SNS NFDD PM-LL-0001-R01

LESSONS LEARNED FROM NEUTRON INSTRUMENT BEAMLINE CONSTRUCTION

December 2008

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NEUTRON INSTRUMENT
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Prepared by Oak Ridge National Laboratory
for

UT-BATTELLE, LLC
under contract DE-AC05-00OR22725
for the
U.S. DEPARTMENT OF ENERGY

Beam Line Lessons Learned

System Integration

Design Criteria Document (DCD) – Insure that this document clearly states all requirements for the project (including interfaces), that it is reviewed by all appropriate personnel, and signed off by the instrument customer(s). The document should be kept up to date so that the engineering team is always designing to the criteria – not rumor or latest desires.

Baseline Debut – Soon after the DCD and P&ID have been drafted, the instrument scientist should present his/her vision of the instrument function, equipment, and operation to a panel consisting of the engineering team, management, key IDT members and other appropriate scientists. This has been found to be very helpful in insuring that everyone understands what equipment is needed and how the instrument will actually be operated. The DCD and P&ID are then updated and used to guide the project.

Design Guide – Generate and keep up to date a design guide that includes standard design features used by all beam lines. This is a good communication device that will enhance standardization and prevent engineers from re-inventing the wheel. For SNS the guide is Technical Document 17000000-TD0001-R05, General Guide for the Design and Installation of SNS Neutron Scattering Instruments and Components.

Naming – Assign a name and/or number to WBS elements, equipment components, and systems and use only that name throughout the project. This is especially important in equipment specifications used for procurements. Using different names on drawings and specifications leads to confusion which can easily lead to field re-work.

Process & Instrument Drawings (P&ID) – This is the usual engineering tool for mechanical systems but adapted to beam line instruments. It shows the location and utilities needs of all major equipment (including DAS and controls racks) and the power source needs for all equipment.

Neutronics Analysis Configuration Drawing – Generate a drawing with floor plans and elevations that show only features needed for neutronics analysis. Locations dimensions should be those used in neutronics models – horizontal distances from moderator, vertical distances from beam height, all distances and thicknesses in meters. This was found extremely helpful in communications with neutronics analysis personnel and keeping the neutronics model consistent with the latest design.

CD-4 Parameters Measurement Drawing – Prior to issuing drawings for mechanical equipment, generate a drawing showing all measurements and alignments needed to be verified in order to prove the CD-4 parameters will be met. Conduct a workshop with survey and alignment personnel to determine what will be measured by whom and how measurements will be made. This will identify design features needed to accomplish the measurements and alignments.

Get Subject Matter Experts Involved Early in Design – Involve appropriate subject matter experts for advice and counsel early in the design phase. Two to three hour workshops are a good way to do this. In particular

Electrical group for code compliance and cabling needs
Chopper, Detector and DAS groups for locating hardware and cable needs
Survey and Alignment group for everything requiring alignment and for S&A techniques and appropriate testing of motion control devices
Vacuum group for all tanks, pressure vessels, and other vacuum applications
Installation group for constructability advice
Neutronics group for advice on shielding requirements and optimization
PPS and ISSC for sweep plans and PPS needs
ISSC for all non-standard safety-related issues such as special shielding needs, safety of choppers or other specialized equipment, etc.
Life safety for code compliance
Site Services Building Manager for interfaces with the Target building and SNS site

Integration of Electrical Systems – Planning for electrical power and signal equipment and cabling should be done very early in the project (much earlier than at present). Generating the P&ID mentioned earlier is a good start on this. Detectors comprise over 80% of the cables on most instruments and must be planned for early. Work with the detector group to generate a system block diagram for detector equipment and cabling. Show the location of all equipment and at least pathways for cabling in the 3-D model. Also, show the location of all racks (chopper, DAS, motion control, PPS, etc), large junction boxes, and equipment needing power in the model. Generate a preliminary cable pull list early (as soon as the detector system block diagram is available), have it reviewed by stake holders, and add cable to it as they are discovered. The pull list should include power, communications (including phone and PA) and signal cabling.

System Integration Review – The system integration aspect of the design should be performed early. As soon as the instrument team can be ready a review to insure the system integration is appropriate should be conducted. Further the reviewers be people who will have to live with the design (stakeholders). Some suggested stakeholders are:

Electrical group for code compliance and cabling needs
Chopper, Detector and DAS groups for locating hardware and cable needs
Survey and Alignment group for everything requiring alignment and for S&A techniques and appropriate testing of motion control devices
Vacuum group for all tanks, pressure vessels, and other vacuum applications
Installation group for constructability advice
Neutronics group for advice on shielding requirements and optimization
PPS and ISSC for sweep plans and PPS needs
ISSC for all non-standard safety-related issues such as special shielding needs, safety of choppers or other specialized equipment, etc.
ES&H for life safety for code compliance
Site Services Building Manager for interfaces with the Target building and SNS site

The review should confirm that the design meets the CD-4 performance parameters and DCD requirements, provides adequate instrument operation, has had involvement of appropriate subject matter experts, is based on adequate neutronics, seismic, and other calculations, and has reasonable cost and schedule risk.

