Appendix H

Lessons Learned

LL Number	WBS	Success or Opportunity	Category	Description & Discussion
1	1.5	**O**	Management/Organization	DCPS was a project unto itself and had too many conflicting “cooks” spoiling the soup. The specifications and requirements changed very late in the project after our main FDR. The functional organization stepped in and inappropriately communicated ways yet made key improvements to the requirements. Software was new and made use of new tools and languages not employed at PPPL much before. Teaming among the several branches of the project was very low and communication was at times poor or non-existent except that the COG who was gifted in many areas of this project held it all together. Unfortunately we lost this COG and had to make do. Yet, the effect of this loss on this team was a cautious yet palpable coming together to finish their own scope such that the system arrived on time. The false starts, rework, changes in direction early, and the overall inefficiency cost dollars and clock time but it came together in the end.
2	1.1	**O**	Organization/Staffing	Better balance in assigning CAM's to scope. The centerstack design and fabrication was assigned to one CAM who was the laboratory's expert in coil manufacturing. The work scope should have been distributed to at least 3 CAM's. The failure to do so led to some oversights in procurement inspections, timely reconciliation of cooling wave analysis, more complete field supervision, support of EVMW CAM duties. The Center stack WBS relied heavily on one senior COG who quickly became overloaded. The main bottleneck was for tooling which required a lot of attention. Some earlier support on engineering the tooling might have helped save some rework.
3	All	**O**	Resources	Earlier recognition of the need for an independent QC receipt inspector. During the last 20 years PPPL has reacted to budget challenges by reducing overhead cost (and staff) by transferring work scope to directly funded project staff. One of the positions eliminated was a full time QC receipt inspector whose responsibilities were transferred to the project procurement technical representative (CAM in most cases). Mid way through the project it became apparent that hardware deliveries for non critical, small hardware (at the time) did not receive timely and complete inspections. The project requested, and PPPL agreed to hire a QC inspector which offloaded the CAM's..

Appendix H
Lessons Learned (continued)

LL Number	WBS	Success or Opportunity	Category	Description & Discussion
4	ALL	**O**	Procurement	Causal Analysis – Vendor "X", Inc. February 2/8/2013. (Detailed report available upon request) Multiple awards (6) to a new, unknown supplier for NSTX/U components resulted in unacceptable quality, rework, and/or re-award of contracts, all of which resulted in a delay in schedule for the project and additional costs. After award, one of the work activities covered by these six awards became part of the critical path and, as a result, had a significant impact on the schedule. As a result, PPPL initiated an analysis to identify the causal factors so that actions can be taken to prevent this from recurring. The root cause identified was the evaluation and oversight of the vendor was inadequate. Contributory causes were: A. Inadequate incoming inspections and supplier oversight due to lack of appropriate resources assigned to these procurements. B. Inadequate hold points/first article inspections for jobs requiring weld preparation. Recommendations include; 1. Develop a process for the evaluation and oversight of new and unknown fabrication suppliers until adequate confidence is achieved. Such a process should consider financial stability, types of contracts to be awarded to this supplier, time frames of the contracts, performance parameters, risks associated with work to be done, references, timely feedback from first wards, etc 2. Insure adequate staff for the timely inspection of hardware and components. 3. Insure hold points/first article inspections, which are especially important for vacuum welds or other welds with high loads.
5	All	**O**	Resources	Key pacing resources like welding required careful handling and often became pinch points. Veteran welders were in high demand throughout the project. The PPPL Tech Shop work order system was well managed and the Work Control Center (WCC) did an outstanding job applying timely use but early training of welders in anticipation of this peak need might have eased project problems.
6	ALL	**O**	Testing	Insufficient time was budgeted for testing. The troubleshooting time always takes more than expected and should be included in future estimating considerations.
7	1.7	**O**	Management/Organization	Number of Project reviews. The time spent in preparing for, conducting and follow-up from both PPPL and DOE initiated reviews was under estimated. This project conducted 34 high level reviews that utilized over 72 externals reviewers from 22 institutions. While somewhat beneficial, impacts to project cost, schedule, and resources should be more adequately budgeted.

