NSLS-II Accelerator Systems Advisory Committee Review October 14-15, 2010 REPORT

Attendance

Present:
c. Biscari, G. Decker, D. Hartill, R. Hettel, P. Kuske, D. Mills

Absent:
R. Boyce, K. Finkelstein

Executive Summary

The NSLS-II Accelerator Systems Advisory Committee met on 14-15 October 2010. The committee was impressed with the quality and quantity of progress since the last review. NSLS-II is well on its way to becoming a world-leading research facility. The review presentations reported progress of magnet vendors, production of accelerator components, installation planning and preparations for commissioning. The Committee made the following recommendations:

- Start preparations for a shift of scope of storage ring magnet production as soon as possible, rather than losing time while addressing or remediating deficient performance by a vendor.
- Take appropriate purchasing actions (letter of concern, cure letter, etc. as appropriate) to give due notice to non-performing vendors.
- Plan more comprehensive in-house measurements to address the risk of continued poor vendor performance in meeting field quality specifications.
- Consider options for accelerated girder assembly to make up for delays in delivery of magnets, and preemptively implement such options as a risk mitigation measure.
    - Consider adding and staffing girder assembly stations.
- Maintain close communications with APS concerning vacuum chamber work.
- Ensure that material delivered to APS for welding arrives on time and has had adequate QA.

- Place additional resources on planning top-up strategy and developing/testing the hardware.
- The issue of chamber heating by synchrotron radiation, and the strategy to protect the chambers, should be subjected to internal and external reviews on a routine basis.
    - X-ray beamline designers who will be tasked with the similar effort for the beamlines should get involved now as it will be a good learning process.
- Review the specified limits on the disturbance to the stored beam during the injection process, to confirm that the major effort necessary to achieve these limits on “day 1” is justified.
- The Committee recommends to reconsider reserving a space of the order of 1 meter in the straight section in the storage ring, located to enable the equivalent of “pulsed sextupole” injection at some later date, if necessary. BESSY had good results with this strategy.
- Put tolerances on chamber alignment into determination of safe current.
- Follow the ID review recommendation to do a cost-benefit analysis of the in-vacuum cryocooled gap control.
- Consider use of new SR bldg for thermal stabilization of magnet girders/magnets.
- Complete the analysis of top-up injection safety requirements as quickly as possible to avoid unfortunate impacts on the design of other components, including dimensions and locations of photon masks in the beamline front end areas.
- The commissioning strategy, the high level applications, and instrumentation and diagnostics should be looked at in view of the ALARA principle. The traditional "trial and error" method should be replaced by a more considerate approach: How much injected charge do I really need to get sufficiently clear signals? Can I even slow down the 1 Hz injection rate in order to extract and digest all the relevant information from just one or as few trial shots as possible?
- Test the final version of the spring-finger protected bellows at APS.
- The committee would like to see a presentation on the flexibility of the sextupole correction system at the next ASAC, and on the tracking results, including the solutions with positive chromaticities, which were mentioned in the commissioning plans.
- A clear definition of the injector vendor’s responsibilities in terms of the system performances should be defined.
- A seamless integration of Linac and Booster control systems in the general control system is needed. A careful tracking of the schedule for the elements which are to be delivered to vendors for the completion of the system will help in minimizing delays.

1. Introduction

The review began with overview presentations by Steve Dierker and Ferdinand Willeke. As of September 2010, the Project is 39% complete and near maximum rate of spending. Civil construction is ahead of schedule and x-ray beamline construction is on schedule. At $131M, overall Project contingency is 27% of work remaining. The Project Cost Performance Index is 1.01 and the schedule performance index is 0.98. The schedule shows the project completion taking place 16 months ahead of the target date set by the Department of Energy. The critical path is not constrained by civil construction in the later part of the project; the completion date is determined by production, assembly and installation of the technical systems.

