issue of concern is the resolution of the event reconstruction, which is important in cutting out the inelastic background contributions, estimated to be up to 10% for GEp, 25% for GEn, and 40% for GMn (where this is the dominant uncertainty at the highest Q^2 value for GMn). If the resolution is lower than projected, then tighter cuts will need to be applied to limit the background correction, which will reduce the statistical precision of the measurements. In this case, it may be non-gaussian tails in the track reconstruction, rather than the RMS resolution, that could become a limiting factor. Again, reliable online diagnostics of the tracking performance will be important.

“For the other detectors which are included as part of the SBS proposal, there are fewer concerns about their ability to achieve the necessary performance. There is still some design work to do for the SBS magnetic shielding, but there do not appear to be any significant issues in the development of an appropriate shielding configuration. Relatively modest changes must be made to reconfigure the BigCal calorimeter, and to maintain high efficiency with regular UV curing. The use of the GEM detectors for the Coordinate Detector for BigCal, which also acts as a veto counter for the hadron calorimeter, does require high-rate operations in a high-background environment, but has significantly lower performance requirements than for use in the proton recoil polarimeter.

“There are several critical hardware components that are not part of the SBS project, but which do not yet exist and are critical for completion of the SBS form factor program. The first plane GEM tracker for the proton recoil polarimeter, the hadron calorimeter, and the particle identification detector for the existing BigBite spectrometer are all needed, but not part of the scope of the project. Most of these appear to be relatively straightforward, although the GEM tracker has to deal with the issues related to high rates discussed above and the hadron calorimeter needs to achieve significantly better timing resolution than the calorimeter that it is based on. Again, simulation and prototyping has been performed which suggest that the required performance should be achievable, and this tracker is already at a more advanced stage than those included in the project scope. The other detector components appear to be more straightforward, and there are no special technical concerns about achieving the desired performance.

“The collaboration has provided a draft Research Management Plan (RMP) with detailed breakdown of responsibilities among the collaborating institutions. One aspect that is not clearly spelled out is responsibility for ensuring that the BigBite spectrometer and its detectors (apart from the new GEM trackers) are ready for the experiments. Jefferson Lab has responsibility for “coordination of the experiment preparation,” and perhaps it is included under this, but including responsibilities related to all existing or off-project hardware will be beneficial, as it may be that this will be the first use of the BigBite spectrometer after sitting idle for 4-5 years. Of particular concern is the BigBite Cerenkov detector. It is not part of the SBS project, but is needed for the neutron measurements. It was stated in the presentations that this would be built for the A1n (spin asymmetry of the neutron) measurement, which they anticipate will run before the SBS program. However, there was no discussion of the timeline or management for this effort. In addition, the JLab schedule for 12 GeV operations is not final and it is possible that the A1n measurement will not run before the SBS program, in which case it is not clear who has responsibility for the Cerenkov detector.

“The draft Project Management Plan (PMP) needs to be significantly reworked. Because this is a large project, with work (on-project and off-project) divided between Jefferson Lab and several US and foreign institutions, a strong project management plan is required to manage the activities and monitor technical progress and manage the costs and schedule of the various components. While the PMP provided relatively detailed timelines, there are several cases where somewhat arbitrary start dates or deadlines led to items or paths with insufficient flexibility, even though there did not seem to be any fundamental reason that these could not be reorganized to remove these issues. Most of the items included cost estimates appear to have a reasonable cost basis, but there appear to be significant uncaptured costs and a relatively informal estimate of contingencies. The risk assessment also appears to be based on a fairly informal analysis, and not well integrated in the cost estimates. As such, it is hard to make a clear evaluation of the project requirements. While no additional funding is requested, the project will require money and manpower from the JLab budget, and reliable cost and manpower estimates are needed to ensure that the requirements will not conflict with the rest of the JLab program. The milestones and key performance parameters need to be evaluated and updated as appropriate, including any potential uncertainty related to the scheduling of the SBS package of experiments as part of the broader JLab accelerator scheduling."