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8	1.7	**O**	Resources	Sharing the analysis engineers with the ITER project led to delays in the completion of calculations. This led to late receipt of drawings and subsequent late delivery of materials/components to the field. This required the project plans to be adjusted on a weekly basis which resulted in cost inefficiencies. While this did not impact critical paths tasks it did impact the cost and schedule for machine assembly (i.e. structural supports).
9	1.7	**O**	Policy/Procedures	Institutional overtime policy led to lost scheduling opportunities during those weeks that included holidays. Holidays were not counted toward the 40 hour work week calculation for premium time hence staff were not inclined to work overtime. The project schedule could have been shorten by an estimated 20 work days.
10	ALL	**O**	Design	Consider better management of design tolerances. Be surgical in requiring small tolerances. This will drive the vendor's procurement cost, require extensive in-house engineering time to disposition nonconformance reports (NCR's), and increase assembly time. The impact manifests itself in both increased cost and schedule stretch-out. This has been a chronic challenge on projects at PPPL. 'Better is the enemy of good enough"
11	1.1	**O**	Design	PPPL calculation documentation was complete and accurate but lacked clear and definitive conclusions and summaries. This led to misunderstandings and time wasted in completing designs/drawings. Crisp conclusions and design direction needs to be included in the final closing statements.
12	1.1 and 1.5	**O**	Resources	Personnel single point failures has led to schedule impacts when critical people were not available (due to prolonged illnesses and deaths). These could not have been anticipated but for projects spanning long periods of time they are likely to occur and should be factored into cost and schedule contingencies. Also, critical corporate skills should be identified with backup people assigned to be mentored.

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13	ALL	**O**	Estimating	Under estimates of several skills manifested itself into resource shortages and schedule delays. The work estimating procedure should be revised to require supervisors of the skill organizations (i.e. welding, machining, field crew installation, drafting etc.) to review and provide input to all work estimates. Furthermore, technician supervisors should be required to attend design reviews to better promote value engineering. At the very least ensure early on that what is designed can be built.
14	1.1	**O**	Design	Some of the components designed for this project did not take as-built field conditions into consideration**.** Accurately manufactured parts required re-work before they could be assembled to components that did not match the NSTX CAD model. **Recommendation**: Individuals responsible for the design should engage with the field (inspect/measure the field condition and speak with operations people) to ensure that the designs for new components integrate into the imperfect, as-built conditions that actually exist.
15	All	**O**	Policy/Procedures	Establish a policy for field installations – when does a review have to be completed of field design. Develop field installation policy; Revise WP procedures accordingly
16	All	**O**	Policy/Procedures	Clarify existing Design review procedures to ensure all applicable subject matters experts are represented. The PPPL Design Review Process needs to be comprehensive, cover all important aspects or components of a work activity, and include all technical disciplines involved in the work activity. A broader review of the PPPL Design Review Process should be performed post CD--4 as part of CAP25---75(IER).
17	All	**O**	Management/Organization	Ensure that a full time dedicated project engineer actively oversees the design process. The project had to "share" an experienced individual which had cost and schedule implications.
18	All	**O**	Policy/Procedures	PPPL needs a rigorous process to ensure that each component or system is assigned to a clearly identified individual who is aware of its current and ongoing status and history, and is someone who is both capable and responsible for its technical aspects. A broader review of the PPPL use of SME's should be performed post CD--4 as part of CAP25--75(IER).

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19	All	**O**	Policy/Procedures	During the design phase and after the FDR, the project needs to ensure that the review process extends to as--built configurations including field changes.
20	All	**O**	Policy/Procedures	Rigid adherence to established engineering procdures to prevent inadvertent installation errors.
21	1.1	**O**	Design	We spent too much conceptual mechanical engineering design and analysis time trying to meet the GRD full power supply recommendations and eventually had to punt and do DCPS. Recommendation would be to craft the GRD more carefully or consider ramifications sooner. CDR was extreme. For example, GRD shot spec was also over the top. 60000 full power shots eventually became 20000 shots total, 2000 full power on OH with 6000 full power plasmas. Chewed up a lot of analysis and fatigue allowables.
22	1.7	**O**	Management/Organization	KPP development. The PEP section 2 on KPPs wshould have been more concise. This led to many conversations about what was required to meet the KPPs and project completion. There were several meetings where the demonstrated performance activities were treated as "design points", when they are far below NSTX performance criteria; definitely below NSTX-U design capabilities. Additionally,
23	1.2	**O**	Resources	On beams we had some trouble with jobs taking too long. We had some new people and bringing the crew up to speed took a lot of hard work and training. In the end though not only did we build a new beam we built a new Beam Team too.
24	ALL	**O**	Procurement	Ensure that supplier fabrication contracts are awarded based on best value and not best price. More thoroughly vet suppliers qualifications.
25	ALL	**O**	Fabrication of components.	We were burned more that once when the vendor chosen to fabricate our components did not possess the capability to perform the job correctly. **Recommendation**: we establish criteria for matching vendor capabilities to fabrication complexity. See "Procurement Lessons Learned Causal Analysis Report" under review documents.