The Light Sources Directorate has been reorganized to become the Photon Sciences Directorate, consisting of Accelerator, Photon, Facilities and Business Divisions. The Accelerator Division, headed by Ferdinand Willeke, is responsible for construction of NSLS-II and operation of the NSLS accelerators.

In response to recommendations from the last ASAC, it was reported that

- Construction of the booster synchrotron was awarded to the Budker Institute in May 2010.
- NSLS-II has committed to in-house development of storage ring beam position monitor electronics.
- The potential for overheating RF button electrodes has been assessed by calculations and found not to be a problem.
- Beam Containment System design is underway with due consideration to preservation of commissioning and operations flexibility.
- A commissioning plan has been developed.
- Top-up safety simulations are ongoing at an accelerated pace as a result of more efficient computing algorithms.
- The NSLS-II team recognizes the potential for disturbance of ID field measurements by activities in the adjacent pulse magnet test station, and will schedule activities to avoid interference.
- Booster ramp waveform control can be adjusted to update rates greater than 10 kHz if necessary.
- The Project has chosen to accept the technical and schedule risks associated with changing some design features of the superconducting RF cavity and coupler. In the event of delays in completion of the cavity, a PETRA 7-cell cavity will be installed to support commissioning.
- The Project has chosen not to modify the storage ring lattice to preserve the option of “pulsed sextupole” injection.

- Multipole field error specifications have been updated. The verification methodology has been developed and accepted by the magnet vendors.
- The option of using “sweeper” magnets to ensure top-up safety has been preserved. Space in the x-ray beamlines has been reserved for these magnets.
- A Global Parameters Document has been written and posted on the ASAC website.

The ASAC was informed that some of the storage ring magnet first article units did not meet specification. NSLS-II management has responded by increasing vendor oversight, and by developing alternative vendors for magnet construction.

Overall the ASAC was impressed with the progress since the last review. Difficulty with magnet vendors is not an unusual occurrence. NSLS-II management is taking appropriate actions to ensure that Project performance requirements and schedule goals are not adversely affected.

2. Commentary on Presented Material

Injector Status

See the Committee response to the charge, regarding progress on injection systems.

Storage Ring Magnets

Findings

All storage ring magnet production contracts were awarded to six vendors by the end of October 2009. Storage Ring dipoles and large-aperture multipoles were awarded to Buckley. Standard quadrupole production was split between two vendors, Everson-Tesla (UK) and Budker Institute. Standard sextupole production was split between Danfysik and IHEP Beijing. Correctors were awarded to Everson-Tesla (US) and Sag Harbor Industries. Danfysik and Everson-Tesla (US) have been authorized to start mass production. Tesla (UK) has overcome problems with coil impregnation and will soon deliver a first-article quadrupole. BINP has overcome quality control problems and will soon ship a first-article quadrupole to BNL. IHEP has built three 1st article sextupoles with a field quality close to specification. All of these magnets needed individual shimming to obtain acceptable field quality. NSLS-II anticipates that the manufacturing procedure has been improved considerable and will provide acceptable magnet for production. Buckley has not yet built good prototypes. NSLS-II personnel have monitored Buckley's progress closely. There is evidence that this vendor had lost its core competency in magnet construction, and is now reconstituting this capability. However, Buckley has accepted new orders for other magnets for other facilities and other items, and is likely overloaded with work. NSLS-II management is taking steps to move some or all of Buckley's multipole production to another vendor.

Comments

It is almost inevitable that one or another major vendor will underperform on a project of the size of NSLS-II. Project management is taking appropriate steps to manage these vendor problems and shift work to a different vendor if necessary. Project management was wise to make awards to several vendors for similar magnets (multipoles), making it easier to respond to poor performance by one vendor. Time lost in production startup is difficult to regain. Perhaps a better strategy is to prepare to accelerate girder assembly and alignment.

Recommendations

- The committee supports plans to start another vendor (IHEP, perhaps) producing magnets as back-up for Buckley.
- The committee supports the Project's intent to plan more comprehensive in-house measurements to address the risk of continued poor vendor performance in meeting field quality specifications.