Reviewer:
"In commenting on management and likelihood of success, we did not review the Cherenkov or the HCal or BigCal or BigBite. These are taken as givens. The Ck detector consists of ~500 PMTs viewing a gas volume reflected by parabolic mirrors. The HCal consists of ~200 cells each 15cm x 15cm alternating layers of Fe and scintillator with relatively poor energy resolution. BigCal consists of 1744 PbGl cells that come with their own electronics. I'd strongly advise the group to consider replacing this with the much superior 12-bit 250 MHz FADC modules being purchased for the HCal end, providing DOE can find the funds. BigBite consists of a much smaller electromagnetic calorimeter and comes with all of its electronics and cabling. These ancillary detectors appear adequate to accomplish the physics goals of the three review experiments."

Reviewer:
"The conceptual design and various technical details of the overall SBS project have of course been reviewed previously as it was developed/ presented as a single project for agency MIE funding. In particular the documentation prepared for the technical review 22 January, 2010 and the subsequent written response to the ensuing committee report serves as an important "backbone" of information for the present review. Indeed, the response document indicates substantial progress in addressing the questions raised during that 2nd technical review. I found the information in these documents very useful and also indicative of the substantial effort that has gone into this "project" already. The technical approach, employing large open geometry magnets with tracking detectors to open the solid angle and with calorimetric triggering to select events of interest builds on the experience successfully used with the BigBite spectrometer setup in Hall A.

"The larger SBS magnet and increased rates make selection of GEM detector technology for the tracking detectors eminently reasonable (although rate-wise not absolutely required). Echoing the previous reviews I find that the overall the feasibility and merit of the SBS technical approach is sound.

"For the present review, the panel were asked to assess feasibility, status, and completeness of the plan and structure for a SBA "program" but now with a phased approach and funded through TJLAB base capital equipment support. By in large the new plan most impacts the presentation of budget, schedule and management issues (discussed below), although there are some residual technical details to be addressed.

“The approach in the phased plan separates the effort into 3 parts:"SBS Basic": acquisition, modification, and infrastructure development to run the new magnet for SBS; "Neutron Form Factor": develop the needed GEM detectors for these first experiments; "Proton Factor": involves the full complement of GEM detectors for the polarimetry as well as clamping of the magnet, etc. Overall this is a quite reasonable plan in that it gets going on the initial magnet modifications and its support infrastructure while also pursing building the more modest detector additions needed for the first experiments. The most elaborate setup (and hardest experiments) are saved for last. From the overview presentations we understood that the earliest 12 GeV beams might get to Hall A is in the latter part of 2014. Then there is a "SBS window" of ~ 3-4 years before larger installations "Moller" and "Solid" are planned. How all this works of course depends on how realistic is the plan (see budget and schedule remarks below) and to what extent these plans might be upset by priorities related to the 12 GeV machine upgrade.

“Here we comment on i) magnet and infrastructure, ii) GEM detectors and iii) DAQ and trigger electronics (see section "d)" for calorimetry). Overall, the strategy with the SBS program experimental configuration is based on experience with the BigBite spectrometer program, but now pushed further to deliver substantially increased solid angle (required for the low yields at higher Q^2), a switch to GEM technology tracking chambers to better handle the increased rates and use of high threshold calorimetric triggers to better select events of interest.

“Issues related to procurement of one of the surplus 48D48 magnets from BNL seem essentially resolved and efforts to specify the needed magnet modifications, configurations required by the different initial SBS experiments and associated support infrastructure are underway. The decisions to run the new 484D48 coils in series and use a new power supply are good ones; a moderate coil excitation current of 2000A will suffice for all the experiments with some pole shims required for SIDIS. Initial field calculations indicate that target and detector region limits can be achieved with suitable clamping plates. The magnet modifications for the later experiments (GEp5) are most demanding (beam goes through a cutout in the magnet yoke) but of course most be completed at the outset. Here additional magnet entrance clamps, a multilayer pipe through the magnet with bucking fields (likely at both entrance and exit) will reduce the integrated transverse field seen by the beam to an acceptable level and transverse kick. Of course it is essential to close the loop concerning materials and vendors to ensure that the requirements can be met before cutting metal. It is good to see that that the magnetic field calculations are being moved to TOSCA; it is suggested that all important elements be added to the calculation, including elements of various configurations (e.g., the BigBite magnet package) in order to get a more full and accurate picture.

