Report of the SNS Beam Diagnostics Advisory Committee

July 17, 2001 Wire Scanner PDR Review

Committee members in attendance were: Tom Powers, Joe Preble, Marc Ross, and Bob Webber

General scope of the review as identified by Mike Plum: Evaluate the preliminary design against design requirements (specified, e.g., in the System Requirements Document and the Design Criteria Documents). Evaluate interface definitions. Evaluate high-level schedule. Comment on design decisions, the design process, and the design approach.

Charge to committee

Review the Design

1. Are the design requirements adequately defined?
2. Is the wire scanner system design at PDR status?
3. Does the work from PDR to FDR (Winter '01) look reasonable?
4. Are there "gaps" in the design?
5. Are the interfaces defined, understood, and addressed?

General Remarks and Comments Relevant to the Charge

The review committee was presented with plans, requirements, and designs for wire scanners to be used throughout the SNS accelerators and beam transport lines. There was a presentation on the status of R&D on a "laser wire" for H- beam measurements.

Traditional wire scanners are expected to provide beam profile information during low power commissioning, machine development, and troubleshooting operations. During high power beam operation, however, excessive wire heating and the creation of unacceptably high beam losses render these devices useless for profile measurements. The installation and use of wire scanners in the immediate vicinity of superconducting Linac cavities hold uncertainties that may not be able to be completely resolved *a priori*.

The "laser wire" promises to eliminate most of the shortcomings of traditional wire scanners – it interacts with only a small time slice of the beam thereby reducing beam loss and permitting measurements at full beam power and it appears perfectly suitable for the "clean" environment required for the superconducting RF. Early results look promising, but the laser wire still appears to be very much a science experiment as opposed to a production beam instrument.

On the requirements side of the picture, little information was provided from the beam physics perspective to serve as the basis for an instrumentation performance budget or to define a quantitative tie between pertinent measurements and instrumentation requirement specifications. For example, justification was not provided for the quantities and locations of wire scanners. Although beam halo was identified an important issue in numerous instances, specific requirements for halo measurement are not detailed. The staff performing the detailed subsystem designs needs

to be given specific requirements or told where there are none, so that they may proceed toward technical solutions. Uncertainty and indecisiveness cost the project money and time.

Specific observations and recommendations follow. The committee appreciates correction where its observations may be off the mark and offers recommendations as hopefully constructive ideas or approaches toward a successful, affordable, and on schedule SNS.

Observations and Suggestions

Committee Observation – Important questions remain unanswered concerning the advisability of and conditions for installation and use of **wire scanners near superconducting RF cavities**. Concerns center on the formation or release of particulate matter that may contaminate superconducting surfaces (from actuator mechanisms, hot wires, breaking wires, etc.) A secondary concern is the heat load on the cryogenic system due to energy deposited by beam loss caused by the wires. It is not likely that conclusive data will be available to address all concerns before implementation decisions must be made.

Recommendation – LANL, JLAB, and ORNL collaborators should determine **whether or not any useful tests could be defined** and carried out at the JLAB vertical test facility.

Committee Observation – LANL has completed a good candidate mechanical design for the **superconducting linac wire scanner actuator**. Work remains on wire material selection and mounting design.

Recommendation – LANL, JLAB, and ORNL collaborators should very soon begin detailed **specification of the processing, cleaning, and assembly steps** for wire scanners that will need to be performed probably in a JLAB clean room. It is important to identify if and how these procedures may drive design parameters.

Committee Observation – The **laser wire** is appealing as a cool and clean solution to the beam profile measurement problem in the superconducting linac and everyone would like the idea to work. The efforts at BNL are to be commended. However, the committee has several **questions and concerns**:

1) Can comparison of before and after neutralization signals from beam current monitors provide the required profile resolution? Over what range of beam currents? Over what range of beam energies? (Neutralization cross sections are significantly smaller at 1GeV than at the energy of the BNL demonstration.) Are there alternate signal detection methods? If direct measurement of the neutral atoms is necessary to provide sufficient signal-to-noise for the required profile measurements, this is probably a showstopper.
2) Is the bandwidth of the proposed SNS beam current monitor system adequate? (Presumably the duration of the laser pulse and the resulting neutralized slice of beam will be only nanoseconds.) Is the installed system noise adequately understood and controlled for detection of small differences between two current measurements? Are the laser timing control and the beam current signal digitization rate sufficiently accurate and compatible for reliable capture of the required signal? What will be the impact of normal beam current variations during the beam pulse and pulse to pulse?
3) Are commercially available lasers compatible with the radiation environment near the beam line or is remote location required?