- The committee recommends that NSLS-II consider options for accelerated girder assembly to make up for delays in delivery of magnets, and preemptively implement such options as a risk mitigation measure. For example, it may be possible to accelerate girder alignment by securing more space for temperature-stabilizing "soaks" of girder assemblies and additional alignment fixtures. Perhaps the first pentant of the storage ring can provide enough temperature-stabilized space for parallel girder assembly

RF Systems

Findings

The presentation on RF systems covered the booster (cavity and transmitter) and storage ring (SCRF cavity, transmitter, 3rd harmonic SCRF cavity and cryosystem). The linac RF system was addressed in the Linac presentation.

The NSLS-II team seeks to inject up to 15 nC per injection cycle from the linac in many ring bunches (up to ~100) with <1% energy spread in variable fill patterns. The booster 7-cell cavity and 90-kW IOT are capable of accelerating 10 nC, given the booster's 0.7% energy acceptance. Cavity HOMs need to be tuned using cavity temperature to avoid transverse instabilities, especially when the beam is stored for extended periods at low energy for multi-shot beam stacking.

Two SCRF cavities in ring provide 4 MV @ 500 mA using a 310-kW klystron for each cavity and a digital low-level RF (LLRF) system. The Cornell and KEK SCRF cavity designs are being considered, and procurement bids for the first two cavities will go out soon. The dimensions of the high power coupler for the CESR-type cavity have been revised to support higher beam loading. An order for two cavities will be put out to bid, with award scheduled for the end of the calendar year. I In the event of delays in cavity delivery, a PETRA 7-cell cavity will be installed to support commissioning. Two SBIR initiatives are in place to develop a new cavity design for light sources that might be used for the 3rd and 4th cavities in the future. Solid state amplifiers will be considered for powering these cavities. The 4.5 K cryogenic system will have >850-W capacity; it has an in-house design that is presently out for bid and for which the final design will be done by the vendor. NSLS-II will have a blockhouse for testing couplers and SCRF cavities externally from the ring.

A 1500-MHz SCRF 3rd harmonic passive cavity operating with 1 MV at +90° phase will be used for bunch lengthening. Niowave is completing an SBIR for the fabrication of this cavity and is presently working on tuning schemes to separate 0- and pi-modes.

Comments

The Committee suggests that if the plan to use solid state amplifiers for the 3rd and 4th SCRF cavities is pursued, the team should collaborate with others on developing these amplifiers rather than pursuing an independent development program.

Recommendations

None.

Production of Vacuum Components

Findings

After a review of NSLS II Absorber components in Sept 2010, there was a redesign of the stick and crotch absorbers to improve cooling reliability, corrosion resistance, and ease of manufacture. There has also been a redesign of the S4A vacuum chamber (among other changes, it is now to be fabricated from aluminum) and a redesign of the RF-shielded bellows to improve the thermal and electrical contacts and reduce the number of components. Absorbers and RE bellows have been prototyped.

Even with the redesigns mentioned above, NSLS II staff state that the vacuum design is now almost completed.

Vacuum pump procurements are ahead of schedule. TSPs and their power supplies, vacuum gauges and controllers, gate valves procurements are to be placed within a month.

12 dipole and 24 multipole chambers completed (about 20%). APS welding production of vacuum chambers is currently at 8 per month but need over 10 per month to meet the schedule.

Comments

There have been several components targeted for redesign. These components are needed by May 2011 for ring installation. That's not too far away. Need to keep an eye on this activity.

The APS vacuum group is split between APS operational tasks and NSLS II VC welding and priorities need to be agreed upon by all parties.

Recommendations

To meet stated schedules:

- Maintain close communications with APS.
- Ensure that material delivered to APS for welding arrives on time and has had adequate QA.