“One question arose during the magnet discussions concerned how the field would be "mapped" and how accurately that would need to be known. In particular, the "spin tracking" requirements of the GEp5 experiment would seem to be the most stringent since the ratio GE/GM is proportional to the ratio of transverse to longitudinal spin components of the recoiling proton which must be inferred backtracking through the SBS magnet from the the polarimeter/ detector stack. Previously such field measurements in Hall A have used a "sieve" slit and known kinematical trajectories elastic scattering to infer all the field components (dispersive and non- dispersive). From the discussions, it was not clear in this application if a more conventional mapping procedure would be needed or not (experts weren't readily available).

“Other aspects of the scattering chamber (use of replaceable clamshell pieces, support platforms and experiment configuration changing procedures are under study and making progress.

“The choice of GEM technology for the various tracking detectors that need to operate in a high rate environment with good positional readout is a good one. Such detectors have been used successfully now in several large experimental applications. That said it is always an interesting exercise to get new technology going in one's own laboratory. The present application does not push rate nor GEM foil size technology and proposes to use modular triple-GEM detectors of ~ 40x50 cm^2 (e.g., the size of GEM foils and readout board) to "tile" the needed detector areas. The INFN group has already pushed ahead with prototype triple-GEM assemblies using a readout system prototyped/developed over several years employing the AVP25 chip for the FEE cards. First beam tests at DESY a little over a year ago were successful. The most recent (September 2011) high intensity beam tests at Mainz used 3 prototype detectors built at the University of Virgina. Data are being analyzed.

“For the SBS program INFN plans to build 18 modules needed for the front tracker; the 76 modules needed for the polarimeter trackers and coordinate detector are to be built at the University of Virgina. Beyond the good prototyping/testing progress, there are some concerns as one looks toward the production phase. In particular the foil delivery rate required from CERN seems to severely tax their total production capacity. It was brought up during the review that there is now at least one commercial supplier of large GEM foils in the States (Tech-Etch) that uses a glass masking process and produces foils, comparable or better in quality than those from CERN. This potential source of GEM foils should be checked out vis-à-vis CERN. Further, for the production phase a clear set of QA specifications and procedures will need to be in place. For GEM foils these would include cleanliness in production and tests on uniformity and HV vs. leakage current performance for the produced foils. Clearly practice and documentation in all aspects of component performance and all assembly steps is warranted for such a large production effort.

“It does appear, from the preparations in terms of facility expansion (e.g., at UVa) and associated manpower, that this is beginning to be addressed. It is a bit early to get into any more detail of tested/ mounted foils, stacked detectors/week, electronics fabrication/testing and other details of a true production schedule.

“The main SBS detector components to be triggered and read out are the triple-GEM tracking detectors, the hadron calorimeter (HCAL) and the BigCal and BigBite ECal calorimeters. The trigger electronics and DAQ system envisioned is a mixture of old (Fastbus) and new (pipelined) components: The electronics for BigBite and BigCal (with existing summing amplifiers producing clusters) are both based on quite old Fastbus readout (requires external trigger and clear); the GEMs of course use the trigger-able pipelined capabilities of the APV25 chip which feed commercial digitizing electronics; HCAL uses the new TJNAF designed flash ADC (FADC) electronics which has modern discriminated clustering capabilities. For the most demanding of the initially envisioned SBS experiments, a high threshold (a very important and crucial criteria to meet) coincidence (30 ns) between HCAL and ECAL still gives rise to a ~9 kHz rate. Subsequent FPGA based coincidence logic (based on geometrical constraints from the elastic events of interest) reduce the rate to ~ 2 kHz DAQ and ~ 60 MB/s data rate. This general scheme appears to be workable with no major worries except perhaps detector performance (e.g., resolution degradation of BigCal, etc.). It is too bad budgets don't allow the upgrade of all the old electronics, although there are no really serious issues degrading performance with its use. I suppose if these modules have lasted up to now maybe they will last at least during the initial SBS program "window."