4) Are the procurement, installation, operational, and maintenance costs of the laser wire system adequately understood and acceptable? Might it be more cost and maintenance effective to use a small number of lasers and switch or split the light beam to multiple profile measurement stations?

Recommendation – **Continue laser wire R&D**; transforming that idea into a useful instrument would be a valuable contribution to beam instrumentation. Until satisfactory answers can be provided to the above questions it would be **risky for SNS to rely on the laser wire as a baseline beam profile monitor**.

Committee Observation – **Halo measurement** remains a lively topic though requirements have not been quantified or specified. Ultimate SNS performance may be limited by halo development and the resulting beam loss.

Recommendation – SNS management is encouraged, for the sake of efficiency, to explicitly state the extent to which direct halo measurement capability is or is not to be included in the baseline instrumentation. Halo measurement is not likely necessary to meet initial project milestones. Nevertheless, the committee believes it will **ultimately** be **important** for SNS to not simply observe beam loss due to halo, but **to actually measure and diagnose halo** properties to control losses.

Committee Observation – The question was asked by an audience member whether the **quantity and location of Linac wire scanners** had been agreed upon. Mike Plum answered in the affirmative and cited quantities of 5 in the DTL, 8 in the CCL, and 32 (minus empty cryomodule locations) in the SCL. Quantitative beam physics justifications were not offered in support of the quantity and location requirements.

Committee Observation – Selection of **wire material** for scanners was identified as an unresolved design issue.

Recommendation – Take advantage of the LEDA setup to **study wire material and heating issues** under real beam conditions.

Committee Observation – Quantitative specifications for **lifetime radiation dose** do not seem to exist for wire scanner actuators and other beam line instrumentation devices.

Recommendation – **Radiation dose tolerance requirements should be specified**. SNS Oak Ridge should provide best estimates of the radiation environment as a function of position within the tunnel. These estimates should include the short-term loss conditions experienced during tune up; the steady state losses expected during beam delivery and an overall dose estimate per year of operation.

Committee Observation – The plan presented for detecting signals from Linac wire scans is to use **secondary emission signals** AC coupled from the wires. This is compatible with the **three-wire mounting geometry** that presents multiple wires simultaneously to the beam. This geometry precludes using loss monitor or photomultiplier signals to obtain unambiguous profile information with the wires and may be a limiting factor in using the wire scanners to measure beam halo where secondary emission signals will be very small. The geometry was chosen to reduce the required actuator stroke; a stroke that must be quite large in the Ring and some transport locations, but not so much in the Linac.

Committee Observation – Fly mode and step mode operation of the wire actuators were identified and scan times for individual profiles were presented. It was not apparent if these individual **scan times** are consistent with making enough measurements in a timely manner to represent a useful set of beam data. How many wires can scan at once? … from the beam physics perspective? … from the allowable beam loss perspective?

Committee Observation – Tom Shea stated his **requirement for remote calibration/health monitors** on all beam instrumentation systems, but detailed functionalities appear to be left up to designers, not supplied to them based on operational requirements. News of the calibration/health monitoring requirement apparently had not reached at least one of the presenters.

Recommendation – Timely **communication** between "customer" and "supplier" should be strengthened in this area.

Committee Observation – **Ring beam profile measurement specifications** are in a very preliminary stage with incomplete and unresolved requirements.

Recommendation – Effort needs to be put into **understanding and documenting what beam physics information** is expected, required, and obtainable from beam profile measurements in the Ring. This will lead to quantifiable instrument specifications.

Committee Observation – Secondary emission from the wire was proposed as the preferred **Ring wire scanner signal**, although it was mentioned that the situation was different one week prior to the review. The committee noted two potential signal contamination sources with this approach: 1) electromagnetic pick-up on the wire of the strong 1Mhz beam signal frequency component due to the gap in the circulating beam, and 2) interactions between the wire and background electrons in the Ring.

Recommendation – **See recommendation above**. When requirements and specifications are clear, then consider whether using some type of beam loss monitor might not provide a cleaner, more unambiguous signal.