Detailed Assembly and Installation Planning

Findings

The Project has planned to oversee the vendor's installation of the injector linac. The Project plans to provide the technician manpower to the vendor of the injector synchrotron. The vendor will supervise installation of the synchrotron subject to NSLS-II oversight. For the storage ring, NSLS-II will staff and supervise all aspects of storage ring girder assembly and systems installation. The vendor of the RF transmitter will install this system.

Storage Ring girder assembly will take place on Building 902. Working two shifts per day, it is expected that a girder can be assembled, aligned and installed in the tunnel in under three days, once production has settled into a routine. It is anticipated that girder assembly will start in December 2010 and finish in October 2012. Phased beneficial occupancy of the storage ring is not expected to limit the installation schedule.

Installation of storage ring RF is scheduled for April 2011 – March 2012, and installation of the injector is scheduled for May 2011 to May 2012.

Comments

Plans and manpower estimates for installation appear to be very detailed and carefully scheduled. The committee was favorably impressed by this presentation.

Recommendations

- Consider what can be done to recover schedule if magnet deliveries are delayed. Consider adding and staffing girder assembly stations.

Controls System

Findings

The presentation on the NSLS-II control system covered the progress off implementation of the Fast Orbit Feedback System (FOFB), high level applications, database, EPICS-based accelerator controls, the Control System Studio (CSS) tools, and the status of accelerator sub-system implementation and the adopted software and hardware standards for those sub-systems.

The digital FOFB is being implemented with a distributed processing architecture over 30 "cells". Using the in-house BPM processors, the 100-μs processing time budget needed for 10-kHz sample intervals. System implementation is well underway and should be ready for commissioning during the initial machine start-up.

The team is implementing the control system architecture and requisite servers to interface with high level physicist application scripts. An effective and powerful database (IRMIS) is being

developed that will contain a large amount of component documentation and system information. The CSS tools provide useful functions for data browsing and analysis.

Comments

While the FOFB is likely to be ready for initial user operations, it is not absolutely necessary. A MATLAB-based slow feedback system could be used at first if there is some delay in FOFB implementation.

The Committee congratulates the Controls Group for their impressive progress on control system design and implementation.

Recommendations

None.

High Level Applications

See responses to charge, covering control system and high-level applications.

Synchrotron Radiation Protection

Findings

Recently (July 26, 2010) a NSLS II Synchrotron Radiation Protection Task Force was initiated by ASD Director Willeke with the principal goal of ensuring an overall integrated design for synchrotron radiation protection.

The Task Force is responsible for not only defining beam positions and angles that will protect the accelerator, but are also responsible for defining the BPM detection system, determining the requirements for the equipment protection system (EPS) interlocks for protecting the storage ring vacuum chamber, lay out the procedure for calibrating BPMs, defining a procedure for testing the interlock system and define interfaces between the EPS and personnel protection system (PSS).

Comments

This seems rather late in the game to develop such a task force, but clearly better late than never. It appears that this Task Force will focus only on the accelerator components.

It seems that even in a “stay clear” situation, 100 watts of power will be allowed to impinge on the vacuum chamber. This may be OK but needs to be looked at carefully.

Recommendations

- Since this topic is so critical, internal and external reviews should be carried out on a routine basis (it is pretty tough for a review committee to comment intelligently on this from only one 30 minute talk).

- It would seem that extending the purview of this group to look at beamlines would be prudent and/or to incorporate whomever will be tasked with the similar effort for the beamlines to get involved now as it will be a good learning process.

Accelerator Commissioning with Beam

Findings

A project commissioning schedule has been presented.

The commissioning of the complex will start as soon as the Linac is delivered and installed, followed by the Booster commissioning. Linac and Booster commissioning will be shared between respective vendors and NSLS-II team.

The commissioning team will be organized into task forces, whose leaders will report to the AD director, and will be assisted by run coordinators.