Address Instrument Operation Early –We seem to address instrument functions such as CD-4 performance parameters well but that we do not focus enough on how the instrument operates (sample preparation, change out, alignment in the beam, etc). The operational aspect needs to be addressed in more detail in the DCD and reviewed in the Preliminary Design Review. Needed features should be included in the 3-D model prior to the Integrated Design Review. As part of planning for instrument operation, think through what needs to be performed during commissioning to prepare for the instrument entering the user program (called CD-5). Where appropriate, have the project provide what is needed during this phase.

PPS Beam Sweep Plan Early – Soon after the instrument operation is understood and cave access areas are known, meet with the PPS and radiation safety teams and generate a beam sweep plan that will serve as the system requirements for the PPS system. This will identify the need for PPS, ODH, and radiation monitor equipment, any additional neutronics calculations needed to fix equipment locations, the need for fences, rails, and other personnel entry features, and the need for trapped keys and shield block configuration management features. If possible, this should be performed prior to the Integrated Design Review (IDR).

Shielding Configuration Control & Operation - Early in the design phase, think through how all shielding (blocks, hatches, B4C, etc) will be placed under configuration control and operated. Be aware that using PPS trapped keys only require closing the shutter, but shielding locks require shutdown of the accelerator. Be aware that anything in the analysis showing 0.25 mrem/h ("you take credit for") must be under configuration control (be trapped in place and/or have some kind of lock and have special marking). Also, blocks allowing personnel to receive greater than 100rem/h whole body dose are called critical shielding and have special configuration management requirements.

Think through what is needed for commissioning as well as operation in the user program. Obtaining PPS Trapped keys takes several months and the PPS system may not be able to accept all that are really desired. Thinking through this early will allow the normal design process to accommodate what is needed. It is also a good idea to include extra trap keys in the design.

Drafting the Configuration Management procedure needed for the IRR and having it reviewed by appropriate safety personnel may be the best way to think this through. A reviewed draft at the time of the Integrated Design Review (IDR) is not too early.

Tolerances – Be careful to specify tolerance that are needed and achievable in the target building (not laboratory conditions) and can be verified by our survey and alignment group. The CD-4 Parameters Measurement Drawing mentioned earlier should help to understand what is important and what is not. Keep the survey and alignment group and the installation group constantly involved in setting tolerances to make sure they are reasonable and achievable during construction.

Develop 3-D Model Early – The model should quickly be developed to the point that all equipment on the P&ID has a workable "home" in the model.

Complete Shielding Design Early – Neutronics analyses should be performed as early as possible to determine shielding needs and all shielding and features to eliminate streaming paths should be included in the model immediately afterward. At this point, a constructability review conducted to ensure weights of blocks and locations suit crane access. After the constructability review, the design should be taken to the Instrument Systems Safety Committee for review. All of this should be conducted prior to issuing drawings for shielding construction.

Confirm As-Built Conditions Early – Prior to performing significant detailed design work, have Survey and Alignment personnel build the local S&A network and determine the as-built locations of neighboring beam line equipment, target building columns; utility trenches; mezzanines; etc, and other essential existing features. Update the 3-D model with this information before starting significant design tasks.

Design

Shielding - Managing gaps between shield blocks and between shielding and components (like choppers) is a problem on all beam lines. Also installing seismic hold down bolting is problematic.

The beam line engineering group has conducted a workshop to address this issue. Neutronics was involved. Conclusions are that later beam lines do not have as many of these problems as the earlier ones did (so lessons are being learned). Requirements for gaps have been relaxed to be 1 in the chopper cavity and ¾ in off the shelf. This and our now standard practice of involving Survey and Alignment to obtain as-built conditions test stacking cans prior to filling them with concrete are expected to greatly help the problem. All new features have been included in the Beamline Engineering Design Guide.

Documentation – In addition to the usual need to keep design documentation up to date, seismic analyses and their peer review documentation and neutronics calculation documentation should be completed as the analysis is performed and transmitted to the document control system. Waiting until they are needed for the Instrument Readiness Review strains team resources at the end of the project.