“A summary of the above detailed comments would be: yes, in concurrence with the results of previous reviews the SBS approach should be technically capable and effective in delivering the physics data needed for the science.

“This part of the documentation and presentations I found particularly difficult to understand and assess (well, even beyond the seemingly "volatile" nature of things during the budget, schedule and management part of the review). Regarding the budget, estimated cost and timeline were given in the updated Program Management Plan (PMP) made available to the committee. While summed cost amounts are listed for the 3 different SBS program phases (e.g., \$1.652M, \$1.076M, \$1.597M, total = \$4.325M), there is little breakout to enable an understanding of the different components, how much (if any) is JLAB personnel/cost and how much is to be distributed among the SBS program constituents and in what proportions. However, I do note that Table 3 (pg. 33) in the MIE proposal dated February 2011 (the antecedent to the current SBS plan) indicates a budget (equipment only) of \$4.529M, hence it seems unlikely that there is any labor included in the estimated costs for any of the SBS program phases. Indeed, only one of the individual presentations detailed any effort (e.g., magnet and installation), and that presented an estimate of 2.4 FTE-years to complete design/engineering. If this were all the effort there was in the project it would suggest a rather large imbalance (~10:1) of equipment/labor costs for mounting the SBS program. Certainly there must be other JLAB resources that should be more fully and fairly represented in the cost/effort analysis.

“To properly access where this new version of the SBS Project -> SBS Program sits in a cost/effort analysis, one needs additional information that more accurately takes into account the real impact on JLAB/Hall A resources (both monetary resources and effort) and any amount of double booking/conflict with the 12 GeV upgrade (the big elephant in the room). In addition, what is the actual amount of resources being distributed to the SBS collaborative institutions, how sufficient is that support in combination with what the institutions are providing and what is the resulting impact on JLAB resources? The committee had a difficult time to dig out this information. That said, one does get the impression that things may not be quite as dire as they may have appeared, as many other reviews (but under a different project structure) have apparently proceeded smoothly in this regard and a lot of work has already been done.

“There are well established methods to estimate risk (generally including technical, design, cost, and schedule components) and the associated contingency (estimate with a combination of weighted risks) which I am sure are known at JLAB. At present the contingency for components of the SBS program seem to be estimated more at the "gut" level and an average of 21% applied uniformly. A more sophisticated approach would seem warranted.

“Similarly the detailed schedule (here also evolving during the review) seems at an early stage of development. The identification of the real critical paths (after some active conflict resolution!) and appropriate schedule float would also seem to need attention/revision. I think the deficiencies and remedies are now known during the review discussion and it is not useful to comment further here.

“The SBS program is a large endeavor involving many institutions and with significant international collaboration/contribution. The important subsystems to be developed have been identified and responsibilities assigned to the different collaborating institutions. That is all well and good, although as mentioned in the budget section, there may be some issues with institutional resources that fall outside the SBS program funded scope but short of those outlined in the Research Management Plan (RMP). We weren't given enough information as to the numbers and what should be in the accounting (and what not).

“The Program (a.k.a. Project) management is to be resident at JLAB. In reality (as with all projects) there are both strict "project management" as well as "technical" issues related to the "project." Because of the large amount of work taking place and supported at the many collaborating institutions, both aspects, project management as well as technical oversight, will be extremely important. It was not clear from the presentations/documents that appropriate resources were being committed to ensure the success of the SBS Program from a management point of view. I concur with the committee consensus, this appears also to need further work.”

<u>Other issues related to project:</u>

Reviewer:
"The research management plan appears sound, with well distributed workloads and participation from a number of different institutions. Although not explicitly discussed I conclude from history that this is a strong group that will distribute the analysis load and rewards for results well.