The synchrotron ring commissioning will start with a day-one configuration with no insertion devices. Among the main Day-One target results are the optimization of injection at 1Hz, a good characterization of the ring linear and non-linear optics through the debugging of beam diagnostics, studies on beam instabilities, accumulation of several tens of mA.

The second phase of commissioning will start after the installation of six insertion devices. The first priority will be the calibration and testing of the Equipment Protection Interlock System, followed by the front end radiation survey, the gap opening/closing control. Performance of the ring with IDs will then be optimized.

Comments

The proposed structure of the commissioning team based on task forces with a pyramidal organization is sensible.

The initial commissioning strategy is well defined, with a beneficial collaboration with the control system group, through the definition and the development of HL Applications.

A comprehensive list of commissioning steps has been shown, and the matching of well-experienced people with young team will be effective.

The six sextupoles families are electrically in series. For fully exploiting the light source capabilities, optics flexibility is necessary. Is the ability and desire to tune beta functions in each sector supported by the series wiring of the sextupole families? If not, what provisions are in mind for developing aperiodic lattice solutions?

The committee agrees with the proposed structure of the commissioning team and with the commissioning strategy. It appears that the software support will be very good from the earliest stages.

The committee endorses the effort on early and exhaustive integrated system testing, which will support speedy commissioning.

Recommendations

- The committee would like to see a presentation on the flexibility of the sextupole correction system at the next ASAC, and on the tracking results, including the solutions with positive chromaticities, which were mentioned in the commissioning plans.
- A clear definition of the injector vendor's responsibilities in terms of the system performances should be defined.
- A seamless integration of Linac and Booster control systems in the general control system is needed. A careful tracking of the schedule for the elements which are to be delivered to vendors for the completion of the system will help in minimizing delays.
- The commissioning strategy, the high level applications, and instrumentation and diagnostics should be looked at in view of the ALARA principle. The traditional "trial and error" method should be replaced by a more considerate approach: How much injected charge do I really need to get sufficiently clear signals? Can I even slow down the 1 Hz injection rate in order to extract and digest all the relevant information from just one or as few trial shots as possible?

Insertion Device Design and Procurement

Findings

In the past year, three people have joined the group. Three more positions are to be opened to support additional construction funded by NIH. Damping wiggler gap and period have been increased to avoid potential chamber damage due to a mis-steered beam. A vendor has been selected for the damping wigglers, and requests for proposals have been issued for the 3-pole wigglers and elliptically polarized undulator. A preliminary design has been developed for the in-vacuum undulator. The undulator measurement facility enclosure will be completed by the end of October. Specifications for insertion devices have been finalized.

Comments

A technical review of the insertion device program took place September 14-15 2010. The reviewers recommended that a cost analysis of the in-vacuum undulator (IVU) magnet design, to determine if the incremental cost of making all IVUs ready for cryocooling. Since the review, the committee was informed that the cryocooling design has additional attractive features, such as more robust isolation of coolant from vacuum and better thermal contact of coolant to the magnet material. The ASAC supports the earlier recommendation of a cost comparison of alternate designs if they are similar in technical performance margin and technical risk.

Good progress has been made on procurement of undulator systems. The experience of the multipole magnet procurements should not be forgotten in this context. Frequent vendor visits will be important to assess progress and respond to delays.

Recommendations

The ASAC supports the ID review recommendation of a cost comparison of cryocooled versus uncooled IVU mechanical system. A parametric comparison may be sufficient to clarify the issue, or perhaps lead to a strategy of a standardized design with certain components deleted or interchanged for non-cryocooled applications.

The ASAC requests an update of NSLS-II long-term strategy for insertion device R&D and the role of the ID group in these plans.

Instrumentation Progress

Findings

An overview of injector and storage ring diagnostics was presented, including layout and basic performance requirements for the injector systems.

The storage ring diagnostics beamlines were described. A focused review of these diagnostics was held in July of 2010, and design of these beamlines is nearing completion.