Integration of PPS and Non-Safety Cables – PPS cabling must be separated from non-safety cables (such as in a separate section of a cable tray) and its documentation requires different configuration management than non-safety cabling. However, it is most efficient to communicate cabling work to be done in a coordinated way and in most cases to install all this cabling at the same time. Further, we have had difficulty in the past with PPS equipment locations interfering with instrument operation needs or the location of non-safety equipment. Thus, the following is recommended:

> All electrical designs (safety and non-safety) should be reviewed by the Instrument Lead Engineer before they are sent to the field. The lead engineer should insure that an acceptable location exists for all racks, junction boxes, PPS equipment, cable tray, conduit, etc. The lead engineer should obtain Instrument Scientist and Scientific Associate concurrence with the locations and design prior to transmitting it.
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> The routing of all cables (safety and non-safety) should be shown on a single set cable tray and conduit drawings. This will insure communication of all the work to be done up front and allow for effective construction planning and installation. Note: This drawing may need to be abandoned after construction and substituted with separate drawings for safety and non-safety to provide the appropriate configuration management provisions.
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> If possible, only one cable pull list should be used. At most, two pull lists should exist – one for safety and one for non-safety. This means that the single non-safety pull list should identify power cabling and circuit assignment, detector power and signal cabling, chopper power and signal cabling, motion control, phone, data lines, etc.

Mechanical Interferences - A chronic problem on most instruments is mechanical interferences (sprinklers in the wrong place relative to cable trays or other physical construction, mezzanine stairs run through the middle of cable trays, piping across doors, etc.)
The following is recommended:

> All designs (safety and non-safety) should be reviewed by the Instrument Lead Engineer before they are sent to the field. The lead engineer should insure that an acceptable location exists for all equipment, cable tray, large conduit (above 2 in), large piping (above 2 in), duct work etc. The lead engineer should obtain Instrument Scientist and Scientific Associate concurrence with the locations and design prior to transmitting it. Further all designs should show exclusion zones where piping and conduit should not be run.
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> To a reasonable degree, equipment, cable tray, large conduit, duct work, and large piping should be shown in the model. The model should also show exclusion zones where piping and conduit should not be run.
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> Using the model as a starting point, composite drawing(s) should be created that also show equipment, cable tray, large conduit, duct work and large piping for all disciplines. These drawings should also show exclusion zones where piping and conduit should not be run. These drawings should used to hold workshop(s) with all stake holders to that everyone knows where all the equipment is to be located. The composite drawings should be kept up to date only to the degree needed to support construction and do not need to show the final as-built condition.

Vacuum Compatibility – Materials to be used under vacuum conditions should be reviewed and/or tested by the vacuum group for compatibility.

Ergonomics Features – Designs should incorporate features to prevent head banging dangers, allow easy insertion of samples, easy moving of sample environment equipment and other ergonomic aids. These features should be addressed in appropriate design reviews.

Motion Control – The survey and alignment group has equipment and expertise in testing the operation of motion control equipment and can help in specifying requirements that are achievable. Get this group involved in planning and specifying motion control equipment.

Crane Design – Prior to generating a crane specification and as part of designing crane installation, contact Brooks Coleman of NScD Site Services. He is the subject matter expert for crane specifications and for allowing proper clearances to make sure the crane operates properly.

Vessel Penetrations – Provide plenty of spare penetrations. Additional penetrations are almost always needed.

Procurement

Involve Procurement Early – As soon as you know what you are going to buy, contact procurement and let them help you with planning. You will not know the answers to their questions at this point, but that is OK. Let them start helping you think through what needs to be done. Early discussions include procurement award strategy (ex. competitive best value, competitive low price, or sole source), evaluation criteria (if competitive procurement), procurement timeline/schedule for solicitation process, proposal(s) evaluation, procurement management review, and final award.

Advanced Procurement Plans – As soon as you know about procurements over $500K, go to the Advance Procurement Planning System located at https://www-internal2.ornl.gov/https/procurement/APP/ and input your APP (Don't wait until a requisition is input). This starts the planning early and gives procurement a heads up that a major effort on their part is coming at them, but it is also a Contracts Division requirement that must be completed prior to any procurement over $500K being awarded.

Scheduling

Fire Suppression Design – Ask for this design and installation at least one year prior to the CD-4 early finish. It takes longer to do than one would think.

PPS and Detectors – Allow 2 months at the end of the schedule for this installation and certification. Pulling cabling takes longer than we usually anticipate and PPS need most construction activities out of the way to do their job. Also, this needs to be coordinated with detector installation, which also must be done last to prevent damaging the detectors.

Neutron Guide Deliveries – Guide vendors routinely deliver product 6 months later than promised. Account for this when scheduling. Also, allow time to inspect the guide before installation and inspect it as soon as possible after it arrives.

Interfaces to Target Building Mezzanine – Design, analysis, and Design Change Notice processing takes longer than usual design tasks. Allow extra time for this.