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26	1.1	**O**	Coil Molds	TF Inner bundle molds with too tight-fitting around copper. Imperfect molds and imperfect copper bars resulted in quadrant and ultimately full bundle to be larger diameter than designed. This resulted in modifications to many of the parts that interfaced to the coil's over-sized diameters and also resulted in the misaligned TF connector faces. The only factor that allowed the coil to fit into the case was the fact that we had thicker ground layer around the TF Inner bundle and the OH coil. The compliance of the ground layers allowed us to "squeeze" the TF and OH coils into their molds. Conversely, if we did not have a generous ground layer we might not have been able to get the TF and OH into their molds. **Recommendation:** If we had more fiberglass on the individual TF legs, we could have built quadrants much closer to the design dimensions.
27	1.1	**O**	Coil VPI	Plan to sand off resin rich areas from coils that VPI'd in hard molds. Allocate sufficient time in the schedule and cost estimate. Epoxy typically cures at ~100 centigrade, a temperature at which the mold had expanded, resulting with coils that have larger than nominal dimensions.
28	1.4	**O**	Estimating	An accurate global as-built model was not available at the start of design. This led to much field rework when CADD designed hardware was attempt to be fit up to the actual machine. Suggest performing detail metrology measurements and updating CADD models as a first step in the design process.
29	ALL	**S**	Safety	The attention to worker safety resulted in only 6 reportable minor injuries in over 573,000 hours worked. While we have a robust safety organization and up front Management buy-in, it came down to people not taking risks or short cuts in the name of schedule or cost. The safety culture at PPPL is one of its strongest assets.

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30	1.7	**S**	Supervision	Work control center again provide real value in establishing daily communication of field activities. Support needs (QC weld inspections, Safety support for walk downs, Health Physics) were determined in this daily 10 minute meeting. This process was established during the TFTR D&D project which was successful in finishing safely on schedule and $3.6M under budget.
31	1.7	**S**	Scope	Be clearer in establishing project scope by establishing clear "fences" around the project scope. Define what's excluded as well as what's included. Also, document potential scope contingency as part of the CD-2 baselining requirement. The project benefited by establishing scope contingency source terms some of which was utilized (and documented) which save time and money.
32	1.7	**S**	EVMS	**EVMS the good;** monthly statusing methodology adopted, CPR reports, change control mandated good discipline. **EVMS an Opportunity;** However, the requirement for written variance analysis reports provide little value to the project management office. Causes of cost and schedule variances were discussed real time during the formal monthly status meeting. Staffing issues that drove schedule slippages were resolved many times by the PPPL engineering division and department heads that were in attendance.
33	All	**S**	Policy/Procedures	Adherence to PPPL engineering procedures eng-033 provided discipline in the design process. However, the project provided additional requirements that; 1) provided for tracking and QA verification of design review chits and 2) Required calculations to be signed by the cog engineer whom was the ultimate customer
34	1.7	**S**	Management /Organization	Project was very well organized from the beginning. We have an excellent, very strong project team. We had excellent project initiation, requirements were well defined if over the top here and there, and the work planning and WAFs were outstanding. Project Controls went very well. Project status and EVMS went nearly flawlessly. We were very well supported by the NSTX program as well (Masa and Jon as well as Stefan)
35	ALL	**O**	General	On April 24, PPPL ESU responded to alarms from the NSTX-U experimental area. An active water leak from NSTX-U was observed. Staff discovered that several of the Ohmic Heating coils external cooling paths were damaged at the top end of the OH coil. Additionally, indications of electrical arcing were observed in the vicinity of the water leaks. Initial inspection showed no damage to the OH or other coil systems. The water was secured and investigation into the cause was initiated. As a result of this event, the Laboratory has commissioned a number of reviews to evaluate the cause, determine what actions are necessary to repair the coil, what actions are necessary to improve processes and prevent recurrence. The following teams were commissioned: An Internal Independent Review team, an Extent of Condition Review Team, an Independent External Review Team, and formal Root Cause Analysis Team. Lessons learned relative to deisgn and construction are incorportaed in the above lessons learned. Additionally, since many findings and corrective actions were related to conduct of operations and machine operation, the entire corrective action report is included in its entirety in Appendix O.