TE modes of the storage ring vacuum chambers have been shifted upward in frequency to about 800 MHz in most geometries, by insertion of short-circuiting screens in the light exit slot of the storage ring vacuum chamber.

Plans for layout of racks and cable inputs for storage ring beam position monitors demonstrate adequate room for cable connections.

The tolerance budget for RFBPM output was quoted as <0.2 microns are each for vibration, temperature variation and electronics.

Analysis of beam-induced heating indicates that the RF button electrodes should be 31 mW per button or less with the anticipated nominal stored beam currents and bunch patterns.

NSLS-II has designed and tested an in-house design for the storage ring RFBPM electronics. Bench tests and tests on the Advanced Light Source storage ring show < 0.4 μm resolution. An in-band calibration pilot tone will be injected in the booster RFBPM electronics, and an "out-of-band" calibration will be injected in the storage ring RFBPM electronics. Tests of the SR calibration will take place in the next 6-9 months.

NSLS-II continues to develop the design, systematically tracking down issues with filtering and interference from the instrumentation power supply.

The schedule for RFBPM production and installation predicts that these systems will be ready 3 months before the start of commissioning.

Comments

Instrumentation for NSLS-II has made impressive progress since the last review. The RFBPM development is significant for LCLS and other light sources. With the TE mode shifted out of the bandwidth of the electronics, orbit control will be very positively affected.

The ASAC gave close consideration to the findings and recommendations of the July 2010 preliminary diagnostic beamline review, and concluded that the proposed system should be implemented as designed.

The ASAC endorses early testing of the efficacy of calibration signal injection for the RFBPMs. Other labs have run into problems implementing diplexers in a way that allows good calibration results.

Recommendations

None.

Survey and Fiducialization

Findings

A strategy has been developed for alignment of the NSLS accelerators and x-ray beamlines, based on study and simulation of alignment within an extensive reference network. The estimated manpower to support alignment of magnets on girders and survey of the installed accelerators is 10.5 FTE.

Comments

The committee was impressed by the quality of work and planning evident in the presentation. Manpower requirements were quoted as a fixed number, with a schedule extending to June 2014. If an assessment of peak manpower demand in the event of delays in magnet delivery has not been done, it might be useful to do so.

Recommendations

None

Integrated Testing

Findings

The committee was impressed by the approach presented and the extensive experience of the electrical systems group.

A detailed plan was presented for comprehensive integrated testing of electrical, mechanical, and supporting utility systems. This plan depends on a close coupling between controls software and the technical groups. The control system is very far along and appears to be up to the task of supporting the necessary testing. The first tests are scheduled to begin in the spring of 2011.

Comments

All test data will be stored electronically, which is strongly supported. It is suggested that controls personnel integrate this test data into their equipment tracking database tools for easy access by the technical groups in a standardized way.

Recommendations

None

3. Committee Response to Charge

Plans for production, assembly, and installation of magnets

Progress toward mass production of storage ring magnets has been slower than planned due to lapses in vendor performance. The NSLS-II team has done and excellent job of increasing vendor surveillance. The ASAC supports the development of a strategy to shift some or all of one vendor's scope to another vendor if this proves practical.

Recommendations of the Committee:

- Start preparations for a shift of scope as soon as possible, rather than losing time while addressing or remediating deficient performance by a vendor.
- Take appropriate purchasing actions (letter of concern, cure letter, etc. as appropriate) to give due notice to non-performing vendors.

Review the progress on the Injection systems including pulsed magnet facility

In general the progress in the design and procurement of NSLS-II injection systems has been very good. The contracts for the Linac, Booster and Booster RF transmitter have been awarded, proposals for transport line magnets are being evaluated, and the design of storage ring injection components is in progress. Nevertheless there are still some implementation challenges to be faced, including those discussed below.