"Regarding documentation, I note that the excellent MIE report discusses U,V planes for GEMs, an outdated idea. The CDR appears out of date as well and does not reflect clearly the plans as presented at the review. We did not really review cost and schedule so I will not comment further on them.

"I think this is an excellent group of people. The JLab infrastructure, both at the mechanical infrastructure level and in data acquisition support appears excellent. The physics is interesting, potentially exciting, and clearly achievable."

Reviewer:
"Required experimental components and technical developments outside those explicitly part of the SBS program: In addition to the existing Hall A infrastructure and associated experimental equipment we heard about key items to be constructed or technical upgrades to be achieved for the SBS program including i) a new hadron calorimeter (HCAL), ii) reconfigurations and a demonstrated radiation recovery protocol for the lead glass calorimeter BigCal, iii) a ^3He target with upgraded performance, iv) for the SIDIS experiment, refurbishment of the HERMES RICH detector and further upgrades to the ^3He target. [Note: as I understand, a new Cerenkov counter is already scheduled for use with the BigBite setup for an A1n measurement projected for 2014?].

"i) A new segmented hadron calorimeter (HCAL) is needed for the SBS program. Although not formally a part of the Program, its construction/availability and performance to specification are indeed required. While there is still ongoing important development, the design settled upon is a modified version of that used (HCAL1) at the COMPASS experiment. Overall the HCAL performance (based on HCAL1 achieved and documented) matches SBS requirements with the exception of the timing properties. Currently there are 9 COMPASS modules (from JINR) deployed at Carnegie for optimization studies and comparison with quite sophisticated GEANT4 simulations. In particular, details of the timing response are being investigated and it appears that faster Wave length shifting (WLS) fiber (e.g., faster decay time) along with faster PMT response may get the time resolution down to ~ 0.5 ns as desired for the experiments to reduce backgrounds. Since the construction of the new HCAL modules is to begin in the JINR (Dubna) shops in calendar 2012 it is imperative that these development studies conclude, that the results and their desired implementation be known and that clear updated specifications for HCAL are the upgrades timing performance as well as the overall specification/agreement on the material components, fabrication and Q/A procedures to be used in the HCAL construction. It is strongly suggested as well that the SBS collaboration provide "good communication" to launch this effort at JINR and then to follow on with help in providing production oversight (including interaction with ongoing Q/A) for this important construction project.

“ii) The BigCal calorimeter is needed for electron ID in the GEp(5) experiment. Currently at BNL, the calorimeter has been used before in JLAB experiments and is well characterized (e.g., from GEp(3)) in terms of energy and spatial resolution performance; its return and stacking rearrangement required for the SBS program are not anticipated to have any issues. However, GEp(5) running conditions are expected to cause significantly more radiation damage (crystal darkening) than heretofore experienced. Detector recovery ("curing") via UV is well known and there has been some experience with such procedures with BigCal as used in Hall C. The demands of GEp(5) may push this to an extreme in terms of damage and needed recovery timescale. Prototype testing of lead glass damage and cure rates is needed under realistic conditions: full cure in 1 hour after 7 hours of high radiation dose (for example, different damage and cure rate time components may result in a degradation of detector performance over time, etc.). Furthermore, since the UV curing is envisioned to take place in situ (with ~ x5 increased UV intensity compared to that used previously, and with HV left on), any effects (particularly those associated with long term exposure) on the photo-cathode and PMT performance should be monitored and studied.

“iii) Among the first SBS experiments, GEn will require ~ x6 improvement over the previous use of the ^3He polarized target. Ongoing developments project to meet that goal with 60 uA beam current and a 50% increase in target length. In order to ensure good FOM performance various technical improvements are needed, including use of multiple high-performance pumping cells and more rapid convection driven gas movement. In addition metal end windows will be used to withstand the high high beam currents (but with possible detrimental effects on the polarization of the stored gas; appropriate R&D is in progress). All these developments are well underway with promising results; before SBS, the target will be used in its upgraded configuration for the A1n experiment. Progress in polarized ^3He target development by the community over the years has been impressive and the prognosis in the effort proposed here is good!