Motion Control Testing – Allow at least one day per axis for testing motion control systems. Equipment should accessible (not covered with shielding etc.) during this testing. Also, if at all possible assemble the system outside the cave and pre-test the operation.

Construction

Survey and Alignment – The survey and alignment group has performed a detailed lessons learned analysis for the recently completed beam line 6 (EQ-SANS). They have also described how these lessons apply to all beam lines.

In summary, make sure that tolerances are reasonable, that alignment devices are included where appropriate, that mechanisms to secure equipment in place after alignment are provided, that commercial devices are used where possible, that clean conditions exist when alignment is being performed, and that alignment operations are not interrupted while being performed.

Construct Cave Instrument Equipment Away from the Target Building – The time after cave construction is taken up with installing utilities, PPS, and other construction. This leaves very little time for assembling the instrument technical equipment in the cave and confirming that it operates as desired. Also, it is difficult to determine the best cable and cooling piping routing for this equipment until is assembled for the first time. Consider assembling and testing instrument technical equipment at a location outside the target building (this has been done at a vendor plant in some cases). As this assembly operation is performed arrange cabling and piping in "kit" form so that equipment can be dis-assembled, transferred to the cave, and installed in an efficient manner.

Oxygen Deficiency Hazard (ODH) Detectors – Don't install these until conditions are clean.
At a minimum, make sure that they are covered and protected from dust and other debris.
Otherwise they will need to be replaced.

Tank Shielding Construction – It has been found that using DB forces in the target building is not an efficient way to install non-concrete shielding. Try to use industry to perform these tasks off site.

Project Management

Schedule Block Diagram – This is a diagram about the size of an E-size drawing that shows mostly the schedule logic for installation and construction. It also shows all items needed to be performed in accelerator shutdowns, or that need to be performed in concert with neighboring beam lines. It shows PEP milestones (including CD-3) and long lead procurements. The diagram is generated before making the Primavera schedule and is adjusted as needed to be consistent with the finished resource loaded schedule. It is extremely useful in aiding the technical team and reviewers understand the key elements of the schedule. It is also very useful in determining the need for items needing Advanced Procurement Approval.

Advanced Procurement Approvals – These are DOE approvals to place contracts for low risk, long lead procurements prior to receiving CD-3. The reason for this is avoid delaying construction completion due to waiting for the approval. A good way to include these approvals in the normal DOE Order 413.3A process is to have the instrument design team propose what approval items make sense at the Preliminary Design Review, adjust the list based on the PDR review team's recommendations and then propose them to the EIR review conducted by DOE. Hopefully at the EIR review, agreement can be reached on what approvals should be granted.

Schedule Activity Numbers Indicate Activity Function – Communication with the engineering teams and generating schedules for future beam lines by copying and changing existing beam line schedules was greatly enhanced by having the activity number coded to indicate the activity type (procurement package design, installation drawings, installation & testing, fabrication, etc) and its level 3 and 4 WBS element (which is the system and type of equipment). Note, as the project progresses, this may become more trouble than it is worth. If so, abandon it.

IRR Procedures – History has shown that procedure approval holds up the IRR process more than anything else. Seismic and neutronics calculation documentation should be completed, signed off and transmitted to Project Wise as the work is done – not at the end of the project. The approval process for procedures is very long. Procedures should be started very, very early. Also, an IRR checklist has been evolving over the last few instruments. Managing this effectively really helps getting things done. Start with the documents from the most recent IRR so that all the latest requirements and desires from comments on previous IRR's are incorporated.

Drafting these procedures early (as soon as the 3-D model has all the shielding in it) can pay big dividends because they usually identify design features that are needed. The sooner these needs are known, the easier it is to incorporate them in the design. A good goal is to draft and review (not signed off) all of them by the IDR.

Approach to the IRR – When it gets close to the end, last 6 months or so, generate detailed punchlist type schedule that is updated several times a week (up to daily, depending on the complexity). This schedule should always be current, independent of the baseline and when items need to be added (even if they are not in the baseline), they should be added to this schedule.

Three to four months prior to the IRR start regular meetings with the team to go over paperwork, the punchlist and manage the IRR checklist. For CNCS, daily meetings were needed. For SNAP and

POWGEN, 3 meetings per week worked. The longstanding routine weekly meeting worked for SEQUOIA. SANS, has 2 meetings per week.

Project Close Out - Project close out takes longer than expected and one needs to start looking at de-obligating POs several months in advance of trying to close the account. This is a lesson learned from SNAP and SEQUOIA. It would be a good idea to put a milestone in the schedule that will remind us to start this process early- one for initiate closeout for design, initiate closeout for procurement and initiate closeout for installation.