The specification for 15-nC injection into the booster and ~10-nC injection into the ring in a single shot is placing significant demands on the performance requirements for the linac and pulsed kicker magnets. The team is looking at multi-bunch injection of this charge from the linac over a period of 160 to ~300 ns, which poses a beam-loading problem in the linac and places a difficult tolerance of ~0.3% flat-top constancy over ~300 nS for pulsed injection kicker magnets having 100-ns rise- and fall-times. To mitigate the linac beam-loading problem, the team is considering stacking two 7.5-nC injection pulse trains in the booster, a mode that might also reduce the kicker flat-top time requirement to 160 ns. The Committee recommends that the NSLS-II team re-evaluate the need for 10-nC per shot injection, to determine if these demanding performance requirements can be relaxed.

The Committee is concerned that the manpower assigned to storage ring injection kicker design is too light. The beam lifetime and protection of the in-vacuum undulators are strongly dependent on clean injection, which is related to the degree of matching between individual kicker waveforms. The challenge of disturbing the stored beam by no more than the equivalent of 10% oscillation – a goal set by the NSLS-II team - is extremely challenging and has yet to be reached at any lab using a multi-kicker injection scheme. A very large manpower investment might be needed in pursuit of this goal.

- The Committee recommends that the benefit of this effort should be evaluated before expending it. Related to this issue is
- the Committee's recommendation to reserve a space of the order of 1 meter in the next straight section downstream of the injection straight to enable installation of a pulsed multipole injection magnet at some later date.

This single-magnet injection scheme, which meets the requirement of minimally disturbing the stored beam, has been implemented at BESSY with excellent results.

The Committee notes that a significant effort will likely be needed to achieve the tracking between Booster power supplies necessary for successful electron energy ramping. The plan for doing this should be closely coordinated with BINP.

Finally, related to all of the above issues, the Committee recommends that additional resources be assigned to planning the top-up injection strategy in general and to developing and testing the related hardware.

Progress on instrumentation including beam position monitor systems

See the commentary on the presentation.

Progress on Control System Including High Level Applications

The Control System will be ready for its first test during the injector commissioning. Several applications have been already tested and the Committee congratulates the Controls Group for their impressive progress on control system design and implementation.

A High Level Application user guide and API manual have been produced.

The adoption of an open-access language, Python, for HLAs, is of great interest, and could be used as example to follow by other laboratories.

The committee is pleased to realize the young composition of the Control System HLA Group, and recommends pursuing the already undertaken close collaboration with AD members, who have an overall view of the Control Room needs.

The committee recommends putting care into maintaining the Control System equilibrium between flexibility and stability.

It appears that a large number of applications have been identified supporting operation and physics studies. These should be prioritized to make the best use of resources to support early startup and commissioning. In particular, the following priorities are suggested for the storage ring:

1. Magnet power supply (DC and pulsed) configuration control (save/ compare / restore), including standardization / degaussing.
2. Injection timing tools, likely including a few oscilloscopes to observe kicker timing relative to beam arrival.
3. Transport line diagnostic support / trajectory correction.
4. First turn trajectory correction and analysis (useful for finding mis-wired multipoles).
5. Orbit display, including difference orbits (orbit variation).
6. Orbit correction configuration control (choice of steering correctors, BPMs, number of modes).
7. Orbit correction implementation, static first, and then real time.

This list is clearly not exhaustive. The development of high-level applications is expected to continue for the life of the facility and the committee is encouraged to see a close collaboration between accelerator physics and controls at this early stage of the project.

The Synchrotron Radiation Protection System

See the commentary on the radiation protection presentation

Progress on Insertion Devices for 6 Project Beamlines

See the commentary on the Undulator presentation.

Plans for Assembly, Installation and Integrated Testing

The committee was impressed with the careful planning of installation and integrated testing. A good plan is in place. As stated earlier, good risk management measures must be enacted in response to delayed production of storage ring magnets. The committee encourages preemptive action to recover schedule delays.

Plans for Start-up and Commissioning of Accelerator Systems

See the commentary on the presentation