Committee Observation – The committee was left with an uncomfortable feeling following Liaw's presentation on **carbon wire heating in the Ring**. Many numbers presented in the talk, e.g. wire temperatures, were different by nearly a factor of three from those contained in the handout. The committee did not understand the reason for the large changes within a day of the review. Also, heating of a conductive wire in the Ring due to electromagnetic coupling to the circulating beam current (up to 50 amperes) was not included in the analysis. This heating has proven to be a problem at CERN causing them to choose ceramic wires.

Recommendation – Take advantage of the LEDA setup to **study wire material and heating issues** under real beam conditions.

Committee Observation –Integration of the **wire scanners with the Machine Protection System** (MPS) is an important issue to protect from burning out wires and/or causing excessive beam loss. It is likely that this integration for normal operational modes is well in hand, but of more concern is how "off-normal" modes, like putting wires near the edge of high power beam to measure halos, will be handled with the MPS. Of course, "false trips" must be minimized also.

Recommendation – Attempt to **identify** as many **"off-normal" modes** as possible early on, perform some risk analysis, and define how these modes will be handled with the MPS. Determine

acceptable margins of safety and recognize residual risk. Is it necessary or even feasible to develop and incorporate wire temperature monitors into the MPS in a useful manner?

Committee Observation – **Uniformity of electronics** systems remains a goal that should be pursued. The committee observed instances where this goal is being compromised.

Committee Observation – **Stepper motor drive electronics** – The super conducting cavity tuners use approximately 100 stepper motor drive "bricks". They are probably different than the one chosen for the beam diagnostics actuators. Additionally, they are designing a "snubber" module which is provides signal conditioning between the motor and the drive "brick".

Recommendation – The beam diagnostics team and SRF electronics team at LANL should consider standardizing on a single set of drive electronics. The need for the snubber electronics should be understood, as a similar circuit may be required in the linac portion of the machine.

Committee Observation – Consider using the standard BPM/BCM data acquisition systems. One should be able to reduce the clock rates and improve the effective bit counts to 14 bits. There probably isn't a strict requirement for synchronizing of data acquisition and motor drive electronics. With a one-minute scan time, software synchronization should be sufficient. Consider ways to combine multiple channels into one computer chassis. Evaluate the option of using higher density data acquisition modules. The main concern with using higher density National Instrument modules may be sampling the data synchronously, as is done on the NI-6110. What is the impact on the measurement? Additionally, consider using a NI SC2040 sample and hold module as a combination signal conditioning and terminal block for increasing the density of signals within a single computer chassis. For instance, a pair of SC2040 modules, a pair of 8-differential channel NI-6052 DAQ modules and a quad stepper motor driver module would allow four wire scanners to be controlled by one computer chassis. Of course cable run lengths, computing speeds, and many other factors may make such a change impractical.

Committee Observation – The planned **presentation** on HEBT, Ring, and RTBT wire scanner actuators was **omitted** due to lack of time.

Committee Observation – In the big picture, it is clear that **management of the beam instrumentation effort** is still in flux. This is not necessarily a surprise or a problem in an enterprise at this stage. We observe shuffling of responsibilities between BNL and LANL, new assignments for software integration responsibility, remaining confusion about requirement/specs e.g. for on-line/remote calibration/health monitor for instruments, etc. The committee commends the staff for recognizing the need to adapt and to formally address changing needs as the project develops. The review acknowledged the necessity to address systems issues such as:

1) Handoff strategy for task responsibilities and for pieces of hardware – It is important that each collaborator knows the scope of his responsibility and when each piece of the job is complete. This is an important cost issue; if handoff is not defined, everyone will continue to hang around at the expense of the project until the machine is running.
2) Systems integration – This is SNS Oak Ridge responsibility and represents a cost and schedule issue. Are there reviews of systems issues? There would be a much better framework within which to review detailed designs if the integrated plan was clearly understood.

Committee Observation – Biggest performance and cost **risks** are in the areas of incomplete and/or misunderstood requirements and specifications, hand-off considerations between collaborators and SNS Oak Ridge, and systems integration issues.

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Committee Observation – Within the framework of the presently understood requirements, the design of the **Linac wire scanners**, especially the mechanical actuators, **appears to be well in hand for the PDR stage**. Selections of wire material and wire attachment are outstanding issues, as is the definition of processing requirements for scanners destined for the SCL. **Ring wire scanners**, requirement definitions and designs, are at a considerably more **premature stage**. We see good progress and no obvious showstoppers, but there is much work to be done.