“iv) Technical developments for the SIDIS (E12-09-108) experiment are needed toward the latter (mature) part of SBS program. There are more spin directions required of the ^3He polarized target (not a big issue) and perhaps better target performance will require additional pumping chambers, lasers, etc; "refurbishment" of the HERMES RICH was not presented as a big item although details were not discussed (viewed as task to keep some colleagues "busy"?).

“1) A research management plan (a relatively new kind of document) presumably is to help ascertain if there is adequate "off project/ program" support from the research groups for the research effort needed in connection with the construction, commissioning, successful operation and timely extraction of physics results from the SBS program. There is relevant information in the RMP concerning these issues although much of the writeup is a repetition of the research goals and setup layout details for the 3 SBS nucleon form factor measurements (ok, it makes it a self-standing document).

“Here I should mention that I seem to have two different RMPs: one I'll call "official" as it is linked from the SBS review website and dated 8 October, 2011, and one I will call "earlier" as it is dated 5 October, 2011 (I don't know how/where I got this printed copy) and strangely seems to have more information in some regards. In either document, Section 4 (List of tasks) states without further elaboration that the list of tasks "includes simulation and commissioning required for: Magnet, Beam line, GEM chambers, Lead-glass calorimeter, Hadron Calorimeter, Trigger, DAQ, and the analysis software." Ok, in Section 6, "official" version Table 2 ("earlier" version Table 3) does make a few-word matching of areas of responsibility/various tasks with the core institutions. Subsequent Tables 3-12 (in the "official" version) give "FTE x years" contributions vs. institution for faculty/staff, post-docs and PhD. students (sum total: 28.4, 27.2, 27.6) which are "committed resources within existing base grants" (typically 3-4 years); institutional spokespersons extend the commitment through 2018. The "earlier" version has no statements but Tables 4-13 with a year-by-year breakdown of FTE, name, and task. Here, for different institutions these tables span subsets of the years 2011-2016 (anywhere from 3 to 7 years) with the FTE sums adding up as reported in the "official" table. It is clear that, while the latter part of the document may be a bit "drafty", there has been thought by the various institutions put into coming up with appropriate research support effort for the various areas to which they are taking responsibility. From the "earlier" version one sees that the tasks/efforts do seem to be concentrated around SBS construction and commissioning with not much effort delineated in the out years to produce physics from the data. So, while one can say the RMP "document(s)" is (are) a good faith draft start, and they outline the milestones and general areas of activity. It is a little hard to say (at least without a bit of estimating and head scratching) whether or not the integrated effort is sufficient and hence physics time line attainable, platitudes about other Hall A support, past experience, etc., notwithstanding.

“A Program Management Plan (PMP) is maybe a more familiar and better understood beast (e.g., as compared to a RMP), and the SBS Program draft presented to the committee by the end of the first day began to have at least many of the right ingredients. However, as mentioned above, it was a little disconcerting (well I guess it could also be encouraging in some sense) to watch the "evolution" of the document's content during the course of the review. Clearly it was, and some extent is (e.g., now as I look at the latest posted on the SBS review web site -- there are even "KPP's" not available during the review) a work in progress. As mentioned (above) in the budget/schedule/management comments section, there are remaining questions for the PMP regarding actual costs, critical path/schedule, risk and contingency analysis, etc.

“2) Regarding the other SBS Project/Program documentation made available to this review committee (e.g., MIE proposal, CDR's and replies, etc.): as mentioned at the outset, I found these documents to be extremely useful for this review. It is clear there has been a great deal of work as well as a great deal of progress in the effort to make the SBS Program a funded reality. This documented background provided substantial support for the redefined SBS Program in spite some of the apparent glitches caused by the transition in approach. The PMP will need of course to be updated to fully reflect that transition and the concerns that have been raised.

“Finally, thanks to the presenters and TJNAF management for a lively and hospitable review. It was interesting; I enjoyed it and also learned a few things. I hope we'll be able to see the SBS program go forward ... the science program is compelling, feasible and likely to produce among the earliest physics impacting results from the upgraded beam energy capability at the TJNAF.”